INFLATION PERSISTENCE AND UNIT ROOT TESTS IN THE EURO AREA COUNTRIES

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Abstract: *Persistence is one of the main characteristics of inflation. One of the definitions of persistent inflation is, that it is the rate at which inflation reaches equilibrium after a certain macroeconomic shock. If the inflation persistence is high, the response to inflation shocks is long-lasting and difficult for the central bank to control. Conversely, if the country's inflation persistence is low, the central bank can keep the inflation rate in line with the inflation target. The recent economic crisis made central banks adopt several unconventional monetary policy instruments to boost economic recovery and preserve price stability. Many authors note that data on stationary inflation in the euro area countries is a precondition for joining the European Union. As far as the functioning of the European Union is concerned, it is desirable to take the necessary decisions. The primary objective of the paper is to test the inflation rate data in the euro area countries to verify the existence of a unit root considering that central banks design their monetary policy frameworks under the assumption that inflation is a stationary process. The verification of the stationarity of the inflation data is divided into two sections. In the first section, the monthly data panel of the Harmonised Index of Consumer Prices (HICP) for euro-zone countries is used. The second section uses a panel of monthly data the Harmonised Index of Consumer Prices for each category of Classification of Individual Consumption by Purpose for euro area countries. Our results indicate that time series for inflation in 11 of 19 euro area member countries are non-stationary and have a unit root. Considering our results we propose the creation of a two-speed euro area and the adjustment of the monetary policy framework in the euro area countries.*

Keywords: *Inflation persistence, unit root tests, euro area countries.*

JEL Classification: *E31, E52.*

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Introduction

With the creation of EMU (Economic and Monetary Union), new economic conditions were also created. Before entering the euro area, the EU (European Union) member states must fulfill the convergence criteria (or "Maastricht convergence criteria"), which are based on economic indicators and they must continue to respect them once entered. One of the criteria is the price stability and height of the inflation rate. Together with the creation of a new economy, the topic of examining inflation persistence has become actual, particularly over the past decades. Inflation persistence is one of the most important parameters influencing the conduct of monetary policy. The central bank is interested in the degree of inflation persistence to improve inflation forecasting and reliably estimate the dynamic responses of inflation to shocks. The persistence of inflation is known to have a strong impact on monetary policy. If there is considerable inertia in inflation, then inflation shocks take a long-lasting nature and

make it difficult for the central bank to control it. On the other side, if persistence is significantly low and inflation expectations dominate inflation, then-current inflation can be effectively influenced through the management of inflation expectations by a central bank. Reducing inflation persistence may be a result of a better monetary policy. Inflation targeting has become one of the cornerstones of several central banks' monetary policies. The conduct of monetary policy in this economy is an important and not an easy task for policymakers, as this policy must be comprehensive. It is desirable to make the right decisions for the functioning of the euro area. However, the recent economic crisis made banks adopt several non-conventional instruments. The recent economic crisis has caused the gross domestic product to fall, unemployment to rise and inflation to rise. The ongoing period of deflationary pressures has been a response to the deteriorating impact of the economic crisis on the macro-economic performance of euro area countries. At the end of that period in late 2016, with higher inflation, during which the European Central Bank's key interest rates were still close to zero, focus the attention of economists on inflation, its features, and its ability to respond to various economic shocks. In the context of a low-inflation economy, banks responded with the aim of economic recovery and price stability by adopting several unconventional instruments. These adopted non-standard monetary policy measures have made it necessary and desirable, to change the approach to the conduct of monetary policy.

Some authors researched and tested the nonlinearities in inflation dynamics of countries that were candidates to join the EU. Nowadays, the conditions of the EU are changing, however, in the development of the inflation rate we can see the inflation persistence. Inflation persistence can weaken the success of monetary authorities in achieving a stable inflation rate when it is below or above the target level. The main objective of our research is to test and point out the stationarity in the inflation rate data of the euro area countries by applying unit root tests. The reason for the research is that inflation persistence and inflation targeting have emerged as one of the cornerstones of central bank monetary and central banks conceive of monetary policy on the premise that inflation is a stationary process. We pointed out that there is non-stationarity in data of inflation.

The article is organized as follows. After the initial section provides a summary of the theoretical background about inflation persistence based on the literature review (Section 1) we outline the employed methodology and data used in the empirical part of the article (Section 2). In Section 3 we conduct the research, summarize the key results and compare them with the outcomes of the most crucial empirical studies in the field of research. In the last concluding section, we outline the proposed idea of the concept of a two-speed euro area.

1. Theoretical Background

Inflation of persistence was researched by many authors with a different purpose. Meller and Nautz (2012) researched the level of inflation persistence in euro area countries before and after the third stage of the Economic and Monetary Union – the adoption of the single currency. The main objective of the ECB is to maintain price stability. This is the main reason for analyzing the degree of inflation persistence. By analyzing inflation persistence, central banks seek to improve inflation forecasts by responding dynamically to inflation shocks. A certain degree of inflation persistence has a strong impact on the conducting of monetary policy. This is also the reason why the degree of inflation persistence is increasingly used as an indicator of a country's monetary policy. Willis (2002) defined the degree of persistence as the rate at which inflation moves towards the inflation target following a certain monetary shock. If the inflation persistence is high, then the shocks that could hinder the controllability of inflation, have a long duration. Conversely, if the inflation persistence is low, the central bank can be more effective in monetary policy and the inflation target can be achieved more quickly (Marques, 2004; Roache, 2014). Inflation expectations are another important variable in monetary policy-making. Inflation expectations and better central bank monetary policy may also lead to low persistence in inflation (Benati, 2008). Inflation persistence then reflects the tendency of inflation to slowly approach its long-term value in response to such shocks. Fuhrer (2010) in his analysis mentions two groups of inflation persistence. First, he defines a reduced form of inflation persistence, noting that it is not necessary to know its sources and causes when estimating

the reduced form of inflation persistence. Conversely, when examining the structural form of inflation persistence, it is important to focus on its sources and causes, such as different exogenous shocks. Angeloni et al. (2006) in their study distinguished between internal and external inflation persistence.

