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Research Article

Food Price Inflation Rates in the Euro Zone: Distribution Dynamics and Convergence Analysis

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It is widely recognized that inflation as a monetary phenomenon is determined by money supply changes. In the short run, however, several factors may lead to inflation rate differentials among different regions in the same country or among different countries in a monetary union. This paper examines the mean reversion attitude of food price inflation rates in the Euro zone, borrowing the concepts and developments from the recent growth literature and using panel unit root tests. Additionally, in order to capture sufficiently the evolving distributional dynamics, nonparametric econometric methods are also implemented. Finally, the comovement of the inflation rates among different food subgroups is also explored. The data consist of monthly observations of the EU harmonized consumer price indices of food and three different food subgroups (meat, bread and cereals, and vegetables) for the 12 older member states of the Euro zone, covering the period from 1997 to 2010. The results do not fully support the hypothesis of the food price inflation rates convergence for the whole period under investigation. Mean reversion shows up in different time periods and in different food categories. Moreover, the analysis of distribution dynamics sheds light to different aspects of convergence and highlights processes like club formation and polarization.

1. Introduction

The subject of inflation rate convergence gained the attention of economists due to its importance for monetary and regional policies. In a monetary union, homogeneous inflation is expected to prevail due to the increased economic integration after the formation of the single currency area. Inflation rates and their convergence within the Euro area have been a major concern for policy makers, even before the advent of the single currency ([1, 2]).

Persistent differences in inflation rates within a monetary union may affect real interest rates, thus, creating important disparities in inflation expectations and increasing the likelihood of asymmetric inflationary shocks ([3]). Inflation alignment within the Euro zone is directly related to the relative price competitiveness of each country ([4–7]). The recent financial crisis and its strong impact on several Euro zone countries with higher inflation rates have strengthened the interest towards this direction.

It is widely recognized that inflation, as a monetary phenomenon, is determined by money supply changes. In the short run, however, and until the full impact of such changes is felt, other forces may play a role too, especially for small range changes of price indices. Such forces can be used to explain, at least partially, longer-term inflation rate differentials at the commodity or regional level.

The purpose of this study is to examine convergence and the distribution dynamics of food inflation rates for the twelve older countries of the Euro zone (see Table 1). The examination of food inflation is of great interest. As Walsh [8] emphasizes, food inflation is in many cases more persistent than nonfood inflation, and shocks in many countries are propagated strongly into nonfood inflation. Under these conditions, and particularly given high global commodity price inflation in recent years, a policy focus on overall inflation—excluding food prices—can misspecify inflation, leading to higher inflationary expectations, a downward bias to forecasts of future inflation, and lags in policy responses. The importance of food price inflation is further emphasized in the study of Cecchetti and Moessner [9] who report evidence suggesting that food price inflation has explanatory power for future headline inflation.

Table 1: Descriptive statistics for the "food", "bread and cereals", "meat", and "vegetables" inflation rates.

		Austria	Belgium	Finland	France	Germany	Greece	Ireland	Italy	Luxembourg	The Netherlands	Portugal	Spain
Food	M*	0.019	0.023	0.016	0.019	0.012	0.031	0.020	0.017	0.025	0.017	0.017	0.027
		(7)**	(9)	(2)	(6)	(1)	(12)	(8)	(5)	(10)	(3)	(4)	(11)
	SD*	0.021	0.020	0.034	0.020	0.024	0.025	0.018	0.035	0.016	0.029	0.028	0.025
Bread and cereals	M	0.023	0.029	0.015	0.018	0.014	0.040	0.021	0.022	0.027	0.016	0.030	0.030
		(7)	(9)	(2)	(4)	(1)	(12)	(5)	(6)	(8)	(3)	(10)	(11)
	SD	0.025	0.026	0.027	0.016	0.021	0.031	0.038	0.024	0.018	0.021	0.030	0.025
Meat	M	0.016	0.020	0.009	0.021	0.011	0.027	0.010	0.018	0.021	0.015	0.010	0.025
		(6)	(8)	(1)	(10)	(4)	(12)	(3)	(7)	(9)	(5)	(2)	(11)
	SD	0.022	0.018	0.039	0.022	0.027	0.018	0.040	0.018	0.018	0.029	0.035	0.032
Vegetables	M	0.016	0.024	0.017	0.022	0.006	0.029	0.018	0.025	0.028	0.029	0.032	0.038
		(2)	(6)	(3)	(5)	(1)	(10)	(4)	(7)	(8)	(9)	(11)	(12)
	SD	0.050	0.086	0.079	0.057	0.065	0.114	0.079	0.041	0.049	0.083	0.122	0.044

*M and SD stand for mean and standard deviation, respectively.
**The numbers in parenthesis indicate the relevance ranking for each country in the specific group.

The food price spike preceding the 2008 global financial crisis set off a number of studies on the role of food price inflation in the development of monetary policy. Catão and Chang [10] point out that the distinctive role of food in household utility and the presence of high food price volatility may have important implications for the welfare effects of different monetary policy regimes. Anand and Prasad [11] also conclude that in an environment of credit-constrained consumers, a narrow policy focus on nonfood inflation can lead to suboptimal outcomes.

In this study, both stochastic convergence (in particular the mean reversion case of β-convergence) and σ-convergence are considered. Additionally, nonparametric econometric methods are implemented to study the evolving distribution dynamics of food price inflation rates. The latter methodology allows the exploration of the entire distribution of relative inflation rates, rather than just the first two moments of the distribution, and its dynamics over time.

Most of the studies on price inflation convergence focus on price indices which are either general or refer to largely aggregated groups of commodities. Following the same approach, the data used consists of monthly estimates of the Harmonized Indices of Consumer Prices (HICPs) for the "food" group and for three specific subgroups, namely, "bread and cereals," "meat," and "vegetables." The data set covers a period from January 1997 to November 2010.

Dynamic panel data analysis and panel unit root tests according to Levin et al. [12] are used to examine stochastic convergence. Changes in standard deviation are used to examine σ-convergence, according to its concept [13]. Examination of the evolving distribution dynamics is also conducted using an alternative kernel density estimator proposed by Hyndman et al. [14] and Hyndman and Yao [15]. This estimator was introduced in the growth and income convergence analysis by Arbia et al. [16] and it is used in a similar manner in this analysis to study inflation rate distribution dynamics, since it offers certain advantages.

2. Literature Review

Throughout the literature, inflation rate differentials are often associated with the productivity catching-up process (e.g., [17]) and with monetary and fiscal factors (e.g., [18, 19]). Moreover, Dalsgaard [20] and Beck et al. [21] emphasize the role of market concentration, mergers and acquisitions, and cartel formations on the phenomenon of inflation rate differentials. Campolmi and Faia [22] and Jaumotte and Morsy [23] point out the importance of labor and product market institutions, which can generate significant and persistent inflation differentials.

Several other studies (e.g., [24, 25]) also emphasize the importance of sectoral inflation. Different sectoral inflation rates among countries provide evidence of dissimilarity in the industrial structure of the European Union (EU) which itself leads to differences in regional inflation ([26]). As Nagayasu [1] claims, in the absence of convergence in industrial structure, regional inflation rates do not converge even after the establishment of monetary union. Altissimo et al. [27] also point out the importance of the different responses of Euro-zone countries to common, Euro-area shocks, while Stavrev [28] recognizes the influence of price convergence, business cycle, and past inflation differentials for the formation of inflation differentials.

