A Work Project, presented as part of the requirements for the Award of a Master’s degree in Economics from the Nova School of Business and Economics.

Unraveling Monetary Policy Impacts Beyond the Mean: Insights from the Euro Area

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20/01/2025

Abstract:

This study investigates the heterogeneous effects of monetary policy shocks across economic states in the Euro Area, introducing a novel QSVAR methodology to analyze asymmetric responses in expansions and recessions. The analysis reveals that monetary tightening reduces real GDP and inflation during expansions but counterintuitively stimulates both during recessions. Furthermore, unemployment dynamics are shown to be predominantly shaped by structural labor market rigidities, and significant heterogeneity across member countries is observed. These results deepen our understanding of key macroeconomic dynamics and highlight the need for a refined, state-aware approach to monetary policy design, enhancing economic stability and policy effectiveness across the Euro Area.

Keywords:

QSVAR; QIRF; Monetary policy shocks; Euro Area, Heterogenous Effects

Acknowledgements:

I would like to express my sincere gratitude to my advisor, Paulo Rodrigues, for his support, insightful guidance, and continuous encouragement throughout this Work Project. His expertise and mentorship have been critical in shaping this work, and I am deeply grateful for his dedication and patience.

This work used infrastructure and resources funded by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209), POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences DataLab, Project 22209) and POR Norte (Social Sciences DataLab, Project 22209)

INTRODUCTION

In recent years, the landscape of monetary policy has undergone a dramatic transformation, driven by global challenges such as the COVID-19 pandemic, geopolitical tensions, and persistent supply chain disruptions. These disruptions have destabilized economies worldwide, underscoring the critical need for innovative and effective policy interventions to mitigate their significant economic consequences. Effectively addressing these complexities requires a deeper understanding of the behavior of key macroeconomic variables and their responses to both conventional and unconventional monetary policies, particularly under distinct economic regimes, such as recessions or expansions, where monetary interventions are primarily targeted to influence. This work project seeks to enhance our comprehension of monetary policy dynamics while proposing practical approaches to design more effective policy actions.

Monetary policy is an essential tool by which central banks manage the supply of money and interest rates to influence economic activity, with the primary focus of economic stability, controlling inflation (typically around a 2% target), and promoting economic growth. Central banks, such as the European Central Bank (ECB), implement monetary policy using a range of instruments including interest rate adjustments, open market operations, reserve requirements, quantitative easing and forward guidance. Despite extensive research in this area, most of the existing literature focuses on large economies like the USA, using Structural Vector Autoregressive (SVAR) methodologies with various identification schemes that analyze mean responses. However, this raises an important question: Do macroeconomic variables exhibit heterogeneous effects across their distributions in response to monetary policy shocks? If so, simply relying on mean-based models risks overlooking crucial non-linearities, which would result in inefficient and poorly targeted policy interventions. Capturing these non-linearities will allow more effective policy intervention aligned with the state of the economy. To address this significant gap, this work project introduces an advanced methodology: the Quantile Structural

Vector Autoregressive (QSVAR) model. This approach goes beyond traditional mean-based models, enabling a more in-depth exploration of the impact of monetary policy shocks across different parts of macroeconomic variables' distribution. By analyzing responses across conditional quantiles, this study provides insights on how economies behave under conditions of recession and expansion, offering practical guidance for more effective monetary policy. Specifically, it explores the impact of monetary policy on output, prices and unemployment in the Euro Area. Furthermore, it delves into the heterogeneity within the Euro Area by comparing Portugal, a small and open economy with structural issues, high public debt and vulnerable to external shocks, with a leading economy such as Germany, a large, industrialized, export-driven country with a robust fiscal position and strong financial system. These nations, with their unique economic structures, may respond differently to monetary interventions, giving insights into how the economic factors described above shape the dynamics of a country. To complement, the study also distinguishes between the effects of conventional and unconventional monetary policy shocks, evaluating their respective roles in influencing macroeconomic dynamics. Therefore, our goal is to empower policymakers with targeted tools and valuable insights to design more adaptive and efficient monetary interventions and enrich our understanding of macroeconomic dynamics. Such a contribution is particularly relevant in today's volatile and uncertainty economic environment, characterized by rapid changes and the need for adaptive policy measures.

