

Primary submission: 10.09.2023 | Final acceptance: 05.10.2023

Unraveling the Dynamics of Inflation Persistence: A Long-Memory Analysis of Headline Inflation Convergence and Divergence in European Economies

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ABSTRACT

This comprehensive study delves into the Harmonised Consumer Price Index (HCPI) behavior across European economies from the early 2000s to the post-pandemic period. By analyzing the patterns of convergence and divergence in HCPI persistence, the study aims to uncover the common external and country-specific factors driving these dynamics. Utilizing the local Whittle estimation method, the research examines the long-memory properties of headline inflation through monthly data from January 1996 to January 2023. The study expands upon existing knowledge of inflation persistence by exploring its changes and the various patterns of inflation persistence in Europe. The findings reveal significant differences in the persistence of inflation and the underlying factors behind it. As such, the study emphasizes the need for tailored policy approaches and a deeper understanding of inflation's true nature, expectation formation, price-setting behavior, and monetary policy in shaping inflation persistence. Given its important policy implications, this research is highly relevant to the European Central Bank (ECB) and national governments within the Eurozone.

KEY WORDS:

headline inflation, Inflation persistence, European economies, monetary policy, inflation expectations, price-setting behavior, Local Whittle function.

JEL Classification: E31, C22, E52.

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1. Introduction

The economic landscape of the European Union (EU) is a complex and dynamic system woven over decades of integration, policy-making, and market dynamics. Countries such as Germany, France, and Italy have historically played pivotal roles in shaping the economic direction of the union.

Acquiring quantitative knowledge on the nature of inflation is crucial to policymakers and managers on the micro- and macro-levels (Wang et al., 2022; Skare et al., 2020; 2021; Lv et al., 2023). With such

empirical knowledge of inflation, a tailored policy approach is possible. The synchronization of inflation persistence across countries has significant implications for the effectiveness of monetary policy, inflation expectation formation, price-setting behavior, and rigidity. This paper investigates the synchronization of the Harmonized Consumer Price Index (HCPI) persistence in European economies. Our study covers several distinct periods, including the early 2000s, mid-2000s, global financial crisis, post-crisis period, pandemic period, and post-pandemic period.

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The study aims to uncover potential explanations for the observed patterns of convergence and divergence in the HCPI persistence parameter across these countries, focusing on the common external factors and country-specific factors that drive these dynamics. This paper helps better understand the interconnectedness of European economies while shedding light on the unique global and national factors that can lead to divergent inflation persistence patterns. This has important policy implications for the European Central Bank (ECB) and national governments within the Eurozone.

The persistence of inflation remains an area of ongoing research, with various studies investigating its sources, consequences, and potential political implications. Some literature has investigated the role of expectations in inflation persistence, as seen in Bems et al. (2021) and Łyziak & Paloviita (2017), who investigated the impact of anchored inflation expectations on inflation persistence. Darvas & Varga (2014) addressed inflation persistence in central and eastern European countries, and Isoardi & Gil-Alana (2019) addressed inflation persistence in Argentina. Caporale et al. (2022), Kato et al. (2021), Oloko et al. (2021), and Gil-Alana & Monge (2020) have all examined the persistence of inflation in relation to structural breaks, market concentration, and oil price shocks, respectively. Although there are extensive findings, there are still gaps in understanding the full dynamics and variations of inflation persistence across countries and the precise role of various factors in influencing it.

Recent research has also focused on the implications of inflation persistence for monetary policy. Although Wu & Wu (2018) explored the link between flexible exchange rate regimes and inflation persistence, Tetlow (2018) highlighted the challenges policymakers face in responding to uncertain inflation persistence. The effects of central bank transparency on inflation persistence were examined by Oikonomou et al. (2021), and the impact of sectoral price stickiness was examined by Leszczyńska-Paczesa (2020). Chin (2022) used a DSGE-VAR approach to analyze the relationship between inflation persistence and monetary policy.

Despite the wealth of literature on individual economic analyses, there needs to be more compre-

hensive research comparing the economic trajectories of Italy, Germany, and France within the same timeframe. This gap in knowledge hinders our understanding of the intricate economic interplay among these nations and its broader implications for the EU.

This study seeks to bridge this research gap by offering a comparative analysis of the economic behaviors of Italy, Germany, and France. We aim to show the synergies and conflicts among their economic policies, providing policymakers and scholars with a holistic view of their collective impact on the EU's economic future.

Further research is needed to understand how monetary policy can be optimally designed to address inflation persistence, especially given the various sources of persistence (inflation expectation, wage-setting mechanism, energy transition, post-pandemic dynamics, labor-market rigidity, and war in Ukraine) and their interactions. However, these studies provide valuable insights. In addition, more investigation is warranted to determine how different policy regimes and economic structures may influence the effectiveness of policy interventions in managing inflation persistence.

We study the nature of inflation in Europe using the global inflation database (Ha et al., 2021). The data set contains a variety of inflation indicators, including headline inflation, core inflation, wholesale price inflation, and GDP deflator inflation. Our research is centered on headline inflation in the EU, EA, EEA, and member states. We utilize monthly data on EU member states from January 1996 to January 2023.

Some European countries exhibit higher inflation persistence than others. This variation highlights the need for tailored policy approaches, emphasizing the importance of understanding the specific factors that drive inflation persistence in different countries.

Crucial in determining inflation persistence is the role of expectation formation. Countries with more adaptive or forward-looking expectations may see a quicker inflation adjustment. In contrast, countries with more persistent inflation expectations may face challenges in returning inflation to target levels.

Price-setting behavior and rigidity can have an impact on inflation persistence. Countries with more rigid mechanisms for setting prices or higher nominal rigidity may experience slower adjustments of prices to shocks, leading to higher inflation persistence. On the other hand, countries with more flexible price-setting mechanisms may have lower inflation persistence.

Monetary policy's role in shaping inflation persistence is significant. Central banks' credibility and the effectiveness of their policy tools in different countries can impact inflation persistence. Credible central banks and a more effective monetary policy framework can contribute to lower inflation persistence.

The rest of the paper is structured as follows: the body of literature on inflation persistence is presented in section two. Section three explains the choice of method and data sample we use in the study. Section four summarizes the study results and findings, while the discussion section compares our findings with other relevant studies in the field. Finally, the conclusion section identifies our research's key point and contribution with study limitations stressing the importance of further research on inflation persistence.