The empirical studies on inflation convergence literature deal with the issue of inflation convergence among different regions in the same country or inside a cluster of countries. Beginning with the former group, Cecchetti et al. [18] and Roberts [29] examine inflation convergence trends within USA, while Dayanandan and Ralhan [30] investigate price index convergence among Canadian districts and cities. Fan and Wei [31] investigate inflation convergence among Chinese cities and Busetti et al. [32] test for convergence among Italian regions. Moreover, Yilmazkuday [33] tests for inflation rate convergence among different Turkish regions. Finally, Nagayasu [1] examines regional inflation differential in Japan.

The cluster of countries for which inflation convergence is examined usually refers to members of the European Monetary Union (EMU) or the new members of the European Union[1]. Kočenda and Papell [34] and Lopez and Papell [35] using panel unit root test find a strong evidence of inflation convergence among EU countries. However, several other studies cast doubt on the convergence hypothesis in Europe (e.g., [19, 36]). Also, Busetti et al. [3] detect two convergence clubs, while Erber and Hagemann [37] find that there is still a considerable degree of prevail heterogeneity in the national inflation rates. However, the stochastic long-term convergence could be accomplished after a sufficiently long time period. A number of studies also focus on the examination of the inflation convergence of the new member states relative to the EMU benchmark (e.g., [38–43]). The findings are not similar among these studies but vary considerably depending on the period under investigation and the applied methodology.

According to Lünnemann and Mathä [44], even though the available international evidence focuses mainly on aggregate inflation data, the usage of more disaggregated inflation data may prove a useful complement in identifying the key drivers of aggregate inflation persistence. A disaggregate analysis may uncover inflation persistence differences and allow their categorization according to sectors. Moreover, several authors provide evidence that aggregate inflation persistence is predominantly driven by the most persistent disaggregate inflation components (e.g., [21, 45]).

In the above context, the examination of food inflation is of great interest. Weber and Beck [19] examined inflation rate convergence in two samples of European countries. Their study considers changes in HICPs for several groups of products including the "food and nonalcoholic beverages" subgroup. For the latter, β-convergence was found but the estimates of half-lives were not provided since the solution of the nonlinear expression for β-convergence that was used produced complex numbers. Even though β-convergence took place during the whole period examined, it was slower for the period after the introduction of the common currency implying also the existence of nonlinearities in the convergence process. This result is also supported by the existence of σ-convergence during the first half of the period they examined but σ-divergence for the second half of the period.

Dayanandan and Ralhan [30] used panel unit roots tests suggested by Levin and Lin [46] and Im et al. [47], and they found evidence of β-convergence for the food price index in Canada with a half-life equal to 7.4 years. Sturm et al. [48] estimated coefficients of variation for the consumer price index of several commodity groups including food commodities and for different groups of European countries. They found a variety of results for different commodity and food commodity groups, with regards to β- and σ-convergence. Results vary also with respect to country groups (EMU and non-EMU members) and time periods.

Faber and Stokman [49] found evidence of convergence for the consumer price index of food and nonalcoholic beverage products in Europe, for the period 1980–2003. In early 90s, there was a strong price level convergence for all "second-level" commodity groups including food and non-alcoholic beverages. In the study of Fan and Wei [31], panel unit root tests were used to study convergence of the food price inflation rates across 36 major Chinese cities and over a seven-year period. They found contradictory results on β-convergence based on the panel unit root test implemented and the time lag selection model. They argued that these results are stemming from the fact that high-frequency data (monthly) were used, which better capture the time period needed for price convergence.

Lünnemann and Mathä [50] analyze the degree of persistence of inflation in the EU for more than 1500 HICP sub-indices (94 HICP subindices and 17 countries or country aggregates). The results indicate a very moderate median and mean inflation persistence at the disaggregate level based on a nonparametric measure of the mean reversion.

Several authors have also provided possible explanations for the food inflation rates differentials. Fousekis [51] points at the fragmentation of the European market and claims that inflation rate differentials are not efficiently confronted by horizontal EU measures but by changes in the market structures in EU countries. Bukeviciute et al. [52] argued that food price inflation differentials are caused by the different ways and degrees in which the food supply chains of different countries absorb external shocks such as the rapid increase of energy prices. This in turn is due to different food market structures and regulatory frameworks. In this sense food price inflation differentials are a signal that the EU food market still remains fragmented.

Davidson et al. [53] show that there are a range of factors that determine retail food prices like the exchange rate, manufacturing labor costs, and oil prices. In addition, given the underlying characteristics of commodity price behavior on world markets (i.e., relatively low prices punctuated by spikes), the impact of world commodity prices on retail food price inflation will depend on the duration of the shock. Given the expectation that world commodity prices are likely to be higher and more volatile in the future, understanding the dynamics of commodity price (and other) shocks on domestic retail prices is an important issue for macroeconomic policy.

A large part of the empirical studies on the subject of inflation convergence follows the introduction and development of quantitative methods in the area of economic growth and convergence. Consequently, the concepts of stochastic convergence and σ-convergence have dominated the relevant literature (e.g., [34–36, 38]). Recently, another methodological tool, the distribution dynamics analysis, borrowed from the economic growth literature, has also been introduced in the analysis of inflation rates differentials. The study of Cavallero [54] presents an example of this alternative approach. After the decomposition of the EU-12 inflation series into trend and cyclical component, Cavallero [54] concludes that inflation trends converged, although the convergence process was not constant over time. Especially the launch of the EMU and the introduction of a single currency have boosted convergence. Moreover, although inflation cycles converged in the long run, they still lack synchronization over short time horizons. In search for an

economic explanation for cyclical inflation dynamics, he suggests that country-specific labor market institutions are likely to affect inflation outcomes especially in high inflation countries.

Additionally, Nath and Tochkov [55] examine the distribution dynamics of inflation rates in ten new EU members relative to the EMU accession benchmark inflation over the period 1990–2009 using nonparametric methods. Over the entire sample period, they detect a general shift in the new EU members' 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 new EU members' 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, the emergence of a bimodal distribution signaled the stratification of relative inflation in new EU members into two convergence clubs, which has intensified since the start of the global economic crisis.

3. Data and Descriptive Statistics

Monthly data on HICPs for the "food" group and the "bread and cereals," "meat," and "vegetables" subgroups have been used in the analysis. Inflation rates are computed as annual percentage changes of the price index as follows:

$$\pi_t = 100(\ln P_t - \ln P_{t-1}) = 100(p_t - p_{t-1}), \qquad (1)$$

where π_t denotes the food price inflation rate in period t, P_t represents the price index at period t, and p_t is the natural logarithm of P_t. Table 1 provides some descriptive statistics—mean (M) and standard deviation (SD)—of the monthly data for the "food," "bread and cereals," "meat," and "vegetables" groups.

On average, Greece and Spain have the highest food price inflation rates during the period under investigation, while Finland and Germany have the lowest. Even though there are many similarities in the relevant rankings of the countries, in each subgroup, some significant differences can also be observed. Finland and Germany possess high rankings in all the categories, while Greece and Spain possess low ranking in all categories. On the other hand, Portugal is the second in the "meat" group but the tenth in the "vegetables" group. Moreover, Austria ranks the second in the "vegetables" group but the seventh in the "bread and cereals" group.

These statistics illustrate the high degree of complexity in the data. Apart from economic policies (EMU or national) other country and product specific factors, such as market structures, may be contributing to the observed inflation "heterogeneity" between countries and products.

