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# Driving Forces of the Consumer Price Index During the Crises in the Eurozone: Heterogeneous Panel Approach

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**Abstract:** This paper examines key driving forces of inflationary pressures, taking into account supply and demand side determinants and actions of policy makers, during the pandemic and geopolitical crises in the Eurozone. Using heterogeneous nonstationary macro-panel models, especially the Mean Group (MG) and Pooled Mean Group (PMG) methods in the period 2020q1–2024q4, it is concluded that the dominant determination of inflationary pressures comes from the supply side. There is a long-run positive equilibrium relationship between the growth of energy prices and the growth of the consumer price index (CPI), and between the index representing supply bottlenecks (SBI) and the growth of CPI, while the relationship with the unemployment rate is insignificant. Also, the existence of a long-run equilibrium between the interest rate and CPI is homogeneous due to the unique monetary policy on a sample, and negative, indicating the efficiency of that policy. However, the speed of adjustment of individual economies is heterogeneous, and in the case of Greece and Ireland, insignificant. The heterogeneous or insignificant response of Eurozone member states, especially related to core-periphery asymmetry, refers to the vulnerability and structural weakness of the Eurozone economies, and the need for deeper integration.

**Keywords:** consumer price index; energy price; interest rate; heterogeneous panels; Eurozone



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## 1. Introduction

Shocks that are inherently exogenous, pandemic crisis, and geopolitical crisis, have drastically affected the economies of the European Union (EU). The most visible macroeconomic outcome was the marked increase in inflation, which achieved a historical pick in mid-2022. Due to the pandemic crisis spread, the official response of many governments around the world led to the locking of national borders, as well as transport. The increase in energy prices thus led to a sharp decline in economic activities in the second half of 2020 in the majority of the EU countries (Bigerna 2023). Not long after, the Russian military intervention in Ukraine at the beginning of 2022 complicated the already difficult macroeconomic situation, by limiting the delivery of petroleum products to the territory of the EU. Almost interrupted supply chains and reduced demand were inevitable during the pandemic crisis, and then the reduction in aggregate supply was present during geopolitical turbulence.

In the years of pandemic and geopolitical crises, the driving forces of inflation were multiple, but the most important ones are related to energy prices, food prices, demand shifts, and supply bottlenecks.

The rise in energy prices was ubiquitous during the analyzed period, and it is one of the main indicators of the creation of inflationary pressures (Ďurčová 2021). However, it is particularly important to point out the vulnerability of the EU economy due to its huge dependence on energy products imported from Russia. The lack of crude oil led to a decrease in production, a sharp rise in the prices of agricultural and food products, and an increase in energy prices.

On the demand side, a crucial role had government spending programs which created strong consumer and business demand. On the other hand, demand shifts might stem as well from unemployment because of the tightened labor market, which put upward pressure on wages and prices (Blanchard and Bernanke 2023; Blanchard 2022).

On the supply side, supply chain disruptions and shortages had an important inflationary impact, particularly in 2021 and 2022. Shortages are defined as a lack of sufficient supply to meet demand. In the period of the pandemic crisis, the combination of strong demand and supply chain bottlenecks led to further pressure on prices (Baqaee and Farhi 2020; Caldara et al. 2020). Supply chain bottlenecks are cost-push shocks, that decrease employment and output while increasing prices, meaning important trade-offs for monetary policy (Burriel et al. 2023). Therefore, this paper analyzes the reaction of the monetary authorities (European Central Bank—ECB) observed through the growth of interest rates as a response to inflationary pressures. The reaction was restrictive monetary policy, through an increase in interest rates in order to realize downward pressure on prices.

In this context, the basis of this work is to examine and determine the key driving forces of the consumer price index (CPI), which systematizes inflationary pressures. The time period taken into account is from the first quarter of 2020 to the last quarter of 2023, covering pandemic and geopolitical crises. The observation sample includes twelve economies that are initial members of the European Monetary Union, i.e., the Eurozone (Austria, Belgium, Finland, France, Germany, Greece, Italy, Ireland, Netherlands, Luxembourg, Portugal, and Spain). Although the sample of observed countries may appear rather homogeneous at first glance, this should be considered carefully as the analyzed economies often have diverse economic environments and coordinated but heterogeneous fiscal policies. This is precisely the reason why the paper uses a heterogeneous panel model in order to determine possible differences between countries (Huang and Liu 2005). Since all economies are part of the Eurozone assuming homogeneity, while the time dimension is relatively long assuming heterogeneity, the issue of heterogeneity vs. homogeneity in the model is analyzed with special attention in this paper, through three alternative estimators: the Pooled Mean Group (PMG) estimator, the Mean Group (MG) estimator, and Dynamic Fixed-Effects (DFE) estimator. This analysis could be useful, especially in exploring the long-run relationship between those variables which are expected to be homogeneous across the Eurozone economies, due to a single monetary framework; however, short-run coefficients could be heterogeneous. Therefore, if adjustments toward long-run equilibrium exist in the model, that could be a sign of a stabilization mechanism within a monetary union.

Three basic objectives of this paper are: (1) to indicate and interpret the harmfulness of the sudden increase in energy prices, supply bottlenecks, and demand shifts on inflation; (2) to analyze the effects of the change in the interest rate on the CPI, e.g., (in)efficiency of monetary policy; and (3) using a heterogeneous nonstationary panel model, to determine whether there is a long-run equilibrium relationship between analyzed variables and CPI, on a sample of 12 Eurozone economies in the period 2020q1–2023q4. Although the relation between those driving factors and inflation is well known in macroeconomic theory, the idea of this paper is to empirically show the relative importance of each factor determining inflationary pressures, and to analyze the heterogeneity of those influences in the Eurozone economies, discussing potential repercussions for policymakers.

The rest of this paper is organized as follows: after the introduction, the second part presents a review of the literature, the third part presents a descriptive analysis of the CPI and energy price fluctuations, the fourth part presents the methodology used in the paper, while the fifth part presents empirical model and discussion of the results, based on the PMG estimator. In the last part of the paper, concluding considerations were presented.

## 2. Literature Review

The growth of inflationary rates was the most pronounced anomaly of the pandemic and geopolitical crises, along with the ubiquitous depreciation of economic activities. Inflation at the global level reached multi-decade highs in 2022, far exceeding the monetary

targets in many economies, including the Eurozone, as well as the forecasts of economic policymakers. The year 2023 is marked as the year in which inflation decreases within the EU member states and the Eurozone, precisely because of the reaction of economic policymakers in the form of an increase in interest rates in order to suppress inflationary pressures.

Focusing on inflationary pressures, the majority of research papers were oriented toward energy price increases, and consequently supply-side shock, as the main triggers of inflation. In their research, Hansen et al. (2023) strive to identify the reasons for the sudden increase in inflation. They indicated that the general increase in price levels in the territory of the Eurozone was mainly caused by shocks that occurred in the goods market and resulted in an enormous increase in commodity prices, as well as in limited supply during the pandemic and geopolitical crisis. In line with previous studies, Nickel et al. (2023) concluded that the main drivers of inflation in the Eurozone are increases in energy prices and agricultural and food prices, which are the commodities that the Eurozone countries import the most from Russia and Ukraine. This suggests that the shock was on the supply side, caused by constrained imports and supplies, implying an external nature and therefore, directly dependent on the evolution of the military conflict situation in the east. Neri et al. (2023) and Neri (2024) pointed out in their research that the pandemic and geopolitical crises led to direct shocks on the supply side, with a special focus on electricity price shocks, gas, and fuel. Based on empirical research (including Vector AutoRegressive models, time-varying Phillips curves, and dynamic factor models), it is estimated that about 60 percent of inflationary pressures were generated by the growth of energy prices and that this growth was sharpest in the fourth quarter of 2022. In their work, Piergiorgio and Gazzani (2023) showed that the sudden increase in energy prices has largely spilled over into a general increase in price levels, generating inflationary pressures in many European countries, while the output has mostly remained at the level of previous years, with a slight tendency to fall. Moreover, a broader context of the EU's vulnerability to external shocks in the form of fluctuations in the price of crude oil, gas, electricity, and other energy sources on inflation, unemployment, investments, production, and GDP are analyzed in the paper by Goutsmedt (2021), Kostin et al. (2021), Diego (2021), Demary and Hüther (2022), Prohorovs (2022), Pejčić et al. (2023), Neri et al. (2023), Stojkov et al. (2023), and Pejčić et al. (Forthcoming).