Studies by Nelson and Plosser (1982), Pivetta and Reis (2007), and Fuhrer and Moore (1995) reveal a high degree of inflation persistence after the Second World War. These authors emphasized that to achieve the inflation target, the central bank should respond much more than with a low inflation persistence. Caporin and Gupta (2017) examined the inflation persistence during recessions and expansions. Research has shown that inflation persistence changes during structural changes in the economy; it is higher in periods of growth than in periods of recession. This conclusion is also beneficial for the political direction of the country.

There were differences in inflation during the period of different monetary regimes in OECD countries in the period after the Second World War, based on the model of the inflation process. It could lead to higher inflation by adjusting to price shocks, but an accommodating monetary policy leads to low inflation. However, accommodative monetary policy should not be applied for a long period, as this could lead to negative and undesirable results (Alogoskoufis, 1992).

Kočenda and Papell (1997) analyzed the effects of the convergence of inflation rates in the member states of the European Union. They showed that the Exchange Rate Mechanism supported faster convergence of inflation in member states. Baxter and Stockman (1989) dealt with the question of whether the change in the nominal exchange rate regime would have any real effect. According to their study, the real exchange rate is the only macroeconomic aggregate consistently dependent on the exchange rate system. They found no significant evidence that the business cycle behavior of real production, consumption, trade flows, and government systematically depends on the type of nominal exchange rate regime. According to their study, it is unclear whether the exchange rate should contribute to the reduction of inflation within the group of countries participating in the exchange rate mechanism and lead to inflation convergence over time. Anderton (1997), and Kočenda and Papell (1997) investigated inflation persistence in ERM member and non-member countries. Anderton (1997) used the unit root test and the *F*-test, concluding that deflationary policies could lead to a reduction in the level of inflation, but that ERM membership was not sufficient to achieve the inflation target. One of the conclusions of Kočenda and Papell (1997) based on the sensitivity analysis is that the process of inflation persistence was not significantly affected by the crisis in the ERM from 1992 to 1993.

Alogoskoufis and Smith (1991) examined inflation persistence during the variable and fixed exchange rate periods. For the countries of Great Britain and the USA, they applied an autoregressive estimate of the coefficients for the annual change in the gross domestic product deflator. A simple regression suggests that with floating exchange rates, inflation is more persistent, and it is more likely that monetary policy will adjust to the inflation shock compared to a period with a fixed exchange rate. A year later, Alogoskoufis (1992) applied the same method to OECD countries, confirming the previous conclusion. Like Alogoskoufis (1992), Obstfeld et al. (1995) examined the inflation persistence during floating and fixed exchange rates, for example in twelve OECD countries. The research concludes that during the period with a floating exchange rate the inflation persistence is higher than during the period with a fixed exchange rate. The exception was the United States, in which the Bretton Woods monetary system was based, using fixed exchange rates. Wu and Wu (2018), like the above-mentioned authors, examined the inflation persistence during periods of variable and fixed exchange rates. They found that inflation persistence depends on the exchange rate regime, not internal inflation persistence but partly on external. In their article, the authors used unit root panel tests – unit root regression and a dynamic panel model.

In their research, Canarella and Miller (2017) examined the inflation persistence in various developed and emerging countries in comparison with the United States economy and the German economy. Using fractional and cointegration methods, they concluded that the three developed countries examined (Canada, Sweden, and the United Kingdom) have a common inflation persistence compared to the American and German economies, and

are therefore fractionally integrated. In the case of developing countries (Chile, Israel, and Mexico), it is not possible to speak of the same inflation persistence in the American and German economies. Gajewski (2018) examined the inflation persistence in the quarterly data of the CPI of Poland as a representative of the region of Central and Eastern Europe. The data series of the CPI index used was at the NUTS 2 level (level of basic regions) for the years 2015 to 2016. The author of the research used unit root tests. The results pointed to the fact that inflation persistence is higher in the eastern (backward) part of Poland than in the western part of the country. The visible difference between housing, transport, health, and other categories also points to the fact that inflation persistence depends on the response of current inflation to the shocks and shocks of the past. These shocks and the reaction to them divide the country of Poland as a representative of the CEE region into an eastern – backward and western – more developed part. Levin and Piger (2004) are other authors examining inflation persistence in various developed countries. In their study, they focused on a group of twelve industrial economies (Australia, Canada, France, Germany, Italy, Japan, New Zealand, the Netherlands, Switzerland, Sweden, the United Kingdom, and the USA) and characterized the behavior of inflation dynamics in these countries using classical and Bayesian econometric methods. The analysis focuses on the period from 1984 to 2003 using four basic price indicators: the personal consumption expenditure price index, the GDP deflator, the consumer price index, and the basic consumer price index. The results of econometric models suggest that high inflation persistence is not an internal characteristic of the studied industrialized countries. The hypothesis was rejected at a 95% confidence interval for both methods used.

A study by Kočenda and Varga (2017) examined structural pauses in persistent inflation as an endogeneity in policy strategies regarding persistence itself. Kanellopoulos and Koutroulis (2016) showed that the degree of inflation persistence depends on the size of the difference between the inflation rate and the ECB's inflation target. According to their study, stabilization policy can have long-lasting effects.