Figures 1 and 2 provide some additional insight on the inflation rates within the Euro-zone. In Figure 1, each dot represents a country's inflation rate at a specific time (monthly observation). The white line represents the cross-country average inflation rate. Consequently, each graph illustrates the dispersion of the inflation rates at a specific month and additionally depicts the comovements of inflation rates. As we can see in Figure 1, there is a significant comovement of the inflation rates in each group. However, in the case of the "vegetables" group, this comovement is less obvious, while there is also a significant dispersion of the inflation rates. Additionally, Figure 1 reveals that the evolutions of the inflation rates of the groups under consideration are characterized by a high degree of seasonality, with the exception of the "bread and cereals" group. In the latter case, there is a remarkable shift in the inflation rates that corresponds to the "food spike" of the 2007-2008 period.

Figure 2, shows the number of times (monthly observations) that each country has been included in the "high," "medium," or "low" inflation group. The "high" inflation group includes the four countries with the highest inflation rates; the "low" inflation group includes the four countries with the lowest inflation rates, while the rest of the countries are included in the "medium" inflation group.

It is obvious that even countries with low average food inflation (e.g., Germany and Luxemburg) have in some occasions been placed in the "high" inflation group. This reflects the complexity of the data and indicates the presence of the "leapfrogging" phenomenon. The latter refers to cases where countries with high (or low) relative inflation rates move towards the mean and end up with a low (or high) relative inflation rate. This phenomenon is common in the economic convergence studies (see Magrini [56]).

4. Methodology

4.1. Stochastic Convergence. The concept of stochastic convergence was firstly introduced in the growth literature by Bernard and Durlauf ([57, 58]). According to the authors, stochastic convergence is not the outcome of a negative relation between initial income and growth during a predetermined time period, as β-convergence is. It is the outcome of the relationship between the long-term income estimates of two economies, subject to the initial conditions. Thus, giving the available information at initial period t, $\Im_t$ economies i and j converge stochastically if (Bernard and Durlauf [57]):

$$\lim_{T \to \infty} E\left(y_i(t+T) - y_j(t+T) \mid \Im_t\right) = 0. \qquad (2)$$

In the stochastic convergence study researchers usually apply either time series or panel data unit roots tests for the examination of the mean reverting behavior. Several studies use this analysis to examine the mean reverting behavior in price and inflation rates (e.g., [7, 16, 19, 31, 35, 40, 43, 59–62]). According to Gregoriou et al. [63], discovering that inflation differentials are characterized by a unit root implies that the idiosyncratic shocks in individual countries' inflation rates have persistent effects. This finding raises issues on whether EMU really constitutes an optimal currency area that can be effectively managed by the ECB. In addition, it raises questions on whether the member countries have truly converged during the pre-Euro-zone period.

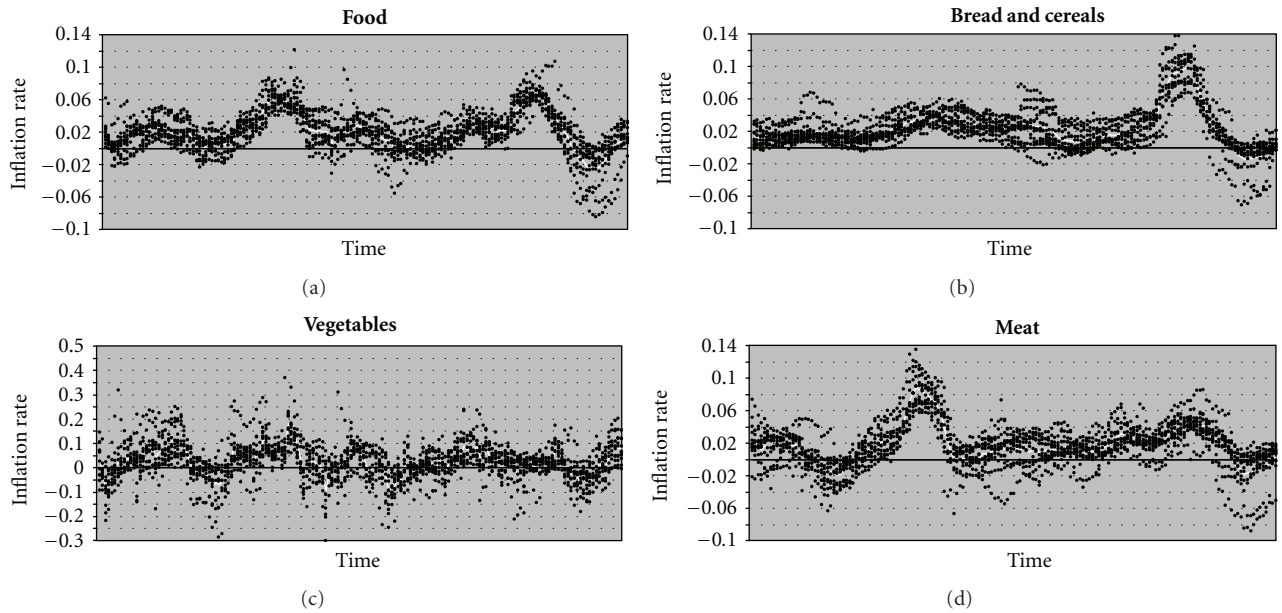

Figure 1: Evolution of the "food," "bread and cereals," "meat," "vegetables" inflation rates. Each dot for each month (horizontal axe) represents a country observation on the inflation rate (vertical axe) of this group.