In the context of this paper, the most important papers are those related to supply shortages and the creation of inflationary pressures. Celasun et al. (2022) showed that half of the rise in manufacturing producer price inflation in the Eurozone would not have occurred in the absence of supply bottlenecks. The empirical studies that analyze the macroeconomic impact of supply bottlenecks are very limited due to a lack of data. Therefore, further authors made important contributions to the literature, since they proposed measures of supply bottlenecks and made them available to other authors. Caldara et al. (2020) used predictive regressions and a structural vector autoregressive (VAR) model in the USA, analyzing the period from 1900 to 2023, covering periods such as the World Wars, the oil shocks of the 1970s and the 1980s, and the COVID-19 pandemic. They showed that shortages (supply bottlenecks) lead to persistently higher inflation and lower economic activity. Pitschner (2022) and Blanchard and Bernanke (2023) have tackled the intersection of shortages and the behavior of inflation during the pandemic crisis and further. In particular, the main goal of Pitschner (2022) was to assess to what extent shortages are common during the pandemic crisis. Blanchard and Bernanke (2023), analyzed a model which seeks to explain the causes of pandemic-era inflation, with a conclusion that supply bottlenecks have a "strong, but temporary effect" on inflation. Burriel et al. (2023) for a sample of six developed European economies and the USA, defined the supply bottlenecks index (SBI) covering period of early or middle-2000s till 2024 on daily and monthly data. The authors showed that the shock of the standard deviation in the SBI raised prices and unemployment and decreased output.

Along with identified shocks on the supply side, Buelens and Zdarek (2023), indicated that the pandemic crisis caused various economic shocks on the demand side as well in the Eurozone. The findings of Cline (2023) coincide with previous research, showing that supply shortages and excess demand are the main generators of global inflation. On the opposite, Bryson et al. (2024) point out that inflationary pressures are directly determined by a problem on the supply side, rather than increasing or excessive demand created by the economy or households. In current geopolitical conditions, as a foundation for the decisions taken by the world's largest number of central banks, a decrease in inflation is expected, but likewise is a rise in unemployment and a negative rate of economic growth.

Namely, when the economic environment is affected by shocks regarding uncontrolled and frequent fluctuations in energy prices, as well as limited production performance, then the attitude of the monetary authorities is crucial, and the trade-off between high inflation and the amortized economy is a reality. Ha et al. (2022) point out that high and fast-growing inflation has prompted central banks around the world to increase interest rates, in order to amortize harmful and overheated economic activities and thereby bring down inflation, expecting that in the medium term, the inflation rate would return within the monetary targets. However, that implies that the central bank's decision to increase interest rates in order to suppress inflationary pressures may cause negative repercussions on economic growth, the unemployment rate, and other objectives. Wellink (2024) points out that the pandemic and post-pandemic crisis undoubtedly produced sharp uncertainties in terms of inflationary pressures and the unified monetary policy within the Eurozone. The author adds that the supranational management of monetary policy has seriously made it difficult to solve problems arising in the real sector in terms of stability.

In mitigating inflationary pressures, the dominant role was played by the European Central Bank (ECB), since Eurozone economies accepted the achievement of monetary goals (inflation stability) at the expense of fiscal goals (lower rate of economic growth). Therefore, Ozil and Arun (2022) highlighted that the biggest discontinuity of the global economy is the occurrence of the recession. Bayraktar (2024) points out that fears of a recession around the world have never been greater, the evidence is the fact that the GDP is slowing down in some developed countries. Komarovskaia (2023) points out that the appearance of stagflation and the dramatic economic scenario of the 1970s has become extremely apparent due to the global crisis. The main reasons for the emergence of stagflationary pressures are directly determined by the uneven and incomplete recovery from the pandemic crisis, which was further prolonged by the conflict in Ukraine.

Analyzing the effects of supply and demand shock during pandemic and geopolitical crisis, some authors proposed the conclusion that those effects were heterogeneous and asymmetric in the Eurozone economies. Carnazza and Liberati (2021) investigated what happened to interest rates on government bonds in the countries of the Eurozone during 2020–2022. They considered the pandemic emergence to be a symmetric shock, while the economic fallout—which manifested as an increase in interest rates—was asymmetric in character. From the other perspective, but with a similar conclusion, Rant et al. (2024) analyze the impact of monetary and fiscal policy on production trends in countries that are part of the Eurozone in the period 2005–2022 with a special focus on the period of the pandemic crisis, using a structural vector autoregressive (SVAR) approach. Based on empirical results, they reveal that the tightening of monetary policy in the form of an increase in interest rates, and due to the suppression of inflationary pressures, produces a negative and delayed effect on both output and inflation, whereby the effects differ between countries. In their research, Pejčić et al. (2024) analyze the key macroeconomic repercussions of the pandemic and geopolitical crisis in the form of growing inflationary pressures, which were generated by the limited supply and the increase in the price of crude oil on a sample of 15 developed EU economies. The research indicated that countries such as France and Portugal faced more severe inflationary pressures, compared to Austria, Belgium, and Finland, where inflationary pressures were far less present. Asymmetric effects are detected in the research of Neri (2024), who pointed out that the insufficient

amount of energy had produced sharper economic anomalies in the form of inflationary pressures in developing countries, compared to highly developed economies. Ceron and Palermo (2020) highlighted that the pandemic crisis deepened economic differences in development, simultaneously the vulnerability within the economies of the EU. Namely, the pandemic crisis revealed heterogeneity in the Eurozone economies, and it represents a warning for the potential further deviation between the core and the peripheral economies of the Eurozone in the coming years.

The contribution of this paper is primarily to provide a comprehensive descriptive and empirical analysis in relation to the generation of inflationary pressures, as well as the reaction of monetary authorities in the form of rising interest rates in the Eurozone. The research will fill a gap in the existing literature in relation to heterogeneous and asymmetric effects of the Eurozone economies during pandemic and geopolitical crises, and modelling of inflation heterogeneity.

## 3. Descriptive Statistics—Growing Inflationary Pressures

Essentially, a rise in the price level is present when there is a shortage or high demand for goods or services. In case of a shortage of certain categories of goods, companies will raise the price of the final product because they have to spend more on materials, wages, or transport. Firms will also charge higher prices if they realize that customers are willing to pay more due to the unavailability of goods or increased demand and thereby, improve their profit status. All the mentioned factors have serious implications for macroeconomic indicators, but they are exogenous and short-term in nature. On the other hand, if it is a long-run factor, that represents a certain discontinuity, such as a pandemic or the current geopolitical crisis, then the situation is incomparably more complex and is reflected in reduced or limited production, which implies an increase in prices (Hunt 2022). The prices of energy, agricultural products, food products, and crude oil reached their maximum during the crisis period. Therefore, we can conclude that the sharp rise in energy prices has far-reaching consequences, not only for end consumers but also for the economy as a whole. Also, in order to understand the entire situation regarding the functioning of the economic policy of the Eurozone during the pandemic and geopolitical crises, it is necessary to take into consideration the role and fluctuations of the interest rate.