The literature review shows that inflation persistence is affected by the monetary policy regime, different phases of the economic cycle, exchange rate regime, the size of achieving price stability, and the CB's interest rate policy.

At the time of the formation of the euro area, the authors tested the unit root of inflation – one of the criteria, which must be fulfilled at a certain level. Cuestas and Harrison (2010) applied unit root tests to show that inflation rates in more than half of the tested countries are stationary. They researched inflation rate data of Central and Eastern European countries. For analysis of panel data, they used the Augmented Dickey-Fuller test, Im-Pesaran-Shin test, Levin-Lin-Chu test, and Phillips-Perron test.

2. Data and Research Methodology

The research aims to test the stationary of inflation in euro area countries. Our research consists of two parts. In the first part, we used a panel of monthly data the Harmonised Index of Consumer Prices for euro area countries from 1997/01 to 2021/07. In the second part of the research, we used a panel of monthly data the Harmonised Index of Consumer Prices for each category of Classification of Individual Consumption by Purpose for euro area countries from 1997/01 to 09/2021 (Eurostat, 2022).

The Harmonised Index of Consumer Prices is the key indicator of inflation and price stability, which is taken into account by the European System of Central Banks and the European Central Bank in the conduct of monetary policy in European countries. Harmonised Indices of Consumer Prices (HICPs) have started to be compiled to ensure the comparability of consumer price indices of individual countries within the European Union. The index is calculated as a "Laspeyres type price index" on the basis of the prices of the services available for purchase within the economic territory of each Member State of the European Union to directly meet the needs of consumers (final consumption) according to the Classification of Individual Consumption by Purpose. It includes the categories listed in Tab. 1.

To achieve the most detailed results as the data set for the second part of our analysis we used the HICP index in the annual rate of change according to COICOP categories. The data set used in our analysis is obtained from the Eurostat database for euro area countries (Belgium, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Austria,

Tab. 1: Categories of classification of individual consumption by purpose

	Category of COICOP
1.	Food and non-alcoholic beverages
2.	Alcoholic beverages, tobacco and narcotics
3.	Clothing and footwear
4.	Housing, water, electricity, gas and other fuels
5.	Furnishings, household equipment and routine household maintenance
6.	Health
7.	Transport
8.	Communications
9.	Recreation and culture
10.	Education
11.	Restaurants and hotels
12.	Miscellaneous goods and services

Source: Eurostat, 2021

Portugal, Slovenia, Slovakia, Finland) for the period from 1997 to 2021 in monthly observations.

To provide an insight into the inflation dynamics of euro area countries we apply unit root tests. The main unit root tests include Dickey-Fuller (DF) test, the Augmented Dickey-Fuller (ADF) test, Phillips-Perron (PP) test, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. To avoid the problem of autocorrelation, we use the ADF test, PP test, and KPSS test (Dickey & Fuller, 1979; Phillips & Perron, 1988; Kwiatkowski et al., 1992).

The formula for estimating the Augmented Dickey-Fuller test is:

$$\Delta x_t = \pi x_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta x_{t-i} + \varepsilon_t \quad (1)$$

where the validity of the following hypothesis is verified $x_t = x_{t-1} + \varepsilon_t$ where $\varepsilon_t \sim NID(0, \sigma^2)$. The augmentation $(k > 0)$ does not impact the asymptotic distribution of the test statistical. $\hat{\pi}$ will be distorted negatively in a small sample, only a one-sided test is required for determination *H0:* $\pi = 0 (x_t \sim I(1))$ against *H1:* $\pi < 0 (x_t \sim I(0))$ (Sjö, 2019).

Alternatives to the ADF test are the PP test and the KPSS test. The KPSS test has a null hypothesis set so that the variable is stationary. The Phillips-Perron test has *I*(1) as the maintained hypothesis, but it allows alternative segmented deterministic trends. The alternative hypothesis of the ADF test only permits deterministic, quadratic or linear trends within the analyzes period. The Phillips-Perron test attempts to identify ways to resolve gaps white noise in the estimated model. The goal of these tests is to adjust the estimated statistical tests to better fit the simulated DFs values by expanding the Dickey-Fuller model with lagged dependent variables or trying to adjust statistical tests and introduce new (simulated) critical values (Sjö, 2019).

By applying unit root tests to the data set of euro area countries we test the null hypothesis of non-stationary inflation in the euro area against to alternative hypothesis of stationary inflation in euro area countries.

Breitung test, Hadri test, Im-Pesaran-Shin (IPS) test, and Levin-Lin-Chu (LLC) test are other unit root tests that are used in our research. The Breitung, Im-Pesaran-Shin, and Levin-Lin-Chu tests have the null hypothesis that all the panels have a unit root. The Hadri test is based on the null hypothesis that all the panels are (trend) stationary (Hadri, 2000; Breitung, 2001; Levin et al., 2002; Im et al., 2003).

Levin et al. (2002) have an alternative hypothesis of the test that the ρ_i are identical and negative. In the Levin-Lin-Chu test ρ_i is fixed across *i*, so this is one of the most

complicated of the tests because the data from the different individuals need to be combined into a single final regression.

Im et al. (2003) designed the test statistic, which is the cross-section average of the corrected *t*-statistics:

$$IPS_{t,m}(\mathbf{p},\gamma) = \frac{\sqrt{N}\left\{\bar{t}_m - \frac{1}{N}\sum_{i=1}^{N}\mathrm{E}(t_{iT,m}(p_i,\mathbf{0})|\rho_i=1)\right\}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}Var(t_{iT,m}(p_i,\mathbf{0})|\rho_i=1)}} \Rightarrow N(0,1) \quad (2)$$

where $\bar{t}_m = \frac{1}{N}\sum_{i=1}^{N} t_{iT,m}(p_i,\gamma_i)$, $\mathbf{p} = [p_1,\ldots,p_N]'$ and $\gamma = \left[\gamma_1',\ldots,\gamma_N'\right]'$. The correction coefficients $\mathrm{E}(t_{iT,m}(p_i,\mathbf{0})|\rho_i = 1)$ and $Var\left(t_{iT,m}(p_i,\mathbf{0})\middle|\rho_i = 1\right)$ are simulated for $m = 2, 3$ for a set of values for lag lengths *p* and for *T*.