This work project is organized as follows: Chapter 2 reviews theoretical and empirical research on monetary policy shocks, identifying gaps addressed by this study. Chapter 3 describes the data and the methodology, detailing the QSVAR approach. Chapter 4 presents the findings and limitations of the dynamics of monetary responses on real GDP, inflation and unemployment for EA, Portugal and Germany. Chapter 5 discusses the findings. Finally, chapter 6 suggests areas for future research and concludes with practical guidance for policy makers.

LITERATURE REVIEW

The relationship between monetary policy and macroeconomic variables has been a cornerstone of economic research, evolving significantly over time. Early theoretical frameworks, such as Fisher (1911) with his Quantity Theory of Money, hypnotized a direct relationship between money supply and price levels, assuming constant velocity and output, emphasizing monetary neutrality. Keynes (1936) challenged this perspective with his liquidity preference theory, highlighting the role of interest rates adjustment in balancing money supply and demand. Keynes shifted the focus to aggregate demand management, arguing that in times of cyclical downturn, monetary policy could influence real variables such as output and employment, thus advising for a more active stabilization role. Friedman (1968) introduced the natural rate hypothesis, asserting that inflation is fundamentally a monetary phenomenon, and that monetary policy cannot sustainably reduce unemployment beyond its natural rate. In contrast to the Keynesian and monetarist view, the Real Business Cycle (RBC) theory of Kydland and Prescott (1982) argued that economic fluctuations are driven entirely by real shocks, such as technological advancements. These perspectives laid the foundation for contemporary frameworks. The New Keynesian model, supported, for instance, by Clarida, Galí, Gertler (1999) and Gordon (1990), incorporated price stickiness and nominal rigidities to explain how monetary policy can influence output and inflation in the short run through mechanisms like the Phillips curve. The concept of the Zero Lower Bound (ZLB), has further expanded these frameworks, highlighting the limitations of conventional monetary tools when interest rates approach zero. As noted by Eggertsson, Woodford (2003) and Bernanke, Reinhart (2004) these limitations have led to the adoption of unconventional monetary policies, such as forward guidance and quantitative easing, which aim to manage economic expectations and provide necessary liquidity when conventional tools are ineffective. More recently, theories have begun to emphasize nonlinearities and heterogeneity that challenge traditional linear models. For instance, Heterogeneous Agent New Keynesian (HANK) models, as developed by Kaplan, Moll, and Violante (2018), incorporate differences in income, wealth, and consumption behavior to capture redistributive effects of monetary policy. These models demonstrate how households' responses to monetary policy vary based on their marginal propensity to consume, enriching our understanding of state-dependent and heterogeneous impacts, further supporting the need for nonlinear approaches. Together, these modern theories reflect a progress understanding of monetary policy's role in influencing economic stability.

To validate and refine these theoretical advancements, empirical studies have played a crucial role in exploring how theoretical frameworks play out in real-world scenarios. The predominant approach for analyzing monetary policy effects has been the use of VARs, typically with quarterly data on real GDP, inflation and interest rates. A critical challenge in these studies is identifying exogenous monetary policy innovations. The most widely used identification strategy has been the Cholesky decomposition (Sims 1980), which imposed an ordering of variables to isolate monetary policy shocks orthogonal to the state of the economy. Alternative strategies, such as sign restrictions (Uhlig 2005) and long-run restrictions (Blanchard and Quah 1989), follow a similar principle by imposing sufficient restrictions to identify an isolated shock that is orthogonal to the current economic conditions. This approach enables researchers to trace the effects of such shocks on the variables of interest. Empirical applications of these methods, such as Bernanke and Blinder (1992) demonstrated that monetary policy significantly impacts inflation through changes in short-term interest rates, which affect aggregate demand and consequently price levels. Similarly, Christiano, Eichenbaum, and Evans (1999) showed that monetary policy shocks have substantial short-term effects on output and inflation, highlighting the importance of understanding transmission mechanisms.

