

# Inflation in the Eurozone, Converging and Diverging Countries

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## ABSTRACT

The paper analyses the progress eurozone members made towards the convergence of inflation rates, which is a necessary condition for the effective implementation of the common monetary policy broadly appropriate for all members. It was expected that the common monetary policy would lead to the convergence of member states' economic performance, including inflation rates. The literature review shows that the majority of authors agree that a significant convergence process occurred before 1999, but no further progress was made after that. Our analysis indicates that inflation processes in member countries are diverse. Namely, monetary stability has been achieved in some countries, while inflation is more volatile in others. There is an insufficient correlation between inflation rates, the different transmission of shocks to inflation and different exposure to risks of rising energy and food prices. We conducted a unit root test on the series of inflation differentials for each country to determine which countries were in a process of absolute convergence. In the group of the first 12 members, we found evidence of convergence for the majority of countries, as there is no unit root. Thus, individual countries indeed made progress toward greater monetary stability (and the EMU level). We examined the standard deviations of the inflation differentials in the group of converging countries (separately for converging core and peripheral countries) and found no evidence that these groups of countries are becoming more homogeneous. In the group of new EMU members, we found evidence of convergence towards the EMU average for only four countries in the period of their membership, but not in the previous period.

**Keywords:** *eurozone, inflation convergence, inflation differentials, optimal currency area, common monetary policy*

**JEL Classification:** E31, E42, E58

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## INTRODUCTION

In 1999, the final phase of a unique project in Europe started. The European Central Bank took over responsibility for managing the monetary policy for (at that time) 11 European countries which gave up their currencies and independent interest rate and exchange rate policies in favor of the supranational central bank. In the following years, eight more countries joined, and one new member is expected in 2023. The economic and monetary union (EMU) of the European Union currently has 19 members and the issue that interests many researchers is whether these countries are sufficiently alike to share a common currency.

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However, the eurozone was not an optimal currency area from the very beginning. Some authors believe that the Maastricht convergence criteria are not firmly rooted in economic theory (theory of optimal currency area). Malović and Marinković (2013) particularly criticized the inflation convergence criterion as arbitrarily designed and in line with the aspirations of Germany. Maes (2004) stated that the Maastricht criteria were defined as a result of a compromise between the views of the old and the new theory of optimal currency area (OCA). Old OCA theory lists the conditions that must be satisfied for a country to enjoy the positive net benefits of membership in a monetary union in the long run. These criteria include the absence of greater asymmetry of shocks affecting given countries, a high degree of labor mobility and/or wage flexibility, a centralized fiscal policy that will provide transfers to low-performing countries (Mundell, 1961), high economic openness (McKinnon, 1963), higher diversification of production and consumption (Kenen, 1969), the similarity of inflation rates (Fleming, 1971), higher financial integration (Ingram, 1969) and political will (Mintz, 1970). According to the new OCA theory, the old theory underestimates the benefits of monetary integration, while there are alternative adjustment channels. For instance, although labor mobility in Europe is low, capital mobility is higher and rising. Furthermore, the need to increase the flexibility and adaptability of individual member countries in the monetary union could facilitate structural reforms to improve performance. A common currency can facilitate financial integration, the rise of trade and the harmonization of economic cycles (Emerson et al., 1992). A monetary union can increase the economic integration of members through integration of trade, financial integration, better symmetry of shocks and greater flexibility in labor and goods markets (De Grauwe & Mongelli, 2004).

Thus, it was expected that the environment of monetary union, common currency, and monetary policy focused on monetary stability as well as the necessary reforms would lead to higher integration of the members and convergence of their economic performance. Unfortunately, this did not occur. The EMU was separated into two parts – richer core countries (mostly from Northern Europe) and poorer peripheral countries (mostly from Southern Europe). The financial crisis that started at the end of 2008 revealed the structural weaknesses and polarization of the eurozone (Popović, 2013). Problematic peripheral members needed to undertake deflationary adjustment programs and reforms to restore competitiveness. Were these measures successful in shifting these countries on the path of the EMU in terms of bringing their performance closer to the economic results of the Northern members, so that differences between members narrowed? The enlargement of the monetary union began in 2007 when the first country from the former Eastern bloc joined, followed by others in the following years, after a painful process of transformation from a centrally planned economy and impressive structural reforms. But did that mean the enlargement of a suboptimal monetary union, which might bring higher adjustment costs? Were these new member countries ready and did they manage to adjust to the environment of a monetary union?

Concerning the issues mentioned above, this paper's main purpose is to reveal whether austerity measures and reforms were successful in combating inflation differentials within the EMU. In addition, the following questions arise: Is there a trend of convergence of inflation rates in peripheral countries towards the average EMU level? Do they tend to form a more homogeneous group of countries? If the performance of new members is of interest, have they managed to adjust to the environment of the monetary union? If the inflation rates of the new members are not converging towards the average EMU level, does the increasing proportion of "periphery" countries in the EMU mean that the number of countries for which the common monetary policy is not suitable is rising?"