Figure 1 shows the average fluctuations of energy prices, interest rates, and the CPI for a sample of 12 Eurozone countries in the period 2020q1–2023q4. The conclusion is that since the second quarter of 2021, there has been an exponential increase in energy prices, followed by an increase in the CPI. In the same period, the value of the interest rate hovered around zero, which indicates that loans are economical, money is cheap, and economic activities are entering an overheating phase. The highest level of energy prices was recorded in the fourth quarter of 2022, after which a downward trend is evident. CPI records an almost identical trend as energy prices till the fourth quarter of 2022, but after that the same trend with one-quarter lag, probably due to measures of economic policy. Namely, the report (International Energy Agency 2024) points out that wholesale gas and electricity prices rose to reach an all-time high in 2022 before starting to fall in 2023, due to swift and joint EU emergency measures. The EU's total spending on energy imports was 604 billion euros in 2022, after a historic low of 163 billion euros in 2020. On the other hand, in thin periods when inflationary pressures decrease, the level of the value of the interest rate starts to rise. During the second and third quarters, the level of the interest rate reaches its maximum value and moves above 4%. This kind of interest rate growth was last recorded during the global financial crisis in 2008.

Important drivers of inflation could be variables on the supply and demand side. In the analysis of the supply side, the most important trigger of inflation would be supply bottlenecks. Burriel et al. (2023) developed the supply bottlenecks index (SBI) which measures supply side issues related to wars, natural disasters, strikes, and, most recently, the COVID-19 pandemic, based on textual searches in national newspapers. The high-frequency nature of the indicator, which can be retrieved daily, or monthly allows for

real-time analysis of bottlenecks and helps to better identify supply shock effects on macro variables. Figure 2 (primary axis) shows SBI for the average of the Eurozone economies during pandemic and geopolitical crises. Higher values indicate the higher intensity of the shock. The index increased dramatically in the second quarter of 2020, as a result of the pandemic crisis-related supply disruptions, and has remained at this higher level until the end of the analyzed period. The next spike is related to the disruptions caused by the vaccine shortages, and again in the first quartal of 2022, due to the Russian–Ukraine war. The last spike is related to the lockdown of China in the third quarter of 2022. It seems that during both crises, supply bottlenecks were present and thus acted as potential drivers of inflation.


**Figure 1.** Average movement of energy prices, interest rates, and CPI in the Eurozone economies (2020q1–2023q4). Source: Authors' presentation.

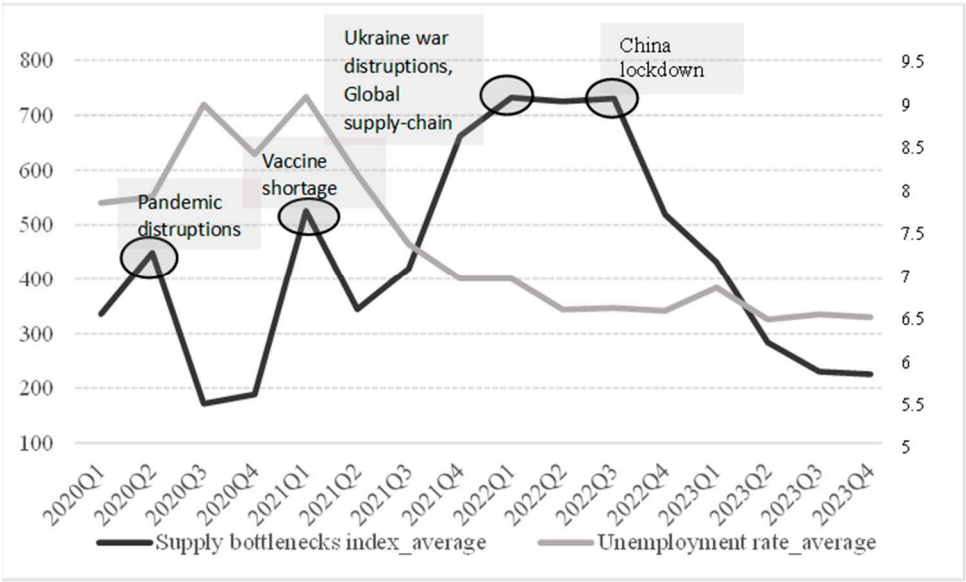


**Figure 2.** SBI and unemployment rate in the Eurozone in the period 2020q1–2023q4. Source: Authors' presentation.

On the demand side, an important variable could be unemployment, since the lack of aggregate demand in the crisis contributed to unemployment. The opposite trend is

identified in the analysis of the average unemployment rate (Figure 2, secondary axis). During the pandemic crisis, the average Eurozone unemployment rate was higher than 8%, while from the first quarter of 2021, a decreasing trend was identified. Namely, during that period downward trend of average unemployment could be a driver of the inflationary pressures.

Although the decline in the CPI began on average in the second half of 2022, this development of the situation was not evident in all analyzed Eurozone economies, showing heterogeneity in the sample. In the analysis that follows, we represented economies with the highest and lowest inflationary pressures in the Eurozone in the analyzed period. Figure 3 shows the CPI and the price of energy on the primary axis, while the interest rate is on the secondary axis. Inflationary pressures measured in selected economies from the sample (Portugal, Germany), were the most pronounced in the whole sample (achieving around 13%) and were present until the fourth quarter of 2023. We conclude that disruptions in the supply chain are key energy products leading to an increase in the prices of energy products, and thus to the generation of inflation, which had a negative impact on population consumption, budget planning, and investments. Also, it is noticeable that the response of the ECB through the implementation of a restrictive monetary policy and an increase in interest rates, led to a fall in the general level of prices and a reduction in inflationary pressures (Di Bucchianico 2020). This dynamic of CPI and interest rate was most correlated during the last two quarters of 2023.

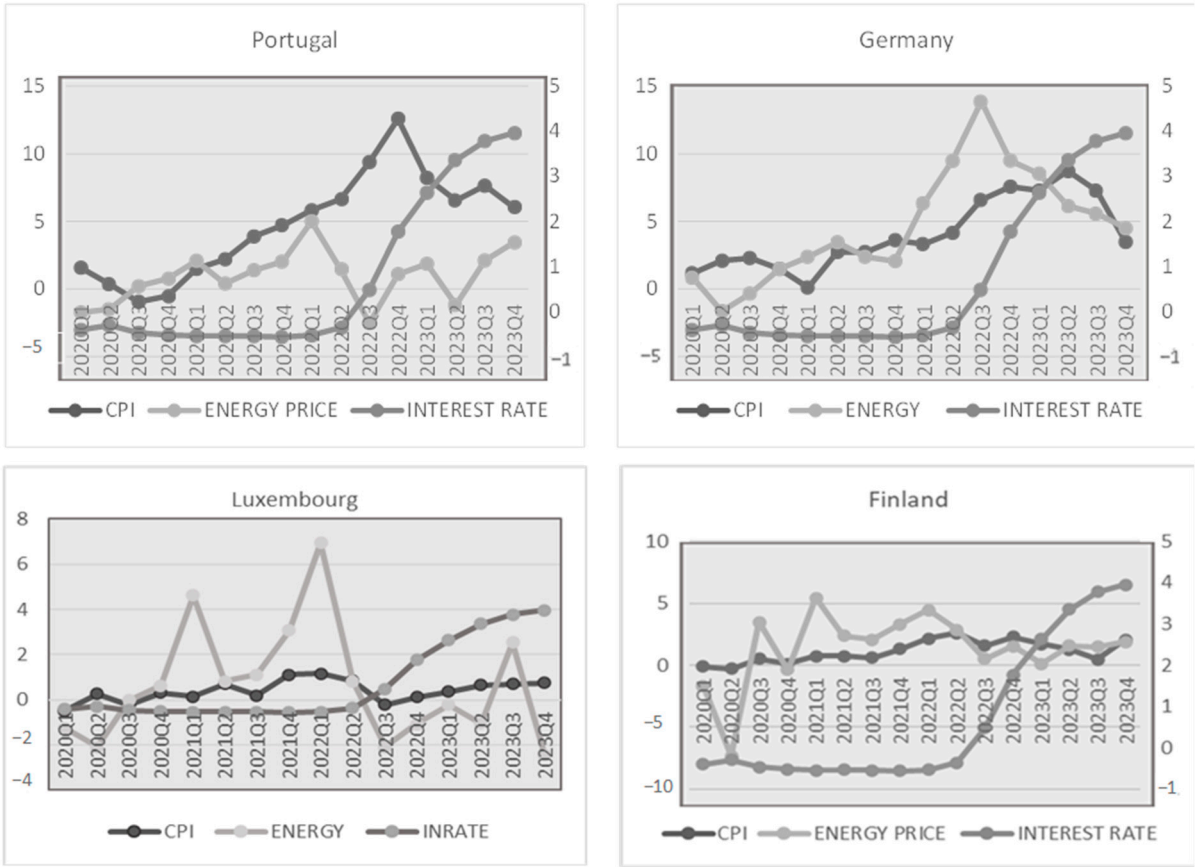


**Figure 3.** Heterogeneity of inflationary pressures in the Eurozone economies in the period 2020q1–2023q4. Source: Authors' presentation.