Recently new methodologies to reinsure previous findings have been introduced. One significant advancement was the introduction of Local Projections (LP) by Jordà (2005), which gained popularity due to its flexibility in estimating impulse response functions without requiring the strict assumptions of VAR models. For instance, Murgia (2020) applied LP to analyze monetary policy shocks, revealing that inflation responses are more persistent than previously recognized in a VAR approach. Another breakthrough was the Instrumental Variable Structural VAR (Proxy-VAR), introduced by Stock and Watson (2012). This method integrates external instruments into VAR models to ensure exogenous identification of monetary policy shocks. For example, Stock and Watson (2018), provided robust evidence on the effectiveness of monetary policy shocks, demonstrating that contractionary shocks lead to significant declines in both output and inflation over time, highlighting how incorporating external instruments reduces bias in shock identification. Building on these advancements, subsequent studies further refined shock identification methodologies. Romer and Romer (2004) employed a narrative approach, analyzing historical records of the Federal Reserve's policy decisions to isolate exogenous monetary shocks. Their research confirmed that monetary contractions lead to significant and prolonged declines in inflation. Gertler and Karadi (2015) advanced the field by introducing a high-frequency identification (HFI) approach using high-frequency financial market data around policy announcements as external instruments, capturing exogenous monetary policy shocks with improved precision. Similarly, Jarociński and Karadi (2020) refined this approach using high-frequency data with sign restrictions to distinguish "pure" monetary shocks and “information shocks”. Their innovative approach mitigated biases inherent in earlier models, providing clearer insights into monetary transmission mechanisms. Valuable contributions, such as Miranda-Agrippino and Ricco (2021), Altavilla et al. (2019) and Andrade and Ferroni (2021), extended these methods further, emphasizing the role of external proxies and advanced econometric techniques in improving the accuracy and robustness of shock identification. While much of the early empirical research focused on the USA, the Euro Area (EA) offers a distinctive environment due to its shared monetary policy under the European Central Bank (ECB) and its diverse member economies. Smets and Wouters (2003), provide a comprehensive analysis of how monetary policy actions influence inflation dynamics across member states. Their findings, using a DSGE model, highlight the complexities of monetary transmission and its impact on inflation and output. In periods where traditional tools were constrained, Altavilla, Carboni, and Motto (2021) analyzed the ECB's asset purchase programs, demonstrating that these measures significantly reduced borrowing costs and stimulated demand, particularly in countries with weaker financial systems. Similarly, Altavilla et al. (2019) highlighted the effectiveness of these unconventional tools in stabilizing financial markets during crises, reducing long-term interest rates, and supporting aggregate demand across the EA. Further insights, Jarociński and Karadi (2020) showed that "pure" monetary shocks aligned with expected adjustments in inflation and output. In contrast, "information shocks," reflecting ECB projections of economic conditions, often produced opposing effects, complicating the intended outcomes of monetary interventions.

Despite the advancements outlined above, key debates continue to shape academic discourse and policymaking, highlighting the complexity of monetary policy and its evolving analysis. It may come as a surprise that even today, there remains considerable uncertainty about the true effects of monetary policy. These uncertainties have given rise to diverse economic theories, many of which complement yet occasionally contradict each other, reflecting the multifaceted nature of monetary policy and its transmission mechanism. One of the most fundamental debates concerns whether monetary policy affects real economic variables or merely nominal ones. Sims (1980) applied zero restrictions within a VAR framework, concluded that monetary policy shocks show strong feedback effects on the real economy. On the other hand, Uhlig (2005) using sign restrictions, concluded that monetary policy shocks have no clear impact on real GDP.

Another significant debate centers around methodologies. As highlighted in Ramey (2016) Table 1, differences in identification schemes and shocks can produce varying conclusions about the effects, magnitude, timing, and persistence of monetary policy, emphasizing the importance of methodological rigor, although consistent conclusions emerge. Similarly, the choice of monetary indicators is crucial. While short-term interest rates, as suggested by Bernanke and Blinder (1992), are commonly used to measure the policy stance, critics such as Christiano and Eichenbaum (1992) argue that these indicators can be "polluted" by external factors like productivity growth, potentially distorting results. The emergence of shadow rates, as employed by Wu and Xia (2016), offer an alternative for periods when nominal rates are at the zero lower bound, yet their use introduces additional complexities in interpreting policy impacts. The rise of unconventional monetary policies has also brought debates regarding their effectiveness and potential side effects. While some studies suggest that these policies can successfully stimulate the economy and control inflation, (Gagnon et al. 2011 and Dell'Ariccia, Rabanal, Sandri, 2018), others warn of risks like asset bubbles and financial market distortions (Rajan 2006 and Borio, Disyatat 2010). The EA shared monetary framework has intensified debates over cross-country heterogeneity. Early studies, such as Peersman and Smets (2001), emphasized differences in monetary transmission due to structural and institutional variations. However, more recent research, including Altavilla et al. (2019), suggest growing convergence in policy effects.