2. Literature Review on Inflation Persistence

The persistence of inflation is a vital subject in macroeconomics, as it has significant implications for the conduct of monetary policy and the stability of an economy. This literature review aims to synthesize the various perspectives and findings on inflation persistence from multiple studies conducted over the past few decades.

Among the early researchers to examine inflation persistence, Baum et al. (1999) analyzed the phenomenon in the context of international inflation rates. Their study laid the foundations for subsequent research by highlighting the importance of understanding inflation dynamics in a global context. In the *Handbook of Monetary Economics*, Fuhrer (2010) emphasizes the role of inflation expectations and monetary policy in shaping persistence, providing a comprehensive overview.

While Darvas and Varga (2014) focused on persistence in central and eastern European countries, Bratsiotis et al. (2015) studied the impact of inflation

targeting on inflation persistence. The authors noted that, in the latter case, these countries experienced higher inflation persistence than their advanced European counterparts. Finally, Bems et al. (2021) found that well-anchored expectations can reduce persistence by investigating the role of expectations' anchoring in inflation persistence.

Multiple studies have investigated the presence of structural breaks in inflation persistence (Canarella & Miller, 2016; Caporale et al., 2022; Misztal, 2017). These studies typically show that accounting for structural breaks can lead to different conclusions about the degree of inflation persistence in other economies.

Kato et al. (2021) analyzed inflation persistence in the context of specific factors, such as sectoral characteristics, oil price shocks (Oloko et al., 2021; Gil-Alana & Monge, 2020), and exchange rate regimes (Wu & Wu, 2018). These studies contribute to our understanding of how different factors and market conditions can influence the dynamics of inflation persistence.

Recent research has also examined the role of monetary policy and central bank transparency in shaping inflation persistence. Oikonomou et al. (2021) investigated the effect of central bank transparency on persistence, while Tetlow (2018) discussed the monetary policy response to uncertain inflation persistence. Leszczyńska-Paczesna (2020) used a two-sector DSGE approach to analyze sectoral price stickiness and inflation persistence in Poland. Finally, Lovcha and Perez-Laborda (2018) examine the relationship between monetary policy shocks, inflation persistence, and long memory. They note that unconventional monetary policy measures can increase inflation, suggesting that central banks should consider these potential effects.

The literature on inflation persistence is vast and diverse, covering various topics, methodologies, and economic contexts (Table 1). Multiple factors, such as sectoral characteristics and oil price shocks, play a crucial role in shaping inflation dynamics, in addition to well-anchored inflation expectations and the role of monetary policy in mitigating persistence. Further research in this area will be vital to understanding and addressing the challenges of inflation persistence as the global economy evolves.

3. Data and Methods

3.1. Introduction

Here, we present the methodology employed for estimating the long-memory parameter using the local Whittle function, as proposed by Baum et al. (2020). The method is applied to the dataset containing headline inflation data for European countries. The local Whittle function is a semi-parametric technique that offers a more efficient and precise estimation of the long-memory parameter compared to traditional methods.

3.2. The Local Whittle Function

The local Whittle function is a semi-parametric

estimator based on the spectral representation of a time series. It minimizes the mean-squared difference between a long-memory process's estimated and theoretical spectral density. The local Whittle estimator improves the classic Whittle estimator by incorporating a local approximation of the spectral density, increasing the estimate's efficiency and accuracy.

3.3. Model Specification

Let $\{X_t\}$ be a zero-mean stationary time series with a long-memory parameter d . The local Whittle function focuses on the log-spectral density function:

$$g(\lambda; d) = \log f(\lambda; d) \quad (1)$$

Table 1
Systematic Review on Inflation Persistence Literature

Reference	Methods	Key Findings
(Baum et al., 1999)	GARCH models and panel data	Persistence in international inflation rates varies significantly among countries and over time.
(Baum et al., 2020)	Local Whittle estimation	Provides an estimation method for the long-memory parameter in time series data.
(Bems et al., 2021)	DSGE model and survey data	Expectations anchoring affects inflation persistence, with more anchored expectations leading to lower persistence.
(Bratsiotis et al., 2015)	Time-varying parameter model	Inflation-targeting regimes have lower inflation persistence.
(Caporale et al., 2022)	Fractionally integrated autoregressive moving average (ARFIMA) model	G7 countries exhibit different degrees of inflation persistence with evidence of structural breaks.
(Darvas & Varga, 2014)	Panel data analysis	Central and Eastern European countries exhibit different inflation persistence levels.
(Fuhrer, 2010)	Literature review	Explores factors affecting inflation persistence and its implications for monetary policy.
(Kato et al., 2021)	DSGE model	Sectoral inflation persistence is influenced by market concentration and imperfect common knowledge.
(Lyziak & Paloviita, 2017)	Survey-based measures of inflation expectations	Inflation expectations anchoring in the euro area have become more heterogeneous over time.
(Oloko et al., 2021)	Fractional Cointegration VAR approach	Oil price shocks contribute to inflation rate persistence.
(Gil-Alana & Monge, 2020)	Fractional integration techniques	COVID-19 shock had persistent effects on crude oil prices.

Table 1
Systematic Review on Inflation Persistence Literature (Continued)

Reference	Methods	Key Findings
(Belaire-Franch, 2019)	Univariate models	Inflation persistence varies across countries and sample periods.
(Tetlow, 2018)	Bayesian modeling	Discusses monetary policy response to uncertain inflation persistence.
(Jain, 2017)	Time-varying parameter model	Perceived inflation persistence varies over time and across forecasters.
(Jung, 2019)	ARFIMA models	Evaluates inflation persistence considering model uncertainty and structural breaks.
(Gaglianone et al., 2018)	Quantile autoregression	Inflation persistence exhibits quantile-specific unit roots.
(Lovcha & Perez-Laborda, 2018)	Time-varying parameter model	Monetary policy shocks affect inflation persistence and long memory.
(Wu & Wu, 2018)	Panel data analysis	Flexible exchange rate regimes increase inflation persistence.
(Misztal, 2017)	ARFIMA models	Investigates inflation persistence in Croatia between 2005 and 2013.
(Canarella & Miller, 2016)	Time-varying parameter model	Inflation persistence is affected by structural breaks.
(Brissimis & Migiakis, 2016)	Learning model	Learning dynamics influence inflation expectations and persistence.
(Antonakakis et al., 2016)	Panel data analysis	Inflation persistence differs between reality and expectations.
(Kanellopoulos & Koutroulis, 2016)	Time-varying parameter model	Non-linearities exist in euro area inflation persistence.
(Isoardi & Gil-Alana, 2019)	Fractional integration techniques	Analyzes inflation persistence in Argentina.
(Vaona & Ascari, 2010)	Panel data analysis	Regional inflation persistence varies across Italy.
(Gil-Alana et al., 2017)	Fractional integration techniques	Investigates stationarity of inflation in Croatia.
(Meller & Nautz, 2012)	Time-varying parameter model	Inflation persistence in the Euro area changed after the European Monetary Union.
(Romero-Ávila & Usabiaga, 2011)	Panel data analysis	Disaggregate evidence shows varying inflation persistence in Spain.
(Chin, 2022)	DSGE-VAR approach	Inflation persistence is affected by monetary policy.
(Oikonomou et al., 2021)	Panel data analysis	Central bank transparency impacts inflation persistence.
(Leszczyńska-Paczesna & Agnieszka, 2020)	Two-sector DSGE model	Sectoral price stickiness influences inflation persistence in Poland.