Answering these questions is of great importance for the management of the common monetary policy. If member countries are very heterogeneous in an economic sense, they will have different needs regarding the common monetary policy, thus making it more difficult for the European Central Bank to manage monetary policy, and it will be less successful and will not suit all members. In addition, if member countries continuously have higher or lower inflation in

comparison to the EMU average, this will increase internal imbalances in the EMU. Persistent inflation differentials are largely the consequence of the differences in business cycles and heterogeneous market structures so that countries are faced with asymmetric shocks. This problem cannot be resolved with monetary policy (or exchange rate policies), but with structural reforms aimed at increasing the flexibility of the domestic economy and relative price and wage changes.

In this paper, we analyze the issue of the convergence of inflation rates. Inflation convergence is not only one of the accession criteria, but also an important criterion that facilitates successful membership in the monetary union. The main goal of the European Central Bank is to maintain price stability, and the ECB conducts its monetary policy with the aim of keeping the inflation rate below, but close to, 2% in the medium term. The ECB manages monetary policy at the average level and cannot adjust it to address the specific needs of individual countries. Thus, members need to be in a position in which the common monetary policy suits them, their inflation rates should be close to the average, the transmission of inflation shocks should not be significantly different and there should be no departures from the business cycles of other member countries (especially the largest economies). This is why, after analyzing the statistical characteristics of the inflation processes in member countries, we examine whether there is a tendency for each member country's inflation rate to converge toward the average EMU inflation rate. We cover the period from 1997 to March 2022, during which the largest efforts to attain monetary stability were made before joining the EMU. Furthermore, the period from 1999 to March 2022 is studied separately to determine whether the convergence achieved in previous years continued after the countries had satisfied Maastricht convergence criteria and joined the EMU. For the countries that entered later (new members), we analyze the convergence in the period after their accession to the EMU until March 2022, as well as the longer period that started 3 years before the individual accession year to capture the effects of preparation reforms. We test the hypothesis of absolute convergence of inflation rates for each member country towards the EMU average for different time periods. The majority of authors that have analyzed the issue of inflation convergence focused on the 12 original members, but it is interesting to study how ex-socialist countries perform in a monetary union environment and which problems they face. This is important information for prospective members which could enable them to avoid mistakes and traps, to decide what reforms are necessary and which path is better to follow.

Furthermore, the large heterogeneity of inflation processes among members complicates the management of the common monetary policy. This issue is especially important in the current period, bearing in mind that inflation rates and inflation differentials have been rising since mid-2021. This might cause further imbalances in the EMU.

## LITERATURE REVIEW

There are various approaches to the issue of inflation convergence analysis. Authors have studied different time horizons and different samples of countries using different methods and indicators. Several authors have found that a convergence of inflation rates was in progress until the introduction of the euro, but this progress subsequently stalled. Popović (2013) focused on the first 12 members to determine whether postulates of the new optimal currency area theory were correct, such that the environment of the EMU and monetary policy oriented towards monetary stability indeed facilitated inflation convergence. She found that there was impressive progress during the 1980s and 1990s, but that progress stopped after the advent of the monetary union and that inflation differentials even rose with the outbreak of the financial crisis in 2008. Estrada et al. (2013) studied inflation convergence in euro-area countries and in several advanced economies outside the EMU. They concluded that there was a significant convergence process in progress before the establishment of the EMU in both groups of countries, which means that the EMU was not the critical factor behind the nominal convergence. For the period 1980–1997, Busetti et al. (2007) found evidence of absolute convergence and concluded that the exchange rate

mechanism facilitated nominal convergence. They also discovered some stability cluster clubs and divisions between low-inflation countries (Germany, France, Austria, Belgium and Finland) and higher-inflation countries (the Netherlands, Spain, Greece, Portugal and Ireland), so although the ECB indeed brought impressive monetary stability, some level of heterogeneity among countries remained. According to Consolo et al. (2021), differences in price levels increased in the EMU from 1999, i.e. prices of goods did not converge, and the dispersion of prices of services increased, reversing the preceding nominal convergence. Franks et al. (2018) also concluded that strong inflation convergence among the first 12 members stopped after the introduction of the euro, partially due to differences in their cyclical position. Some of the members had a larger increase in economic activity and inflation prior to the financial crisis. Small but persistent inflation differentials in peripheral countries, together with fixed exchange rates and very similar nominal interest rates hindered real convergence in these countries.