The primary reason for these uncertainties and debates are essentially in the challenges of establishing causality. Unlike randomized experiments, Central bank's actions are often endogenous to the economic environment they aim to influence, because Central banks generally implement monetary policy for a reason, making it difficult to disentangle the effects of monetary interventions from broader economic conditions. Incorporating these debates into a comprehensive analysis can provide valuable insights and reinforce our understanding of monetary policy's role in managing the economy. This study hopes to contribute to these discussions by advancing theoretical frameworks and addressing critical gaps in literature. Our goal is to provide actionable insights into the central banker's dilemma of efficiently balancing inflation control with economic stability.

METHODOLOGY

DATA and Model Specifications

The dataset consists of monthly observations for the Euro Area (EA) and Germany from January 1999 to October 2023, and for Portugal from January 2000 to October 2023 with the difference in the time span attributed to data availability constraints. The sample period covers critical challenges of monetary policy, including the Zero Lower Bound (ZLB), economic crises, and periods of considerable uncertainty, requiring careful consideration of variable selection and modeling techniques. For this purpose, the Shadow Interest Rate (SIR), developed by Wu and Xia (2016), is employed as the monetary policy indicator. The SIR is a theoretical construction particularly suited to this analysis as it estimates the effective interest rate under ZLB constraints, incorporating both conventional and unconventional monetary policy actions into a single measure. This ensures that the analysis appropriately reflects the monetary policy environment across the entire sample period. The endogenous vector ($\boldsymbol{Y_t}$) includes four key macroeconomic variables: the Industrial production index (Proxy for Real GDP), the Harmonized Index of Consumer Prices (HICP) as a measure of inflation, the unemployment rate, and the monetary policy indicator (SIR). To account for potential external shocks and uncertainty, as control variables, the exogenous vector $\mathbf{X_t}$, includes Commodity prices, which help explain the "price puzzle" and the Composite Indicator of Systemic Stress (CISS), to account for periods of uncertainty. The model is estimated across the 10th and 90th quantiles to capture macroeconomic behavior under extreme economic conditions, such recession and expansion periods, highlighting the state-dependent dynamics of monetary policy. Cholesky identification restrictions are employed as the identification strategy, with the SIR placed last in ordering, preceded by unemployment, inflation, and real GDP, in line with established literature. This ordering reflects the assumed contemporaneous relationships between variables, ensuring proper identification of monetary policy shocks by allowing the monetary policy indicator to respond contemporaneously to macroeconomic conditions while other variables adjust with a lag.

The selection of the optimal lag length is a critical step in estimating a QSVAR model to ensure residuals are free from autocorrelation and the dynamics of the system are properly captured. In this analysis, the lag length was chosen based on the Likelihood Ratio (LR) criteria, which tests whether adding additional lags significantly improves the model fit (see Lütkepohl 2005, pp. 143–144). While other criteria such as AIC, HQIC, and SBIC offer viable alternatives, the LR criterion was preferred because it resolved issues of residual autocorrelation that were observed with the AIC-selected lag length. Furthermore, the LR-selected lag length aligns with other studies using monthly data, providing additional empirical support for its validity. Ensuring no autocorrelation in the residuals is crucial for the reliability of Quantile Impulse Response Functions (QIRFs), as it guarantees the model captures the true interactions among variables without leaving serial correlations unexplained. Additional specifications and data treatment details are provided in the Appendix.

The Quantile Structural Vector Autoregressive Model

The QSVAR builds on the classical SVAR framework, which identifies and interprets structural shocks to disentangle the effects of policy interventions from other macroeconomic disturbances. While the SVAR framework is effective at analyzing average relationships among variables, it does not capture distributional heterogeneity or nonlinear dynamics. QSVAR addresses these limitations by extending SVAR to analyze conditional quantiles of the dependent variables, enabling a more robust exploration of asymmetric and nonlinear effects of shocks across the entire distribution, particularly in the tails. The foundation of QSVAR lies in quantile regression, introduced by Koenker and Bassett (1978), a semiparametric technique that allows covariates to affect different parts of the distribution. Quantile regression has seen numerous applications, (Koenker, 2005; 2017), including macroeconomic modeling, where it provides critical insights into tail risks and the behavior of economic variables under varying conditions. QSVAR leverages this approach to analyze the impact of shocks across quantiles, capturing nonlinearities and asymmetries. Additionally, it accounts for outliers and tail behaviors, which are particularly significant during periods of economic stress.