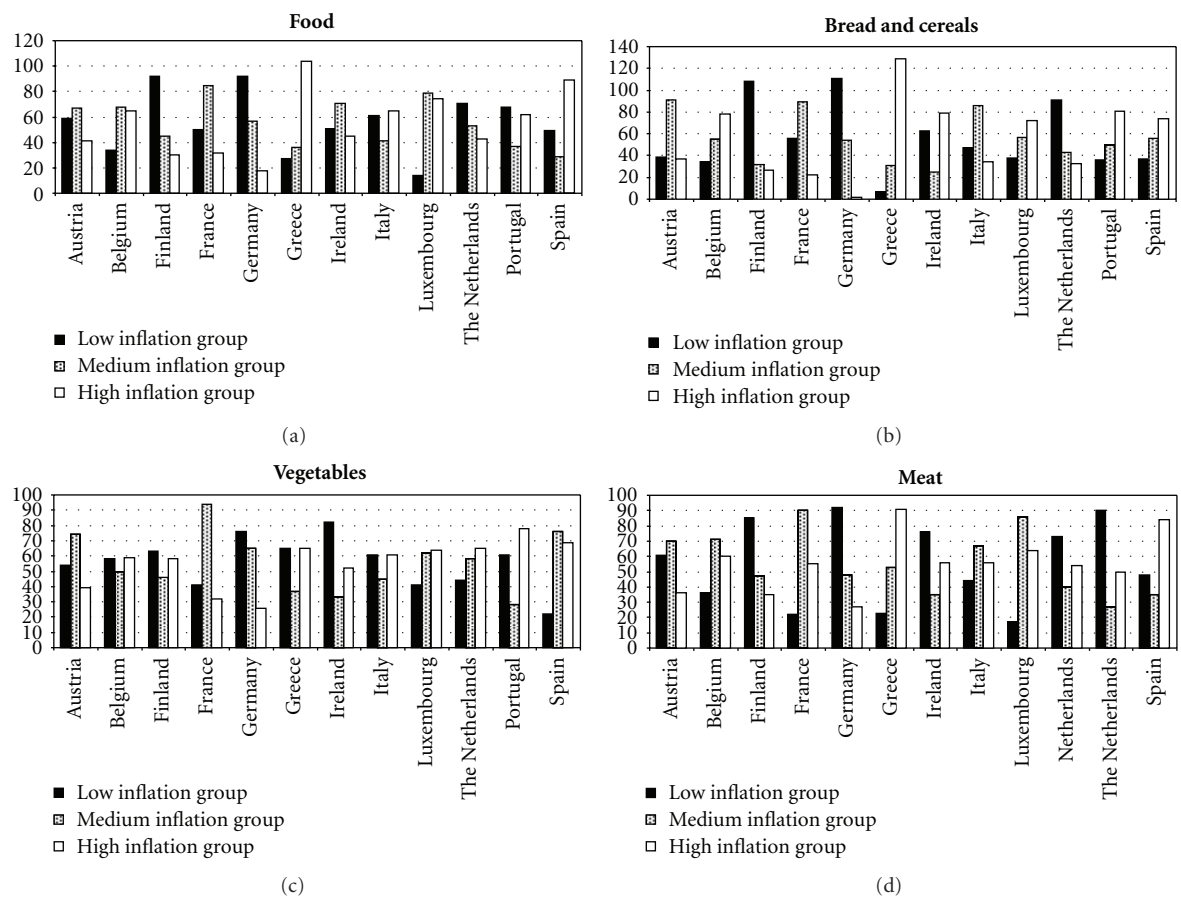

Figure 2: Times that each country has been included in the "high," "medium," and "low" food inflation rate category.

On the other hand, if inflation differentials are only temporary, ECB can effectively implement and communicate its policies without exacerbating the differences that exist between EMU countries. Therefore, the degree of persistence of inflation differentials is of primary importance in order to establish whether the economic area exhibits imbalances that require structural interventions, or whether the asymmetries are just temporary phenomena which in the long run eliminate themselves [63].

Bernard and Durlauf ([57, 58]) use time series unit root tests to explore the issue of stochastic convergence. The major problem associated with this group of tests is their low power, especially in small samples. The use of panel unit root tests has alleviated this problem to a great extent by exploiting both cross- and time-series variation [64]. In this analysis the Levin et al. panel unit root test (LLC) [12] is implemented[2]. The LLC test has been widely used in the inflation convergence literature (e.g., [10, 43, 59, 60, 62]).

Let $i = (1, 2, \ldots, N)$ denote the countries and let $t = (1, 2, \ldots, T)$ represent the time index. Then, the test for food inflation convergence is based on the following equation:

$$\Delta\pi_{i,t} = a_i + b\pi_{i,t-12} + \theta_t + \sum_{j=1}^{k_i} \varphi_{i,j}\Delta\pi_{i,t-j} + \varepsilon_{i,t}, \tag{3}$$

where Δ denotes the annual, month to corresponding month, change of $\pi_{i,t}$, $b = \rho - 1$, θ_t represents a common time effect, and $\varepsilon_{i,t}$ is assumed to be a stationary idiosyncratic shock. The inclusion of lagged differences in the equation serves to control for serial correlation. Their respective number is determined using the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC). The inclusion of a common time effect is supposed to control for cross-sectional dependence caused by an external shock. To take control of this effect, the variable is transformed by subtracting the cross-sectional mean leading to

$$\Delta\widetilde{\pi}_{i,t} = a_i + b\widetilde{\pi}_{i,t-12} + \sum_{j=1}^{k_j} \varphi_{i,j}\Delta\widetilde{\pi}_{i,t-j} + \varepsilon_{i,t}, \tag{4}$$

where $\widetilde{\pi}_{i,t}$ is computed as

$$\widetilde{\pi}_{i,t} = \pi_{i,t} - \frac{1}{N}\sum_{j=1}^{N} \pi_{j,t}. \tag{5}$$

The examination of the mean reverting behavior is implemented by testing the null hypothesis that the common b's[3] equals zero against the alternative hypothesis that they are all smaller than zero. The rejection of the null hypothesis implies stationarity, that is, inflation rates exhibit mean reverting behaviour. Thus, any shock that causes deviations from equilibrium will eventually die out. The speed at which this occurs can be directly derived from the estimated value[4] of ρ (denoted $\widehat{\rho}$) using the half-life formula: $t_{\text{half}} = \ln(0.5)/\ln(\widehat{\rho})$. In addition to the analysis for the total period and in order to get a rough indication of nonlinearities in the convergence process, we also implement the LLC panel unit root test, in three distinct time periods. The first period starts from January 1997 and finishes at December 1999, just before the creation of the Euro-zone. The second period is the largest one and covers all the years up until the beginning of the global financial crisis at August 2008. The last period covers the period from September 2009 to November 2010. If the results, concerning the existence of convergence and the value of ρ differ among the subperiods under investigation then as Goldberg and Verboven [65] and Berka [66] argue, we have an indication of nonlinearity in the convergence process.

4.2. Distribution Dynamics. Despite the information on the transition towards a steady state that stochastic convergence contains, it does not provide an insight on the dynamics of the entire cross-sectional distribution. It does not conclude on certain conclusions on rising, declining, or stationary dispersion of the cross-section distribution over time and any method that cannot differentiate between distribution convergence, divergence, and stationarity is of limited use [16]. The concept of σ-convergence approach, which refers to the evolution of the overall cross-regional dispersion, is also an insufficient solution since it does not offer information on the intradistribution dynamics. A constant dispersion can coexist with very different dynamics of the distribution ranging from crisscrossing and leapfrogging to constant ranking and no changes in distribution at all [56].

The distribution dynamics analysis overcomes the above limitations as it examines the evolution of the entire distribution over time [19]. It enables researchers to simultaneously detect and analyze shifts of the distribution of inflation rates relative to the mean, intradistributional convergence, and stratification into different convergence clubs [55]. This methodology has been firstly introduced in the economic growth literature by Quah [67].

The idea behind the distribution dynamics approach is to find a law of motion that describes the evolution of distribution over time. One of the techniques most commonly used in this analysis involves the calculation of stochastic kernels (see [64]). This approach is based on the estimation of the conditional density of a variable Y given a variable X. In our case, X refers to the absolute deviation of a country's food inflation from the average at month t, while Y refers to the absolute deviation of a country's food inflation rate from the average at month $t + 12$ (transition period equal to 12 months). Thus, the conditional density function describes the probability of a country to move to a certain level of inflation deviation from the cross-sectional mean at time $t + 12$ given its current inflation rate deviation (time t).

The traditional stochastic kernel estimator (see, among others, [16]) is defined as

$$\widehat{f}_\tau(y \mid x) = \frac{\widehat{g}_\tau(x, y)}{\widehat{h}_\tau(x)}, \tag{6}$$

where

$$\widehat{g}_\tau(x, y) = \frac{1}{nab}\sum_{i=1}^{n} K\left(\frac{\|x - X_i\|_x}{a}\right)\left(\frac{\|y - Y_i\|_y}{b}\right) \tag{7}$$

is the estimated multiplicative joint density of (X, Y) and

$$\hat{h}_\tau(x) = \frac{1}{na}\sum_{i=1}^{n} K\left(\frac{\|x - X_i\|_x}{a}\right) \tag{8}$$

is the estimated marginal density. In the above equations, a, b are bandwidth parameters controlling the smoothness of fit, $\|\cdot\|_x$ and $\|\cdot\|_y$ are Euclidean distance metrics on spaces X and Y, respectively, and $K(\cdot)$ is the Epanechnikov kernel function.