On the other hand, the rise in energy prices did not have a dominant influence on the creation of inflationary pressures in Finland and Luxembourg. In those economies, the CPI indices were stable and low, achieving monetary targets, not only during the pandemic crisis but also during the geopolitical crisis (Figure 3, shows the CPI and energy price in the

primary axis, while interest rate in the secondary axis). This indicates that the growth of the interest rate and the tightening of monetary arrangements only confirmed the adequate conduct of the monetary policy and the stability of the functioning of the economic system.

Based on the descriptive presentation and analysis, we conclude that Portugal and Germany recorded a sudden increase in price levels, which was largely generated by the increase in the price of energy products. This is followed by an increase in interest rates and a fall in the general price level in the analyzed countries. The development of the situation was far different in Finland and Luxembourg, where the growth of energy prices did not play a decisive role in increasing the CPI in the observed period and creating inflationary pressures. Therefore, it can be concluded that the effects of energy price growth had a heterogeneous impact on determining the inflationary pressures of the analyzed economies in the mentioned period. Based on everything taken into account, we can claim that the common goals in terms of monetary policy, as well as the common currency, were not sufficient in the analyzed period to create a similar inflation trend in Eurozone economies. Namely, the analyzed countries have a different economic structure, as well as the tax system and public spending, which were decisive in these circumstances. Also, the reaction of the ECB in the form of a tightening of monetary policy and an increase in interest rates led to the fact that the trend of current inflation approached or equaled the defined monetary target (Conflitti and Luciani 2019).

## 4. Methodological Framework and Data

On the basis of stylized facts, and theoretical and empirical assumptions related to the analysis of the effects of energy shocks, supply and demand side effects on CPI during the crises, the nonstationary panel data model is defined in this paper. The idea of the model is to estimate key determinants of dependent variable *CPI* (direct calculation). Explanatory variables in the model are ENERGY PRICE (covering fluctuations in the price of gas, electricity, fuel), UNEMPLOYMENT RATE, INTEREST RATE, and supply bottlenecks index, SBI. The introduction of the SBI provides additional information about the generation of inflationary pressures that are not captured by traditional indicators. We expect to confirm that the increase in the ENERGY PRICE and SBI have a positive effect on the CPI, that the UNEMPLOYMENT RATE has a negative effect on the CPI, as well as that the increase in the INTEREST RATE in the form of a restrictive monetary policy has a positive effect on reducing inflationary pressures and ensuring price stability.

The availability of data with higher frequency, in this case quarterly data, made it possible to analyze the mentioned relationships during the period 2020q1–2023q4, covering pandemic and geopolitical crises in the Eurozone economies. However, the time dimension of 16 observations ($T$ = 16), indicated a relatively large panel (instead of the classical panel model with a small $T$) and consequently, the estimation of non-stationary heterogeneous panels. On the other hand, the focus is on 12 economies that are initial members of the Eurozone: Austria, Belgium, Finland, France, Germany, Greece, Italy, Ireland, Netherlands, Luxembourg, Portugal, and Spain indicating cross-section dimension 12 ($N$ = 12). Since all economies are part of the Eurozone assuming homogeneity, while the $T$ dimension is relatively long assuming heterogeneity, the issue of heterogeneity vs. homogeneity in the model is analyzed with special attention in this paper. Therefore, the research provides three alternative estimators, taking into consideration the different forms of heterogeneity in the model: a Dynamic Fixed-Effects (DFE) estimator, and the PMG and the MG estimators. The MG estimator (Pesaran and Smith 1995) relies on estimating $N$ time-series regressions and averaging the coefficients, whereas the PMG estimator (Pesaran et al. 1997, 1999) relies on a combination of pooling and averaging of coefficients, while DFE is based on pooling of all coefficients. Those methods are used to estimate and check the robustness of the results related to hypotheses $H_1$, $H_2$, and $H_3$:

**$H_1$:** *The driving forces of the CPI are energy prices, supply bottleneck, and unemployment rate assuming a homogeneous relationship on a sample of 12 Eurozone economies in the period 2020q1–2023q4.*

**$H_2$:** *The long-run equilibrium relationship between interest rate and the CPI is homogeneous and negative due to unique monetary policy on a sample of 12 Eurozone economies in the period 2020q1–2023q4.*

**$H_3$:** *The speed of adjustments of individual economies to the long-run equilibrium relationship is heterogeneous in a sample of 12 Eurozone economies in the period 2020q1–2023q4.*

The econometric procedure performed in order to test the defined hypotheses and to obtain final estimates of PMG/MG estimators consists of the following empirical steps:

(1) Test of cross-sectional dependence (CSD) using Pesaran (2004) CD test, with hypotheses: H0: ij = ji = 0, i ≠ j; H1: ij = ji ≠ 0, i ≠ j;
(2) In order to account for CSD, second generation Pesaran (2006) CIPS panel stationarity test, with hypotheses: H0: I(1); H1: I(0);
(3) Cointegration test using Westerlund's (2007) cointegration test between non-stationary variables, with hypotheses: H0: no cointegration; H1: at least one/all panel units is/are cointegrated;
(4) Homogeneous coefficients in the PMG and MG estimators and Hausman test in order to identify efficient and consistent estimators;
(5) Estimation of error correction and heterogeneous short-run coefficients using an efficient estimator;
(6) Robustness check using the DFE estimator and reduction in the sample.

In order to estimate PMG/MG model, first we assume an autoregressive distributive lag (ARDL) dynamic panel specification model:

$$y_{it} = \sum_{i=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta_{ij} X_{i,t-j} + \mu_i + u_{it}, \quad (1)$$

where the cross-section units are represented by $i$ = 1, 2,. . ., $N$; the number of periods $t$ = 1, 2,. . ., $T$; $y_{it}$ represents the dependent variable, while $X_{it}$ explanatory variables; $\lambda_{ij}$ is the coefficient of the lagged dependent variable, $\delta_{ij}$ is short-run parameters for each panel unit, $\mu_i$ represents individual effects, and $u_{it}$ is the stochastic disturbance term. Its panel error-correction model, where deviation from equilibrium represents a short-run dynamic, could be described as:

$$\Delta y_{it} = \varphi_i (y_{it-1} - \theta_i X_{it}) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{it-1} + \sum_{j=0}^{q-1} \delta_{ij} \Delta X_{it-j} + \mu_i + u_{it}, \quad (2)$$

where $\theta_i$ represents long-run equilibrium relationship between variables; $\varphi_i$ is an error-correction parameter, indicating the speed of adjustment to the equilibrium relationship.

