

Article

Asymmetric Transmission of Monetary Policy Shocks in the Euro Area: Evidence from a Panel VAR Analysis

Angeliki Anagnostou  and Nikolaos Marios Galatis * 

Department of Economics, University of Thessaly, 38221 Volos, Greece; aganag@uth.gr

* Correspondence: galatis@econ.uth.gr

Abstract

This study examines the transmission of monetary policy shocks across euro area economies using a Bayesian Panel Vector Autoregressive (PVAR) framework over the period 2010Q1–2024Q4. The analysis focuses on three country groups—Core, Periphery, and Central and Eastern European (CEE) economies—in order to assess whether monetary policy transmission differs across structurally distinct segments of the monetary union. Monetary policy shocks are identified using high-frequency surprises from the Euro Area Monetary Policy Database (EA-MPD). The results indicate substantial heterogeneity in monetary policy transmission across country groups. Core economies generally exhibit more stable adjustment patterns, whereas Periphery economies tend to display greater sensitivity to monetary disturbances, particularly during periods of financial stress. The CEE economies follow a distinct adjustment path associated with their structural characteristics and ongoing convergence processes. Regime-specific estimations further reveal that transmission mechanisms vary across alternative monetary policy environments, with the strongest statistically supported responses observed during the post-sovereign-debt adjustment period. Overall, the evidence indicates that monetary policy transmission within the euro area remains both structurally asymmetric and regime dependent. The study contributes to the literature by combining externally identified monetary policy shocks, Bayesian PVAR estimation, and regime-specific analysis within a unified empirical framework.

Keywords: monetary policy transmission; panel VAR; euro area; asymmetric effects; monetary policy regimes; impulse response functions

1. Introduction

The transmission of monetary policy within the euro area remains a central issue in macroeconomic analysis, particularly given the structural heterogeneity characterising member-state economies. Although euro area countries operate under a common monetary policy framework administered by the European Central Bank (ECB), differences in financial structure, fiscal capacity, labour-market conditions, and macroeconomic resilience may generate asymmetric responses to common monetary policy shocks. In this context, understanding how monetary policy is transmitted across different groups of economies remains particularly important for evaluating the effectiveness of ECB interventions and the broader stability of the monetary union. The ECB's primary objective is the maintenance of price stability, while policy-controlled interest rates constitute one of the main instruments through which monetary authorities influence output, prices, financial conditions, and market expectations (Galariotis et al., 2018).



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A useful way to understand monetary policy across different periods and targets is to examine the transmission mechanisms separately. These mechanisms operate through distinct channels, with varying intensity and speed depending on the problem at hand, in order to influence targeted variables and markets. Selecting the appropriate channels—and identifying them correctly—is essential for the effective use of policy tools. Timing is also critical, as it often determines the practical limits and constraints central banks face in decision-making.

Previous literature identifies multiple monetary transmission channels, including interest-rate, credit, exchange-rate, and expectations channels, whose effectiveness may vary substantially across countries and macroeconomic environments (Loayza & Schmidt-Hebbel, 2002). Consequently, the transmission of monetary policy cannot be assumed to operate uniformly across euro area economies, particularly during periods characterised by financial stress, unconventional monetary policy interventions, or elevated macroeconomic uncertainty.

Further research shows that monetary policy evolves over time, reflecting changes in both transmission mechanisms and the nature of external shocks. Careful examination suggests that the parameters governing transmission and exogenous disturbances exhibit gradual rather than abrupt variation (Koop et al., 2009).

A substantial body of research has already documented that euro area countries respond heterogeneously to common monetary policy shocks (e.g., Barigozzi et al., 2014; Georgiadis, 2015; Cavallo & Ribba, 2015; Mandler et al., 2022). Building on this literature, the present paper does not merely re-establish the existence of such heterogeneity, but characterises how it varies across structurally distinct country groups and, crucially, across alternative monetary policy regimes, using externally identified high-frequency policy surprises over an extended post-crisis sample. Rather than treating the euro area as a homogeneous entity, the analysis explores how national characteristics—such as financial structure, fiscal capacity, and economic openness—shape the effectiveness of common monetary policy actions. Monetary policy shocks are identified using an external-instrument approach based on high-frequency financial market reactions to ECB policy announcements, allowing for a cleaner identification of exogenous policy innovations.

This study contributes to the existing literature in several important ways. First, it employs an extended dataset covering the period 2010Q1–2024Q4, allowing the analysis to capture multiple monetary policy regimes, including the post-crisis adjustment period, the unconventional monetary policy phase, and the recent tightening cycle following the post-pandemic inflation surge. Second, monetary policy shocks are identified using an external instrument based on high-frequency financial market reactions to ECB policy announcements, ensuring a more credible identification of exogenous policy innovations. Third, the analysis explicitly accounts for cross-country heterogeneity by grouping euro area economies into Core, Periphery, and Central and Eastern European (CEE) countries. This classification reflects structural differences in financial development, fiscal capacity, and exposure to external shocks, which are expected to influence the transmission of monetary policy across countries. In contrast to previous studies, this paper combines an extended post-crisis dataset with externally identified monetary policy shocks and an explicit cross-country grouping framework, providing new evidence on how transmission mechanisms differ across euro area economies under different monetary regimes.

Beyond its contribution to the empirical literature on monetary policy transmission, this study provides evidence that is directly relevant for macroeconomic policy coordination in open and integrated economies. The documented cross-country heterogeneity in the transmission of monetary policy shocks highlights the limits of uniform policy effects within monetary unions such as the euro area. These findings contribute to ongoing discussions

on policy coordination, stabilization mechanisms, and the interaction between common monetary policy and national fiscal frameworks, emphasizing the role of structural and institutional differences in shaping macroeconomic outcomes.

The central objective of this study is to assess whether, and to what extent, the transmission of common ECB monetary policy shocks differs across structurally distinct groups of euro area economies—Core, Periphery, and CEE—and across alternative monetary policy regimes. The rest of the paper is organised as follows. Section 2 presents the Literature Review. Section 3 describes the Methodology and Data. Section 4 presents the Empirical Results. Section 5 discusses the policy implications of the findings, while Section 6 concludes.

2. Literature Review

The findings of the present study are consistent with a large body of research on the transmission of monetary policy shocks in the euro area. For example, [Ciccarelli et al. \(2013\)](#) show that transmission varies with countries' banking and fiscal conditions, supporting the view that national characteristics materially shape policy effectiveness. Countries with more flexible and better capitalised banking systems tend to respond more favourably to accommodative monetary policy measures. While much of the literature focuses on monetary policy shocks in general, a growing strand of research identifies such shocks using external instruments based on high-frequency financial market reactions to central bank announcements (e.g., [Gürkaynak et al., 2005](#); [Altavilla et al., 2019](#); [Jarociński & Karadi, 2020](#)). Following this approach, the empirical analysis in this study identifies monetary policy shocks using an external instrument derived from high-frequency financial market reactions to ECB policy announcements, ensuring a cleaner identification of exogenous monetary policy innovations.

Beyond the traditional interest rate channel, several alternative transmission mechanisms have been identified in the literature, including the bank lending channel, the exchange rate channel, and external demand spillovers. In economies with higher external debt or stronger export dependence, exchange rate movements and external conditions can materially influence the effectiveness of monetary policy. High external indebtedness can dampen the favourable effects of expansionary measures by tightening balance sheet constraints, especially when a portion of debt is foreign currency denominated. As a result, differences in financial structure, external exposure, and institutional resilience may generate substantial heterogeneity in the transmission of monetary policy shocks across euro area economies.

2.1. Monetary Policy Shocks

The identification of monetary policy shocks constitutes one of the central methodological challenges in empirical monetary economics. [Champagne and Sekkel \(2018\)](#) emphasise VAR-based approaches and their variants. Existing evidence often reports relatively moderate output responses and identification-sensitive price dynamics, highlighting the importance of credible shock identification. A complementary narrative approach constructs a series of intended policy changes from historical records (e.g., FOMC documents), isolating innovations that are orthogonal to the central bank's information set and often yielding stronger identification.

An alternative perspective exploits shifts in volatility to identify policy shocks. Using monthly U.S. data for GDP and prices, [Lanne and Lütkepohl \(2008\)](#) argue that, despite careful modelling, results can remain sensitive to identification, underscoring the inherent difficulty of isolating true policy innovations. Event-study evidence also highlights multi-factor policy shocks: for Japan, [Kubota and Shintani \(2022\)](#) document that

unexpected restrictive policy surprises depress equity returns while raising government bond yields, with stronger effects at longer maturities; conventional easing produces the opposite pattern.

A key contribution to the identification of monetary policy shocks in the euro area is provided by [Altavilla et al. \(2019\)](#), who construct high-frequency monetary policy surprises (EA-MPD) based on financial market reactions to ECB policy announcements. This dataset allows researchers to disentangle different dimensions of monetary policy communication and provides a reliable external instrument for identifying exogenous monetary policy shocks.

Monetary policy announcements may influence market expectations not only through policy actions, but also through the information they convey about the central bank's assessment of economic conditions. [Jarociński \(2022\)](#) shows that these “central bank information effects” constitute an important channel of international monetary policy spillovers. Using both vector autoregressions and high-frequency event study methods, the study finds that such information effects account for a substantial share of the co-movement observed in financial markets around ECB policy announcements, including spillovers to US government bond yields.