The conditional density estimator can be rewritten as

$$\hat{f}_\tau(y \mid x) = \frac{1}{b}\sum_{i=1}^{n} w_i(x) K\left(\frac{\|y - Y_i\|_y}{b}\right), \tag{9}$$

where

$$w_i(x) = \frac{K(\|x - X_i\|_x/a)}{\sum_{j=1}^{n} K\left(\left\|x - X_j\right\|_x/a\right)}. \tag{10}$$

This estimator is in fact the Nadaraya-Watson kernel regression estimator. Equation (8) shows that the conditional density estimate at $X = x$ can be obtained by the sum of n kernel functions in Y space weighted by the $\{w_i(x)\}$ in X space. Using $w_i(x)$, the estimator of the conditional mean is given as

$$\hat{m}(x) = \int y\hat{f}_\tau(yx)dy = \sum_{i=1}^{n} w_i(x) Y_i. \tag{11}$$

Hyndman et al. [14] noticed that when the conditional mean function has an exacerbate curvature and when the points utilized in the estimation are not regularly spaced, the above estimator is biased. In order to correct this bias, they propose an alternative estimator whose mean function has better bias properties than the traditional kernel regression, as well as a smaller integrated mean square error (for further details on this alternative estimator, see the Appendix). For the bandwidth selection, we follow the Hyndman and Yao [15] proposed algorithm.

In addition to the reduced bias estimator, Hyndman et al. [14] proposed two new ways to visualize the conditional densities, namely, the "stack conditional density" and the "high density region" (HDR) plots. The former was introduced for the direct visualization of the conditional densities, which is considered as a sequence of univariate densities. Thus, it provides better understanding than the conventional three-dimensional perspective plots. The HDR plot consists of consecutive high density regions. A high density region is defined as the smallest region of the sample space containing a given probability. These regions allow a visual summary of the characteristics of a probability distribution function. In the case of unimodal distributions, the HDRs are exactly the usual probabilities around the mean value. However, in the case of multimodal distributions, the HDR displays multimodal densities as disjoint subsets in plane.

The "stacked conditional density" plots present the location of the univariate conditional densities relative to the x-axis which refers to time t and, unlike the HDR plots, is the vertical axis. If the mass of the distribution concentrates parallell to x-axis line at zero point, it is an indication that any existing deviation in time t almost disappears at time $t + \tau$ (inflation convergence trend). On the other hand, if the mass of the distributions is located on the 45° degree line (when t and $t + \tau$ axes are similarly scaled), the deviations at time t still exist at time $t + \tau$ (inflation persistence). In the examination of the HDR plots, the existence of multiple modes in the conditional densities is also of great importance. If there are more than one peaks in a univariate conditional density, this implies that from a certain inflation rate deviation in time t, countries tend to end up in two (or more) different point masses of inflation deviations.

When examining the "high density region" plots, we observe whether the 25% or the 50% HDRs are crossed by the 45-degree diagonal (again t and $t + \tau$ axes should be similarly scaled) or if they are crossed by the horizontal axis. If the majority of the 25% or 50% HDRs are crossed by the diagonal, strong convergence trend is present. If the majority of the 75% HDRs are crossed by the diagonal, weak convergence trend is present. On the other hand, if the majority of the 25% or 50% HDRs are crossed by the x-axis, there is a strong persistence of inflation differences among countries. Finally, if the majority of the 75% HDRs are crossed by the x-axis, weak persistence prevails in inflation distribution. The 25%, 50%, 75%, and 90% are shown to be beginning with the darker shaded region and moving towards the lighter respectively. Arbia et al. [16] emphasized also the importance of analyzing central points like modes, the values of y, where the density function takes on its maximum values. When, in particular, the distribution function is bimodal, the mean and the median are only "compromise" values between the two peaks. The highest modes for each conditional density estimate are superimposed as bullets on the HDR plots.

5. Results

Table 2 summarizes the findings from the stochastic convergence analysis. For the entire period under investigation, stochastic convergence is only statistically significant in the "vegetables" product group and only when the SIC criterion for the determination of the number of lags is applied. The values of ρ's and the corresponding half-lives are only reported in cases where the unit root hypothesis is rejected at a 95% level of significance.

In the first subperiod, "bread and cereals" is the only group where no convergence evidence appears. On the other hand, the general "food" group, as well as the "meat" and the "vegetables" subgroups, appears to have strong convergence trends. However, in the cases of "food" and "meat" groups, the convergence is only supported when the lags selection is based on the SIC criterion. In the second period, there is no inflation convergence evidence in the "bread and cereals" and "meat" subgroups. Stochastic convergence only appears in the general "food" group as well as in the "vegetables" subgroup and only when the number of lags is determined by the SIC criterion. Finally, in the last subperiod (global financial crisis), stochastic convergence appears everywhere

Table 2: Unit root tests for food and eleven food product subgroups' inflation rates.

Categories		Total period			1997M01–1999M12			2000M01–2008M09			2008M10–2010M11		
		ρ-adj	t-stat	adj. 1/2 life	ρ-adj	t-stat	adj. 1/2 life	ρ-adj	t-stat	adj. 1/2 life	ρ-adj	t-stat	adj. 1/2 life
Food	S*		−0.51		**0.89**	**−2.14**	**5.74**	**0.91**	**−1.37**	**7.56**		−1.02	
	A*		5.62			−1.12			3.53		**0.92**	**−1.70**	**8.61**
Bread and cereals	S		0.49			−0.67			−0.32		**0.79**	**−5.12**	**3.00**
	A		6.12			−0.67			5.44		**0.79**	**−5.14**	**3.00**
Meat	S		2.23		**0.90**	**−2.26**	**6.84**		−0.72		**0.94**	**−1.89**	**11.64**
	A		7.27			−1.39			5.40		**0.94**	**−1.99**	**11.15**
Vegetables	S	**0.8**	**−8.86**	**3.06**	**0.81**	**−2.64**	**3.22**	**0.77**	**−8.28**	**2.70**		−1.04	
	A		1.19		**0.79**	**−2.78**	**2.96**		0.28			−0.92	

* S, A: Schwarz and Akaike information criterion for the selection of the lags number, respectively.

with the exception of the "vegetables" group. Unlike the second subperiod under investigation, mean reversion in the "food" group is present, only when the analysis is implemented using the AIC criterion for the lags selection.

To summarize, the results of the stochastic convergence analysis are rather mixed. There are no similar convergence patterns among groups or among time periods. However, for the entire period under investigation, the general conclusion is the absence of convergence, with the notable exception of the "vegetables" group. Moreover, it is important to mention that the implementation of the AIC or the SIC criterion is crucial for the estimation of the statistical significance of the estimated ρ's.