where λ is the Fourier frequency, and $f(\lambda; d)$ is the spectral density function of the time series X_t .

3.4. Estimation Procedure

To implement the local Whittle estimator, the following steps are taken:

1. First, we compute the periodogram of the time series, $I(\lambda)$, for each Fourier frequency, λ .
2. We select a frequency range $[\lambda_L, \lambda_U]$ for estimation. The range is chosen to avoid low-frequency and high-frequency noise affecting the estimation (from 0.20 to 0.60).
3. The local Whittle function takes the form:

$$L(d) = (1/M) \sum [\log I(\lambda) + g(\lambda; d)] \quad (2)$$

where the summation is over the selected frequency range, and M is the number of frequencies within the range.

4. We estimate the long-memory parameter d by minimizing the local Whittle function with respect to d :

$$\hat{d} = \operatorname{argmin} L(d) \quad (3)$$

3.5. Application to Headline Consumer Price Index Data

To estimate long memory in the headline inflation dataset, we use the following procedure:

1. Since we use monthly data, prior to estimation, the data are seasonally adjusted using X-13ARIMA-SEATS, means removed to ensure stationarity.
2. We compute the periodogram for each country's time series data.
3. Considering the dataset's characteristics and potential noise, we elect an appropriate frequency range for the estimation (number of harmonic ordinates).
4. We estimate the long-memory parameter d for each country by minimizing the local Whittle function with respect to d .
5. Finally, we compute the rolling long-memory parameter d to observe changes and shifts in d over time, reflecting the true nature of inflation.

By applying this semi-parametric technique to the inflation dataset, we obtain precise and efficient estimations of the long-memory inflation properties across European countries.

3.6. Data and Sample

We use the global inflation database to study the nature of inflation in Europe (Ha et al., 2021). The dataset includes numerous inflation indicators, such as headline inflation, core inflation, wholesale price inflation, and GDP deflator inflation. We focus our research on headline inflation in the EU, EA, EEA, and member countries. To this end, we use monthly data on EU member countries from January 1996 to January 2023. For more details on the methodology calculation and inflation measures definition, see (Ha et al., 2021). Studying core inflation, energy and food inflation, and producer prices in Europe is too extensive for a single study, so we narrow our choice to HCPI following the arguments below.

Headline inflation is sensitive to short-term economic fluctuations, such as changes in energy or food prices, which can affect inflation. Therefore, researchers can capture the potential impact of these fluctuations on the inflation dynamics in Europe by studying inflation persistence using the HCPI.

The HCPI captures the price changes in an economy comprehensively. A wide range of household goods and services are included, making it a representative indicator of the general price level. This comprehensive coverage gives researchers a holistic understanding of inflation persistence in Europe.

The HCPI, calculated using a similar methodology across European countries, enables comparability in the analysis of inflation persistence. This consistency is especially crucial when examining cross-country differences in inflation dynamics because it ensures that methodological inconsistencies will not impact the results.

The HCPI is often used as a primary target for inflation by central banks and monetary authorities in Europe, including the ECB. By studying the persistence of inflation using the HCPI, researchers can provide insights directly relevant to policymakers' objectives and decision-making processes.

Data is readily available to European countries, with data provided by national statistical agencies and international organizations such as Eurostat and the International Monetary Fund (IMF). This accessibility ensures that researchers have a consistent and reliable data source to analyze inflation persistence. In addition, data are frequently updated, typically monthly,

enabling researchers to study inflation persistence in near real-time. This timely data enables the investigation of recent trends and the potential impact of policy changes or external shocks on inflation persistence.

Countries and areas in the sample include Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, EA, EEA, EU.

We derive our comprehensive European inflation persistence database using the local Whittle estimation procedure described below (Ha et al., 2021).

3.7. Method Selection and Robustness

We choose the local Whittle estimation method over other long-memory estimation methods, as we find the local Whittle estimator more efficient in estimating the long-memory headline inflation. The local Whittle estimator is relatively robust to short-term dependence in the inflation data. Its simplicity reduces the computational burden and time required to perform the estimate compared to more complex estimation techniques. By focusing on a specific frequency range, the local Whittle estimation method reduces the influence of low-frequency and high-frequency noise on estimation. This leads to more precise and accurate estimates of the long-memory parameter, even in the event of noise in the data. The local Whittle estimator is a semi-parametric method that does not rely on a specific parametric data model. This flexibility allows the estimator to be applied to a wide range of time series data, which makes it suitable for the analysis of inflation persistence. The local Whittle estimation method proposed by (Baum et al., 2020) presents many advantages over alternative long-memory estimation techniques. The method's efficiency, robustness, flexibility, computational simplicity, and reduced noise sensitivity make it an appropriate choice for estimating long-memory inflation in European countries.

4. Results

Here, we present the evidence on long memory (inflation persistence) for HCPI. Table 1 shows the local Whittle estimates of the fractional differencing parameter d for HCPI inflation series 01/01/1996 -

01/01/2023 for countries and regions. Next, we estimate the long memory parameter d for individual countries and regions for headline inflation rates. Following the (Baum et al., 2020; Baum et al., 1999) approach, the choice of our estimation sample size is based on results for different sample sizes ($v = 20, 30, 40, 50, \text{ and } 60$). The lowest standard error for the HCPI series for individual countries and regions is obtained for the sample size $v = 60$ (standard error testing results not presented here due to publication space). The Whittle's maximum likelihood estimator results are visible in Table 1. Finally, we explain in detail the results for the sample size $v = 60$, being the most robust (sample size sensitivity).