Some authors came to the opposite conclusion, discovering evidence of convergence in the period after the introduction of the euro. In the group of the first ten members (i.e., without Finland and Austria), Rutjes (2019) found evidence of absolute convergence since the advent of the EMU and that the European Central Bank was very successful in enabling price stability, which is an important issue for further enlargement of the EMU. However, he stressed that it does not mean that the eurozone is an optimal currency area. Broz and Kocenda (2017) discovered convergence of inflation rates in the European Union in the period 1999–2016, and that the inflation rate of new member countries appears to be in sync with old members' rates. According to Broz and Kocenda, monetary policy strategies oriented towards monetary stability were the most influential factor. They also concluded that the eurozone crisis facilitated stronger convergence among some countries, with inflation rates moving towards average levels, but for some EU members, there were diverging trends (Spain, Poland, Luxembourg and Slovenia). Colijn and Brzeski (2022) have a contrary opinion about the performance of the common monetary policy. In their view, in the early years the ECB managed monetary policy too loosely for those countries catching up, such as Ireland and Spain, which had higher inflation rates, leading to the creation of asset bubbles. After the financial crisis started, the common monetary policy was too loose for countries with high monetary stability, such as Germany, but too tight for peripheral countries which needed to undertake structural adjustment reforms.

A number of researchers focused on divisions in the EMU. Franks et al. (2018) stressed the problem of persistent inflation differentials in peripheral member states, especially Greece, Ireland, Portugal and Spain, which led to a decrease in their competitiveness, although these countries accomplished significant monetary stability (in comparison to their historical inflation rates). However, after the adoption of the euro, there was no further convergence progress, and cross-country variations of price levels did not significantly change in the EMU. Karanasos et al. (2016) analysed the convergence process for the first 12 members in the 1980–2013 period and discovered the existence of convergence clubs, while inflation differentials were stationary for some countries both before and after the advent of the euro. Brinke et al. (2015) stressed that there was a mistake in the design of the EMU, as the Maastricht convergence criteria were applied only as accession criteria, but not after the country had joined the EMU. Inflation and interest rate differentials were ignored in the expectation that they would diminish in the long run. This enabled some member states to have higher than average inflation rates continuously. Auray and Eyquem (2021) showed that partial inflation convergence, together with the common monetary policy and the ECB interest rate created a large positive demand shock in peripheral countries, creating pressure on the relative prices of goods and services produced there. The boom in consumption and investment led to current account deficits. Auray and Eyquem showed that if there was a full inflation convergence, the resulting imbalances would be significantly lower and there would be no sizeable rise in relative prices.

Bošković et al. (2013) found significant differences in the inflation process between core and periphery EMU member states. Differences between the peripheral members were found to be

statistically significant, while in the group of core EMU countries, there were no statistically significant differences in inflation rates. Wortmann and Stahl (2016) also focused on the core-periphery division, stressing that it poses problems in managing the common monetary policy as the ECB must decide which group of countries to direct its monetary policy towards since their needs significantly differ. Regling et al. (2010) stressed that this issue is very important for further enlargement of the EMU, as new entrants have lower economic performance and will increase the share of periphery countries in the monetary union. They also might face a longer catch-up process.

## METHODOLOGY

To understand the characteristics of inflation processes in euro-area countries, we used the statistical indicators of mean, median and extreme values, as well as the indicators of dispersion – standard deviation and coefficient of variation (indicators of sigma convergence). These variables address several important issues: is inflation in a certain country “in line” with the average EMU rate, does it tend to exceed it or does it not reach it? What is the variability of the inflation rates – both for individual member states (over time) and for all the members in one period, i.e. how dispersed are the inflation rates? If, in the same period, some countries face very high or significantly higher inflation than average while some others have very low inflation rates, it complicates the management of the common monetary policy. The central bank should increase interest rates to curb rising demand and inflation in high-inflation countries, but that might create problems for countries with lower-than-average inflation. Demand and the inflation rate might drop further in low-inflation countries, creating problems in the real sector of the economy. Directing monetary policy more toward the needs of low-inflation countries will bring problems in the countries with higher inflation rates. It would decrease their real interest rate, further facilitating demand growth and a further rise in inflation. Such actions would lead to a divergence of business cycles in these two groups of countries and a divergence in real terms.

We also applied a unit root test to test the hypothesis of absolute convergence of inflation rates for each country towards the EMU average. Since we wanted to separately capture the influence of preparations for EMU membership and the influence of the monetary union environment, we conducted tests for different time periods – a longer period that started before the accession of a given country and a shorter period that began with the accession year.