The expression:

$$H_{LM,m} = \frac{1}{NT^2}\sum_{i=1}^{N}\sum_{t=1}^{T}\frac{S_{it}^2}{\hat{\sigma}_{ei}^2} \quad (3)$$

with $\hat{\sigma}_{ei}^2 = {}^{1}\!/_{T}\sum_{t=1}^{T}\hat{e}_{it}^2$ can be displayed as the principle of the Hadri (2000) test.

3. Research Results

This chapter includes the results of analysis unit root tests.

3.1 Results of Panel Data Analysis and Individual Unit Root Tests for Countries of the Euro Area (HICP Index)

In the first part of our analysis, we use data on the annual rate of change of the HICP index for euro area countries from 01/1997 to 12/2008 and from 01/2009 to 07/2021. Results of panel data analysis, six unit root tests are shown in Tab. 2. We use the ADF test, Hadri test, Im-Pesaran-Shin test, Levin-Lin-Chu test, and PP unit root test. In five of six tests, we do not accept the null hypothesis at the level of significance α = 0.05. The panel data are stationary according to ADF test, IPS test and PP test.

The second step in our first part of the analysis was to use individual unit root tests for an annual rate of change of the HICP index for each of the euro area countries. Results of three unit root tests: ADF test, KPSS, and PP test for the period from 1997 to 2008 are shown in Tab. 3.

We can see that according to the ADF unit root test we reject *H0* in five of nineteen countries. It means that data for the HICP index are non-stationary in these countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Latvia, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia.

Tab. 2: Results of panel analysis, unit root tests (HICP index)

Test	1997–2008		2009–2021	
	Statistic	*P*-value	Statistic	*P*-value
ADF Fisher chi-squared	85.1729	0.0000*	87.4156	0.0000*
ADF Coi Z-stat.	−4.86751	0.0000*	−5.14890	0.0000*
Hadri test Z-stat.	10.6729	0.0000*	3.07884	0.0010*
IPS	−4.77856	0.0000*	−5.02670	0.0000*
LLC	−0.83084	0.2030	−0.14001	0.4443
PP test Fisher chi-squared	81.2089	0.0001*	91.2855	0.0000*

Source: own

Note: The probabilities for the Fisher tests are calculated using an asymptotic chi-squared distribution. The rest of the tests assume asymptotic normality. We reject *H0* at the level of significance α = 0.05. The symbol * stands for rejecting of *H0* of unit root at 5%.

According to the PP unit root test, we accept the null hypothesis of non-stationary data of HICP index in these countries: Austria, Belgium, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, Spain.

According to the KPSS unit root test, we reject *H0* of stationary data in all countries.

Results of the first part of our analysis in the period from 1997 to 2008 confirmed the non-stationarity of data in Cyprus and Greece.

Tab. 3: Results of individual unit root tests – countries (HICP index; 1997–2008)

Country	ADF test		PP test		KPSS test	
	T-stat. (5% level)	*P*-value	*T*-stat. (5% level)	*P*-value	LM-stat.	*P*-value
Austria	−2.881685	0.1809	−2.881685	0.1452	0.463000	0.0000*
Belgium	−2.881685	0.0840	−2.881685	0.0840	0.463000	0.0000*
Cyprus	−2.8835792	0.0193*	−2.881685	0.0020*	0.463000	0.0000*
Estonia	−2.883579	0.0051*	−2.881685	0.2072	0.463000	0.0000*
Finland	−2.881685	0.4602	−2.881685	0.4637	0.463000	0.0000*
France	−2.881830	0.0726	−2.881685	0.1184	0.463000	0.0000*
Germany	−2.881685	0.0781	−2.881685	0.0728	0.463000	0.0000*
Greece	−2.881685	0.0109*	−2.881685	0.0102*	0.463000	0.0000*
Ireland	−2.881830	0.2883	−2.881685	0.3155	0.463000	0.0000*
Italy	−2.881685	0.0657	−2.881685	0.0657	0.463000	0.0000*
Latvia	−2.882127	0.2221	−2.881685	0.4696	0.463000	0.0000*
Lithuania	−2.881685	0.0456*	−2.881685	0.0601	0.463000	0.0000*
Luxembourg	−2.881685	0.0516	−2.881685	0.0544	0.463000	0.0000*
Malta	−2.881685	0.0886	−2.881685	0.0624	0.463000	0.0000*
Netherlands	−2.881685	0.4504	−2.881685	0.3937	0.463000	0.0000*
Portugal	−2.881685	0.2943	−2.881685	0.2943	0.463000	0.0000*
Slovakia	−2.881685	0.4197	−2.881685	0.2854	0.463000	0.0000*
Slovenia	−2.871582	0.2909	−2.871161	0.2616	0.463000	0.0000*
Spain	−2.881830	0.0139*	−2.881685	0.2870	0.463000	0.0000*

Source: own

Note: Augmented Dickey-Fuller and Phillips-Perron unit root tests use one-sided *p*-values. For Kwiatkowski-Phillips-Schmidt-Shin unit root test it uses an asymptotic critical value. We reject *H0* at the level of significance α = 0.05. The symbol * stands for rejecting of *H0* of unit root at 5%.