We see significant differences in the estimated long-memory parameters between the countries (Table 2). For most countries, the inflation persistence parameter is below 1 (order of integration). Thus, we can reject the null hypothesis of the unit root in the HCPI series. Also, countries like Bulgaria, the Czech Republic, Estonia, Germany, Hungary, Italy, Latvia, Lithuania, the Netherlands, and Poland have a d much smaller than 1. However, if $d = 0.97$, the unit root null can not be rejected, as it cannot be for Iceland, Luxembourg, or Spain. We can see shocks in the HCPI's transitory effect for most countries in the sample. We found permanent effects of a shock in HCPI (unit root) in Spain, Luxembourg, and Iceland. We check the data for Iceland using the Whittle estimator on detrended data and the exact local Whittle estimator. Both estimators in the case of Iceland show d close to 1 (0.970). This suggests that the impact of a shock on the HCPI rate in these countries is likely to persist over time. More research might be needed to determine what is causing this inflation's persistence and what it might mean for monetary policy.

From the data in Table 2, we can see that persistence levels in European countries are different. This suggests that headline inflation may be sensitive to shocks and take longer to adjust. For example, Luxembourg and Spain have high d values (0.982 and 0.975, respectively), which shows their persistent inflation rates.

On the other hand, Bulgaria has one of the lowest d values, which is 0.834. This means its headline inflation rate is mean reversing and responds more

Table 2*Local Whittle Estimates of the Fractional-Differencing Parameter d for Headline consumer Inflation Rates (HCPI)*

Inflation series	Number of Harmonic Ordinates				
	$\nu = 20$	$\nu = 30$	$\nu = 40$	$\nu = 50$	$\nu = 60$
(HCPI)					
Austria	0.998	0.999	0.880	0.879	0.914
Belgium	0.968	0.976	0.831	0.872	0.917
Bulgaria	-	0.993	0.905	0.828	0.834
Croatia	-	0.921	0.814	0.831	0.907
Cyprus	-	-	0.847	0.877	0.943
Czech Republic	0.755	0.766	0.706	0.773	0.885
Denmark	0.959	0.973	0.851	0.850	0.907
Estonia	0.992	0.972	0.768	0.808	0.898
Finland	0.973	-	0.880	0.894	0.946
France	0.990	-	0.899	0.910	0.948
Germany	0.992	0.974	0.832	0.856	0.899
Greece	-	-	0.865	0.878	0.940
Hungary	0.838	0.869	0.833	0.838	0.858
Iceland	0.979	-	0.895	0.907	0.970
Ireland	0.925	0.989	0.847	0.888	0.933
Italy	-	-	0.869	0.874	0.890
Latvia	-	-	0.842	0.836	0.890
Lithuania	0.986	0.937	0.739	0.771	0.858
Luxembourg	-	-	0.885	0.923	0.982
Malta	-	-	0.907	0.903	0.944
Netherlands	0.759	0.889	0.796	0.828	0.896
Norway	0.868	0.907	0.869	0.901	0.926
Poland	0.669	0.695	0.743	0.798	0.868
Portugal	-	-	0.892	0.882	0.928
Romania	0.852	0.960	0.927	0.935	0.963
Slovakia	0.791	0.862	0.863	0.878	0.925
Slovenia	0.860	0.996	0.876	0.898	0.940
Spain	-	-	0.876	0.918	0.975
Sweden	0.834	0.966	0.836	0.852	0.907
Switzerland	0.500	0.339	0.228	0.506	0.928
UK	-	-	0.890	0.898	0.931
EA	0.987	-	0.857	0.876	0.918
EEA	0.976	0.989	0.855	0.871	0.916
EU	0.976	0.990	0.854	0.870	0.915

Note: Unreliable Whittle estimate - value too close to the upper boundary

quickly to shocks. Lithuania and Hungary also display lower persistence levels, with d values of 0.858.

The d values for the Euro Area (EA), the European Economic Area (EEA), and the European Union (EU) are close, ranging from 0.915 to 0.918. This shows that all three regions have about the same

persistence. Therefore, the headline inflation rate will likely stay the same in the Euro Area, the EEA, and the EU. This means that economic shocks may have a longer-lasting effect on prices in these areas. However, the fact that Lithuania and Hungary have lower persistence levels shows that their economies

are more responsive to change.

Current energy supply shocks (war in Ukraine) and COVID-19 post-supply-chain exogenous shocks on headline inflation in Europe will have long-term consequences for consumers, firms, and markets.

Italy, Germany, and France were chosen as benchmarking group for comparison in the results section for several salient reasons:

- **Economic Significance:** Germany, France, and Italy are three of the largest economies in the European Union. Their economic performance and policies can have significant ripple effects throughout the region.
- **Diverse Economic Profiles:** While Germany is known for its robust industrial base and export-driven economy, France boasts a mix of private and public enterprises. Italy, on the other hand, with its rich history in arts and culture, offers a different economic landscape with a focus on tourism and luxury goods. This diversity allowed us to draw comparisons across varied economic profiles.
- **Historical Context:** Historically, these countries have been key players in the European integration process. By focusing on them, we can trace the roots of specific policies and their impacts over the decades.
- **Availability of Data:** Comprehensive and reli-

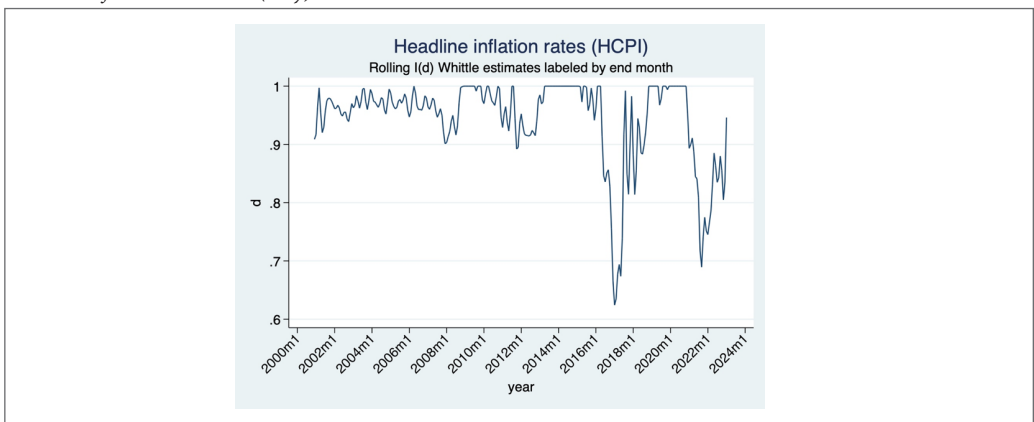
able economic data were readily available for these countries, ensuring the robustness of our analysis.