Figure 3 presents the results of the σ-convergence analysis. It presents the cross-section, countrywise, inflation rate dispersion in terms of standard deviation from January 1997 to November 2010. As can be observed for the "food" and for the "bread and cereals" groups, there was an increase in dispersion, which was totally counterbalanced by the last few monthly observations. On the other hand, the "vegetables" group, regardless of the seasonalities of the inflation rate dispersion, presents a downward trend which is steady during the period under investigation. Finally, the results for the "meat" group are similar to the "food" group, but with almost no increasing trend. Both the "food" and "meat" groups present a high increase in their inflation rates during the year 2008. Moreover, the "bread and cereals" group suffers a sharp increase in year 2007. This may be related to the rapid increase in some agricultural commodity prices and energy prices, which were observed during the second half of 2007.

A closer look at the above figures indicates that σ-convergence analysis provides similar results with the β-convergence analysis, especially when the total period is under investigation. Another important implication from the above figures is the rapid decrease in the inflation rates dispersion that was observed in the last few months of the period under investigation. This is the main reason for the significant convergence trends that are provided by the stochastic convergence analysis in the third subperiod.

Turning now to the results of the distribution dynamics analysis, Figure 4 presents the "high density regions" and the "stack conditional density" plots for each group under investigation. It can be seen that for most of the product groups the mass of the distributions in the HDR plots concentrates around a line, close to the parallel of the x-axis which crosses the zero point on the vertical axis. This implies that the existing deviations at month, t, are significantly reduced at time $t + 12$. This is an indication of strong inflation convergence. Thus, in general, countries with relatively higher or lower food price inflation rates are expected to move back towards the mean in a one-year period. It is important to emphasize that the above results demonstrate the argument in favor of the convergence hypothesis, better than the previous results.

Although the trend of reversion to the mean appears in each group, each case presents several different characteristics. The degree of mean reversion is not similar across groups. The "meat" group appears with the most obvious mean reversion trends. On the other hand, the mass of the distribution of the "vegetables" group is less obviously concentrated to the parallel of the x-axis which crosses the zero point on the vertical axes. In the other two groups ("food" group and "bread and cereals" group) there are still obvious mean reversion trends but they are restricted in cases where the absolute values of the inflation deviations in the initial period are relatively low in absolute values.

Another important characteristic of the distribution dynamics analysis is the presence of multimodality cases, in different frequencies among product groups. The presence of multimodalities indicates that, in some cases, a low or a high inflation rate deviation does not result in a common point mass after the transition period, but to two or more point masses. These cases do not appear in the same "areas" of each product group plot and do not show the same sharpness. However, according to Figure 2, multimodalities mostly appear in the edges, that is, when the initial deviation of the inflation rate has a high absolute value (either positive or negative). In these cases, the distributions of the inflation rate deviation in the next period ($t + 12$) tend to be multimodal. It is important to mention that the presence of multimodalities is more common in the subgroups distributions than in the distribution of the general "food" group.

Another interesting result from the nonparametric analysis is the existence of threshold points in our sample. A closer look at the plots reveals that after a certain point of inflation deviation (either negative or positive), the mass of

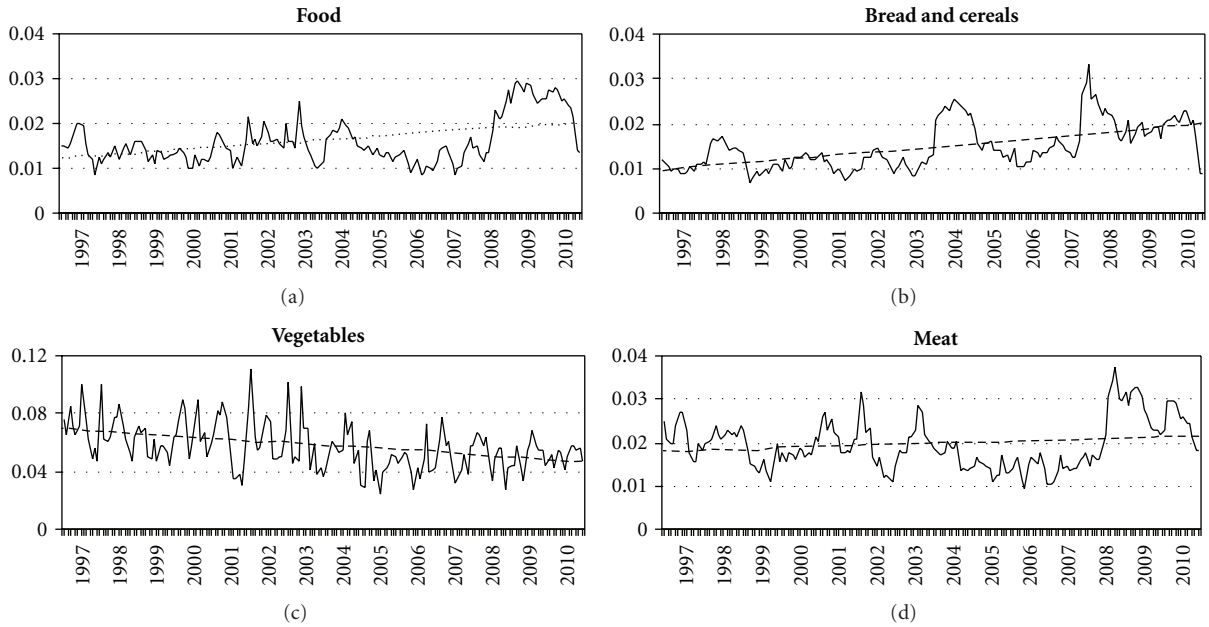

Figure 3: Inflation rate dispersion for "food," "bread and cereals," "vegetables," and "meat" product groups.

the conditional distribution does not remain close to zero, but near to the opposite point of inflation deviation. In the case of "meat" group, for example, when the inflation deviation is greater than 0.06 or lower than –0.08, the mass of the next year inflation deviation is concentrated around −0.06 and 0.02, respectively. In the other groups, threshold points also exist but they are "one sided," that is, cases of initial negative or positive values of inflation rate deviations from the mean end up with positive or negative values of inflation rate deviations from the mean, respectively, after the transition period. As in the case of multimodality, thresholds mostly appear in the distributions of the subgroups.

For a further investigation of the distribution of food inflation rates in the Euro-zone, the results of the distribution dynamics using stochastic kernels are accompanied with a Markov transition probability matrix (Table 3). Following Cavallero [54], three states are considered for the construction of this matrix. The first state represents low inflation countries (with respect to the areawide mean, henceforth, L-state); the second state stands for countries with inflation performances in line with the areawide mean, therefore it represents the "convergence" state (henceforth, C-state); the third state represents high inflation countries (with respect to the areawide mean, henceforth, H-state).

Each cell in a given row of the matrix in Table 3 shows the probability of a transition from the initial state to one of the three states; hence, row probabilities add to one. The values along the diagonal represent the cases where relative inflation remains in the same interval (state) from one period to the next and are thus indicative of inflation persistence. As in the continuous case, probabilities are estimated for transitions over 1-year horizon.

Estimated transition probabilities close to 1 along the main diagonal point to persistence in EU-12 inflation rates, while large offdiagonal values imply high mobility. The final raw of each matrix reports the ergodic distribution and represents the long-run steady state that the system could eventually reach if nothing structural were to change.

The probabilities for annual transition along the diagonal of the first matrix (referring to the general "food" group) of Table 3 are lower than those off the diagonal. This is an indication of inflation convergence during the period under investigation. It is also important to mention that the two lowest values occur in the upper-right and the lower-left cells (about 20%). This fact suggests that the countries with high and low relative inflation in the initial state are less likely to move to the low or to the high inflation state, respectively. Furthermore, the fact that the highest values occur in the second column of the matrix (44%–51%) suggests that most countries tend to concentrate on the "convergence" state, that is to an inflation rate close to the average. The estimated ergodic distribution confirms this trend in the long run.