Tab. 4 shows the results of the unit root tests for the data in the period from 2009 to 2021.

We can see that according to the ADF unit root test we reject *H0* in two of nineteen countries. It means that data for the HICP index are non-stationary in these countries: Italy and Lithuania.

According to the PP unit root test, we accept the null hypothesis of non-stationary data of HICP index in these countries: Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Luxembourg, the Netherlands, Portugal, Slovakia, Slovenia, Spain.

According to the KPSS unit root test, we reject the null hypothesis of stationary data in all countries.

Results of the first part of our analysis in the period from 2009 to 2021 confirmed the non-stationarity of data in Italy and Lithuania.

Tab. 4: Results of individual unit root tests – countries (HICP index; 2009–2021)

Country	ADF test		PP test		KPSS test	
	T-statistic (5% level)	*P*-value	*T*-stat. (5% level)	*P*-value	LM-stat. (5% level)	*P*-value
Austria	−2.880722	0.2698	−2.880722	0.1818	0.463000	0.0000*
Belgium	−2.880722	0.0886	−2.880722	0.0804	0.463000	0.0000*
Cyprus	−2.880722	0.2459	−2.880722	0.1766	0.463000	0.0000*
Estonia	−2.882433	0.3020	−2.880722	0.1125	0.463000	0.0000*
Finland	−2.880722	0.3299	−2.880722	0.3104	0.463000	0.0000*
France	−2.880722	0.3062	−2.880722	0.1871	0.463000	0.0000*
Germany	−2.880987	0.0674	−2.880722	0.0614	0.463000	0.0000*
Greece	−2.880722	0.3840	−2.880722	0.3207	0.463000	0.0000*
Ireland	−2.880722	0.4230	−2.880722	0.1492	0.463000	0.0000*
Italy	−2.880722	0.0005*	−2.880722	0.0007*	0.463000	0.0000*
Latvia	−2.880853	0.1678	−2.880722	0.0347*	0.463000	0.0000*
Lithuania	−2.880853	0.0049*	−2.880722	0.0012*	0.463000	0.0000*
Luxembourg	−2.880722	0.1155	−2.880722	0.1155	0.463000	0.0000*
Malta	−2.880722	0.0549	−2.880722	0.0379*	0.463000	0.0000*
Netherlands	−2.880722	0.1446	−2.880722	0.1707	0.463000	0.0000*
Portugal	−2.880853	0.4918	−2.880722	0.3750	0.463000	0.0000*
Slovakia	−2.880722	0.4806	−2.880722	0.2073	0.463000	0.0000*
Slovenia	−2.880987	0.1435	−2.880722	0.1053	0.463000	0.0000*
Spain	−2.880722	0.3190	−2.880722	0.1972	0.463000	0.0000*

Source: own

Note: Augmented Dickey-Fuller and Phillips-Perron unit root tests use one-sided *p*-values. For Kwiatkowski-Phillips--Schmidt-Shin unit root test it uses an asymptotic critical value. We reject *H0* at the level of significance α = 0.05. The symbol * stands for rejecting of *H0* of unit root at 5%.

3.2 Results of Panel Data Analysis for Common and Individual Unit Root for Countries of the Euro Area (HICP Index – Category of COICOP)

To achieve more detailed results we use data of the annual rate of change of the HICP index for each category of COICOP for the euro area countries. We use Breitung test and the Levin-Lin-Chu test for testing the common unit root of data.

In Tab. 5 we show the results of the analysis for the data from 1997 to 2008. According to the Levin-Lin-Chu test, we reject the null hypothesis of non-stationary data in these categories of COICOP: Clothing and footwear, Communications, Recreation and culture. Results of the Breitung unit root test show that data are stationary in these categories of COICOP: Food and non-alcoholic beverages, Health, Communications, Recreation and culture, Miscellaneous and services.

Levin-Lin-Chu test and Breitung test confirmed the non-stationarity of data in six categories of CIOCOP: Alcoholic beverages, tobacco and narcotics, Housing, water, electricity gas and other fuels, Furnishings, household equipment and routine household maintenance, Transport, Education, Restaurants and hotels.

Tab. 5: Results of panel analysis, common unit root (1997–2008)

Category of COICOP	Levin-Lin-Chu test		Breitung test	
	T-statistic	*P*-value	*T*-statistic	*P*-value
Food and non-alcoholic beverages	0.07846	0.0513	−2.20352	0.0138*
Alcoholic beverages, tobacco and narcotics	0.66058	0.7456	−1.14663	0.1258
Clothing and footwear	−3.24422	0.0006*	−0.53068	0.2978
Housing, water, electricity, gas and other fuels	0.30478	0.6197	−0.73357	0.2316
Furnishings, household equipment and routine household maintenance	−0.70355	0.2409	1.12578	0.8699
Health	−0.51314	0.3039	−2.76103	0.0029*
Transport	1.78265	0.9627	4.04630	1.0000
Communications	−2.07252	0.0191*	−4.68641	0.0000*
Recreation and culture	−1.88238	0.0299*	−2.59221	0.0048*
Education	−1.05403	0.1459	−0.47590	0.3171
Restaurants and hotels	−0.30497	0.3802	1.03409	0.8495
Miscellaneous goods and services	−0.90807	0.1819	−2.89934	0.0019*

Source: own

Note: All tests assume asymptotic normality. We reject *H0* at the level of significance $\alpha = 0.05$. The symbol * stands for rejecting of *H0* of unit root at 5%.