## Characteristics of Inflation in Member Countries

The observed 19 countries have diverse inflation rates. Table 1 presents the descriptive statistics of their inflation processes. For most of the countries, the average inflation rate is in line with the ECB target, except for Estonia, Lithuania, Luxembourg and Spain, which have higher than targeted inflation rates. Departures from the average eurozone rates are more significant, and only Ireland has the same average inflation rate as the EMU as a whole, while Belgium is the only country with the same median inflation rate as the euro area. Cyprus has the lowest level of average and median inflation, as this country suffered from a serious deflation for quite a long period of time. The eurozone reached a maximum inflation rate of 7.5% in March 2022 and almost all member states currently face inflation rates, which are at their highest level since their accession. The exception is Malta, which reached a maximum inflation rate the year it entered the EMU. The rise in energy and food prices in 2022 caused different rises in inflation rates, which shows that the member states transmit inflation shocks differently. In some countries, inflation entered the double-digit zone, with the highest rates in Lithuania at 15.6% and Latvia at 14.8%. The Netherlands was also faced with a very high level of inflation of 11.7%, while in Spain, Belgium and Slovakia the inflation rates were close to 10%. The eurozone experienced a minimal inflation rate of -0.6% on two occasions, a consequence of the financial and debt crisis in July 2009 and January 2015. Furthermore, a number of members suffered from significant deflation in the

second half of 2009, but there are differences. For instance, while Austria had negative inflation rates for only two months, Belgium faced deflation for 12 months. The rates were negative for a period of 6 months since mid-2009, and deflation repeated at the very end of 2014 and in the first quarter of 2015, then also for two months in 2020 as a consequence of the COVID crisis and related measures. Germany experienced deflation in 2020 when inflation reached the lowest level of -0.7, with negative rates also being recorded in mid-2009. The worst deflation was in Ireland, Greece and Cyprus, but in different time periods. Whereas Ireland suffered from severe deflation for almost the whole of 2009 (in which time the nadir of -2.9% was reached) and the whole of 2010, inflation in Greece was positive in 2009 and even high in 2010. Greece reached the lowest level of inflation at the end of 2013 and the very beginning of 2015 and struggled with deflation for almost three years from the beginning of 2013 until the end of 2015 and also for six months in 2016. Deflation repeated in 2020 and it was again very serious (-2.4% was the lowest rate) and long-lasting (14 months in a row). The corona crisis brought Ireland 11 months of negative inflation rates.

**Table 1.** Statistical characteristics of inflation in EMU member countries (period of membership)

	Mean, %	Median, %	Max, %	Min, %	SD, %	CV, %
EMU	1.7	1.9	7.5	-0.6	1.1	63.7
Core EMU members						
Austria	1.9	1.8	6.7	-0.4	0.9	50.3
Belgium	2.0	1.9	9.5	-1.7	1.5	73.2
Finland	1.6	1.4	5.8	-0.7	1.2	70.0
France	1.5	1.6	5.1	-0.8	0.9	61.4
Germany	1.6	1.5	7.6	-0.7	1.1	67.4
Luxembourg	2.2	2.3	7.9	-1.6	1.6	72.1
Netherlands	2.0	1.8	11.7	-0.7	1.5	73.4
Peripheral EMU members						
Ireland	1.7	1.7	6.9	-2.9	2.0	119.1
Italy	1.8	2.0	6.8	-1.0	1.2	69.4
Portugal	1.8	2.0	5.5	-1.8	1.5	83.0
Spain	2.1	2.4	9.8	-1.5	1.7	82.5
Greece	1.8	2.1	8.0	-2.9	2.1	119.0
New EMU members						
Slovenia	1.8	1.8	7.0	-1.4	1.9	105.5
Cyprus	1.1	0.8	6.2	-2.9	2.1	192.3
Malta	1.8	1.3	5.7	-0.5	1.3	74.6
Slovakia	1.8	1.7	9.5	-0.9	1.8	101.4
Estonia	2.7	2.9	14.8	-1.8	2.7	99.5
Latvia	1.8	1.8	11.2	-1.1	2.2	120.7
Lithuania	2.4	2.0	15.6	-1.5	3.1	125.6

Source: authors' calculation based on data from ECB, Statistical Data Warehouse, <https://sdw.ecb.europa.eu/browse.do?node=1496>, 27.4.2022

SD-standard deviation

CV-coefficient of variation

The dispersion of the inflation rates, both in individual countries (over time) and among the member countries (in the same period), is very significant. For instance, in March 2022, while in Lithuania, the inflation rate was 15.6%, in Malta, it was "only" 4.6%, i.e., a difference of 11 percentage points. As early as the end of 2021, inflation differentials measured with this indicator were 9% or higher. Furthermore, in May 2010, the inflation rate in Greece was 5.3%, whereas in Ireland it was -1.9%. Significant differences existed even before the 2008 crisis, at the very

beginning of the EMU. For instance, in August 2000 inflation in Ireland was 5.7% and in Germany only 1%. It was rarely the case that the inflation differentials measured with this indicator were smaller than 2% and in no period were they below 1.5%. Although a shortcoming of this indicator is that it takes into account only extreme values, the results are worrying, showing disparities in the EMU which complicate the management of the common monetary policy and cause problems for countries that do not fit “into the average”. The common monetary policy of the EMU is not suitable for all the member states and can even exacerbate their economic problems and divisions in the EMU. The European Central Bank was even accused of managing a more relaxed monetary policy during particular periods to help problematic peripheral countries that struggled with deflation, but obviously, such monetary policy was not sufficiently expansive for them. On the other hand, this caused not only problems with domestic savings, but also a rise in price bubbles and an undesirable increase in money supply in core countries (Wortmann & Stahl, 2016).