Benchmark group results are compared to other EU member countries to highlight unique economic behaviors or trends. The European Union is a complex economic entity. While our focus was on three primary countries, it's essential to discuss the broader implications of our findings on the entire region. Comparing results with other EU countries enriches the contribution to inflation persistence, offering a comprehensive understanding of the subject matter.

4.1. Headline Inflation Persistence in Italy

From 2001 to 2007, Italy experienced relatively high inflation persistence, with most values ranging between 0.90 and 1 (Figure 1). This period of economic expansion in Italy was also one of rising inflationary pressures, partly due to the 2002 introduction of the euro. The global financial crisis 2009 significantly impacted Italy, resulting in a considerable rise in inflation persistence. The values for this period are at or close to 1.00, indicating that the crisis's effects on inflation were enduring. Economic contraction, rising unemployment, and increased market volatility marked this period. In the aftermath of the financial crisis, Italy experienced moderately persistent inflation between 2010

Figure 1
Headline Inflation Persistence (Italy)



and 2014, with most values ranging between 0.9% and 1.0%. During this period, the Italian economy struggled to recover due to high public debt levels and slow economic growth. The European Central Bank (ECB) implemented unconventional monetary policies to support the economies of the Eurozone, including Italy, which may have contributed to the stabilization of inflation persistence during this time frame. Italy's inflation persistence ranged from 0.6% to 1.0% from 2015 to 2017. The ECB's quantitative easing program characterized this period, which aimed to stimulate economic growth and bring inflation closer to the ECB's target of just below 2%.

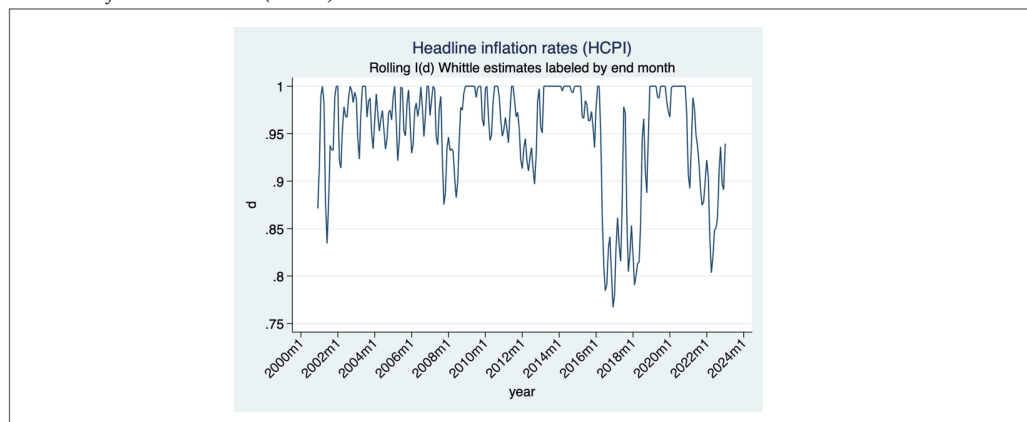
The variation in persistence values during this period may indicate the uncertain economic climate and the Italian economy's challenges, such as high public debt and political instability. During 2018-2021, Italy's inflation persistence remained relatively high, with values mostly near or at 1.00. However, the COVID-19 pandemic significantly impacted the Italian economy, resulting in a substantial economic contraction in 2020. In addition, the ECB's emergency monetary policies, such as the Pandemic Emergency Purchase Programme (PEPP), contributed to the persistence of high inflation during this period. Recent data indicates Italy's inflation persistence decreased between 2022 and 2023, with values ranging between 0.70 and 0.90. This could mean a gradual recovery from

the pandemic-induced economic downturn and reduced inflationary pressures due to quantitative tightening. The introduction of the euro, the global financial crisis, unconventional monetary policies, and the COVID-19 pandemic are just a few factors that have impacted the persistence dynamics of the HCPI in Italy over the past 20 years.

4.2. Headline Inflation Persistence in France

Early in the 2000s, France experienced moderate inflation, with some persistence reflected in the HCPI (Figure 2). This is due to the global economic slowdown that followed the bursting of the dot-com bubble and the 11 September 2001 terrorist attacks. The European Central Bank (ECB) lowered interest rates to stimulate the economy, resulting in inflationary pressure. Inflation in France remained moderate, with some fluctuations, from 2003 to 2007. Increased demand for goods and services and low interest rates contributed to global economic expansion. However, the persistence of inflation during this period can partially be attributed to higher oil prices. The 2008-2009 global financial crisis significantly impacted the global economy, decreasing demand and inflation rates. France's HCPI persistence demonstrates a similar trend with reduced values during this time. To stimulate the economy, policymakers and the ECB implemented stimulus measures, contributing to the persistence of inflation.

Figure 2
Headline Inflation Persistence (France)



A slow economic recovery marked the post-crisis period, particularly in the Eurozone. High public debt and the European sovereign debt crisis led to austerity measures in many countries, which slowed growth and contributed to inflation in France. The ECB implemented unorthodox monetary policy measures to stimulate the economy and combat deflationary pressure, such as low interest rates and quantitative easing. From 2015 to 2019, inflation remained relatively stable. The Eurozone's economic growth has improved due to the ECB's accommodative monetary policy and a more stable global economy. However, several factors, such as geopolitical tensions and Brexit-related uncertainty, may have contributed to the observed persistence of inflation. The COVID-19 outbreak of 2020-2021 substantially impacted the global economy, resulting in sharp declines in output and demand. The world's governments and central banks, including France and the ECB, have taken unprecedented fiscal and monetary measures to support their economies. The fluctuating persistence of HCPI during this time can be attributed to the pandemic's economic disruptions and the political responses that followed. We observe a decline in HCPI persistence during 2022-2023, possibly due to the economic recovery that followed the COVID-19 pandemic and tightening interest rates. Other factors, such as supply chain disruptions, higher energy prices, and