As far as the "meat" group is concerned, the similarities with the general "food" group are remarkable. The values in each cell and the ergodic distributions are similar. In the other two subgroups, there are both similarities and differences with the general "food" group. Two similarities are mainly observed. The first refers to the fact that the highest values are still observed in the second column. The second similarity refers to the structure of the ergodic distribution. These similarities suggest that the mass of the distributions is concentrated on the mean in the long run, and it has similar structure with the long-run distributions of the "food" group.

On the other hand, the transition probability matrix that refers to "bread and cereals" group appears to have the highest persistence as the diagonal elements of the matrix are higher than those off the diagonal. The lower-right cell has

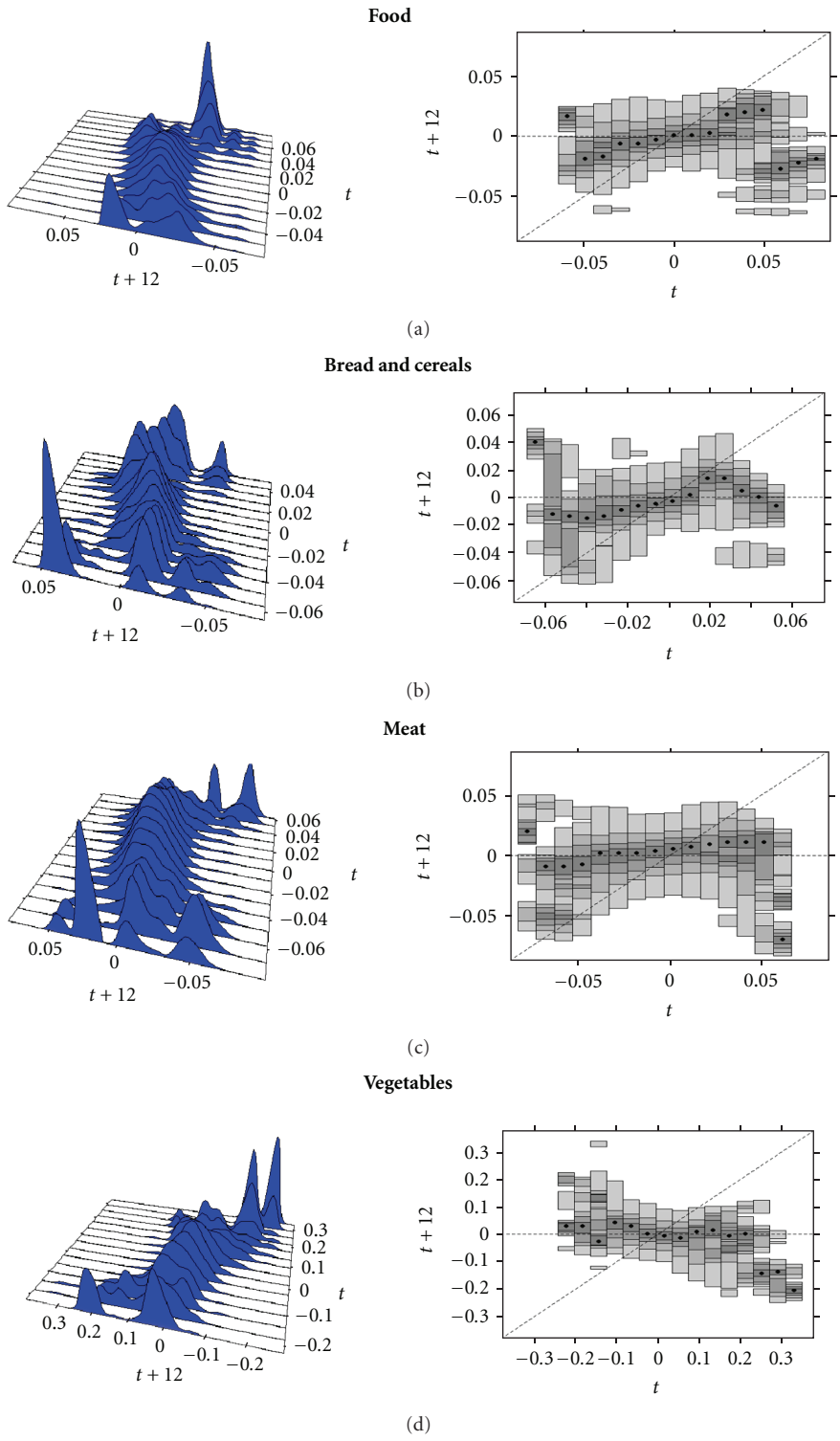

Figure 4: Intradistribution dynamics of annualized inflation rate transitions. "Stacked density" plot (left-hand side panel) and "high density region" plot (right-hand side panel).

the highest value (54%), indicating that the countries that initially belong to the higher state are more likely to stay in it than to move to another state and especially to the lower inflation state (14%). The probabilities for a country that initially belongs to the lower or to the "convergence" state to move to the high inflation state are also very low (12% and 18% resp.).

Finally, the transition matrix that refers to the "vegetables" group seriously deviates from the other matrices. Among the diagonal elements, the upper-left and the

Table 3: Markov transition probability matrices and ergodic distributions for "food", "vegetables", "bread and cereals", and "meat" groups.

		State in period $t+1$			Number of transitions
		L-state	C-state	H-state	
Food					
Grid $(-\infty, -0.008402, 0.00920669, +\infty)$, states: 3					
State in period t	L-state	0.3246	0.4749	0.2004	310
	C-state	0.2497	0.5106	0.2397	682
	H-state	0.2036	0.4412	0.3552	247
	ergodic	*0.2570*	*0.4834*	*0.2596*	
Vegetables					
Grid $(-\infty, -0.031727, 0.0333225, +\infty)$, states: 3					
State in period t	L-state	0.1589	0.4393	0.4018	381
	C-state	0.2249	0.5469	0.2282	700
	H-state	0.4049	0.4336	0.1615	256
	ergodic	*0.2541*	*0.4906*	*0.2553*	
Bread and cereals					
Grid $(-\infty, -0.008490, 0.00914554, +\infty)$, states: 3					
State in period t	L-state	0.4215	0.4559	0.1226	269
	C-state	0.2350	0.5831	0.1818	738
	H-state	0.1435	0.3161	0.5404	305
	ergodic	*0.2597*	*0.4808*	*0.2595*	
Meat					
Grid $(-\infty, -0.009169, 0.01217942, +\infty)$, states: 3					
State in period t	L-state	0.3363	0.4374	0.2264	302
	C-state	0.2493	0.4895	0.2612	563
	H-state	0.2279	0.4338	0.3382	231
	ergodic	*0.2667*	*0.4604*	*0.2729*	

lower-right cells are those with the lowest value (about 16%). These results suggest that there is a very low persistence in the low and high inflation states, as only 16% of the countries that belong to these states will remain in them after the transition period. Moreover, there is almost equal chance of moving to the other two inflation states. This is relevant to the findings of the distribution dynamics analysis about the threshold points in the sample. On the other hand, the fact that the centric cell has the highest value (58%) indicates that the "convergence" state presents the highest persistence (among all the groups under consideration). Thus, countries with food inflation that is close to the average tend to remain in this state after one-year transition.