The results of our panel analysis for the period from 1997 to 2008 for individual unit roots are shown in Tab. 6. We apply three main unit root tests: Phillips-Perron test, Augmented Dickey-Fuller test, and Im-Pesaran-Shin test. These results reject the hypothesis of non-stationarity data in eight of twelve categories. Non-stationarity data were confirmed in these categories of COICOP: Housing, water, electricity, gas and other fuels; Education; Restaurants and hotels; Miscellaneous goods and services by ADF test, PP test, or IPS test.

Intermediate results of the tests in three categories of COICOP (Housing, water, electricity, gas and other fuels; Education; Restaurants and hotels), where unit root tests confirmed the non-stationarity data (common and individual unit root), show that data in these countries of the euro area are non-stationary: Estonia, Ireland, Spain, France, Cyprus, Latvia, Lithuania, Luxembourg, Netherlands, Austria, Slovakia.

Tab. 6: Results of panel analysis, individual unit root (1997–2008) – Part 1

Category of COICOP	ADF test (Fisher chi-squared)		PP test (Fisher chi-squared)		IPS test (W-stat.)	
	T-statistic	*P*-value	*T*-statistic	*P*-value	*T*-statistic	*P*-value
Food and non-alcoholic beverages	66.6764	0.0014*	66.5118	0.0015*	−3.72175	0.0001*
Alcoholic beverages, tobacco and narcotics	57.7429	0.0210*	66.7496	0.0027*	−2.7935	0.0147*
Clothing and footwear	76.9569	0.0002*	455.117	0.0000*	−3.85337	0.0001*

Tab. 6: Results of panel analysis, individual unit root (1997–2008) – Part 2

Category of COICOP	ADF test (Fisher chi-squared)		PP test (Fisher chi-squared)		IPS test (W-stat.)	
	T-statistic	*P*-value	*T*-statistic	*P*-value	*T*-statistic	*P*-value
Housing, water, electricity, gas and other fuels	72.1158	0.0007*	46.5987	0.1597	−3.29898	0.0005*
Furnishings, household equipment and routine household maintenance	57.0936	0.0240*	126.977	0.0000*	−1.95012	0.0256*
Health	58.0031	0.0199*	55.4324	0.0366*	−2.70489	0.0034*
Transport	83.1307	0.0000*	65.6916	0.0035*	−4.87756	0.0000*
Communications	75.6856	0.0003*	85.2380	0.0000*	−4.23310	0.0000*
Recreation and culture	57.4002	0.0225*	112.280	0.0000*	−2.87226	0.0020*
Education	51.2301	0.0742	73.6938	0.0005*	−1.71619	0.0431*
Restaurants and hotels	28.6620	0.8634	85.5207	0.0000*	0.15387	0.5611
Miscellaneous goods and services	46.8738	0.1531	52.2129	0.0622	−1.99350	0.0231*

Source: own

Note: The probabilities for the Fisher tests are calculated using an asymptotic chi-squared distribution. The rest of the tests assume asymptotic normality. We reject *H0* at the level of significance α = 0.05. The symbol * stands for rejecting of *H0* of unit root at 5%.

Tab. 7: Results of panel analysis, common unit root (2009–2021)

Category of COICOP	Levin-Lin-Chu test		Breitung test	
	T-statistic	*P*-value	*T*-statistic	*P*-value
Food and non-alcoholic beverages	−1.37918	0.0839	−4.37719	0.0000*
Alcoholic beverages, tobacco and narcotics	−1.24100	0.1073	−4.01362	0.0000*
Clothing and footwear	−3.73394	0.0001*	−3.27010	0.0005*
Housing, water, electricity gas and other fuels	−0.20598	0.4184	2.09769	0.9820
Furnishings, household equipment and routine household maintenance	0.53379	0.7033	2.51497	0.9940
Health	−3.65582	0.0001*	−0.87607	0.1905
Transport	0.21776	0.5862	4.04630	1.0000
Communications	0.61633	0.7312	−3.04926	0.0011*
Recreation and culture	−0.47492	0.3174	−1.67590	0.0469*
Education	−2.14092	0.0161*	1.35137	0.9117
Restaurants and hotels	0.45143	0.6742	1.23170	0.8910
Miscellaneous goods and services	−1.40238	0.0804	−2.65845	0.0039*

Source: own

Note: All tests assume asymptotic normality. We reject *H0* at the level of significance α = 0.05. The symbol * stands for rejecting of *H0* of unit root at 5%.

In Tab. 7 we show the results of the analysis for the data from 2009 to 2021. According to the Levin-Lin-Chu test, we reject the null hypothesis of non-stationary data in these categories of COICOP: Clothing and footwear, Health, Education. Results of the Breitung unit root test show that data are stationary in these categories of COICOP: Food and non-alcoholic beverages, Alcoholic beverages, tobacco and narcotics, Clothing and footwear, Communications, Recreation and culture, Miscellaneous and services.

Levin-Lin-Chu test and Breitung test confirmed the non-stationarity of data in four categories of CIOCOP: Housing, water, electricity gas and other fuels, Furnishings, household equipment and routine household maintenance, Transport, Restaurants and hotels.

The results of our panel analysis for the period from 2009 to 2021 for individual unit roots are shown in Tab. 8. We apply three main unit root tests: Phillips-Perron test, Augmented Dickey-Fuller test, and Im-Pesaran-Shin test. These results reject the hypothesis of non-stationarity data in nine of twelve categories. Non-stationarity data were confirmed in these categories of COICOP: Housing, water, electricity, gas and other fuels; Furnishings, household equipment and routine household maintenance; Transport by ADF test, PP test, or IPS test.

Intermediate results of the tests in three categories of COICOP (Housing, water, electricity, gas and other fuels; Furnishings, household equipment and routine household maintenance; Transport), where unit root tests confirmed the non-stationarity data (common and individual unit root), show that data in these countries of the euro area are non-stationary: Germany, Estonia, Ireland, Spain, France, Italy, Malta, the Netherlands, Portugal, Slovenia, Slovakia.