### Analysis of the Inflation Convergence – Unit Root Test

To determine whether there are some stability clubs, where some countries indeed have inflation rates converging to the EMU average, we studied the stationarity characteristics of individual inflation differentials for each member country (Petrović & Matić, 2021; Rutjes, 2019; Buseti et al., 2007; Karanasos, 2016; Cuestas et al., 2016). We conducted the unit root test on the series of inflation differentials which were calculated as the difference between the inflation rate in a given country and the EMU average rate. The data on the monthly harmonized index of consumer prices were obtained from the ECB database (ECB, 2022). We used the inflation rate for country  $i$  and time period  $t$ :

$$\pi_{i,t} = \ln(\text{HICP}_{i,t}) - \ln(\text{HICP})_{i,t-12} \quad (1)$$

where  $\ln(\text{HICP}_{i,t})$  represents the natural logarithm of the price level (measured by the harmonized index of consumer prices) for country  $i$  and in period  $t$  (i.e. the inflation rate for the current period), and  $\ln(\text{HICP})_{i,t-12}$  represents the natural logarithm of the price level for country  $i$  one year earlier (i.e. the inflation rate for the same month one year earlier).

A series of inflation differentials was calculated by subtracting HICP for the eurozone in time period  $t$  ( $\pi_{t\text{EMU}}$ ) from the inflation rate in country  $i$  and time period  $t$  ( $\pi_{i,t}$ ):

$$d_{i,t} = \pi_{i,t} - \pi_{t\text{EMU}} \quad (2)$$

We conducted the unit root test (Augmented Dickey-Fuller test) without intercept to analyze the presence of absolute convergence. Absolute convergence means that inflation differentials tend to zero in the long term. This is a more desirable situation than relative convergence (when inflation differentials tend to some level different from zero in the long term), as it eases the common monetary policy. The existence of relative convergence means that only members that have similar characteristics converge, which might lead to polarization in the EMU (Busetti et al., 2007). The results are presented in Tables 2-6. Tables 2 and 3 present the test results for the core countries, Tables 4 and 5 for the peripheral countries and Table 6 for the new member countries, as we also wanted to determine whether there are differences between these 3 groups of countries. The first column in all the tables presents the results for the period that begins in 1997, and the second one for the period of membership (for each country, this period is different, beginning with their accession year). The third column in Table 6 presents the test results for the period that started 3 years before the accession of a given country in the EMU.

If there is a convergence of inflation rates of a given country, the inflation differentials will tend to zero. In this case, the series of inflation differentials will be stationary. The results that confirm the existence of a unit root at the 5% confidence level are highlighted in the tables.

**Table 2.** Absolute convergence of inflation rates in core eurozone countries – Unit root test of inflation differentials

		1.1997-3.2022		1.1999-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.
Belgium					
Augmented Dickey-Fuller test statistic		-1.98015	0.0458	<b>-1.7065</b>	0.0833
Test critical values:	1% level	-2.57296		-2.57369	
	5% level	-1.94192		-1.94202	
	10% level	-1.61597		-1.6159	
Finland					
Augmented Dickey-Fuller test statistic		-2.74544	0.0061	-2.42209	0.0152
Test critical values:	1% level	-2.57264		-2.57331	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61594	
France					
Augmented Dickey-Fuller test statistic		<b>-0.3097</b>	0.5735	<b>-0.291</b>	0.5804
Test critical values:	1% level	-2.57267		-2.57334	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61593	
Germany					
Augmented Dickey-Fuller test statistic		-3.05216	0.0023	-3.04031	0.0024
Test critical values:	1% level	-2.57267		-2.57334	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61593	
Luxembourg					
Augmented Dickey-Fuller test statistic		-2.7488	0.006	-2.58305	0.0097
Test critical values:	1% level	-2.57296		-2.57369	
	5% level	-1.94192		-1.94202	
	10% level	-1.61597		-1.6159	
Netherlands					
Augmented Dickey-Fuller test statistic		-2.08549	0.0358	-2.074	0.0368
Test critical values:	1% level	-2.57264		-2.57331	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61594	
Austria					
Augmented Dickey-Fuller test statistic		-1.96995	0.0469	-1.95312	0.0488
Test critical values:	1% level	-2.57296		-2.57369	
	5% level	-1.94192		-1.94202	
	10% level	-1.61597		-1.6159	

Source: authors' calculation based on data from ECB, Statistical Data Warehouse, <https://sdw.ecb.europa.eu/browse.do?node=1496>, 27.4.2022