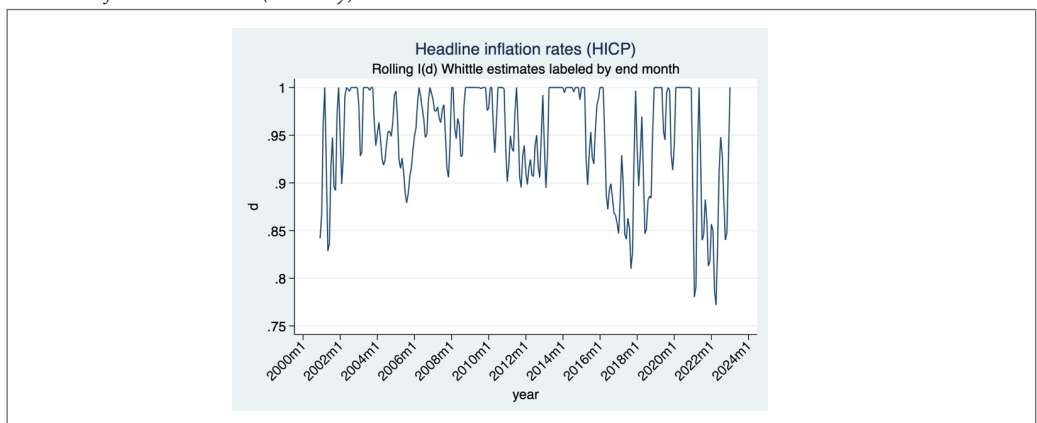
labor market imbalances, may contribute to the inflation dynamics in France.

4.3. Headline Inflation Persistence in Germany

In Germany, inflation persistence has fluctuated between periods of strong persistence (values close to 1) and relatively low persistence (Figure 3). The global financial crisis significantly affected global inflation. Germany suffered continuous high inflation during 2008 and 2009, likely due to the uncertainty and instability of the global economy. The European sovereign debt crisis (2010–2012) hurt eurozone countries, stifling economic growth and causing variable inflation rates. Inflation in Germany fluctuated during this period, reflecting the unpredictability of the Eurozone. The COVID-19 epidemic has badly affected the worldwide economy, which has caused supply chain disruptions, decreased consumer spending, and economic recession.

Germany's inflation fluctuated throughout the pandemic, reflecting uncertain and changing economic conditions. As one of the largest economies in the European Union, Germany's economic growth and productivity substantially impact its persistent inflation. In contrast to periods of sluggish growth or recession, when inflation rates are more likely to fluctuate, periods of robust growth are typically characterized by greater inflation per-

Figure 3
Headline Inflation Persistence (Germany)



sistence. The persistence of inflation in Germany has been affected by interest rate fluctuations, quantitative easing, and fiscal stimulus packages. In addition, Germany has had periods of low unemployment and a robust labor market, which may have contributed to higher inflation. However, periods of high unemployment or disruption of the labor market, such as the COVID-19 pandemic, result in a more volatile inflation rate. From December 2000 to January 2023, global and domestic economic factors influenced the German inflation rate. Significant events such as the 2008 financial crisis, the European sovereign debt crisis, the COVID-19 pandemic, and domestic factors such as economic growth, fiscal and monetary policies, and labor market conditions have significantly impacted the persistence of inflation in Germany.

4.4. Headline Inflation Persistence Convergence and Divergence in Europe

Italy has a higher inflation rate persistence compared to France and Germany. France has moderate persistence among the three nations, while Germany has the least. The persistence of inflation can differ between countries for many reasons, including the unique economic structure of each country. Italy has a more significant proportion of small and medium-sized enterprises and a more rigid labor market than France and Germany. Higher inflation in Italy can be persistent because of these factors. Although the ECB conducts a single monetary policy, the transmission of this policy may vary from country to country due to differences in financial structures and institutions' efficiency. Therefore, the effectiveness of monetary policy in controlling persistent inflation may differ between countries. Different fiscal policies can also influence the persistence of inflation. For a country with high public debt, it may be more difficult for the government to implement fiscal measures to combat inflation, leading to persistent inflation. Finally, inflation expectations can have a significant impact on inflation. If economic actors expect future inflation to rise, they can adjust their behavior accordingly, leading to higher inflation rates. Therefore, inflation persistence can vary between Italy, France, and Germany due to divergences in inflation expectations.

Italy's average HCPI persistence is slightly lower than France and Germany. However, the standard

deviation for Italy is lower, suggesting that Italy's inflation is less volatile than France and Germany. Furthermore, Italy's inflation persistence is relatively stable over time, with fewer fluctuations than France and Germany. This could suggest that Italy's inflation dynamics are more predictable and less influenced by external factors.

France's inflation persistence fluctuates more than Italy's but less than Germany's. France's inflation dynamics appear to be more influenced by external factors than Italy's, but the country is better at maintaining stable inflation than Germany's.

Germany has the highest fluctuations in inflation persistence over time, with periods of high persistence followed by periods of lower persistence. Germany's inflation dynamics appear to be more affected by external factors and economic shocks than Italy and France.

There are periods where all three countries exhibit nearly perfect persistence, such as in March 2001, May 2002, May 2003 - August 2003, and January 2009 - September 2009. These periods might represent common macroeconomic events or shocks that affected all three countries similarly.

The data suggest that Italy, France, and Germany's inflation persistence dynamics are interconnected, as they experience similar fluctuations over time. Regional or global factors, such as European Central Bank monetary policy or global economic trends, may significantly drive the inflation persistence in these countries. The observed trends and fluctuations are due to the interconnectedness of Italy, France, and Germany's economies and shared macroeconomic factors despite exhibiting differences in their inflation persistence dynamics.

Here, we examine key synchronization phases and potential explanations for the observed patterns.

The early 2000s (2001-2003):

There was a relatively synchronized increase in inflation persistence among countries during this period. This is because the ECB established its monetary policy framework in the early years of the Eurozone, coinciding with this event. Therefore, the synchronization of member countries can be attributed to the harmonization of their monetary policies, leading to a more coordinated response to inflationary pressures.

The mid-2000s (2004-2007):

The synchronization between the three countries weakened in this period. Italy's inflation persistence remained relatively stable, while France and Germany experienced increased and decreased persistence periods. Varying national economic conditions, such as differences in labor market structures and fiscal policies, could have led to different inflationary responses across countries, accounting for this divergence.

Global Financial Crisis (2008-2009):

The synchronization of inflation persistence among Italy, France, and Germany strengthened again during the global financial crisis. The common external shock that affected all countries similarly and the concerted efforts of the ECB and other central banks to respond to the crisis, which included lowering interest rates and implementing unconventional monetary policies, can be attributed to this.