Using the described specification, we estimated the following model:

$$\begin{aligned} \Delta CPI_{it} = {} & \varphi_i (CPI_{i,t-1} - \theta_{1i} ENERGYPRICE_{it} - \theta_{2i} INTERESTRATE_{it} - \theta_{3i} SBI_{it} - \theta_{4i} UNEMPLOYMENTRATE_{it}) + \\ & \sum_{j=1}^{p-1} \lambda_{ij} \Delta CPI_{it-1} + \sum_{j=0}^{q-1} \delta_{ij} \Delta ENERGYPRICE_{it-j} + \sum_{j=0}^{q-1} \delta_{ij} \Delta INTERESTRATE_{it-j} + \sum_{j=0}^{q-1} \delta_{ij} \Delta SBI_{it-j} + \\ & \sum_{j=0}^{q-1} \delta_{ij} \Delta UNEMPLOYMENTRATE_{it-j} + \mu_i + u_{it}, \end{aligned} \quad (3)$$

where dependent variable CPI represents the consumer price index for $i$: 12 Eurozone economies during $t$: 2020q1–2023q4, while ENERGY PRICE, INTEREST RATE, SBI, and UNEMPLOYMENT RATE are explanatory variables showing total energy price fluctuations across $i$ and during $t$, and interest rate defined in Eurozone. The most important parameter in Equation (3) is $\theta_{ii}$. For instance, $\theta_{1i}$ containing long-run cointegration relationship between variables ENERGY PRICE and CPI expected to be positive, and $\theta_{2i}$ representing the long-run cointegration relationship between INTEREST RATE and CPI, thought to be negative. Moreover, the existence of a long-run relationship could be indicated through

parameter $\varphi_i$, namely, if the parameter $\varphi_i$ is equal to 0, there would not be evidence for a long-run cointegration relationship. Namely, parameter $\varphi_i$ is expected to be significant and negative, showing a speed of return to the long-run relationship.

Mention specification could be estimated in various ways depending on whether data are pooled or differ across the cross-section data. One extreme is the MG model, allowing all coefficients in the model to differ across $N$ dimensions. In the case of the MG model, cointegrating vectors are estimated for each economy, as well as the short-run dynamic coefficients. On the other extreme, in a DFE model, only intercepts are allowed to differ between economies, other parameters are pooled. In the middle, the PMG model is positioned, since that in the PMG model long-run coefficients are homogeneous (pooled as in a DFE), while short-run adjustment parameters are heterogeneous (as in the MG). According to Blackburne and Frank (2007) this "pooling" across economies yields efficient and consistent estimates when the restrictions are true. If the slope coefficients are in fact not identical, then the DFE and PMG approaches produce inconsistent and potentially misleading results, while MG estimates are consistent in each case. The key result in relation to efficient and consistent results could be provided by the Hausman test. The analysis based on MG, PMG, and DFE models in the case of CPI and its relationship with explanatory variables, could be useful, especially in exploring the long-run relationship between those variables which are expected to be homogeneous across the Eurozone economies, due to a single monetary framework. On the other hand, short-run coefficients could vary depending on other factors determining key economic characteristics of specific Eurozone economies.

In this empirical research of driving forces of inflationary pressures in the Eurozone economies three important facts have to be emphasized: (1) the long-run relationship between independent variables and inflation is homogeneous due to common policies; (2) heterogeneity is incorporated in the model using PMG/MG approach; and (3) research provides long-run and short-run dynamics in the analyzed variables.

The source of data in this study is Federal Reserve Economic Data (FRED) (2024), Eurostat Database (2024), and Banco de Espana (2004) while the software used in the research is Stata 15. The methodology of SBI calculation is explained by Burriel et al. (2023), and it is based on Baker et al. (2016) who create indices for economic policy uncertainty, Caldara and Iacoviello (2022) for geopolitical risks, and (Caldara et al. 2020) for trade policy uncertainties. We used quarterly data for variables in econometric analysis in order to increase the number of observations in the panel and provide additional reliable results for the analyzed period 2020q1–2023q4. In the turbulent years of pandemic and geopolitical crisis, the use of data with large frequency is more appropriate compared to annual data in order to incorporate specific effects of variables of interest across the Eurozone economies.

## 5. Empirical Model and Discussion of the Results

### *5.1. Results of CSD, Stationarity and Cointegration Testing*

The empirical analysis is based on a panel analysis that includes 12 cross-sectional units during the analyzed period 2020q1–2023q4, so the number of observations included in the panel is 192. There are large differences in the case of minimum and maximum values of the dependent variable, the consumer price index. The lowest CPI level was recorded in the 4th quarter of 2020 in Greece (−2.051), while the highest CPI level was achieved in Ireland in the fourth quarter of 2023 (12.76). The variable ENERGY PRICE refers to the price of energy whose mean value is 1.2141. Also, as with the dynamics of the reduction in ENERGY PRICE, large differences are evident. The lowest level of ENERGY PRICE was recorded in Belgium which is −21.09 in the first quarter of 2023, while the maximum value was achieved in the first quarter of 2021 in the same country which is 19.62. On the other hand, the movement of the interest rate had special obstacles, which indicate that the negative interest rate was present in as many as ten analyzed quarters (the first quarter of 2020, until the second quarter of 2022), after which it started to grow and be above zero.

As indicated in the previous section, the procedure for determining the long-run equilibrium relationship between CPI and ENERGY PRICE, SDI, UNEMPLOYMENT RATE, INTEREST RATE, and short-run adjustment parameters, consists of the following pre-estimation empirical steps: Pesaran CD test, Pesaran CIPS test, and Westerlund cointegration test. The first step is to test cross-section (in)dependence using the Pesaran (2004) CD test. Namely, the strong institutional framework in Eurozone economies and common policies, from monetary policy to the common market, common agricultural policy, customs union, and tax harmonization, inevitably result in connections, spillover effects, and dependencies between Eurozone economies (Glavaški et al. 2023). In fact, the Pesaran CD test showed the existence of cross-section dependence (CSD) in the sample, since the null hypothesis of cross-section independence has to be rejected for all analyzed variables (Table 1, part a). The mentioned result, in the case of further analysis of stationarity, conditioned the application of the second-generation panel unit root test—the Pesaran CIPS test (2006). Based on unit root tests (Im et al. 2003), the analyzed variables: CPI, ENERGY PRICE, INTEREST RATE, SBI, and UNEMPLOYMENT RATE are non-stationary, i.e., panel unit root tests fail to reject the null hypothesis of variable non-stationarity at 5% statistical significance in the model with two lags, which implies that the variables are non-stationary (Table 1, part b). The results of the Pesaran CIPS test showed the stationarity of the variables in the first differences, regardless of the lag number. Therefore, all the variables in the model are integrated into the first order, which is the basis for the further cointegration relationship.

**Table 1.** Pesaran's CD and CIPS tests.

| **Part (a) Pesaran CD Test** | | | **Part (b) Pesaran CIPS Unit Root Test** | | | | |
|---|---|---|---|---|---|---|---|
| **$H_0$: ij = ji = 0, i ≠ j; $H_1$: ij = ji ≠ 0, i ≠ j** | | | **$H_0$: I(1); $H_1$: I(0)** | | | | |
| **Variables** | **CD Test** | ***p*-Value** | **Lags** | **CIPS Test (Level)** | ***p*-Value** | **CIPS Test (First Differences)** | ***p*-Value** |
| | | | 0 | −5.117 | 0.000 | −9.939 | 0.000 |
| CPI | 13.15 | 0.000 | 1 | −2.481 | 0.007 | −7.069 | 0.000 |
| | | | 2 | 1.821 | 0.966 | −3.575 | 0.000 |
| | | | 0 | −8.431 | 0.000 | −10.460 | 0.000 |
| ENERGY PRICE | 16.74 | 0.000 | 1 | −4.711 | 0.000 | −5.145 | 0.000 |
| | | | 2 | 2.683 | 0.998 | −4.728 | 0.000 |
| | | | 0 | −4.492 | 0.000 | −6.214 | 0.000 |
| INTEREST RATE | 32.50 | 0.000 | 1 | −4.234 | 0.000 | −4.222 | 0.000 |
| | | | 2 | −0.411 | 0.340 | −4.511 | 0.000 |
| | | | 0 | −5.369 | 0.000 | −9.696 | 0.000 |
| SBI | 26.20 | 0.000 | 1 | −3.758 | 0.000 | −7.628 | 0.000 |
| | | | 2 | −0.019 | 0.560 | −2.267 | 0.000 |
| | | | 0 | −5.572 | 0.00 | −11.326 | 0.000 |
| UNEMPLOYMENT | 11.59 | 0.000 | 1 | −6.315 | 0.00 | −6.154 | 0.000 |
| RATE | | | 2 | 0.513 | 0.696 | −5.799 | 0.000 |

Source: Authors' calculation based on Stata 15.