Importantly, unexpected increases in ECB policy rates that transmit to US financial markets may reflect positive information about the European economic outlook, and are therefore often associated with easing rather than tightening in US financial conditions. In this sense, they resemble favourable macroeconomic news shocks rather than conventional contractionary monetary policy shocks. By contrast, “pure” monetary policy shocks—those not contaminated by central bank information—have more limited international spillover effects.

These identification approaches provide the methodological foundation for analysing how exogenous monetary policy shocks propagate through macroeconomic and financial variables across different economic environments. The next strand of the literature focuses on the mechanisms through which such shocks are transmitted to real and financial variables.

2.2. Shock Transmission Mechanisms

Research focusing on monetary transmission channels highlights substantial heterogeneity in the importance and effectiveness of different transmission mechanisms over time. [Endut et al. \(2018\)](#), using a structural VAR with sign restrictions and bank-loan quantities, quantify the relative importance of exchange-rate, interest-rate and bank-lending channels. The bank lending channel remains economically significant in the aggregate, although its importance declines markedly since the early 1980s; the change is not directly tied to the fall in output volatility associated with the Great Moderation, though it correlates with reduced inflation volatility. [Ciccarelli et al. \(2013\)](#) further show that transmission strength varies with financial fragility—of the sovereign, banks and non-financial borrowers—and intensifies under sovereign stress.

Country specific studies of independent monetary regimes also stress institutional features. For Iceland, [Pétursson \(2001\)](#) describes a framework where policy rates steer money market conditions to influence private sector decisions, aiming to keep aggregate demand near potential and inflation near the 2.5% objective. Transmission is complex and time-varying, reinforcing the need for identification strategies that are robust to changing structures.

Central bank announcements convey not only information about policy actions, but also signals regarding the central bank's assessment of current and future economic conditions. [Jarociński and Karadi \(2020\)](#) propose a structural vector autoregression framework that disentangles these two components—monetary policy shocks and central bank infor-

mation shocks—and examines their distinct macroeconomic effects. Their identification strategy exploits high-frequency co-movements of stock prices and interest rates around policy announcements. Specifically, a positive central bank information shock is associated with simultaneous increases in both stock prices and interest rates, reflecting improved economic outlook, whereas a contractionary monetary policy shock leads to higher interest rates and lower stock prices. The results show that these two types of shocks have fundamentally different implications for the real economy. Ignoring central bank information effects may therefore bias conclusions regarding the non-neutrality of monetary policy.

While these channels describe the mechanisms through which monetary policy operates, an important question concerns the magnitude and persistence of its effects on key macroeconomic variables.

2.3. Effects of Monetary Shocks

A substantial empirical literature has examined the macroeconomic effects of monetary policy shocks on output, capital flows, and business cycle dynamics. [Christiano et al. \(1994\)](#) show that restrictive monetary policy shocks are followed by a temporary rise in private sector net capital flows, which later reverse as recessionary effects materialise. [Milani and Treadwell \(2012\)](#) argue that observed outcomes reflect a mixture of unanticipated, short-lived shocks and more persistent disturbances linked to anticipated news and policy guidance; business-cycle dynamics often react more strongly to the “news” component. Using sign-restricted VARs, [Uhlig \(2005\)](#) finds that a contractionary policy shock has an ambiguous (often small) effect on real GDP, consistent with near-neutrality of money when the general price level exhibits stickiness over horizons of a year or more.

Taken together, this literature establishes that (i) identifying assumptions matter, (ii) transmission channels are state- and structure-dependent, and (iii) country specific financial and fiscal conditions shape outcomes. These insights motivate the present study’s focus on externally identified monetary policy shocks based on high-frequency financial market reactions to ECB policy announcements, while also emphasizing cross-country heterogeneity within the euro area (see also [Galariotis et al., 2018](#); [Loayza & Schmidt-Hebbel, 2002](#)). More recent evidence further suggests that the transmission of monetary policy shocks varies substantially across countries and macroeconomic regimes, reinforcing the importance of structural heterogeneity within monetary unions.

2.4. Heterogeneity in Euroarea

A growing body of literature has examined heterogeneity within the euro area and its evolution over time. A number of studies have specifically documented asymmetries in the transmission of common euro area monetary policy across member states. [Barigozzi et al. \(2014\)](#), using a structural dynamic factor model estimated on a large panel of euro area variables, find that although the introduction of the euro moved national responses towards greater homogeneity, notable differences persist between northern and southern economies, particularly in the responses of prices and unemployment, reflecting country-specific structural characteristics. [Georgiadis \(2015\)](#), employing a mixed cross-section global VAR model, similarly reports that the transmission of a common monetary policy shock differs across euro area economies, and that these asymmetries are driven by differences in structural features such as the composition of output and financial structure. [Cavallo and Ribba \(2015\)](#), identifying common area-wide shocks within a near-VAR framework, find that while contractionary monetary policy shocks generate broadly similar recessionary effects across countries, national shocks play a substantially larger role in a group of peripheral economies—including Greece, Ireland, and Portugal—than in the largest euro area economies. Taken together, these contributions establish that hetero-

geneity in monetary transmission is a robust feature of the euro area; the present study builds on them by combining externally identified high-frequency policy surprises with an explicit Core–Periphery–CEE grouping and a regime-specific analysis over an extended post-crisis sample.

Coudert et al. (2020) examine the evolution of macroeconomic heterogeneity within the euro area by analysing divergences in equilibrium exchange rate paths across member states. Their findings suggest that macroeconomic imbalances and fragmentation increased substantially both before and after the 2008 financial crisis, highlighting persistent structural differences among euro area economies.

Mandler et al. (2022) examine cross-country heterogeneity in monetary policy transmission using a large Bayesian VAR model with endogenous prior selection. Their results indicate that real output and money supply respond more strongly in Germany than in other euro area economies, while price responses are more pronounced in countries such as Spain. Long-term interest rates also exhibit stronger reactions in Germany and France compared to Southern European economies.

In order to estimate the output gap between the euro-area countries, other studies examine euro area heterogeneity using approaches that explicitly incorporate cross-country data variation. For the extraction of an output gap measure for the entire euro-area, the specific technique takes into account data on real GDP, inflation, and unemployment rates for each member state. In addition to country specific counterparts, the setup is an unobserved components model that hypothesises similar output trends and cyclical components across economies in the euro-area. Using data for the 19 euro area nations from 2000: Q1 through 2018: Q3, Gonzalez-Astudillo (2019) proposes an approach to estimating the euro area output gap using a model that incorporates cross-country data heterogeneity. The framework combines information from real GDP, inflation, and unemployment across member states within an unobserved components model. The results suggest that output was only slightly below potential during the Global Financial Crisis, while a more pronounced negative output gap emerged during the European debt crisis.

Overall, the existing literature highlights that the effects of monetary policy shocks depend critically on identification strategies, transmission channels, and country-specific structural characteristics. Despite significant progress, empirical evidence on cross-country heterogeneity within the euro area remains limited, particularly when considering extended post-crisis samples and externally identified monetary policy shocks. This gap motivates the empirical approach of this study, which combines a panel VAR framework with high-frequency identified monetary policy shocks to provide new evidence on the heterogeneous transmission of monetary policy across euro area economies.

3. Data and Methodology

3.1. Methodology

Monetary policy shocks are identified using the high-frequency monetary policy surprise series constructed by Altavilla et al. (2019) from the Euro Area Monetary Policy Database (EA-MPD). This measure captures the unanticipated component of ECB policy decisions, computed as the revision in asset prices within narrow time windows bracketing policy announcements, and is therefore plausibly orthogonal to the lagged macroeconomic state and to information available to market participants before the announcement. Rather than treating this series as a purely exogenous regressor, we embed it in the Panel VAR as an internal instrument, following the external-instrument (proxy-SVAR) approach to structural identification (Stock & Watson, 2018; Ramey, 2016).

Specifically, the surprise series is ordered first in the vector of endogenous variables, $y_{it} = (mp_t, gdp_{it}, emp_{it}, gov_{it}, gfcf_{it}, hicap_{it})'$, and the structural monetary policy shock is

recovered as the innovation to the first equation of the system. [Plagborg-Møller and Wolf \(2021\)](#) show formally that ordering an external instrument first in a recursive VAR recovers the same impulse responses as the proxy-SVAR estimator, even under non-invertibility; the recursive ordering adopted here is therefore the internal-instruments implementation of that identification strategy and does not require the macroeconomic variables to be recursively ordered among themselves. Because mp_t is an externally measured surprise, its reduced-form innovation is by construction approximately uncorrelated with the innovations to the remaining equations, so the impulse responses to the monetary policy shock are invariant to the ordering of the variables placed below it. This strategy is consistent with a growing body of literature that identifies monetary policy shocks from high-frequency financial market reactions to central bank announcements (e.g., [Gürkaynak et al., 2005](#); [Altavilla et al., 2019](#); [Jarociński & Karadi, 2020](#)).