The QSVAR model is specified as follows:

$$\mathbf{Y_t} = \mathbf{A_0}(\boldsymbol{\tau}) + \sum_{\mathbf{i=1}}^{\mathbf{p}} \mathbf{A_i}(\boldsymbol{\tau})\mathbf{Y_{t-i}} + \boldsymbol{\Phi}(\boldsymbol{\tau})\mathbf{X_t} + \mathbf{B^{-1}}\boldsymbol{\varepsilon}_\mathbf{t}(\boldsymbol{\tau}) \tag{1}$$

where $\mathbf{Y_t}$ denotes endogenous variables at time $\mathbf{i}$; $\boldsymbol{A_0}(\boldsymbol{\tau})$ is a vector of quantile-specific intercepts; $\mathbf{A_i}(\boldsymbol{\tau})$ are the coefficient matrices for lag $\mathbf{i}$ at quantile $\boldsymbol{\tau}$, $\boldsymbol{B}$ captures contemporaneous structural relationships, "on impact" effect, and $\boldsymbol{\varepsilon_t}(\boldsymbol{\tau})$ is the quantile-specific structural shock.

The estimation of QVAR closely parallels the standard VAR approach but differs in its error minimization technique. In contrast to standard VAR, which employs Ordinary Least Squares (OLS) to minimize the sum of squared residuals, QVAR uses quantile regression to minimize the quantile loss function. This approach assigns different weights to residuals above and below the quantile of interest, enabling the model to capture the entire distribution of the response variable. Formally, for each quantile τ, the parameters $\boldsymbol{A_0}(\boldsymbol{\tau})$ and $\boldsymbol{A_i}(\boldsymbol{\tau})$ are estimated by solving the following minimization problem:

$$\min_{\boldsymbol{A_0},\boldsymbol{A_i}} \sum_{t=1}^{T} \boldsymbol{\rho}_\tau(\boldsymbol{Y}_t\text{-}\boldsymbol{A_0}(\boldsymbol{\tau}) - \sum_{\mathbf{i=1}}^{\mathbf{p}} \boldsymbol{A_i}(\boldsymbol{\tau})\boldsymbol{Y}_{t\text{-}i} - \boldsymbol{\Phi}\mathbf{X_t}) \tag{2}$$

where $\boldsymbol{\rho}_\tau(\mu)=|\mu|(\tau\text{-}I(\mu<0))$ is the quantile check function, and $\boldsymbol{I}(\cdot)$ is the indicator function, which takes the value 1 if $\boldsymbol{\mu}_\tau<0$ and 0 otherwise. This weighting scheme allows QVAR to provide robust estimates that account for the heterogeneous effects of structural shocks across the distribution.

QSVAR has been developed and applied only recently. For instance, Sulkhan and Manganelli (2024) provide an in-depth analysis of the methodology and employed it to capture asymmetric interactions between the Industrial Production Index (representing economic activity) and Corporate Bond Spreads (representing financial conditions) across quantiles. Their findings reveal significant nonlinear responses to shocks, particularly in the tails of the distribution, underscoring the relevance of QSVAR for analyzing vulnerabilities during periods of financial stress in the EA. Our study extends this framework by incorporating more than two variables and accounting for control variables, offering a broader perspective on state-dependent dynamics and heterogeneous macroeconomic interactions.

RESULTS AND ANALYSIS

This chapter presents the empirical results, analyzing the dynamic and distributional effects of monetary policy shocks through the QSVAR framework. The findings illustrate how monetary interventions influence real GDP, inflation, and unemployment across different quantiles of the conditional distribution, revealing important nonlinearities and state-dependent dynamics. The analysis begins with the EA as a whole, followed by a closer examination of Portugal and Germany to explore heterogeneity across member states. The chapter also distinguishes between the impacts of conventional and unconventional monetary policies, clarifying their roles under varying economic conditions. Finally, the results are synthesized to provide practical insights for specific economic contexts, offering valuable guidance for central banks and policymakers.