The third step is the use of Westerlund's (2007) cointegration test. An important fact that needs to be considered is the existence of cross-sectional dependency in the model. Due to the fact that there is CSD in the panel, Westerlund's (2007) test could provide a relevant conclusion, but only after a bootstrapping procedure. Robust *p*-values are calculated using a 400-step bootstrap procedure. The conclusion related to the Westerlund test using

group mean panel tests (Gt and Ga) and pooled panel tests (Pt and Pa) is that at least one panel unit or all panel units are cointegrated, and therefore it is necessary to estimate heterogeneous coefficients to determine in which panel and in which units (economies) there is a cointegration relationship, and in which countries it does not exist (Table 2). The null hypothesis indicates that there is no cointegrating relationship, compared to the alternative relationship that indicates the existence of a cointegrating relationship between the non-stationary variables.

**Table 2.** Westerlund's cointegration test.

| | **Part (a)** ***CPI* and *ENERGY PRICE*** | | | **Part (b)** ***CPI* and *INTEREST RATE*** | | | **Part (c)** ***CPI* and *SBI*** | | | **Part (d)** ***CPI* and *UNEMPLOYMENT RATE*** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ***p*-Value** | **Robust *p*-Value** | | ***p*-Value** | **Robust *p*-Value** | | ***p*-Value** | **Robust *p*-Value** | | ***p*-Value** | **Robust *p*-Value** |
| | | | | | $H_0$: no cointegration; $H_1$: at least one panel unit is cointegrated (heterogeneous assumption) | | | | | | | |
| Gt | −1.610 | 0.014 | 0.025 | −1.207 | 0.212 | 0.465 | −1.454 | 0.056 | 0.050 | −1.314 | 0.130 | 0.085 |
| Ga | −9.598 | 0.000 | 0.015 | −9.429 | 0.000 | 0.090 | −1.244 | 0.107 | 0.080 | −2.924 | 0.748 | 0.310 |
| | | | | | $H_0$: no cointegration; $H_1$: all panel units are cointegrated (homogeneous assumption) | | | | | | | |
| Pt | −3.530 | 0.074 | 0.035 | −2.932 | 0.175 | 0.470 | −0.496 | 0.310 | 0.410 | −3.174 | 0.114 | 0.024 |
| Pa | −3.501 | 0.001 | 0.045 | −3.880 | 0.000 | 0.045 | −0.007 | 0.497 | 0.430 | −1.174 | 0.430 | 0.370 |

Source: Authors' calculation based on Stata 15.

The results based on the Westerlund test show that the null hypothesis is rejected, which means that the analyzed variables CPI and ENERGY PRICE are cointegrated in all used tests (Table 2, part a). On the other hand, the cointegration relationship between CPI and INTEREST RATE is confirmed in the model Ga (at least one panel unit is cointegrated) and Pa (all panel units are cointegrated), while Gt and Pt accepted the null hypothesis of no integration (part b). A similar heterogeneous result is shown in Table 2 (parts c, d) between three variables: CPI, SBI, and UNEMPLOYMENT RATE, according to both: *p*-values and robust *p*-values. Since the Westerlund test provided some evidence about the cointegration relationship, but not unequivocal results, further analysis is needed, in the context of heterogeneous panel model estimations.

### *5.2. Results Based on Pooled Mean Group vs. Mean Group Estimators*

Estimation of the model realized by MG and PMG methods defined by Pesaran et al. (1997, 1999) are further used when assessing and determining the long-run equilibrium relationship between CPI and ENERGY PRICE, INTEREST RATE, SBI, and UNEMPLOYMENT as well as the dynamics of the speed of adjustment of individual economies to the long-run equilibrium relationship. Table 3 shows the homogeneous coefficients of the MG and PMG estimators.

Based on the obtained results of homogeneous coefficients, the cointegration relationship between ENERGY PRICE, INTEREST RADE, SBI, and CPI is statistically significant in both models (Table 3). However, the long-run relationship between UNEMPLOYMENT RATE and CPI is not significant. Namely, the demand shift which stems from unemployment did not significantly put upward pressure on prices. Therefore, in Table 3, only significant variables are presented. The long-run relationship between ENERGY PRICES and CPI is positive and significant in the PMG and MG model, confirming that energy prices significantly contributed to upward inflationary pressures. The cointegration relationship between INTEREST RATE and CPI is statistically significant in both models, although with a negative sign in the PMG model −0.1802, while positive in the MG model 0.8792. Variable SBI created a positive and significant long-run relationship with CPI, confirming that supply bottlenecks determined inflation. Given that the error correction parameter is

statistically significant and negative, and shows the speed of adjustment towards long-run equilibrium, the total adjustment in the PMG model is −0.6017, indicating that 60.17% of the deviation is corrected in one year. A higher adjustment parameter is estimated in the MG model, and its value is −0.6966, which indicates that 69.66% of the deviation is corrected in an average of one year according to the MG model. However, the Hausman test for the long-run homogeneity of the relationship showed that the PMG method provides the optimal specification, with consistent and efficient estimates, given the homogeneous cointegration relationships and heterogeneous adjustment parameters, due to the heterogeneous structure of the entire economic environment of the observed countries.

**Table 3.** Results of PMG and MG estimator for homogeneous coefficients in 12 Eurozone economies in the period 2020q1–2023q4.

| **Dependent Variable *CPI*** | | **PMG Estimator** | | **MG Estimator** | |
|---|---|---|---|---|---|
| | | **Coef.** | ***p*-Value** | **Coef.** | ***p*-Value** |
| Long-Run equilibrium | ENERGY PRICE ($\theta_{1i}$) | 0.3870 | 0.000 | 0.1493 | 0.000 |
| | INTEREST RATE ($\theta_{2i}$) | −0.1802 | 0.000 | 0.8792 | 0.044 |
| | SBI ($\theta_{3i}$) | 0.0021 | 0.000 | 0.0053 | 0.000 |
| Error-Correction ($\phi_i$) | | −0.6017 | 0.000 | −0.6966 | 0.000 |
| Δ ENERGY PRICE ($\delta_{ij}$) * | | 0.0121 | 0.002 | 0.3596 | 0.049 |
| Δ INTEREST RATE ($\delta_{ij}$) * | | −0.0042 | 0.121 | −0.1225 | 0.001 |
| Δ SBI ($\delta_{ij}$) * | | | | | |
| $\mu_i$ | | 0.0733 | 0.002 | 0.9669 | 0.009 |
| Hausman test statistics | | $Chi^2$ = 0.21<br>*p*-value = 0.9755 | | | |

Note: * Difference between two subsequent periods is marked with Δ, as Δ ENERGY PRICE, Δ INTEREST RATE, and Δ SBI. Source: Authors' calculation based on Stata 15.

Therefore, it is concluded that the PMG model is preferable and that the main results related to the homogeneous part of the PMG model are as follows: (1) The long-run equilibrium relationships between the growth of ENERGY PRICE and SBI with CPI are homogeneous and positive on a sample of 12 Eurozone economies in the period 2020q1–2023q4, confirming hypothesis 1 ($H_1$). Namely, it is concluded that energy shocks and supply bottlenecks shocks determined the growth of CPI indices during pandemic and geopolitical crises, generating higher inflationary pressures. On the other hand, demand shifts represented through the unemployment rate did not significantly affect inflation. (2) The long-run equilibrium relationship between interest rate and the CPI is homogeneous and negative (−0.1144) due to unique monetary policy on a sample of 12 Eurozone economies in the period 2020q1–2023q4, which might be interpreted as acceptance of the hypothesis 2 ($H_2$). Higher levels of intrates in the Eurozone during the geopolitical crisis were one of the key factors for the reduction in inflationary pressures, meaning a long-run relationship, but with negative influence.