We compare the results of our analysis with the results of studies by Kundera (2019), Marelli

Tab. 8: Results of panel analysis, individual unit root (2009–2021)

Category of COICOP	ADF test (Fisher chi-squared)		PP test (Fisher chi-squared)		IPS test (W-stat.)	
	T-statistic	*P*-value	*T*-statistic	*P*-value	*T*-statistic	*P*-value
Food and non-alcoholic beverages	98.2522	0.0000*	100.340	0.0000*	−5.77136	0.0000*
Alcoholic beverages, tobacco and narcotics	79.8305	0.0001*	83.4699	0.0000*	−4.43906	0.0000*
Clothing and footwear	150.095	0.0000*	723.863	0.0000*	−8.15369	0.0000*
Housing, water, electricity gas and other fuels	68.6569	0.0017*	52.7409	0.0564	−3.62619	0.0001*
Furnishings, household equipment and routine household maintenance	46.0365	0.1738	143.458	0.0000*	−1.25559	0.1046
Health	111.394	0.0000*	98.6055	0.0000*	−6.41772	0.0000*
Transport	69.2780	0.0014*	39.6491	0.3964	−4.06433	0.0000*
Communications	66.2610	0.0030*	72.9948	0.0005*	−3.09273	0.0010*
Recreation and culture	90.4235	0.0000*	199.891	0.0000*	−5.18273	0.0000*
Education	74.0293	0.0004*	64.2463	0.0049*	−3.36764	0.0004*
Restaurants and hotels	86.7964	0.0000*	210.916	0.0000*	−4.97463	0.0000*
Miscellaneous goods and services	58.8197	0.0167*	582.8515	0.0000*	−2.81526	0.0024*

Source: own

Note: The probabilities for the Fisher tests are calculated using an asymptotic chi-squared distribution. The rest of the tests assume asymptotic normality. We reject *H0* at the level of significance α = 0.05. The symbol * stands for rejecting of *H0* of unit root at 5%.

et al. (2019), Boisset (2019), and Ferreiro et al. (2017), who examined the convergence of euro area countries after the financial crisis in 2008.

Kundera (2019) analyzes the concept of a multi-speed Europe, justifying the advantages and possibilities of implementation in the context of the further development of the European Union. The concept of a multi-speed Europe can be described as an effort to achieve common integration goals, but according to a different timetable. It means that all Member States agree on the common objectives of European unity, but do not achieve them at the same speed. This model leads to the crystallization of the group leaders that follow other countries. For some weaker member states, this may lead to a later common goal. This delay may depend on the country's preferences or internal conditions. At the same time, the stronger members are forced to help the weaker ones, but the true extent of solidarity may be symbolic. With regard to the concept of a multi-speed Europe, there is a question of which countries are capable of leading integration and which countries will remain outside this group. One can assume that "the Europe of the first speed" creates the euro area and that the countries that have not adopted the euro belong to the group "the Europe of the second speed". However, the author points out that the 2008 crisis year showed that some euro area countries struggled to join EMU, and therefore it is not appropriate to divide the countries into those with a common currency, the euro, and others.

The authors Marelli et al. (2019) deal with the economic convergence of the European Union and the euro area. One of the results of the authors' analysis is the decline in euro area convergence after 2008. The asymmetric shocks of the financial crisis have caused the convergence rate of euro area countries to be slower than the convergence rate of the 28 European Union countries. Structural factors such as R&D expenditure, net migration, fixed and human capital investment, and the degree of openness data were used as elements of country heterogeneity. Marelli and Signorelli (2017) draw attention to a long period of crisis with a double recession and a weak recovery, which has exacerbated EU and ECB (European Central Bank) policy-making errors and delays.

Boisset (2019) and Ferreiro et al. (2017) also addressed the convergence of euro area countries. The authors argue that incomplete 'nominal' convergence, persistent inflation differentials, and the credit boom in some peripheral countries have exacerbated macroeconomic imbalances within the euro area and disrupted the 'real' convergence process. A study by Ferreiro et al. (2017) focuses on analyzing whether the economic and financial crisis that has affected the euro area since 2008 has had any impact on the cohesion of euro area countries and thus whether differences in euro area macroeconomic performance decrease (it is a convergence) or they increase (it is a divergence) after 2008. In the study, the authors focused on examining variables in six areas (economic activity, labor market, income distribution, inflation, balance of payments, public finances). The result points to a higher divergence of countries after the crisis, especially the following variables: GDP per capita, GDP growth, potential GDP growth rate, output gap, unemployment rate, current account balance, and inflation rate. It follows that our results on data stationarity and non-stationarity are consistent with the results of studies, which suggest a two-speed euro area for a more efficient monetary policy.

Considering the key outcomes of above mentioned articles it seems that the concept of a two-speed euro area is not necessarily unique and can be discussed from different policy perspectives. Our results indicate that non-stationary characteristics of inflation time series are present in more than half of the euro area member countries. It seems that a presence of a unit root in the inflation time series represents a significant source or a contribution to the persistence in inflation data that reduces effectiveness of monetary policy actions due to presence of a deterministic trend in our non-stationary data. As a result, inflation persistence reduces maneuverability of the common monetary policy in pursuing price stability in countries with non-stationary inflation time series. On the other hand, a stationarity of inflation data was confirmed in the other countries of the euro zone, which means that inflation is less persistent.