Post-crisis period (2010-2019):

The synchronization of inflation persistence among the three countries was more inconsistent in the years following the global financial crisis. Several factors, such as the sovereign debt crisis in the Eurozone, which affected countries differently, and the ECB's gradual normalization of monetary policies, can contribute to this. In addition, country-specific factors, such as structural reforms and fiscal policies, could have contributed to the different inflation persistence dynamics.

Pandemic Period (2020-2021):

All three countries experienced a sharp decline in inflation during the initial phase of the pandemic, as lockdown measures led to a decrease in consumer demand, disruptions in supply chains, and lower energy prices. High levels of synchronization in the HCPI resulted from this between Italy, France, and Germany.

In response to the crisis, the (ECB) took a comprehensive approach to monetary policy, including lowering interest rates, expanding asset purchase programs, and providing targeted long-term refinancing operations to support credit conditions. As a result, the negative impact on inflation was stabilized and contained by these measures, along with fiscal stimulus packages introduced by national governments.

However, some divergence in the HCPI synchronization was observed between the three countries as the pandemic progressed. The pandemic has had varying degrees of success in different countries, which can be attributed to the structure of each country's economy. For example, economies that rely heavily on tourism or the manufacturing sector were affected differently by the pandemic.

Post-Pandemic period (2022 onward):

The economies began to recover as vaccination campaigns progressed, and countries gradually lifted lockdown measures. As a result, convergence and divergence have characterized the HCPI synchronization between Italy, France, and Germany in the post-pandemic period.

The ECB's continued unconventional monetary policy stance and the implementation of the European Union's Next Generation EU recovery fund, aimed at supporting economic recovery and growth across the bloc, contribute to convergence.

The divergence in HCPI synchronization can be attributed to factors such as the different speeds of economic recovery, supply chain disruptions, and the impact of fiscal policies on inflation. For example, with its strong manufacturing sector, Germany might have experienced higher inflation due to supply chain bottlenecks. In contrast, Italy and France, whose economies depend more on tourism, might have experienced slower price increases as the tourism industry takes longer to recover fully.

A combination of common factors, such as the ECB's monetary policy measures and the EU's recovery fund, as well as country-specific factors related to the management of the pandemic, the structure of each country's economy, and their respective fiscal policies, can explain the HCPI synchronization between Italy, France, and Germany during the pandemic and post-pandemic periods.

The synchronization of inflation persistence among Italy, France, and Germany can be attributed to common external factors, such as global economic shocks, coordinated monetary policy responses, and country-specific factors that influence inflation dynamics. The synchronization and divergence phases between these countries highlight the interconnectedness of their economies while also emphasizing the unique national aspects that can lead to divergent inflation persistence patterns.

5. Discussion

Our study provides recursive estimation insights on consumer price inflation persistence and synchronization in the EU, EA, EEA, and EU country members from 2000 to 2023. For publication space limitations, we discuss the findings for the three most important EU economies: Italy, France, and Germany. The study results are aligned with De Vijlder (2022). Elevated inflation has become widespread, increasing the risk of further price increases and making high inflation more persistent, as highlighted in the study. This persistence could weaken the credibility of central banks, causing long-term inflation expectations to become unanchored. As a result, monetary authorities might aggressively tighten policy in response.

It is easier for central banks to control inflation when inflation expectations are well-anchored, meaning changes in current inflation rates do not significantly affect future inflation expectations.

We can observe varying degrees of inflation persistence across European countries. For example, Luxembourg (0.982) and Spain (0.975) have very high inflation rates, meaning that changes in their previous inflation rates substantially impact current and future inflation rates. On the other hand, countries such as Bulgaria (0.834) and Hungary (0.858) have lower inflation rates, suggesting that the influence of past inflation rates on current and future rates is weaker.

According to the study by (Bems et al., 2021), anchoring expectation is a crucial factor in determining inflation persistence. The central bank can effectively manage inflation by influencing short-term interest rates and lowering inflation persistence when expectations are well-anchored. On the other hand, poor expectations can lead to higher inflation persistence, making it more difficult for the central bank to control inflation.

We can infer from our study results that countries with higher inflation persistence may have weaker expectations anchoring, making it more challenging to control inflation in those countries. Conversely, countries with lower inflation persistence could benefit from well-anchored expectations, allowing their central banks to manage inflation more effectively. In general, inflation expectations

in the euro area are well-anchored, according to the study by (Łyziak & Paloviita, 2017). The degree of anchoring, however, varies across countries and depends on factors such as economic conditions, the credibility of the central bank, and the communication policy of the central bank. Our study results provide insights into how effective expectation anchoring can influence the degree of inflation persistence in various European countries.

The study highlights the importance of understanding the relationship between sectoral inflation persistence, market concentration, and imperfect common knowledge (Kato et al., 2021). This paper studying HCPI persistence can provide insights into the possible relationship between sectoral inflation persistence and inflation persistence.

Economies with higher inflation persistence, such as Luxembourg (0.982) and Spain (0.975), may have industries with higher market concentrations and imperfect common knowledge, which can contribute to more significant sectoral inflation. This could be one of the factors contributing to higher inflation in these countries.

Countries like Bulgaria (0.834) and Hungary (0.858) with lower HCPI persistence parameter values might have industries with lower market concentration and better common knowledge. This could reduce sectoral inflation, contributing to a decrease in inflation in these countries.

Countries such as Luxembourg (0.982) and Spain (0.975) with higher HCPI persistence are more susceptible to the effects of oil price shocks on inflation persistence. In these countries, this could be due to a higher dependence on oil imports, a higher degree of openness in the economy, or a less effective monetary policy. For example, €4.5 billion of petroleum oils were imported from Spain to Luxembourg in 2018.

Countries with lower consumer inflation persistence, like Bulgaria (0.834) and Hungary (0.858), might be less affected by oil price shocks on inflation persistence, conversely. Less reliance on oil imports (especially Russian oil), less openness, or a more successful monetary policy might contribute. Our study results support the findings of (Oloko et al., 2021).

The study by (Bratsiotis et al., 2015) highlights

the importance of understanding the relationship between inflation-targeting policies and inflation persistence. Countries registering lower inflation persistence, such as Bulgaria (0.834) and Hungary (0.858), may have inflation-targeting policies that are more effective. The central bank's commitment to a specific inflation rate in these countries could be the reason for the lower inflation's persistence. This helps anchor inflation expectations and allows quick adjustment toward the target rate.

Countries with higher HCPI persistence parameter values, like Luxembourg (0.982) and Spain (0.975), might be experiencing challenges in implementing effective inflation-targeting policies, leading to higher inflation persistence in these countries. These challenges could result from less credible central banks, weaker institutional frameworks, or less effective monetary policy tools.