The identified shock is normalised so that a positive realisation corresponds to an expansionary (accommodative) monetary policy surprise—an unanticipated downward revision in euro area OIS rates around ECB policy events—whereas a negative realisation corresponds to a contractionary (restrictive) surprise. All impulse responses reported below are interpreted under this convention: a positive shock represents monetary easing, so that a positive response denotes an expansionary effect on the corresponding variable and a negative response denotes a contractionary effect. This normalisation should be borne in mind when interpreting the sign of the estimated responses, particularly in view of the possibility that high-frequency policy surprises may partly reflect central bank information effects ([Jarociński & Karadi, 2020](#); [Jarociński, 2022](#)), an issue examined further in the empirical analysis.

The identified monetary policy shock is ordered first in the Panel VAR system, allowing the dynamic responses of GDP, employment, government expenditure, gross capital formation and harmonised Index of Consumer Prices to be traced through impulse response functions. This framework ensures that the estimated responses reflect identified monetary policy innovations rather than endogenous reactions to macroeconomic conditions, thereby enhancing comparability with related studies (e.g., [Ciccarelli et al., 2013](#); [Anagnostou & Papadamou, 2014](#)). The empirical model can be formally represented as follows:

$$y_{it} = A(L)y_{it-1} + \varepsilon_{it} \quad (1)$$

$$\varepsilon_{it} = \alpha_i + \delta_t + u_{it} \quad (2)$$

where y_{it} is a $G \times 1$ vector of endogenous variables for country i at time t ; with $G = 6$, ordered as $y_{it} = (mp_t, gdp_{it}, emp_{it}, gov_{it}, gfcf_{it}, hicap_{it})'$, so that the externally identified monetary policy surprise (mp_t) is ordered first, followed by real GDP, employment, government expenditure, gross fixed capital formation, and the HICP; $A(L)$ represents the lag polynomial matrix, α_i captures country-specific effects, δ_t denotes time effects, and u_{it} is the disturbance term. As discussed by [Canova and Ciccarelli \(2004\)](#), standard panel VAR specifications often impose restrictive assumptions, such as homogeneous slope coefficients and limited cross-sectional interdependencies. Their framework relaxes these restrictions within a Bayesian setting, allowing for more flexible dynamics and improved estimation in macro-panel contexts. More generally, the VAR framework allows for endogenous interactions among variables, addressing simultaneity concerns and providing a suitable structure for analysing the dynamic transmission of monetary policy shocks.

The empirical specification is estimated separately for each country group using quarterly data over the period 2010Q1–2024Q4. The PVAR framework incorporates country-specific fixed effects and a common externally identified monetary policy shock derived from the EA-MPD database. Lag selection is based on standard information criteria and

model stability considerations. Impulse response functions are computed in order to evaluate the dynamic effects of monetary policy shocks on the endogenous macroeconomic variables across alternative monetary policy regimes.

To assess the statistical uncertainty surrounding the estimated impulse response functions, posterior distributions of the responses were generated using Bayesian simulation techniques. Following model estimation, 5000 posterior draws were obtained for each country group and monetary policy regime. Impulse response functions were computed for each posterior draw over a 40-quarter horizon.

The reported impulse responses correspond to the posterior median response at each horizon. In addition, uncertainty bands were constructed using posterior credible intervals. Specifically, 68% credible intervals were calculated using the 16th and 84th percentiles of the posterior distribution, while 90% credible intervals were obtained from the 5th and 95th percentiles. These credible intervals provide a probabilistic assessment of the uncertainty surrounding the estimated responses and allow the statistical significance of the impulse responses to be evaluated. Responses whose credible intervals include zero should be interpreted with caution, as they indicate limited statistical evidence of a systematic effect at the corresponding horizon. The use of posterior credible intervals follows standard practice in Bayesian VAR and Panel VAR applications and improves the transparency and robustness of the empirical analysis.

To address the high dimensionality and persistence typically observed in macroeconomic data, the Bayesian Minnesota prior is adopted within the panel VAR framework. The Minnesota prior provides a structured shrinkage mechanism that reduces parameter uncertainty while preserving the dynamic properties of the system. Under this prior, the coefficients on the first own lag of each variable are centred around one, reflecting the persistence commonly observed in macroeconomic time series, while coefficients on higher-order lags and cross-variable effects are centred around zero. The prior variance decreases with the lag length, ensuring that coefficients associated with more distant lags are increasingly shrunk towards zero. In addition, the prior imposes tighter restrictions on coefficients associated with other variables relative to own lags, reflecting the assumption that a variable's own past values are more informative for its dynamics. A diffuse prior is assigned to the constant term and other deterministic components, allowing the data to determine their contribution. Overall, this Bayesian framework improves estimation efficiency and mitigates overparameterisation issues, making it particularly suitable for panel VAR models with multiple countries and variables.

Posterior parameter distributions and impulse response functions are obtained using Bayesian simulation techniques implemented in RATS. The Bayesian framework combines prior information with sample information in order to improve estimation efficiency and mitigate over-parameterisation concerns in a multi-country macroeconomic setting. Additional details regarding posterior simulation procedures and credible interval construction are provided in Appendix B.

3.2. Data

The empirical analysis is based on quarterly macroeconomic data for euro area countries over the period 2010Q1–2024Q4. The sample includes 19 euro area economies and is structured as a stacked panel dataset. To account for cross-country heterogeneity, the sample is divided into three groups—Core, Periphery, and Central and Eastern European (CEE) countries—as reported in Table 1. This classification allows for a systematic investigation of differences in the transmission of monetary policy shocks across economies with distinct structural, financial, and institutional characteristics.

Table 1. Groups of examined countries.

Core Countries	Periphery Countries	Central and Eastern Europe Countries
Belgium (BE)	Ireland (IE)	Estonia (EE)
Germany (DE)	Greece (GR)	Latvia (LV)
France (FR)	Spain (ES)	Lithuania (LT)
Luxembourg (LU)	Italy (IT)	Slovenia (SI)
Netherlands (NL)	Cyprus (CY)	Slovakia (SK)
Austria (AT)	Malta (MT)	
Finland (FI)	Portugal (PT)	

The choice of 2010Q1 as the starting point reflects both the composition of the euro area and the focus of the analysis on the post-crisis monetary policy regimes. Several of the CEE economies included in the sample adopted the euro only around or after 2009 (for example, Estonia in 2011, Latvia in 2014, and Lithuania in 2015), so that a meaningful analysis of their exposure to the common monetary policy is possible only from approximately this date. Beginning the sample in 2010 also avoids conflating the global financial crisis of 2008–2009—a global shock with distinct dynamics—with the euro-area-specific transmission mechanisms that are the focus of this study, and aligns the estimation window with the three monetary policy regimes examined below (the post-sovereign-debt adjustment period, the unconventional monetary policy period, and the pandemic and tightening period). Extending the sample backwards would require pooling economies over a period in which several of them were not yet part of the monetary union and would mix structurally distinct monetary regimes, thereby complicating the identification of regime-specific transmission.

The classification of countries into Core, Periphery, and Central and Eastern European (CEE) groups follows a structural rather than purely geographical rationale. The grouping is intended to capture persistent differences in economic structure, financial development, fiscal capacity, and exposure to external shocks that may influence the transmission of monetary policy. The Core group consists of economies characterised by relatively high levels of income, deeper financial markets, stronger fiscal positions, and greater institutional stability. These countries generally exhibit more mature financial systems and stronger macroeconomic resilience, which may contribute to smoother monetary policy transmission. The Periphery group includes economies that have historically displayed greater sensitivity to financial fragmentation, sovereign debt pressures, and banking-sector vulnerabilities, particularly during the European sovereign debt crisis. These economies are generally characterised by higher exposure to external financing conditions and more pronounced cyclical fluctuations.

The CEE group comprises newer euro area members from Central and Eastern Europe that have undergone substantial economic convergence and financial integration during the sample period. Although these economies share membership in the monetary union, they continue to exhibit structural characteristics that distinguish them from both Core and Periphery economies, including stronger convergence dynamics, different labour-market structures, and greater sensitivity to external economic conditions. This classification is consistent with a large body of literature examining euro area heterogeneity and provides a useful framework for evaluating whether monetary policy transmission differs systematically across structurally distinct groups of economies.

The selected sample period encompasses multiple phases of monetary policy in the euro area, including the post-sovereign debt crisis adjustment, the period of unconventional

monetary policy measures, the pandemic-related crisis, and the recent transition toward monetary tightening. In particular, the expansionary phase associated with the European Central Bank's Asset Purchase Programmes (APP), including the Public Sector Purchase Programme (PSPP) implemented between March 2015 and December 2018, represents a key sub-period within the sample. This phase was followed by a period of reinvestments and, more recently, by a shift toward monetary tightening in response to rising inflationary pressures.

In addition, the sample includes the COVID-19 period, during which monetary policy interventions intensified through programmes such as the Pandemic Emergency Purchase Programme (PEPP), thereby incorporating extreme macroeconomic conditions into the analysis. This extended timeframe provides a comprehensive setting for analysing the transmission of monetary policy shocks under different monetary policy regimes.