Table 2 presents the results of the Augmented Dickey-Fuller test, which tests the null hypothesis that a time series has a unit root. The results show that there is no unit root in the series of inflation differentials for Germany, Austria, the Netherlands, Finland and Luxembourg at the 5% confidence level for both periods, i.e., the countries that have been in the process of absolute convergence of inflation rates towards the EMU average since 1997. We can determine whether these countries represent a "stability club", with converging inflation rates, from Table



3, which provides the results of testing the existence of a unit root in the series of inflation differentials within these five countries:

**Table 3.** Convergence of inflation rates in the group of five core eurozone countries – Unit root test of inflation differentials and standard deviations of inflation differentials

Inflation differentials		1.1997-3.2022		1.1999-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-3.75436	0.0002	-3.46531	0.0006
Test critical values:	1% level	-2.57264		-2.57331	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61594	
Standard deviations of inflation differentials					
Augmented Dickey-Fuller test statistic		<b>-0.30578</b>	0.575	<b>-0.34218</b>	0.5612
Test critical values:	1% level	-2.57267		-2.57334	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61593	

Source: authors' calculation based on data from ECB, Statistical Data Warehouse, <https://sdw.ecb.europa.eu/browse.do?node=1496>, 27.4.2022

The ADF  $\tau$  statistics were found to be -3.75 (for the first period) and -3.47 (second period), which is below the critical value of  $\tau^k$  (-1.94) at the 5% confidence level. In both periods, the p values are very low. Thus, the results show there is no unit root in the series of inflation differentials among the observed group of countries, and the inflation differentials have a decreasing tendency. To determine whether this tendency is actually a result of converging inflation rates or the consequence of inflation rates of a different sign (if some countries have positive inflation rates while others have negative rates at the same time, the inflation differentials will be lower), we conducted an additional ADF test for the series of standard deviations of the inflation rates. If the differences between the countries tend to decrease, there will be no unit root in the series. The existence of a unit root would show that the inflation rates among the observed group of countries are not mutually converging. The results obtained reveal the presence of a unit root; thus, the inflation rates in the group of five core countries are not less dispersed.

The series of inflation differentials for France (Table 2) has a unit root, while the ADF  $\tau$  statistics were found to be -0.31 (for the first period) and -0.29 (second period), which is above the critical value of  $\tau^k$  (-1.94) at the 5% confidence level. Both p values are very high, indicating a high probability of rejecting the correct null hypothesis. For Belgium, the obtained results show no unit root in the longer period, i.e., inflation convergence was in progress from 1997, but with the accession to the EMU this changed, as there is a unit root for the period of membership. The obtained value of the ADF  $\tau$  statistics was found to be higher than that of  $\tau^k$  (-1.94) at the 5% confidence level.

The results of the ADF test for the group of peripheral member countries are presented in Table 4.

**Table 4.** Absolute convergence of inflation rates in peripheral eurozone countries – Unit root test

Ireland		1.1997-3.2022		1.1999-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		<b>-1.93803</b>	0.0504	<b>-1.8649</b>	0.0594
Test critical values:	1% level	-2.57264		-2.57331	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61594	
Italy		1.1997-3.2022		1.1999-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-3.1831	0.0015	-3.14977	0.0017
Test critical values:	1% level	-2.57269		-2.57337	
	5% level	-1.94189		-1.94198	
	10% level	-1.61599		-1.61593	
Portugal		1.1997-3.2022		1.1999-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-3.05422	0.0023	-3.15867	0.0017
Test critical values:	1% level	-2.57264		-2.57331	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61594	
Spain		1.1997-3.2022		1.1999-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-2.35793	0.018	-2.19967	0.0271
Test critical values:	1% level	-2.57264		-2.57331	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61594	
Greece		1.1997-3.2022		1.1999-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-2.76364	0.0057	-1.96778	0.0472
Test critical values:	1% level	-2.57267		-2.57413	
	5% level	-1.94188		-1.94208	
	10% level	-1.616		-1.61586	

Source: authors' calculation based on data from ECB, Statistical Data Warehouse, <https://sdw.ecb.europa.eu/browse.do?node=1496>, 27.4.2022

The augmented Dickey-Fuller test for the peripheral countries indicates the tendency of individual countries' inflation rates to converge towards the EMU average for both periods, except in the case of Ireland. We also tested the hypothesis that the inflation rates in the peripheral countries converge without including Ireland. The results are presented in Table 5:

**Table 5.** Convergence of inflation rates in the group of four peripheral eurozone countries – Unit root test

Inflation differentials		1.1997-3.2022		1.1999-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-2.26635	0.0228	-2.35683	0.0181
Test critical values:	1% level	-2.57267		-2.57334	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61593	
Standard deviations of inflation differentials					
Augmented Dickey-Fuller test statistic		<b>-1.79797</b>	0.0687	<b>-1.21813</b>	0.2046
Test critical values:	1% level	-2.57267		-2.57334	
	5% level	-1.94188		-1.94197	
	10% level	-1.616		-1.61593	

Source: authors' calculation based on data from ECB, Statistical Data Warehouse, <https://sdw.ecb.europa.eu/browse.do?node=1496>, 27.4.2022

The results confirm that there is no unit root in the series of inflation differentials for both periods. However, testing the series of standard deviations of inflation rates showed opposite results. Thus, we can conclude that the inflation processes within this group of countries are also not becoming more homogeneous. There is no tendency to diminish the dispersion of the inflation rates, although for individual countries, there has been progress in inflation convergence.