EURO AREA: Quantile Impulse Response Functions

The following QIRFs illustrate the dynamic responses of real GDP, inflation, and unemployment across the 0.1 and 0.9 quantiles for the EA. For simplicity, the 0.9 quantile is proxied as representing expansionary states, characterized by high growth rates of real GDP and inflation, while the 0.1 quantile represents recessionary states, characterized by low (or even negative) growth rates of real GDP and inflation. However, for unemployment these quantiles reflect only high or low growth rates, rather than direct alignment with broader economic conditions, given its structural rigidity and delayed adjustment to shocks. Derived using a QSVAR (14) over a 24-month horizon, these QIRFs provide valuable insights into how monetary policy impacts vary across contrasting economic conditions.

Expansion and High Unemployment: Quantile 0.9

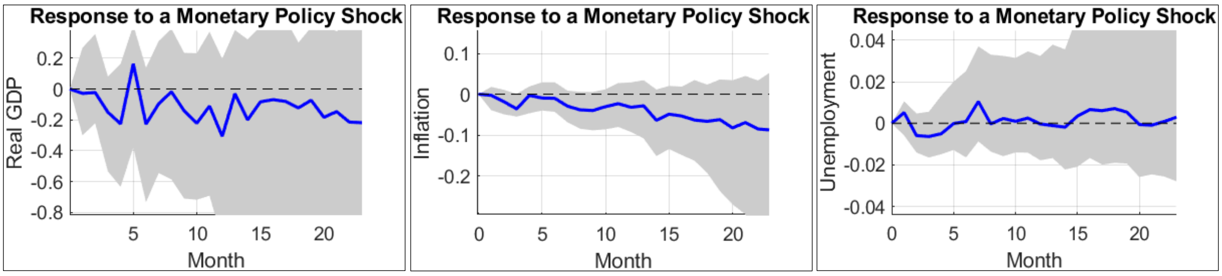

Figure 1 QIRFs at the 0.9 Quantile to a One-Standard-Deviation Monetary Policy Shock (Euro Area). Notes: The y-axis represents the response in percentage points. The x-axis represents the time horizon in months. Variables are in growth rates. The identification of monetary policy shocks follows the recursive approach. Shaded areas denote 95% confidence bands, calculated using 1,000 bootstrap repetitions.

As illustrated in Figure 1, at the 0.9 quantile, a one standard unit increase monetary policy shock (tightening policy) induces clear contractionary effects on real GDP and inflation, while unemployment demonstrates muted adjustments. Real GDP initially exhibits a negative response over the 24-month horizon. Initially there is a small negative response until the third month, reflecting a delayed adjustment to the monetary policy shock, which intensifies over time, peaking at -30 basis points by the 12th month before gradually stabilizing near zero. This delayed but pronounced contraction reflects the typical transmission of monetary tightening, where reduced demand and higher borrowing costs weigh on output. Inflation follows a more gradual and persistent downward trend, with small initial values, consistent with the concept of price stickiness, and then stabilizes at around -10 basis points by the 20th month. This response aligns with traditional monetary theory, highlighting the effectiveness of lowering inflationary pressures through reduced aggregate demand. Unemployment shows minimal immediate effects, with a slight increase emerging after six months and peaking at around 1.5 basis points by the 7th month. This low response suggests that the labor market demonstrates resilience to monetary policy shocks during periods of higher unemployment, due to weaker wage pressures and lower elasticity in the labor market.

Overall, in expansion periods, a tightening monetary policy aligns with conventional expectations, with real GDP and inflation exhibiting contractionary responses, although differing magnitudes and persistence. In high unemployment rates, it shows muted responses highlights the role of structural labor market factors in moderating monetary policy impacts.