The set of endogenous variables includes gross domestic product (GDP), employment, gross fixed capital formation, government expenditure and the Harmonised Index of Consumer Prices (HICP). GDP is used as a proxy for overall economic activity, employment captures labour market dynamics, gross fixed capital formation reflects investment behaviour, and government expenditure represents the fiscal stance of the public sector. HICP is included in order to capture inflation dynamics and price-level responses to monetary policy shocks. All variables are obtained from the Eurostat database and are expressed in logarithmic form. The use of variables in logarithmic levels allows for a direct interpretation of impulse responses in terms of percentage changes, while preserving the long-run relationships among macroeconomic variables. In addition, the adoption of a Bayesian VAR framework mitigates concerns related to persistence and near non-stationarity, as the Minnesota prior imposes shrinkage on higher-order lags and stabilises the estimation. Formally, the reduced-form innovations are Gaussian with zero mean, $u_{it} \sim N(0, \Sigma_i)$, and the autoregressive coefficients are assigned a Minnesota-type prior whose variance declines with the lag order and, for cross-variable coefficients, is scaled by the relative volatility of the variables; the full specification, including the hyperparameter calibration, is provided in Appendix A.

Monetary policy shocks are captured by an externally identified series based on high-frequency financial market reactions to European Central Bank policy announcements (Altavilla et al., 2019). This series is ordered first in the Panel VAR model, allowing the analysis to trace the dynamic responses of macroeconomic aggregates to unanticipated monetary policy innovations.

4. Empirical Results

4.1. Baseline Full-Sample Evidence

The full-sample Bayesian PVAR estimations provide evidence of heterogeneous monetary policy transmission across euro area country groups, although the degree of statistical uncertainty varies considerably across responses. Table 2 reports the peak posterior median responses together with the associated 68% and 90% credible intervals. The results indicate that the magnitude and persistence of monetary policy transmission differ across Core, Periphery, and CEE economies, supporting the presence of structural heterogeneity within the monetary union. However, the posterior distributions also reveal substantial uncertainty surrounding several estimated responses. In most cases, the 90% credible intervals include zero, suggesting that the estimated effects should be interpreted as indicative transmission patterns rather than precise point estimates. The strongest statistical evidence emerges for GDP responses in the Core economies, where the 90% credible interval excludes zero at the peak response horizon. Overall, the results suggest that monetary policy transmission

is not homogeneous across euro area economies, but the strength of the evidence varies across country groups and macroeconomic variables.

Table 2. Baseline Peak Impulse Responses to Monetary Policy Shocks.

Country Group	Variable	Peak Horizon	Posterior Median	68% Credible Interval	90% Credible Interval	90% CI Excludes Zero?
Core	GDP	2	0.000548	[0.000329, 0.000764]	[0.000193, 0.000910]	Yes
Core	Employment	3	0.000084	[−0.000052, 0.000227]	[−0.000156, 0.000342]	No
Core	Inflation	14	−0.000161	[−0.000332, −0.000042]	[−0.000497, +0.000033]	No
Periphery	GDP	2	0.000548	[0.000176, 0.000936]	[−0.000057, 0.001180]	No
Periphery	Employment	2	−0.000105	[−0.000347, 0.000125]	[−0.000509, 0.000277]	No
Periphery	Inflation	2	−0.000375	[−0.000533, −0.000224]	[−0.000639, −0.000123]	Yes
CEE	GDP	2	0.000422	[0.000174, 0.000675]	[−0.000001, 0.000839]	No
CEE	Employment	15	0.000074	[−0.000003, 0.000205]	[−0.000060, 0.000354]	No
CEE	Inflation	29	+0.000253	[+0.000002, +0.001050]	[−0.000182, +0.002410]	No

Source: Authors' calculations based on posterior impulse response distributions obtained from the Bayesian PVAR estimations.

The full-sample results reveal meaningful differences in the transmission of monetary policy shocks across the three country groups. However, the posterior distributions indicate that the degree of statistical uncertainty varies considerably across responses, suggesting that cross-group comparisons should be interpreted with appropriate caution.

For the Core economies, the estimated GDP response exhibits the strongest statistical support among the examined variables. The peak posterior median response is positive and the associated 90% credible interval excludes zero, indicating relatively robust evidence that an expansionary monetary policy surprise raises output in the Core economies, consistent with the conventional transmission of accommodative monetary policy. By contrast, employment responses remain comparatively small and are characterised by wider credible intervals that include zero. Accordingly, the negative point estimate obtained for employment in some groups should not be interpreted as evidence of a contractionary labour-market effect, since these responses are not statistically distinguishable from zero at conventional credibility levels; the apparent divergence in sign between the output and employment responses therefore reflects estimation uncertainty rather than a genuine contradiction in the direction of transmission.

The Periphery economies display larger posterior median responses than the Core group in several horizons, particularly for employment dynamics. Nevertheless, the associated credible intervals remain relatively wide and generally include zero, implying that the estimated responses should be interpreted primarily as indicative transmission patterns rather than statistically precise effects. This result is broadly consistent with the view that peripheral economies remain more exposed to financial and macroeconomic vulnerabilities, although the strength of the evidence varies across variables and horizons.

The CEE economies exhibit a distinct adjustment pattern characterised by moderate output responses and relatively persistent labour-market dynamics. Similar to the Periphery group, however, the posterior uncertainty surrounding many responses remains substantial. Consequently, while the estimated median responses suggest differences in transmission mechanisms relative to the Core economies, the credible intervals indicate that these differences should be interpreted cautiously.

Overall, the full-sample evidence supports the presence of heterogeneous monetary policy transmission across euro area economies. At the same time, the credible

intervals highlight that the degree of statistical certainty differs considerably across variables and country groups. This finding reinforces the importance of evaluating monetary policy transmission within a probabilistic framework rather than relying exclusively on point estimates.

The impulse response functions provide additional insight into the dynamic adjustment patterns underlying the full-sample results. While the peak posterior median responses reported in Table 2 summarise the maximum estimated effects, the impulse response functions illustrate the timing, persistence, and evolution of these responses across horizons. Figures 1 and 2 present the posterior median responses of GDP and employment to identified monetary policy shocks for the Core, Periphery, and CEE country groups. Particular attention is given to output and labour-market dynamics because these variables represent the primary channels through which monetary policy affects real economic activity and because they provide the clearest basis for evaluating transmission asymmetries across country groups.

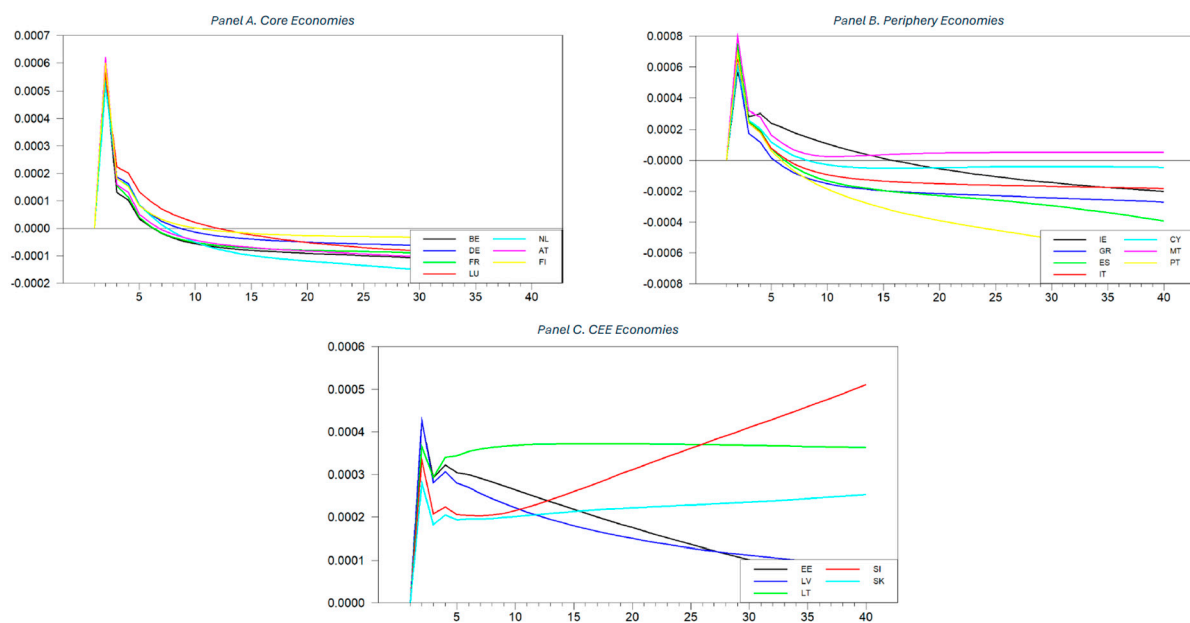


Figure 1. GDP Responses to Monetary Policy Shocks by Country Group.

The figures indicate that the overall transmission mechanism differs not only in magnitude but also in persistence and adjustment speed across groups. Core economies generally exhibit smoother adjustment paths, whereas the responses observed in the Periphery and CEE groups display greater variability over time. However, as highlighted by the posterior credible intervals reported in Table 2, substantial uncertainty surrounds several estimated responses. Consequently, the impulse response functions should be interpreted as probabilistic estimates of transmission dynamics rather than deterministic measures of economic effects. The graphical evidence complements the peak-response analysis by illustrating how monetary policy shocks propagate through different macroeconomic environments within the euro area and by highlighting the role of structural heterogeneity in shaping adjustment dynamics.