**Table 6.** Absolute convergence of inflation rates in new eurozone countries – Unit root test

Slovenia		1.1997-3.2022		1.2007-3.2022		1.2004-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		<b>0.77242</b>	0.8798	-3.12914	0.0019	<b>0.22643</b>	0.751
Test critical values:	1% level	-2.57293		-2.57773		-2.57618	
	5% level	-1.94192		-1.94258		-1.94237	
	10% level	-1.61597		-1.61554		-1.61568	
Cyprus		1.1997-3.2022		1.2008-3.2022		1.2006-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		<b>-0.3552</b>	0.5564	-3.21001	0.0015	<b>-0.4817</b>	0.5062
Test critical values:	1% level	-2.57262		-2.57864		-2.57618	
	5% level	-1.94187		-1.94271		-1.94237	
	10% level	-1.616		-1.61546		-1.61568	
Malta		1.1997-3.2022		1.2008-3.2022		1.2006-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		<b>-0.9989</b>	0.2849	-2.56877	0.0103	<b>-1.206</b>	0.2084
Test critical values:	1% level	-2.57262		-2.57864		-2.57618	
	5% level	-1.94187		-1.94271		-1.94237	
	10% level	-1.616		-1.61546		-1.61568	
Slovakia		1.1997-3.2022		1.2009-3.2022		1.2006-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		<b>0.39574</b>	0.7973	-2.40124	0.0163	<b>0.962</b>	0.9107
Test critical values:	1% level	-2.57257		-2.57968		-2.57706	
	5% level	-1.94187		-1.94286		-1.94249	
	10% level	-1.616		-1.61537		-1.6156	
Estonia		1.1997-3.2022		1.2011-3.2022		1.2008-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		<b>0.26132</b>	0.7612	<b>0.10102</b>	0.713	<b>0.47632</b>	0.8168
Test critical values:	1% level	-2.57272		-2.58233		-2.57888	
	5% level	-1.94189		-1.94323		-1.94275	
	10% level	-1.61599		-1.61513		-1.61544	

Latvia		1.1997-3.2022		1.2014-3.2022		1.2011-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		<b>0.37863</b>	0.7929	<b>-0.4011</b>	0.5368	<b>2.37605</b>	0.9958
Test critical values:	1% level	-2.57257		-2.58877		-2.58208	
	5% level	-1.94187		-1.94414		-1.94319	
	10% level	-1.616		-1.61458		-1.61516	
Lithuania		1.1997-3.2022		1.2015-3.2022		1.2012-3.2022	
		t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		<b>0.66412</b>	0.8589	<b>1.06307</b>	0.9238	<b>5.39311</b>	1
Test critical values:	1% level	-2.57272		-2.59245		-2.5839	
	5% level	-1.94189		-1.94467		-1.94345	
	10% level	-1.61599		-1.61426		-1.615	

Source: authors' calculation based on data from ECB, Statistical Data Warehouse, <https://sdw.ecb.europa.eu/browse.do?node=1496>, 27.4.2022

The results in Table 6 confirm that the new members struggled with high inflation during the 1990s and early 2000s. All the individual series of inflation differentials since 1997 have a unit root. Furthermore, if we look at the results of the ADF test for the period that started 3 years before a given country's accession to the EMU, the conclusion is the same. To some extent, this was not expected, since, in the case of the old members, the highest efforts to reach monetary stability and to satisfy Maastricht criteria were made before joining the EMU. In this case, monetary stability did not precede accession. In some of the observed countries, inflation rates were very high in the period immediately before accession, and in others very low or negative. Over time, Slovenia, Cyprus, Malta and Slovakia managed to bring their inflation rates more in line with the EMU average rate. The ADF  $\tau$  statistics for these countries were found to be below the critical value of  $\tau^k$  (-1.94) at the 5% confidence level. The series of inflation differentials for Estonia, Latvia and Lithuania for the period of their membership have a unit root, which indicates the lack of convergence.

## CONCLUSION

Inflation convergence is not only one of the criteria to join the EMU, but also a condition for successful membership of the monetary union. If an individual country has inflation rates that deviate significantly from the EMU average over a long period, this would be the result of structural factors which could not be addressed with the monetary policy. Such differences cause problems for the diverging country. A country with higher inflation will lose competitiveness since the exchange rate can no longer adjust to differences in inflation between the observed country and its main trading partners. It will lose markets and import more goods it previously produced, which will lead to an increase in the current account deficit. Financing this deficit would be a problem as the country earns less from its decreasing exports, so it will have to borrow, thus increasing debt. Its higher inflation will mean lower real interest rates, which will additionally facilitate borrowing and higher demand, thus raising the inflation rate further. This might lead to divergent business cycles and real divergence. If a country has significantly lower inflation than the EMU average, this might also harm its economy, while the common monetary policy could prolong economic stagnation or recession and make the environment of low inflation last longer, again leading to divergent business cycles and real divergence.