Table 4 shows a heterogeneous part of the PMG model, in the context of the error correction parameters and the impact of the ENERGY PRICE, INTEREST RATE, and *SBI* growth on the CPI. Although there was a homogeneous cointegration relationship between those variables and CPI in the sample, the individual adjustments to the long-run equilibrium relationship were heterogeneous in the analyzed economies. The most intensive adjustments were estimated in Portugal and Germany (excess: −1.4580, −1.1754, respectively), which means that those economies were most exposed to inflationary pressures or reacted at shocks at the highest level; medium intensity of adjustments were detected in Spain, Netherland, Italy, and France, (60.05%, 59.02%, 45.33%, and 40.00%, respectively); the lowest adjustments were in Luxembourg, Finland, Belgium, and Austria (25.47%, 13.53%, 12.99%, and 12.32%). Adjustment parameters were not significant in the peripheral economies of the Eurozone: Greece and Ireland. The empirical result of the

highest adjustment parameters in Germany and Portugal is in line with the tendencies presented in Figure 3, showing high inflationary pressures, while Finland and Luxembourg experience lower inflationary pressures and lower adjustments (Figure 3).

**Table 4.** Results of the PMG estimator for heterogeneous coefficients in the 12 Eurozone economies in the period 2020q1–2023q4.

| | **Error-Correction ($\phi_i$)** | | **Δ *ENERGY PRICE*** | | **Δ *INTEREST RATE*** | | **Δ *SBI*** | | **$\mu_i$** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Heterogeneous Coef.** | **Coeff.** | ***p*-Value** | **Coeff.** | ***p*-Value** | **Coef.** | ***p*-Value** | **Coef.** | ***p*-Value** | **Coeff.** | ***p*-Value** |
| Italy | −0.4533 | 0.004 | 0.0894 | 0.001 | 0.1006 | 0.501 | 0.0072 | 0.200 | −0.0719 | 0.643 |
| Finland | −0.1353 | 0.001 | 0.0310 | 0.410 | −0.3134 | 0.356 | 0.0017 | 0.756 | −0.1989 | 0.344 |
| France | −0.4000 | 0.049 | 0.0221 | 0.003 | 2.3891 | 0.088 | 0.0041 | 0.097 | 0.7824 | 0.111 |
| Greece | −0.0581 | 0.976 | −0.1659 | 0.456 | −2.1981 | 0.348 | 0.0015 | 0.070 | 1.2780 | 0.075 |
| Spain | −0.6005 | 0.000 | −0.0467 | 0.250 | −0.6793 | 0.007 | 0.0048 | 0.038 | 0.3073 | 0.015 |
| Belgium | −0.1299 | 0.007 | 0.0386 | 0.003 | −0.1925 | 0.939 | 0.0095 | 0.635 | 0.4405 | 0.472 |
| Netherlands | −0.5902 | 0.011 | 0.0506 | 0.032 | −0.2553 | 0.024 | −0.0014 | 0.709 | −0.5703 | 0.008 |
| Luxembourg | −0.2547 | 0.000 | 0.0578 | 0.005 | −0.6796 | 0.000 | 0.0012 | 0.817 | −0.2502 | 0.016 |
| Germany | −1.1745 | 0.000 | 0.2844 | 0.000 | −0.8332 | 0.025 | 0.0012 | 0.097 | −0.7937 | 0.002 |
| Portugal | −1.4580 | 0.000 | 0.0367 | 0.701 | −0.0527 | 0.940 | −0.0018 | 0.306 | 0.3850 | 0.306 |
| Ireland | −0.0126 | 0.859 | 0.0301 | 0.271 | 0.3032 | 0.655 | −0.0012 | 0.209 | 0.6812 | 0.018 |
| Austria | −0.1232 | 0.033 | 0.0677 | 0.018 | −0.6956 | 0.164 | −0.0004 | 0.570 | 0.2849 | 0.034 |

Source: Authors' calculation based on Stata 15.

Asymmetry in relation to central/peripheral Eurozone economies was emphasized in the context of insignificant error-correction coefficients for Greece and Ireland, while all central Eurozone economies have significant adjustments toward long-run equilibrium relationship. That could be explained by short-run coefficients, showing different magnitudes of influence of energy and supply side shocks on analyzed Eurozone economies, and especially through monetary policy. Namely, although the common monetary policy is applied, short-run coefficients of *INTEREST RATE* are not significant in Greece and Ireland. Specifically, Greece was one of the most exposed Eurozone economies during the previous global financial crisis, as well as the sovereign debt crisis, and rigid economic policy measures are still in force in this country. Based on previous experience in global crises, restrictive measures were applied during the pandemic and geopolitical crisis, since the government used price control measures, such as temporary energy price freezes or subsidies—so that the direct link between energy prices and CPI, as well as interest rate and CPI, were broken. On the other hand, Ireland is an open economy with diverse access to energy sources, which reduces the sensitivity of *CPI* to changes in energy prices. Due to the heterogeneity and sensitivity of individual countries, the effects of common measures are not the same in the economies of the Eurozone, and the economic policymakers had to implement additional measures in more sensitive economies or strive for deeper integration of the economies, which would imply greater coordination of economic cycles and the avoidance of structural imbalances. This result is in correlation with the results of the paper (Glavaški and Pucar 2020) indicating that in the short-run there is evident divergence and heterogeneity between core and peripheral economies of the Eurozone, as well as Carnazza and Liberati (2021) which are pointing out asymmetric consequences of symmetric shocks. Therefore, the reasons that directly argue the interpreted heterogeneous results can be presented through (1) different intensity of exposure to energy shocks and spillover effects on the *CPI* in central versus peripheral economies of the Eurozone, (2) different intensity and exposure to supply bottlenecks shocks, (3) common monetary policy has heterogeneous

effects in the Eurozone economies, and (4) heterogeneous economic environment, including heterogeneous fiscal policy. The limitation of this research refers exactly to heterogeneous fiscal policy actions that are not included in the model, however, could influence inflation.

Therefore, we could conclude that the majority of the Eurozone economies (10 from 12 economies) reacted in the context of adjustments towards the long-run equilibrium (cointegration) relationship, which is a sign of a stabilization mechanism within a monetary union in the period of inflationary pressures. However, the asymmetric and heterogeneous response of Eurozone member states in the condition of pandemic and geopolitical crises, especially related to the core-periphery dichotomy, refers to the limitation of 'one size fits all' monetary policy. Finally, we conclude that hypothesis 3 (H3) is confirmed because the speed of adjustment of individual economies to long-run equilibrium is heterogeneous in a sample of 12 Eurozone economies in the period 2020q1–2023q4.

### *5.3. Double Robustness Check*

The estimation method, the PMG, was selected based on its ability to show relationships between key variables CPI, ENERGY PRICE, INTEREST RATE, and *SBI* and to solve problems of heterogeneity and non-stationarity in the data. Further robustness check is conducted in two ways: (a) a change in the estimation method using the DFE method; and (b) a change in the sample.

The DFE estimator is chosen since DFE also restricts the coefficients of the cointegrating vector to be equal across all the panels, similar to the PMG estimator; however, the difference is in the error-correction parameters. Namely, a DFE model also restricts the speed of the adjustment coefficient to be equal (Blackburne and Frank 2007), therefore DFE model could represent only homogeneous coefficients. Results of the DFE model (Table 5, part (a)) show that the long-run cointegration relationship is significant between ENERGY PRICE and CPI (0.3980 in DFE, and 0.3870 in PMG), and the error-correction parameter is significant and negative showing adjustments towards long-run equilibrium. Although the same dynamic of adjustment towards long-run equilibrium is noted, the magnitude of the adjustments is lower in the model estimated by the DFE estimator in comparison to PMG (11.77% in a DFE in comparison to 60.17% in the PMG). The relationship with INTEREST RATE is with an expected sign, but insignificant, therefore, this relation is not confirmed by DFE. Moreover, the influence of SBI is with expected sign and intensity of influence. However, the Hausman test could be used in order to select preferred estimators between the PMG, MG, and DFE estimators. Results presented in Table 5 indicate that the Hausman test showed that PMG is preferred over the DFE model.