Research (Fuhrer, 2010) discusses the role of expectations in shaping inflation persistence. Countries like Luxembourg (0.982) and Spain (0.975) may have more persistent inflation expectations, making it more difficult for monetary policy to bring inflation back to target levels. However, economies with lower HCPI persistence parameter values, such as Hungary (0.858) and Bulgaria (0.834), may have more adaptable or forward-looking expectations, allowing for a quicker inflation adjustment. The author also emphasizes how crucial price-setting practices are in determining inflation persistence. Higher nominal rigidity or more rigid price-setting mechanisms may be present in countries with higher inflation persistence, which causes prices to adjust to shocks more slowly. The price-setting mechanisms in economies with lower inflation persistence may be more adaptable, allowing quick adjustment to shocks. In contrast, the opposite may be true for economies with higher values.

Also, (Fuhrer, 2010) discusses the role of monetary policy in influencing inflation persistence. Central banks' credibility and the effectiveness of their policy tools can impact inflation persistence in different countries. Countries with higher HCPI persistence could face challenges implementing effective monetary policies or have less credible central banks. Conversely, countries with lower persistence may have more effective monetary policy

frameworks and more credible central banks.

Our findings for consumer inflation persistence differ from the study of (Darvas & Varga, 2014) using all-items consumer price index and quarterly data for EA, United States, and CEE countries. Since we use monthly data for HCPI and recursive estimation, a difference in the findings is expected, with the inflation persistence calculated here being higher than in the study (Darvas & Varga, 2014).

The study results presented here for France, Germany, Italy, and the UK support the findings from the study (Caporale et al., 2022) on inflation persistence in these G7 countries.

Our analysis demonstrates the value of interdisciplinary research in understanding complex economic phenomena like inflation persistence. We can enhance our understanding of the drivers of inflation persistence and inform better policy decisions by integrating findings from different studies with our own.

6. Conclusions

Our study on headline inflation persistence in the EU provides essential insights into the broader Eurozone and global inflationary environment. The factors influencing HCPI persistence in Europe include:

- Imported inflation, particularly from energy prices, has become a significant driver of inflation in the Eurozone, as evidenced by events such as the war in Ukraine.
- Headline inflation persistence varies across European countries, underscoring the need for tailored policy approaches and emphasizing the importance of understanding the specific factors driving inflation persistence in each country.

- Supply bottlenecks and the normalization of demand as economies reopen after COVID-19 have considerably impacted inflation persistence.

Furthermore, our analysis reveals that inflation persistence can be influenced by price-setting behavior and rigidity, expectation formation, and monetary policy. More rigid price-setting mechanisms or higher nominal rigidity may result in slower price adjustments to shocks, leading to higher inflation persistence. In contrast, countries with more flexible price-setting mechanisms may experience lower inflation persistence.

The role of expectation formation is crucial for understanding inflation persistence. Countries with more adaptive or forward-looking expectations may exhibit quicker inflation adjustments, while those with more persistent inflation expectations may face challenges in reaching target levels.

Monetary policy is instrumental in shaping inflation. Central banks' credibility and the effectiveness of their policy tools can influence inflation across countries. A more effective monetary policy framework and credible central banks can contribute to reducing inflation.

Our study suggests that economies with higher inflation persistence may have weaker anchoring of expectations, making it more challenging to control inflation. In contrast, well-anchored expectations could benefit economies with less persistent inflation, enabling central banks to manage inflation more effectively.

The effectiveness of inflation-targeting policies can also influence the degree of inflation persistence. Policymakers can design more suitable inflation-targeting policies by utilizing quantitative information on inflation persistence.

The recursive insights on HCPI inflation persistence in the EU presented in our study contribute to the existing knowledge on inflation persistence drivers and anchoring/targeting. Furthermore, our analysis enhances our understanding of the potential drivers and dynamics of inflation persistence in various European countries, which can inform the design of more effective inflation management strategies.

Our study's scientific contribution and value on HCPI inflation persistence in the EU are noteworthy, as it provides a comprehensive analysis that synthesizes findings from multiple sources and compares them with our study results. By offering a recursive perspective on the nature of inflation in the EU, our research fills a crucial gap in the existing literature. Furthermore, it identifies factors contributing to convergence or divergence in inflation persistence across European countries and explores the implications of these differences for monetary policy. Moreover, we enhance our understanding of the potential drivers and dynamics of inflation persistence, which can inform more effective inflation management strategies. Overall, this article offers valuable insights for policymakers and

contributes to the ongoing discourse on inflation persistence, expectation formation, and monetary policy design.

It is crucial for policymakers to have a quantitative understanding of inflation to develop effective monetary policies. By recognizing the nuances and dynamics of inflation persistence, policymakers can implement targeted strategies to address inflationary pressures. Additionally, the synchronization of inflation persistence across borders can greatly impact the effectiveness of monetary policies, making coordination between policymakers essential.

Our research highlights the significance of managing inflation expectations through effective communication with the public and markets. By aligning inflation expectations with policy objectives, policymakers can better anticipate and respond to economic shocks. Understanding the patterns of convergence and divergence in inflation persistence is key to ensuring that policy interventions are both timely and effective.

Despite the valuable contributions of our study, it is essential to acknowledge its limitations. First, the analysis is primarily focused on the EU area, which may limit the generalizability of the findings to other regions or economic contexts. Second, the study does not incorporate time-varying coefficient methods, ARMA-ARIMA, or ARFIMA models with stochastic parameter breaks, which could provide more nuanced insights into the dynamics of inflation persistence. Lastly, while the study identifies key factors contributing to inflation persistence, it needs to explore the underlying mechanisms in depth, which could help better understand the complex interactions between these factors. Future research can address these limitations by broadening the scope of the analysis, incorporating advanced econometric methods, and delving deeper into the mechanisms driving inflation persistence. Effective monetary policy and inflation-targeting is only attainable with profound knowledge of inflation persistence nature.

7. Acknowledgements

We want to express our sincere gratitude to Christopher F. Baum, Professor of Economics and Social Work Chair, Department of Economics Boston College, Chestnut Hill MA, USA, Associate Researcher, Centre of Excellence for Science and In-

novation Studies, Stockholm DIW Research Fellow, German Institute for Economic Research [DIW Berlin] for his invaluable support and expertise in assisting with the Stata coding for the rolling local Whittle estimation procedure.

7.1. Funding Sources

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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