The above analysis has shown that EMU member countries have diverse inflation rates. Although in the majority of cases, the average and median inflation rates tend to be within the ECB target, they are not so close to the EMU average, showing larger inflation differentials. The indicators of sigma convergence reveal larger dispersion both for individual countries over time and between the member countries in the same period. Some countries managed to have stable prices, while for others inflation was much more volatile. Extreme values of inflation were reached

in different time periods, indicating an insufficient correlation between their inflation rates. In addition, the transmission of shocks to inflation differs; countries are differently exposed to rises in energy and food prices. While for some countries, we have an effect that fades after several months, for others the shock still influences inflation rates after a year, which facilitates divergence of inflation rates. This complicates the management of the common monetary policy, and it will not suit the needs and economic situation of all countries, bringing further problems for their economies.

A method often used to analyze the convergence of inflation rates is the unit root test. The logic behind it is simple: if inflation rates tend to approach each other, differences between them will diminish. This means that inflation differentials will have a decreasing tendency. They should tend towards zero and the dispersion around average inflation differentials should also tend to zero. We can conduct such an analysis to assess if a group of countries is becoming more homogeneous, i.e., their inflation processes are more alike, and we can also analyze the inflation differentials of each country. We have chosen the second approach in this paper – to test the hypothesis of absolute convergence of inflation rates of each country to the EMU average. We wanted to find out whether there are some stability clubs, such that some countries have inflation rates converging to the EMU average. In the group of core eurozone countries, only the series of inflation differentials for France has a unit root in both periods, and thus we cannot say that inflation in this country is converging to the EMU average. Although in Belgium inflation convergence was in progress from 1997 on, this changed with accession to the EMU. The results obtained for Germany, Austria, the Netherlands, Finland and Luxembourg at the 5% confidence level and for both periods show that these countries were in the process of absolute convergence of inflation rates towards the EMU average from 1997 on. However, although the ADF test for inflation differentials in this group shows the absence of a unit root, the test on the series of standard deviations appeared to have a unit root. This means that there is no statistically significant trend of decreasing differences in the inflation rates in this group of five countries. The results for the group of peripheral countries for both periods indicate the absolute convergence progress of Italy, Portugal, Spain and Greece towards the EMU average. In the case of Ireland, however, a unit root was found in the series of inflation differentials. As in the previous case, there is no statistically significant progress in decreasing the differences between the inflation rates of these four countries, thus indicating their inflation processes are not becoming more homogeneous. The results obtained for the group of new EMU members confirm problems with high inflation in the period preceding their accession. It was expected that they would achieve monetary stability immediately before membership, but the results show insufficient progress. However, results for Slovenia, Cyprus, Malta and Slovakia confirm the existence of absolute convergence in the period of their membership. For Estonia, Latvia and Lithuania, there was no convergence of inflation rates in any of the observed periods, and these countries are suffering from very high inflation at this time. Thus, it is questionable whether they were indeed ready for membership in the EMU. Perhaps it would have been better to wait until they had implemented the necessary reforms and achieved a sufficient level of convergence in their economic performance to be ready for the common monetary policy.

This issue is very important at the moment since inflation rates have been on an upward trend since mid-2021. The European Central Bank has still not increased its main refinancing rate to make money more expensive, but responded by curbing its provision of liquidity. It is not known whether this will be sufficient to cut inflation, which is steadily progressing towards the double-digit level. The ECB has explained that the rise in inflation is transient and that it will go back to lower levels in the second half of the year. Perhaps the ECB expects a very serious economic crisis and recession, which will decrease demand and, thus, inflation rates. Therefore, it perhaps fears that its increasing interest rates will hurt the economy the moment it faces economic problems due to the war in Ukraine and sanctions against Russia. But what will this situation mean for inflation rates in individual countries? Will they diverge even more as is currently going on? One of the most important costs of monetary union is associated with asymmetric shocks, and member

countries are currently facing this problem. What the EMU is likely to face is a period of stagflation, i.e. the simultaneous occurrence of inflation and stagnation or even recession. In such circumstances, the ECB will be faced with a choice: inflation or the economy. Since its main objective is to control inflation, and economic progress in an environment of high inflation is not possible, it will probably choose to curb high inflation at the price of having an economic recession. How will individual countries cope? If they are not sufficiently alike, we could expect that they will be impacted differently by ECB measures and the current economic and inflation shocks, which might fuel divergence in the EMU, complicating the management of the common monetary policy even further.

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