As the variables enter the system in log-levels, the estimated dynamics are highly persistent, consistent with the near-nonstationarity noted in Section 3. To assess this formally, the largest modulus of the companion-matrix eigenvalues was computed across the posterior draws for each group. The posterior median of the largest modulus is 0.987 for the Periphery, 1.012 for the CEE, and 1.013 for the Core group, with 90% credible intervals of [0.933, 1.040], [0.942, 1.085], and [0.928, 1.079], respectively. In every case the

credible interval straddles unity, and posterior mass lies on both sides of one (the share of draws with a modulus above unity is 0.35, 0.60, and 0.62 for the Periphery, CEE, and Core groups). The data are therefore consistent with a largest root at or near unity—as is typical for macroeconomic variables in levels—rather than with genuine explosiveness; the point estimates close to one should be read as evidence of a near-unit-root, not of an unstable system. This high persistence, inherent to the level specification, is what causes the impulse responses to decay only gradually over the reported horizon, directly addressing the observation that some responses do not appear to revert to zero within the window displayed. Because the largest root lies so close to unity, the analysis concentrates on the transmission of shocks over business-cycle horizons, where the responses are well-defined and economically interpretable, and relies on the Minnesota shrinkage prior to stabilise estimation given the short sample.

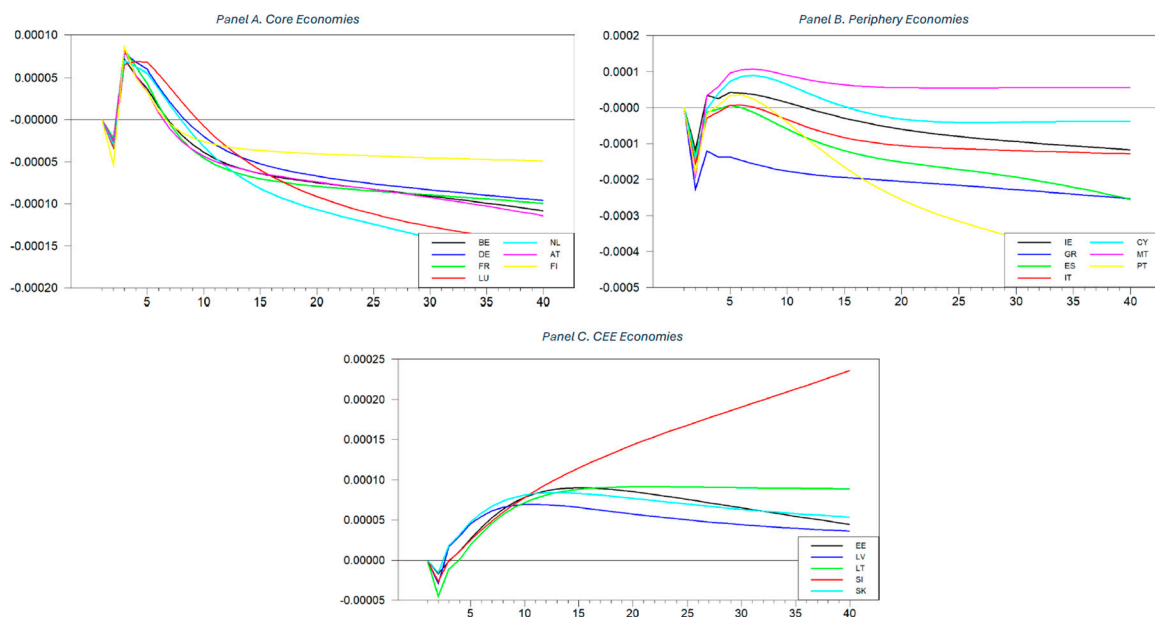


Figure 2. Employment Responses to Monetary Policy Shocks by Country Group. Source: Authors' calculations based on Bayesian PVAR estimations using EA-MPD monetary policy shocks and Eurostat data.

Turning to prices, the peak responses of the Harmonised Index of Consumer Prices are reported in Table 2. For the Core and CEE groups, the inflation responses are not statistically distinguishable from zero at the 90% level and are therefore not interpreted as evidence of a systematic price response. For the Periphery group, by contrast, the peak inflation response is negative and its 90% credible interval excludes zero, indicating a statistically meaningful decline in prices. Under the sign convention adopted here, this implies that an expansionary monetary policy surprise is associated with lower prices in the Periphery—a sign reversal that mirrors the output and employment responses discussed above. Taken together, the joint decline in output, employment and prices in the Periphery is consistent with the central bank information effects emphasised earlier (Jarociński & Karadi, 2020; Jarociński, 2022): an apparently accommodative surprise that partly conveys adverse information about the economic outlook would be expected to depress real activity and prices simultaneously, rather than to raise them as conventional transmission would predict.

These findings can be related to the existing evidence on heterogeneous monetary transmission in the euro area. The stronger and more precisely estimated output response in the Core economies, contrasted with the more volatile and less precisely estimated

responses in the Periphery, is broadly consistent with Barigozzi et al. (2014), who document persistent North–South differences in the responses of euro area economies, and with Georgiadis (2015), who attributes such asymmetries to structural differences across countries. The heightened sensitivity of the Periphery during the sovereign debt crisis accords with Ciccarelli et al. (2013), who show that transmission intensifies with financial fragility and sovereign stress. At the same time, the sign reversal observed for the Periphery during 2010–2014 is consistent with the central bank information effects emphasised by Jarociński and Karadi (2020) and Jarociński (2022), whereby high-frequency policy surprises during periods of acute stress partly reflect the information content of central bank communication rather than pure policy shocks. Overall, the direction and cross-country pattern of the estimated responses are in line with the broader literature, while the regime-specific dimension of the analysis contributes new evidence on how these asymmetries evolve across distinct monetary environments.

4.2. Robustness Across Monetary Policy Regimes

The full-sample estimations provide important baseline evidence regarding the asymmetric transmission of monetary policy shocks across euro area economies. Nevertheless, the extended sample period encompasses multiple episodes characterised by substantially different monetary and macroeconomic environments, including the post-sovereign-debt adjustment phase, the unconventional monetary policy period associated with the ECB's asset purchase programmes, and the subsequent pandemic and monetary tightening episode. As a result, the full-sample responses may conceal regime-specific transmission dynamics. To address this issue, the baseline PVAR model is re-estimated across three sub-periods corresponding to distinct monetary policy regimes.

It should be emphasised that each regime covers a relatively short sample (twenty quarters), which limits the precision with which the regime-specific responses can be estimated. The results in this section should therefore be interpreted as indicative of how transmission evolves across monetary environments rather than as precise estimates; the credible intervals reported in Tables 3 and 4, which include zero for most regimes, convey this uncertainty directly.

Table 3. Peak GDP Responses Across Monetary Policy Regimes.

Group	Regime	Peak Horizon	Peak Median	90% Credible Interval	90% CI Excludes Zero?
Core	2010–2014	2	0.000087	[−0.000211, 0.000387]	No
Core	2015–2019	10	0.000164	[−0.000347, 0.000807]	No
Core	2020–2024	2	0.000498	[−0.000185, 0.001130]	No
Periphery	2010–2014	2	−0.000541	[−0.000855, −0.000242]	Yes
Periphery	2015–2019	2	−0.000227	[−0.000654, 0.000208]	No
Periphery	2020–2024	2	0.000522	[−0.000298, 0.001410]	No
CEE	2010–2014	2	−0.000128	[−0.000456, 0.000147]	No
CEE	2015–2019	3	0.000066	[−0.000330, 0.000475]	No
CEE	2020–2024	2	0.000502	[−0.000220, 0.001200]	No

Source: Authors' calculations based on posterior impulse response distributions obtained from the Bayesian PVAR estimations.

To further examine the heterogeneity of monetary policy transmission across euro area economies, Tables 3 and 4 report the impulse response dynamics of GDP and employment following a monetary policy shock across the three monetary policy regimes.

The analysis is conducted separately for Core, Periphery, and CEE economies in order to capture differences in the magnitude, persistence, and adjustment patterns of macroeconomic responses under changing monetary and financial conditions. By separating the sample into distinct monetary policy regimes, the empirical analysis allows for a more detailed evaluation of how transmission mechanisms evolved across periods characterised by financial fragmentation, unconventional monetary accommodation, and post-pandemic monetary tightening.

Table 4. Employment Responses to Monetary Policy Shocks.

Group	Regime	Peak Horizon	Peak Median	90% Credible Interval	90% CI Excludes Zero?
Core	2010–2014	2	0.000435	[−0.000696, 0.001410]	No
Core	2015–2019	2	0.000173	[−0.000915, 0.001080]	No
Core	2020–2024	3	0.000081	[−0.000139, 0.000342]	No
Periphery	2010–2014	2	−0.000794	[−0.001180, −0.000396]	Yes
Periphery	2015–2019	2	−0.000116	[−0.000776, 0.000553]	No
Periphery	2020–2024	2	0.000369	[−0.000142, 0.000873]	No
CEE	2010–2014	2	−0.000351	[−0.000753, 0.000009]	No
CEE	2015–2019	2	0.000511	[−0.000023, 0.001090]	No
CEE	2020–2024	8	0.000064	[−0.000020, 0.000226]	No

Source: Authors' calculations based on posterior impulse response distributions obtained from the Bayesian PVAR estimations.

The discussion focuses primarily on GDP and employment responses because these variables provide the clearest representation of real economic adjustment following monetary policy shocks and constitute the main channels through which transmission asymmetries emerge across euro area economies. While the remaining macroeconomic variables are also incorporated into the empirical framework and discussed throughout the analysis, GDP and labour-market dynamics offer the most direct evidence regarding the effectiveness, persistence, and cross-country heterogeneity of ECB monetary policy transmission.