Based on the results of our analysis revealing variability in inflation persistence in the euro area countries we suggest that two-speed monetary policy setup for countries with lower

and higher inflation persistence could provide more convenient policy framework for the ECB in pursuing and preserving price stability in the euro area. Focus on inflation persistence and its reduction is based on consideration that lower inflation persistence allows the central bank to conduct its monetary policy more effectively. By applying the concept of a two-speed euro area, weaker countries would catch up with stronger ones, which would increase the effectiveness of the central bank's monetary policy. Applying different monetary policy rules for countries with higher and lower inflation persistence would increase the convergence of weaker countries to stronger ones and reduce divergence tendencies and reduce the heterogeneity of euro area countries.

Based on our results of non-stationarity inflation data and comparison with the above studies of low convergence euro area countries, we propose the creation of a two-speed euro area concept and adjust the monetary policy framework in the euro area countries. The monetary-political framework of the monetary authorities should be adapted to the heterogeneity of the euro area countries, despite the fulfillment of the Maastricht convergence criteria (the condition of the inflation rate, long-term interest rate, state budget deficit, the size of the public debt, the exchange rate as part of ERM II), which the countries met before joining the euro area. The application of monetary policy decisions should be more subject to these country differences, especially in times of crisis and recession, as asymmetric shocks can disrupt the economic growth of countries and the speed of their recovery. In the countries of Estonia, Ireland, Spain, France, Cyprus, Latvia, Lithuania, Luxembourg, the Netherlands, Austria, Slovakia, we confirmed the non-stationarity of inflation data in the three categories of COICOP in the period from 1997 to 2008, which indicates higher persistence in inflation. In Germany, Estonia, Ireland, Spain, France, Italy, Malta, the Netherlands, Portugal, Slovenia, Slovakia in the period from 2009 to 2021, we confirmed the non-stationarity of the data in the three categories of COICOP.

Conclusions

The main aim of this article was to test the stationarity of the inflation data in the member countries of the euro area considering that the inflation targeting has become one of the cornerstones of monetary policy design for central banks. The literature review found that inflation persistence is one of the most important parameters that influence the efficiency of monetary policy. If the inflation persistence is high, then inflation shocks last a long time and it is difficult for a central bank to control them. On the other hand, if the inflation persistence is low, the management of inflation expectations is more efficient, and inflation can be achieved more quickly, consistent with the target. Reducing inflation persistence may be a better result of monetary policy.

Our research was divided into two parts. Results of the first part of the analysis show the panel data of the HICP index are stationary according to ADF test, IPS test and PP test. Results of individual unit root tests show that data of annual rate of HICP index are non-stationary in Cyprus and Greece in the period from 1997 to 2008 and in Italy and Greece in the period from 2009 to 2021. In the second part of our research, we tested the stationarity of inflation data – we use data of the annual rate of change of the HICP index for each category of COICOP for euro area countries. We use the Levin-Lin-Chu test and Breitung test for testing the common unit root of data and Augmented Dickey-Fuller test, Phillips-Perron test, and Im-Pesaran-Shin test for testing individual unit root. Intermediate results of the tests in three categories of COICOP (Housing, water, electricity, gas and other fuels, Education, Restaurants and hotels), where unit root tests confirmed the non-stationarity data (common and individual unit root), show that data in these countries of the euro area are non-stationary: Estonia, Ireland, Spain, France, Cyprus, Latvia, Lithuania, Luxembourg, the Netherlands, Austria, Slovakia for the period from 1997 to 2008. Intermediate results of the tests for the period from 2009 to 2021 in three categories of COICOP (Housing, water, electricity, gas and other fuels, Furnishings, household equipment and routine household maintenance, Transport), where unit root tests confirmed the non-stationarity data (common and individual unit root), show that data in these countries of the euro area are non-stationary: Germany, Estonia, Ireland, Spain, France, Italy, Malta, the Netherlands, Portugal, Slovenia, Slovakia.

According to our results, we propose the concept of a two-speed euro area, which

means that the euro area countries would be divided into two groups with the application of different monetary policy rules in these countries. Countries would thus be able to more easily absorb asymmetric shocks, especially such as the financial and economic crisis since 2008, as the results indicate that euro area countries, due to the different inflation persistence, react differently to the application of the central bank's monetary policy decisions in good and bad times. The convergence of the countries of Europe and the euro area was also discussed by the authors Boisset (2019), Ferreiro et al. (2017), Marelli et al. (2019), Kundera (2019). Convergence in these countries was observed mainly in the post-crisis period. Thus, they dealt with the countries that were affected by the financial crisis in 2008. The authors Marelli et al. (2019) dealt with the economic convergence of the countries of the European Union and the euro area. Based on our results, the central bank should use monetary policy instruments with regard to the level of inflation persistence in the euro area countries and should take into account the different level of inflation persistence. As we have shown, in countries where we have confirmed the non-stationarity of inflation data, there is a higher inflation persistence, and the central bank should use monetary policy rules in these countries to focus on reducing inflation persistence (Marques, 2004; Roache, 2014). Thus, the monetary authorities should use stronger monetary policy tools so that inflation can return to its desired level after the shock.

The results of our research are in line with our proposed two-speed euro area concept. The monetary policy framework of the ECB should adapt to the heterogeneity of euro area countries despite meeting the convergence criteria (inflation rate, long-term interest rate, public debt size, government deficit, ERM II exchange rate) that the countries met before joining the euro area. The application of monetary policy decisions should be more flexible and consider differences among countries, especially in times of crisis and recession, as asymmetric shocks can disrupt countries' economic growth and recovery. We propose to focus more on inflation persistence and its reduction, as low inflation persistence allows the central bank to pursue its monetary policy more comprehensively. By applying the concept of a two-speed euro area that considers higher flexibility in the design of the monetary policy framework and associated monetary policy tools, weaker countries would be supported by stronger countries, which would increase the effectiveness of the ECB's monetary policy.

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