The above findings indicate that despite the similarities among the "food" group and the three subgroups, there are also important differences. The fact that the majority of the 25% and 50% HDRs are crossed by the horizontal axis in each group indicates strong inflation convergence trends. However, the distribution of inflation deviation in each product group has its own characteristics and calls for special treatment. A policy for the elimination of inflation differentials among Euro-zone should focus in each product group, in order to efficiently handle its distinct market structure (e.g., geographical separation of the market, differences in which the food subgroup supply chains can absorb external shocks and differences in competitive pressures) and thus to deal with the elimination of inflation differentials.

The results of the analysis also indicate that countries with small inflation deviations from the mean tend to keep this level of deviation after the transition period. On the other hand, the trend of reversion to the mean does not characterize the inflation evolution in all cases. It is usual that countries with high—in absolute values—initial inflation deviation keep these high levels on inflation deviation, after the transition period. Commonly, these countries go from the lower to the higher state of inflation deviation or vice versa ("leapfrogging" and "crisscrossing" phenomena). These findings have an important implication for the EU policy. They suggest that the EU policy should mainly focus in specific countries where high levels of inflation persist, like Greece and Spain. The elimination of food inflation in this group of countries could lead to a higher inflation convergence trend.

6. Summary and Concluding Remarks

This study explores the inflation convergence and the distribution dynamics of food inflation rates for EU-12. The examination of food inflation is of great interest for the researchers and for the planning of monetary and regional

policy schemes. Especially, after the runup in food prices and the global financial crisis, a narrow policy that is only focusing on the general inflation may be misleading. Shifting the focus from the general inflation index to the disaggregated "food" indices can reveal productwise and countrywise characteristics that are not apparent by the examination of the general inflation index. Apart from the "food" group, the inflation rates are also examined for three subgroups: "meat," "vegetables," and "bread and cereals". The data set covers a period from January 1997 to November 2010.

For the examination of food inflation convergence, both stochastic convergence and σ-convergence analyses are implemented. Additionally, nonparametric methods are also applied to study the evolving distribution dynamics of food price inflation rates, using an alternative conditional density estimator and Markov transition matrices. These methods allow the exploration of the entire distribution of relative inflation rates and its dynamics over time.

The examination of stochastic convergence as mean reversion took place for three different subperiods, in order to find some evidence of nonlinearities in the convergence process. Our results show that during the whole period there is no mean reversion for the overall "food" product group whereas the only subgroup where stochastic convergence appears is the "vegetables" group. The situation appears different for the three subperiods. In addition to the panel unit root tests applied, half-lives for the overall and individual products were estimated. The lack of stochastic convergence for the whole period is consistent with the finding of σ-divergence which as a general rule prevails. The different findings of econometric analysis indicate the existence of strong nonlinearities in the convergence process. The latter supports the use of nonparametric methods to examine the existence of convergence.

The application of nonparametric methods and the use of an alternative kernel density estimator with visualizations show that, in general, countries deviating from the mean tend to move backwards to it, after one-year transition period. Hence, unlike the findings of the parametric research, a more detailed nonparametric investigation of distributions supports in general the existence of convergence. Multimodalities and threshold effects in several cases were also detected.

The findings of the distribution dynamics analysis indicate that despite the similarities among the inflation rates of the "food" group and the three subgroups, there are also important differences. The presence of those differences calls for the examination of disaggregated indices in order to capture the maximum available information about the food markets in the Euro-zone and thus to extract consistent policy implications.

To conclude, the empirical evidence from this study emphasizes the necessity of the EU policy to insist in the elimination of inflation deviations. The results also indicate that in order to sufficiently deal with this issue, the suggested policy measures should not be horizontal (applying to all markets and countries), but they should focus on specific group of products and in specific countries that present higher level of inflation.

Appendix

The alternative estimator of the conditional density that has been proposed by Hyndman et al. [14] is given by the following equation:

$$\hat{f}_{\tau}^{*}(y \mid x) = \frac{1}{b}\sum_{i=1}^{n} w_i(x) K\left(\frac{\|y - Y^{*}\|_y}{b}\right), \tag{A.1}$$

where $\hat{f}_{\tau}^{*}(x) = e_i + \hat{r}(x) - \hat{l}(x)$, $\hat{r}(x)$ is the estimator of the conditional mean $r(x) = E(Y \mid X = x)$, $e_i = y_i - \hat{r}(x)$ and $\hat{l}(x)$ is the mean of $\hat{f}_{\tau}^{*}(e \mid x)$. Instead of estimating $\hat{l}(x)$ by the Nadaraya-Watson smoother, many alternative smoothers with better properties could be applied. In this way, an estimator of the conditional density with lower mean-bias properties can be produced. Moreover, as Hyndman et al. [14] showed, the modified estimator has a smaller integrated mean square error than the standard kernel estimator.

Hyndman et al. [14], proposed a local linear density estimator with lower bias. Let

$$R(\beta_0, \beta_1; x, y) = \sum_{i=1}^{n}\left\{K\left(\frac{\|y - Y_i\|_y}{b}\right) - (\beta_0 - \beta_1(X_i - x))\right\}^2 \times K\left(\frac{\|x - X_i\|_x}{a}\right). \tag{A.2}$$

Then, $\hat{f}_{\tau}^{*}(y|x) = \beta_0$ is a local linear estimator, where $\hat{\beta} = (\beta_0, \beta_1; x, y)$ is that value of β which minimizes $R(\beta_0, \beta_1; x, y)$. The fact that the above estimator is not restricted to be nonnegative leads Hyndman and Yao [21] to propose an alternative estimator, the local parametric estimator, which is based on the following modified $R(\beta_0, \beta_1; x, y)$:

$$R(\beta_0, \beta_1; x, y) = \sum_{i=1}^{n}\left\{K\left(\frac{\|y - Y_i\|_y}{b}\right) - \exp(\beta_0 - \beta_1(X_i - x))\right\}^2 \times K\left(\frac{\|x - X_i\|_x}{a}\right). \tag{A.3}$$

This local linear density estimator can be combined with the mean-bias-correction method of Hyndman et al. [14] in order to force the density function to have a mean equal to any prespecified smoother (see [68]).

Acknowledgments

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Endnotes

1. Notable exemptions are (among others) the studies of Lee and Wu [69] and Borio and Filardo [70] that deal with the issue of global inflation rate convergence and the study of Kishor and Ssozi [71], who investigate the issue of inflation convergence within the East African Community (EAC).
2. Levin et al. [12] suggest a three-step procedure to implement LLC test. In step 1, separate ADF regressions for each individual in the panel are carried out and two orthogonalized residuals are generated. The test allows for different lags in each individual. Step 2 requires estimating the ratio of long-run to short-run innovation standard deviation for each individual. This ratio was obtained using the quadratic spectral kernel ([72]) and the Newey and West ([73] automatic bandwidth selection. The final step includes the estimation of the pooled t-statistics.
3. According to Lopez and Papell [2], while it would be desirable to allow for heterogeneous rates of convergence (different b's), the choices are problematic. Several tests that average t-statistics across the members of the panel have been developed. The alternative hypothesis for these tests, however, is that $\rho_i < 0$ for at least one i, which is not economically relevant for investigating convergence among a group of countries.
4. According to Nickell [74], the estimates for β are biased downward for finite samples. So, following Cecchetti et al. [18], we apply Nickell's formula to correct this downward bias.

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