4.2.1. Post-Crisis Adjustment Period (2010Q1–2014Q4)

The first sub-period corresponds to the aftermath of the euro area sovereign debt crisis, when several member states were still exposed to elevated financial stress, fiscal consolidation pressures, banking-sector fragilities, and fragmented credit conditions. The regime-specific Bayesian PVAR estimates indicate that monetary policy transmission during this period was most pronounced in the Periphery economies.

The strongest evidence concerns the Periphery group. The posterior median GDP response reaches −0.000541 at the peak horizon, with a 90% credible interval of [−0.000855, −0.000242]. Employment displays an even larger response of the same sign, with a peak posterior median of −0.000794 and a 90% credible interval of [−0.001180, −0.000396]. In both cases the 90% credible intervals exclude zero, indicating a statistically meaningful response during the post-crisis adjustment period. Under the sign convention adopted here, these negative responses imply that an expansionary monetary policy surprise is associated with lower output and employment in the Periphery economies during this regime—a reversal of the sign observed in the Core.

This result suggests that monetary policy surprises were transmitted more forcefully to peripheral economies during the sovereign debt crisis aftermath, and that their effects differed qualitatively from those observed in the Core. The sign reversal is consistent with

the presence of central bank information effects during this period (Jarociński & Karadi, 2020; Jarociński, 2022): in an environment marked by financial fragmentation, elevated sovereign-risk premia, and fragile banking systems, accommodative ECB surprises are likely to have coincided with, and partly revealed, adverse information about the economic outlook of the periphery, so that expansionary surprises were associated with weaker output and labour-market conditions rather than with the expansionary effects predicted by conventional transmission. This interpretation accords with the view that high-frequency policy surprises during periods of acute stress are partly contaminated by the information content of central bank communication.

By contrast, the Core economies exhibit comparatively milder and statistically less precise responses. Although the posterior median responses suggest some adjustment following monetary policy shocks, the corresponding credible intervals include zero, indicating weaker evidence of systematic effect. This pattern is consistent with the greater financial depth, stronger institutional capacity, and higher macroeconomic resilience of core euro area economies. The CEE economies also display negative median responses during this period, particularly for employment, but the associated credible intervals generally include zero. Therefore, while the median estimates point to some sensitivity to monetary shocks, the statistical evidence is less robust than in the Periphery group.

Overall, the 2010–2014 results provide the clearest evidence of asymmetric monetary policy transmission in the regime analysis. The statistically robust responses are concentrated in the Periphery economies, where both GDP and employment responses are distinguishable from zero and are of the opposite sign to those estimated for the Core. This finding supports the interpretation that the sovereign debt crisis amplified cross-country asymmetries in euro area monetary transmission, including a reversal in the direction of the estimated response that is consistent with central bank information effects.

4.2.2. Unconventional Monetary Policy Period (2015Q1–2019Q4)

The second sub-period corresponds to the era of unconventional monetary policy, during which the ECB implemented large-scale asset purchase programmes and maintained highly accommodative monetary conditions. This period was characterised by declining sovereign spreads, improved financial conditions, enhanced liquidity provision, and a gradual recovery from the disruptions associated with the sovereign debt crisis. The regime-specific Bayesian PVAR estimates indicate that monetary policy transmission became more supportive of macroeconomic activity relative to the previous period, although the associated uncertainty remains substantial.

Across all three country groups, the posterior median responses generally shift towards more favourable output and employment dynamics compared with the post-crisis adjustment regime. In the Core economies, both GDP and employment responses become positive over several horizons, suggesting that accommodative monetary conditions were associated with improved macroeconomic performance. However, the corresponding credible intervals continue to include zero, indicating that the statistical evidence remains less definitive than the point estimates alone might suggest.

A similar pattern emerges in the Periphery economies. Relative to the negative responses observed during 2010–2014, the posterior median estimates indicate a substantial moderation of adverse effects and, in some cases, a transition towards mildly positive responses. This finding is consistent with the view that unconventional monetary policy may have contributed to easing financial constraints, reducing fragmentation pressures, and improving financing conditions in economies that had been disproportionately affected by the sovereign debt crisis. Nevertheless, the associated credible intervals remain relatively wide, implying that the estimated effects should be interpreted with caution.

The CEE economies also exhibit more favourable median responses during this period, particularly with respect to labour-market dynamics. These results are broadly consistent with stronger financial integration, increased capital inflows, and continued economic convergence within the euro area framework. At the same time, the posterior uncertainty surrounding the estimated responses remains non-negligible, limiting the strength of statistical inference.

Taken together, the 2015–2019 regime is consistent with a more supportive transmission environment than the post-crisis period. The posterior median responses suggest that unconventional monetary policy is consistent with improved macroeconomic conditions across all country groups. However, the credible intervals indicate that the magnitude of these effects remains subject to considerable uncertainty, highlighting the importance of interpreting the results within a probabilistic rather than deterministic framework.

4.2.3. Pandemic and Monetary Tightening Period (2020Q1–2024Q4)

The final sub-period encompasses one of the most complex macroeconomic environments in the history of the euro area. The period includes the COVID-19 pandemic, the subsequent recovery phase, the energy and supply-chain disruptions associated with the post-pandemic inflation surge, and the ECB's return to monetary tightening. Consequently, monetary policy transmission operated within an environment characterised by exceptional uncertainty, extensive fiscal intervention, and multiple overlapping shocks.

The regime-specific Bayesian estimates indicate that the posterior median responses generally become more positive than those observed during earlier periods, particularly for GDP. However, the associated credible intervals remain relatively wide across all country groups, suggesting that monetary policy effects are more difficult to identify precisely during this regime. This result is consistent with the unprecedented macroeconomic conditions that characterised the period and the interaction of monetary policy with large-scale fiscal support measures and extraordinary policy interventions.

For the Core economies, the posterior median responses remain positive, indicating continued adjustment following monetary policy shocks. Nevertheless, the credible intervals include zero, implying that the statistical evidence remains weaker than the corresponding point estimates might suggest. Compared with the unconventional monetary policy period, the transmission mechanism appears less predictable and more sensitive to changing macroeconomic conditions.

The Periphery economies exhibit a notable shift relative to the post-crisis regime. While the posterior median responses no longer display the pronounced negative responses observed during 2010–2014, the associated uncertainty remains substantial. This finding suggests that the combination of fiscal support measures, post-pandemic recovery dynamics, and inflationary pressures altered the transmission mechanism, reducing the persistence of adverse responses while increasing overall volatility.

The CEE economies continue to display a distinct adjustment pattern characterised by relatively strong median GDP responses and comparatively rapid adjustment dynamics. However, as in the other groups, the corresponding credible intervals indicate considerable uncertainty. The results therefore suggest that although transmission patterns differ across country groups, the exceptional macroeconomic environment of the period complicates precise identification of monetary policy effects.

Overall, the 2020–2024 regime highlights the importance of macroeconomic context in shaping monetary policy transmission. While the posterior median responses suggest that transmission mechanisms remained active throughout the pandemic and post-pandemic period, the wider credible intervals indicate that uncertainty surrounding the estimated effects increased substantially relative to earlier regimes. These findings reinforce the view

that euro area monetary transmission is both regime-dependent and sensitive to large-scale economic disruptions.

Overall, the regime-specific analysis confirms that monetary policy transmission within the euro area is neither homogeneous nor stable over time. The estimated responses vary across country groups and monetary policy environments, indicating that the effectiveness and persistence of monetary policy shocks depend critically on the broader macroeconomic context.

The strongest evidence emerges during the post-sovereign-debt crisis period, when the Periphery economies exhibit statistically meaningful responses in both GDP and employment that are of the opposite sign to those in the Core, consistent with central bank information effects. By contrast, the unconventional monetary policy period is characterised by more supportive posterior median responses across all country groups, although the associated credible intervals indicate substantial uncertainty regarding the precise magnitude of these effects. During the pandemic and monetary tightening regime, transmission patterns become more difficult to identify, reflecting the interaction of monetary policy with extraordinary fiscal interventions, elevated uncertainty, and multiple overlapping macroeconomic shocks.

Taken together, the findings support the view that euro area monetary transmission is both structurally asymmetric and regime dependent. While the posterior median responses reveal meaningful differences across Core, Periphery, and CEE economies, the credible intervals highlight the importance of accounting for estimation uncertainty when evaluating the strength and persistence of monetary policy effects. Table 5 summarises these regime-specific findings and their main economic interpretation across the three country groups.

Table 5. Monetary Policy Transmission Across Alternative Monetary Regimes.

Regime	Core Economies	Periphery Economies	CEE Economies	Main Finding
2010–2014	Mild and statistically uncertain responses	Strong negative GDP and employment responses (opposite in sign to the Core) with 90% credible intervals excluding zero	Negative median responses with weaker statistical support	Sovereign-debt crisis amplified transmission asymmetries
2015–2019	Positive median responses under accommodative monetary conditions	Moderation of adverse effects and improved adjustment dynamics	Improved labour-market and output responses	More supportive transmission environment under unconventional monetary policy
2020–2024	Positive but less precisely identified responses	Mixed responses with substantial uncertainty	Distinct adjustment patterns accompanied by elevated uncertainty	Transmission shaped by pandemic disruptions, fiscal interventions, and tightening conditions

4.3. Comparative Interpretation Across Country Groups

The combined evidence from the full-sample estimations and the regime-specific analysis highlights the presence of substantial heterogeneity in monetary policy transmission across euro area economies. Although all countries operate under a common monetary policy framework, the estimated responses indicate that transmission dynamics differ considerably across Core, Periphery, and Central and Eastern European (CEE) economies.