**Table 5.** Robustness check: DFE estimator and PMG estimator in reduced sample.

| **Dependent Variable *CPI*** | | **Part (a) DFE; *N* = 12, *T* = 16** | | **Part (b) PMG; *N* = 12, *T* = 15** | |
|---|---|---|---|---|---|
| | | **Coef.** | ***p*-Value** | **Coef.** | ***p*-Value** |
| Long-Run equilibrium | ENERGY PRICE ($\theta_{1i}$) | 0.3980 | 0.016 | 0.3814 | 0.000 |
| | INTEREST RATE ($\theta_{2i}$) | −0.2528 | 0.706 | −0.1166 | 0.016 |
| | SBI ($\theta_{3i}$) | 0.0076 | 0.030 | 0.0088 | 0.001 |
| Error-Correction ($\phi_i$) | | −0.1177 | 0.008 | −0.3319 | 0.000 |
| Δ ENERGY PRICE ($\delta_{ij}$) | | 0.0064 | 0.000 | 0.0093 | 0.005 |
| Δ INTEREST RATE ($\delta_{ij}$) | | −0.0767 | 0.723 | 0.5792 | 0.073 |
| Δ SBI ($\delta_{ij}$) | | 0.0051 | 0.010 | 0.0075 | 0.000 |
| $\mu_i$ | | −0.1614 | 0.585 | 0.2394 | 0.001 |
| Hausman test | | $\chi^2$ 3.51 | *p*-value 0.3192 | $\chi^2$ 1.86 | *p*-value 0.289 |

Source: Authors' calculation based on Stata 15.

The second way to check the robustness of the results is to change sample size and in that way test whether the results are stable. In the selected sample, it is chosen to leave out data in relation to the first quartal of 2020, therefore the dimension $T$ is shortened to 15 units. Both methods of estimation, PMG and MG, were undertaken in the reduced sample, and results showed that the preferable method of estimation is PMG. All the results in relation to the PMG method (Table 5, part (b)) correspond to the initial results. Namely, the results indicated that *ENERGY PRICE* generates a cointegration relationship with CPI, and that influence is significant and positive, with a similar magnitude of influence (0.3814 in comparison to 0.3870 in the initial model). Moreover, the long-run relationship between *CPI* and *INTEREST RATE* also exists, with negative effects, since the growth of *INTEREST RATE* reduces values of *CPI* ($-0.1166$, and $-0.1802$ in the initial sample). Finally, the estimated error-correction parameter is significant and negative with a similar level of intensity. Those results show that adjustment towards long-run equilibrium is 33.19%, while in the initial model, the estimated value of adjustment is 60.17%.

Double robustness check using the DFE method of estimation and change in the sample, showed that in the homogeneous and heterogeneous part of the model, the same variables significantly affect *CPI*, with the same sign and similar influence for the average Eurozone economies during the crises periods. Hence, we could claim that the results are stable across different estimators and change in the sample.

## 6. Conclusions

After several decades of relatively stable and low inflation, the global pandemic and geopolitical crises overheated inflationary pressure. It seemed that at least in the Eurozone, using common restrictive monetary policy, inflation differential would be suppressed. This research contributes to the vast literature in this area by highlighting two important aspects: key driving forces of the consumer price indices growth and vulnerability of the Eurozone related to heterogeneous adjustment of economies towards long-run equilibrium relationships.

In a heterogeneous, nonstationary, dynamic macro-panel framework, energy prices, supply bottlenecks, unemployment rate, and interest rate are brought into connection with fluctuations in consumer price indices. These relationships are estimated for 12 Eurozone economies in the crisis period 2020q1–2023q4 using PMG/MG estimators. Based on the obtained results, after the double robustness check, we can conclude that taking into account supply and demand side driving forces, the predominant determination of inflationary pressures comes from the supply side. Namely, there is a long-run positive equilibrium relationship between the growth of energy prices and the growth of the CPI, and between the index representing supply bottlenecks (SBI) and the growth of CPI, while the long-run relationship with the unemployment rate is insignificant. That result is in line with Bryson et al. (2024), Hansen et al. (2023), Neri et al. (2023), and Neri (2024) pointing out that inflationary pressures in pandemic and geopolitical crises are directly determined by supply side shocks, and not by demand shift. Namely, in addition to the rise in energy prices, the interrupted supply chains during the pandemic crisis, and the stoppages and restrictions in production detected during the geopolitical crisis put upward pressure on prices.

On the other hand, the paper analyzes the response of economic policy-makers, which was carried out in the form of a tightening of monetary policy through the growth of interest rates, and which manifested itself as an adequate solution for reducing inflationary pressures in almost all analyzed countries. Based on the obtained results, we confirmed the theoretical assumption that there is a long-run equilibrium relationship between the interest rate and the CPI which is homogeneous and negative due to the unique monetary policy on a sample of the Eurozone economies.

However, the heterogeneous speed of adjustment of individual economies to the long-run equilibrium relationship reveals that common policy in the case of the Eurozone could have heterogeneous effects. Different intensity of adjustments towards long-run relationships indicates that economies are affected divergently by the crisis, but also that the effects of countercyclical monetary policy manifest themselves diversly. Namely, the

speed of returning to the long-run equilibrium differs significantly: in the economies with the highest fear of inflation, adjustments are the highest (Germany and Portugal), medium intensity of adjustments were detected in Spain, Netherlands, Italy, and France, and the lowest adjustments were detected in Finland, Belgium, and Austria. In the last group of economies, inflationary pressures were the lowest in the analyzed sample, and in those economies, the inflation could be considered as overcome. Moreover, in some peripheral economies of the Eurozone, it is insignificant, specifically, Ireland and Greece. Namely, the direct link between energy prices and CPI, as well as interest rate and CPI were broken in those economies. Due to the heterogeneity and sensitivity of individual countries, the effects of common measures are not the same in the economies of the Eurozone, and the economic policymakers had to implement additional measures in more sensitive economies or strive for deeper integration of the economies, which would imply greater coordination of economic cycles and the avoidance of structural imbalances.

Insignificant or divergent adjustments towards equilibrium are considered as a source of Eurozone instability and as a trigger for further imbalances. This result is in correlation with the results of the paper (Glavaški and Pucar 2020) indicating that in the short-run there is evident divergence and heterogeneity between core and peripheral economies of the Eurozone, as well as Carnazza and Liberati (2021) which are pointing out asymmetric consequences of symmetric shocks.

It is concluded that the pandemic and the geopolitical crisis have shown the heterogeneity and vulnerability of the Eurozone economies. Reasons that directly argue the interpreted heterogeneous results can be presented through (a) central versus peripheral economies of the Eurozone, (b) heterogeneous economic policies, especially, fiscal policy, and (c) and heterogeneous economic environment. Since the majority of the Eurozone economies (10 from 12 economies) reacted in the context of adjustments toward the long-run equilibrium relationship, that could be a sign of a stabilization mechanism within a monetary union in a period of inflationary pressures. However, the heterogeneous response of Eurozone member states in the condition of pandemic and geopolitical crises, especially related to central-periphery asymmetry, refers to the limitation of "one size fits some" monetary policy. That would be even more pronounced if the sample in the research included all Eurozone economies. The reality is that "one size fits some" policy and that is important to take appropriate measures in the form of countercyclical actions in order to maintain price stability without jeopardizing other macroeconomic indicators. Moreover, (de)coordination of monetary policy actions with implemented fiscal policy instruments, in context countercyclical action on inflation, as well as on real variables, such as real GDP, will be the subject of our future research.

Lessons from the recent crises for the policy-makers is that the question of heterogeneity and unsustainability of the Eurozone would be asked until deeper economic integration since that common monetary policy with heterogeneous (coordinated) fiscal policy is always a sign of the systematic risk for policy-makers. Especially in the period of crisis, if the common monetary policy is supported by common fiscal policy, macroeconomic goals will be fulfilled to a greater extent, both in the context of inflationary pressures and in the domain of the real economy. On the contrary, divergence and heterogeneity within the Eurozone will only intensify, opening the space for national discretionary actions.

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