The Core economies generally exhibit the most stable adjustment patterns throughout the sample. Both the full-sample and regime-specific estimations suggest comparatively

smoother output and employment responses, consistent with stronger institutional capacity, deeper financial markets, and more resilient macroeconomic structures. Although the posterior median responses indicate meaningful reactions to monetary policy shocks, the associated credible intervals often reveal substantial uncertainty, implying that transmission effects are relatively moderate and less volatile than in the other country groups.

The Periphery economies display the clearest evidence of asymmetric transmission. This pattern is particularly pronounced during the post-sovereign-debt adjustment period, when both GDP and employment responses are statistically distinguishable from zero at the 90% credibility level. The results suggest that financial fragmentation, sovereign-risk pressures, and weaker financing conditions amplified the effects of monetary policy shocks in these economies. While the subsequent regimes indicate a moderation of these effects, the Periphery group continues to exhibit greater sensitivity and variability than the Core economies.

The CEE economies follow a distinct adjustment path that differs from both the Core and Periphery groups. The posterior median responses suggest comparatively flexible adjustment dynamics, particularly during the later regimes, although the associated uncertainty remains substantial. These findings are broadly consistent with the transitional characteristics of converging economies, where ongoing structural adjustment and financial integration may influence the transmission mechanism differently from the more mature economies of the euro area.

Taken together, the comparative evidence indicates that monetary policy transmission within the euro area remains both structurally asymmetric and regime dependent. The results suggest that differences in institutional quality, financial development, and macroeconomic resilience continue to shape the effectiveness of common monetary policy across member states. Consequently, a uniform monetary policy may generate heterogeneous economic outcomes even within a highly integrated monetary union.

4.4. Granger-Causality Analysis

As a complementary, reduced-form check on the direction of the estimated relationships, panel Granger-causality tests were conducted for each group, based on a VAR(1) with country fixed effects. The results are reported in Table 6.

Table 6. Panel Granger-Causality Tests.

	Core	Periphery	CEE
MP_SHOCK → LGDP	+0.00059 (0.375)	+0.00063 (0.499)	+0.00044 (0.409)
MP_SHOCK → LEMP	−0.00016 (0.409)	−0.00013 (0.703)	−0.00009 (0.740)
MP_SHOCK → LGOVEXP	+0.00003 (0.903)	−0.00022 (0.381)	+0.00012 (0.409)
MP_SHOCK → LGFCF	+0.00052 (0.408)	−0.00010 (0.959)	+0.00196 (0.020) **
MP_SHOCK → LHICP	−0.00004 (0.738)	−0.00041 (0.215)	−0.00003 (0.877)
Macro → MP_SHOCK (joint, F)	1.55 (0.187)	1.56 (0.185)	1.65 (0.162)

Notes: Panel VAR(1) with country fixed effects, estimated by OLS. Each entry is the coefficient on the one-quarter lag of the row variable, with the *p*-value in parentheses, based on standard errors clustered by time period to account for the common (euro-area-wide) nature of the monetary policy surprise. The final row reports the joint F-test that the five macroeconomic variables do not Granger-cause MP_SHOCK. ** *p* < 0.05.

Two features are worth emphasising. First, the five macroeconomic variables do not jointly Granger-cause the monetary policy surprise in any group (*p*-values of 0.19, 0.19, and 0.16 for the Core, Periphery, and CEE groups), supporting the treatment of the high-frequency surprise as predetermined with respect to the domestic macroeconomic state. Second, in the forward direction the estimated coefficients share the sign of the

corresponding impulse responses—positive for output, negative for prices in the Periphery, and positive for investment in the CEE group—so that the two approaches agree on the qualitative pattern of transmission.

The Granger tests nonetheless indicate limited individual statistical significance, with the investment channel in the CEE group the clearest exception. This apparent contrast with the baseline results reflects the different nature of the two exercises rather than a genuine inconsistency. Because the monetary policy surprise is common to all countries within a group, the effective number of independent observations identifying its effect is governed by the time dimension (sixty quarters) rather than by the full panel, and the standard errors are clustered by time period accordingly; the Granger test, moreover, assesses a single reduced-form lag coefficient in isolation. The Bayesian panel VAR, by contrast, pools information across countries through the hierarchical shrinkage prior and traces the full dynamic response of the system, yielding more precise inference in a short sample. The two sets of results are therefore best read as mutually reinforcing: the impulse responses provide the primary, system-based evidence on transmission, while the Granger tests confirm the direction of the relationships and the exogeneity of the identified surprise.

4.5. Policy Implications and Limitations

The empirical findings of this study carry important implications for the conduct and effectiveness of monetary policy within the euro area. The estimated responses demonstrate that monetary policy transmission remains heterogeneous across country groups and varies across alternative monetary policy regimes. Consequently, the effects of ECB policy interventions cannot be assumed to be uniform across member states, despite the existence of a common monetary authority and a unified monetary framework.

A central implication of the analysis concerns the challenges associated with implementing a common monetary policy within structurally heterogeneous economies. The results indicate that monetary policy transmission differs across Core, Periphery, and CEE economies, reflecting differences in financial structures, institutional characteristics, and macroeconomic conditions. While the posterior median responses suggest stronger transmission patterns in some country groups and periods, the associated credible intervals indicate that the magnitude of these differences should be interpreted with appropriate caution.

The findings further suggest that the effectiveness of ECB interventions depends critically on the broader macroeconomic environment. The regime-specific analysis indicates that transmission dynamics vary substantially across periods characterised by financial fragmentation, unconventional monetary accommodation, and post-pandemic monetary tightening. In particular, the strongest statistically supported responses are observed during the post-sovereign-debt adjustment period, whereas later regimes are characterised by greater estimation uncertainty despite economically meaningful posterior median responses.

An additional implication concerns the importance of financial integration and institutional resilience within the euro area. The stronger responses observed in some country groups during periods of financial stress suggest that fragmentation mechanisms may continue to influence the transmission process under adverse macroeconomic conditions. Consequently, monetary policy alone may be insufficient to ensure homogeneous adjustment across member states. Complementary institutional arrangements, financial integration mechanisms, and national policy frameworks may therefore play an important role in supporting the effectiveness of ECB interventions.

The regime-specific results also speak directly to the interaction between monetary and fiscal policy. The pronounced widening of the credible intervals during the pandemic and tightening regime—the period in which monetary policy operated alongside large-scale

fiscal interventions—indicates that the transmission of monetary policy shocks becomes substantially more difficult to isolate when monetary and fiscal measures act simultaneously. To the extent that this reflects the overlapping of policy instruments rather than a genuine absence of transmission, the finding implies that assessments of monetary policy effectiveness during such episodes should explicitly account for the concurrent fiscal stance, rather than treating monetary policy in isolation.

Overall, the evidence suggests that euro area monetary transmission remains conditional on structural heterogeneity, financial conditions, and regime-specific dynamics. As a result, future ECB policy design may benefit from greater consideration of cross-country asymmetries and macroeconomic context when evaluating the likely effectiveness of common monetary policy interventions.

5. Limitations

Several limitations should be acknowledged when interpreting the findings of this study. First, although the Bayesian PVAR framework provides a flexible approach for analysing dynamic transmission mechanisms, the estimated relationships remain subject to the usual limitations associated with reduced-form models. Consequently, the results should be interpreted as evidence of dynamic responses rather than definitive causal mechanisms. Second, the analysis relies on country-group classifications that necessarily simplify the substantial heterogeneity that exists within each group. While the Core, Periphery, and CEE classifications provide a useful framework for comparative analysis, important country-specific differences may remain concealed within the aggregated results.

Third, the regime-based analysis reduces the number of observations available within each sub-period. Although the Bayesian framework helps mitigate small-sample concerns through parameter shrinkage, estimation uncertainty remains higher within the regime-specific models, as reflected in the posterior credible intervals. Finally, the analysis focuses primarily on macroeconomic transmission channels and does not explicitly model financial-sector heterogeneity, sovereign-risk dynamics, or nonlinear transmission mechanisms. Future research could extend the framework by incorporating these dimensions and by exploring alternative identification strategies for monetary policy shocks.

6. Conclusions

This study examined the asymmetric transmission of monetary policy shocks across euro area economies using a Panel Vector Autoregressive (PVAR) framework covering the period 2010Q1–2024Q4. The analysis focused on three distinct country groups—Core, Periphery, and Central and Eastern European (CEE) economies—and evaluated how monetary policy transmission evolved across alternative monetary policy regimes and macroeconomic environments.

The full-sample estimations indicate that monetary policy transmission remains heterogeneous across euro area economies. Although all country groups respond to common monetary policy disturbances, the magnitude, persistence, and adjustment dynamics of macroeconomic responses differ substantially across groups. The results suggest that Core economies generally exhibit more stable adjustment patterns, while Periphery economies display greater sensitivity to monetary disturbances, particularly during periods characterised by financial fragmentation and macroeconomic stress. The CEE economies follow a distinct adjustment path consistent with their structural characteristics and ongoing convergence processes.

The regime-specific analysis further demonstrates that monetary policy transmission is strongly dependent on the prevailing macroeconomic environment. The strongest statistically supported responses are observed in the Periphery economies during the

post-sovereign-debt adjustment period, where both GDP and employment responses remain statistically distinguishable from zero at the 90% credibility level. By contrast, the unconventional monetary policy and pandemic-period estimations are characterised by generally more supportive posterior median responses but also substantially greater uncertainty, as reflected in the corresponding credible intervals.

Overall, the findings suggest that euro area monetary transmission remains both structurally asymmetric and regime dependent despite the existence of a common monetary policy framework. The effectiveness of ECB policy interventions appears to depend not only on the characteristics of the monetary shock itself but also on country-specific structural conditions, financial integration, institutional resilience, and the broader macroeconomic environment. Consequently, the results support the view that monetary policy transmission within the euro area cannot be treated as homogeneous across member states.

The study contributes to the existing literature in two main ways. First, it provides comparative evidence on monetary policy transmission across structurally distinct groups of euro area economies using a unified Bayesian PVAR framework and externally identified monetary policy shocks derived from the EA-MPD database. Second, by incorporating regime-specific estimations corresponding to alternative monetary policy environments, the analysis demonstrates that transmission mechanisms vary substantially across time and macroeconomic conditions. In this respect, the findings suggest that regime dependence constitutes a central dimension of euro area monetary transmission.

From a policy perspective, the results imply that a common monetary policy may generate heterogeneous economic outcomes across member states. This finding highlights the importance of complementary institutional arrangements, financial integration mechanisms, and national policy frameworks that can mitigate asymmetric responses to common monetary shocks. The evidence also suggests that the effectiveness of ECB interventions may depend critically on the broader economic environment in which monetary policy is implemented.

Future research could extend the analysis by incorporating additional financial variables, examining country-specific transmission channels in greater detail, or exploring nonlinear transmission mechanisms during periods of elevated financial stress and macroeconomic instability. Such extensions could provide further insights into the interaction between monetary policy, financial fragmentation, and structural heterogeneity within the euro area.

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Appendix A. Bayesian Panel VAR Specification

The empirical analysis is conducted using a Bayesian Panel Vector Autoregressive (PVAR) framework estimated separately for the Core, Periphery, and Central and Eastern European (CEE) country groups. The model is designed to capture the dynamic interactions between monetary policy shocks and key macroeconomic variables while accounting for heterogeneity across euro area economies. The estimated system includes six endogenous variables: the identified monetary policy shock (MP_SHOCK), real GDP (LGDP), employment (LEMP), government expenditure (LGOVEXP), gross capital formation (LGFCF), and inflation (LHICP). The general specification can be represented as:

$$Y_t = A_1 Y_{(t-1)} + \varepsilon_t \quad (A1)$$

where y_{it} denotes the vector of endogenous variables, (A_1) is the coefficient matrix associated with the first lag of the system, and (ε_t) represents the vector of innovations. A constant term is included in all specifications.

The reduced-form Panel VAR for country i is

$$y_{it} = c_i + A_i y_{\{i,t-1\}} + u_{it}, u_{it} \sim N(0, \Sigma_i),$$

where y_{it} is the $G \times 1$ vector of endogenous variables ($G = 6$), c_i is a vector of intercepts, A_i is the $G \times G$ matrix of first-lag autoregressive coefficients, and u_{it} is a vector of Gaussian reduced-form innovations with zero mean and country-specific covariance matrix Σ_i . Let β_i collect the coefficients of country i . Following the Bayesian Panel VAR approach of [Canova and Ciccarelli \(2004\)](#), the country-specific coefficient vectors are treated as random draws around a common mean β ,

$$\beta_i | \beta \sim N(\beta, \Omega),$$

which permits cross-country heterogeneity while pooling information through the common mean. The prior covariance Ω is diagonal and follows the Minnesota structure. Denoting by $a_{\{mk\}\{l\}}$ the coefficient on lag l of variable k in the equation for variable m , the prior variance is

$$V(a_{\{mk\}\{l\}}) = (\lambda_1 / l^{\{\lambda_3\}})^2 \text{ if } k = m,$$

$$V(a_{\{mk\}\{l\}}) = (\lambda_1 \lambda_2 \sigma_m / (l^{\{\lambda_3\}} \sigma_k))^2 \text{ if } k \neq m,$$

while the intercepts are assigned a diffuse prior. Here λ_1 is the overall tightness, λ_2 the cross-variable (relative) weight, and λ_3 the lag-decay parameter; σ_m and σ_k are scale factors set equal to the residual standard deviations from univariate autoregressions of variables m and k . The calibration used throughout is $\lambda_1 = 0.1$, $\lambda_2 = 0.5$, and $\lambda_3 = 0.5$. This structure shrinks the coefficients toward the common mean, with shrinkage increasing in the lag order through the factor $l^{\{\lambda_3\}}$ and, for cross-variable coefficients, scaled by the relative volatility of the variables involved. The common mean β is assigned an uninformative (flat) hyperprior, and each innovation covariance matrix Σ_i is assigned a non-informative prior, yielding a conditional inverse-Wishart posterior. Posterior inference is obtained by the Gibbs sampler described in Appendix B, which iterates between drawing each β_i given (β, Σ_i) , drawing each Σ_i given β_i , and drawing the common mean β given the country-specific coefficients $\{\beta_i\}$.

To mitigate over-parameterisation and improve estimation efficiency in a relatively high-dimensional macroeconomic setting, the model is estimated using Bayesian techniques with a Minnesota prior. The Bayesian approach combines prior information with

sample information to generate posterior distributions for model parameters and impulse response functions.

The Minnesota prior is calibrated using an overall tightness parameter equal to 0.1, a cross-variable weighting parameter equal to 0.5, and a lag-decay parameter equal to 0.5. These settings impose moderate shrinkage on parameter estimates while preserving sufficient flexibility to capture dynamic macroeconomic relationships across countries and variables. The empirical specification is estimated using quarterly data for the period 2010Q1–2024Q4. Separate estimations are conducted for each country group in order to evaluate potential heterogeneity in monetary policy transmission across different segments of the euro area.

Appendix B. Posterior Simulation and Credible Intervals

Posterior inference is conducted using a Gibbs sampling algorithm implemented within the Bayesian PVAR framework. Following model estimation, an initial burn-in period of 1000 iterations is discarded in order to reduce the influence of starting values on the posterior distribution. After convergence, 5000 posterior draws are retained for statistical inference. For each posterior draw, impulse response functions are computed over a 40-quarter horizon, generating a complete posterior distribution for every response variable at each forecast horizon.

The reported impulse response functions correspond to posterior median estimates. To evaluate statistical uncertainty, posterior credible intervals are constructed directly from the simulated posterior distributions. Two credibility bands are reported throughout the analysis:

- 68% credible intervals based on the 16th and 84th posterior percentiles.
- 90% credible intervals based on the 5th and 95th posterior percentiles.

The credible intervals provide a probabilistic assessment of uncertainty surrounding the estimated responses. Impulse responses whose 90% credible intervals exclude zero are interpreted as providing stronger evidence of a systematic transmission effect. Conversely, responses whose credible intervals include zero should be interpreted more cautiously, reflecting greater uncertainty regarding the magnitude and persistence of the estimated response. The use of posterior median responses and credible intervals follows standard practice in Bayesian VAR and Panel VAR applications and provides a more informative assessment of monetary policy transmission than point estimates alone.

Appendix C. Regime-Specific Robustness Analysis

To evaluate the stability of monetary policy transmission over time, the baseline Bayesian PVAR model is re-estimated across three alternative monetary policy regimes:

- Post-sovereign-debt adjustment period (2010Q1–2014Q4).
- Unconventional monetary policy period (2015Q1–2019Q4).
- Pandemic and monetary tightening period (2020Q1–2024Q4).

The objective of the regime-based analysis is to assess whether the transmission mechanism remains stable across substantially different monetary, financial, and macroeconomic environments.

The results indicate that monetary policy transmission is highly regime dependent. The strongest statistically supported responses are observed within the Periphery economies during the post-sovereign-debt adjustment period. During this regime, both GDP and employment responses exhibit 90% credible intervals that exclude zero, indicating a statistically meaningful response of the opposite sign to that of the Core, consistent with central bank information effects during the sovereign debt crisis. By contrast, the

unconventional monetary policy regime is characterised by generally more favourable posterior median responses across all country groups, reflecting improved financial conditions and accommodative ECB policies. However, the associated credible intervals indicate substantial uncertainty regarding the precise magnitude of these effects.

The pandemic and monetary tightening regime exhibits the highest degree of uncertainty. Although posterior median responses remain economically meaningful, the corresponding credible intervals widen considerably, reflecting the interaction of monetary policy with extraordinary fiscal interventions, pandemic-related disruptions, energy-price shocks, and elevated macroeconomic volatility.

Overall, the robustness analysis confirms that euro area monetary policy transmission is both structurally asymmetric and regime dependent. The estimated responses vary across country groups and monetary environments, highlighting the importance of accounting for macroeconomic context when evaluating the effectiveness of common monetary policy within a heterogeneous monetary union.

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