Recession and Low Unemployment: Quantile 0.1

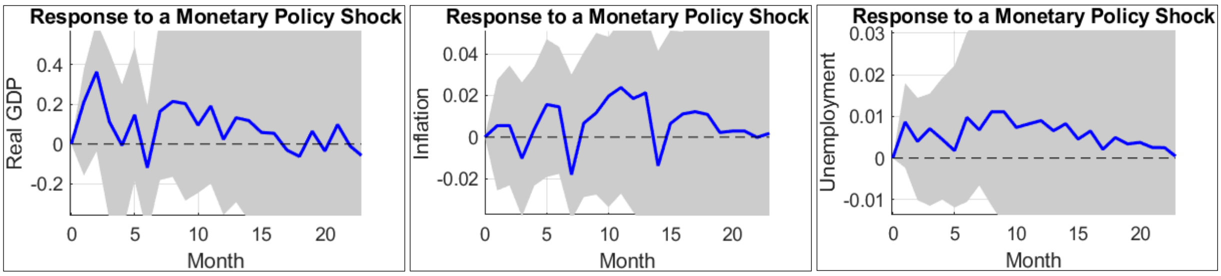

Figure 2 *QIRFs at the 0.1 Quantile to a One-Standard-Deviation Monetary Policy Shock (Euro Area). Notes: The y-axis represents the response in percentage points. The x-axis represents the time horizon in months. Variables are in growth rates. The identification of monetary policy shocks follows the recursive approach. Shaded areas denote 95% confidence bands, calculated using 1,000 bootstrap repetitions.*

Figure 2 represents dynamics at the 0.1 quantile, where the QIRFs reveal unexpected and counterintuitive dynamics. In contrast to the contractionary effects observed during expansions, monetary tightening appears to stimulate both real GDP and inflation, while unemployment in lower states shows a moderate increase. Real GDP responds positively to the monetary policy shock, throughout the 24-month horizon, with an immediate increase around 35 basis points within the first three months. Although the magnitude declines over time, the response remains positive until stabilizing near zero after the 15th month. Similarly, inflation exhibits the same dynamics. While the initial response remains close to zero, inflation begins to rise noticeably after the 4th month, peaking at approximately 2 basis points around the 12th month, before stabilizing around zero. These responses clearly suggest asymmetries and state-dependent effects in the transmission mechanism, where tightening policies during recessions might signal a credible commitment to stability, boosting confidence and encouraging investment. Unemployment, when having a low growth rate, aligns more closely with traditional expectations, showing increasing responses. However, this immediate increase remains low, peaking at around 1 basis point by the 9th month before gradually stabilizing to zero.

Overall, the 0.1 quantile QIRFs underscore the heterogeneous impacts of monetary policy during economic distress, revealing counterintuitive positive responses in real GDP and inflation. However, these responses are of smaller magnitude and shorter persistence compared to expansionary states. The underlying reasons for these unexpected dynamics will be examined in the discussion section. Unemployment demonstrates a positive response, although with low magnitudes, suggesting that structural factors in the labor market continue to play a significant role in moderating the effects of monetary policy shocks. These findings confirm and highlight the importance of accounting for state-dependent and heterogeneous effects in monetary policy evaluations to design more effective and targeted interventions.

To ensure the robustness of our findings, a series of validation tests were conducted. First, the monetary policy indicator was replaced with the Shadow Short Rate (SSR) estimated by Krippner (2013), which captures unconventional monetary policy effects. Second, the variable order in the Cholesky decomposition was altered to evaluate the sensitivity of the identification strategy. Third, the dataset was restricted to the pre-COVID-19 period to account for potential biases arising from the exogenous nature of the pandemic crisis. Finally, to address concerns regarding overidentification problem, the model was re-estimated to use fewer lags and excluding unemployment to reduce the number of parameters. Across all these adjustments, the results remained consistent, with no significant deviations from the original findings. Detailed QIRF of the robustness checks is available in Figures 4-16 in the Appendix. Collectively, these tests underscore the stability of the analysis and validate the key insights derived from the model.

Building on the findings for the EA, this study now aims to explore whether heterogeneity exists within the EA's shared monetary policy framework, given the structural differences between member states. Specifically, we investigate whether the effects of monetary policy shocks differ significantly between countries like Portugal and Germany or if there is evidence of convergence in their responses. This analysis provides valuable insights into how shared policies interact with diverse economic structures, further enriching our understanding of the EA's monetary dynamics.

Heterogeneity effects in Euro Area: Portugal and Germany

The following QIRFs are derived from a QSVAR (15) for Germany and a QSVAR (14) for Portugal. Both countries exhibit dynamics that broadly align with those observed for the EA. However, important differences emerge in the magnitude, persistence, and timing of their responses. To avoid redundancy, this section focuses on the key heterogeneities between the two countries.

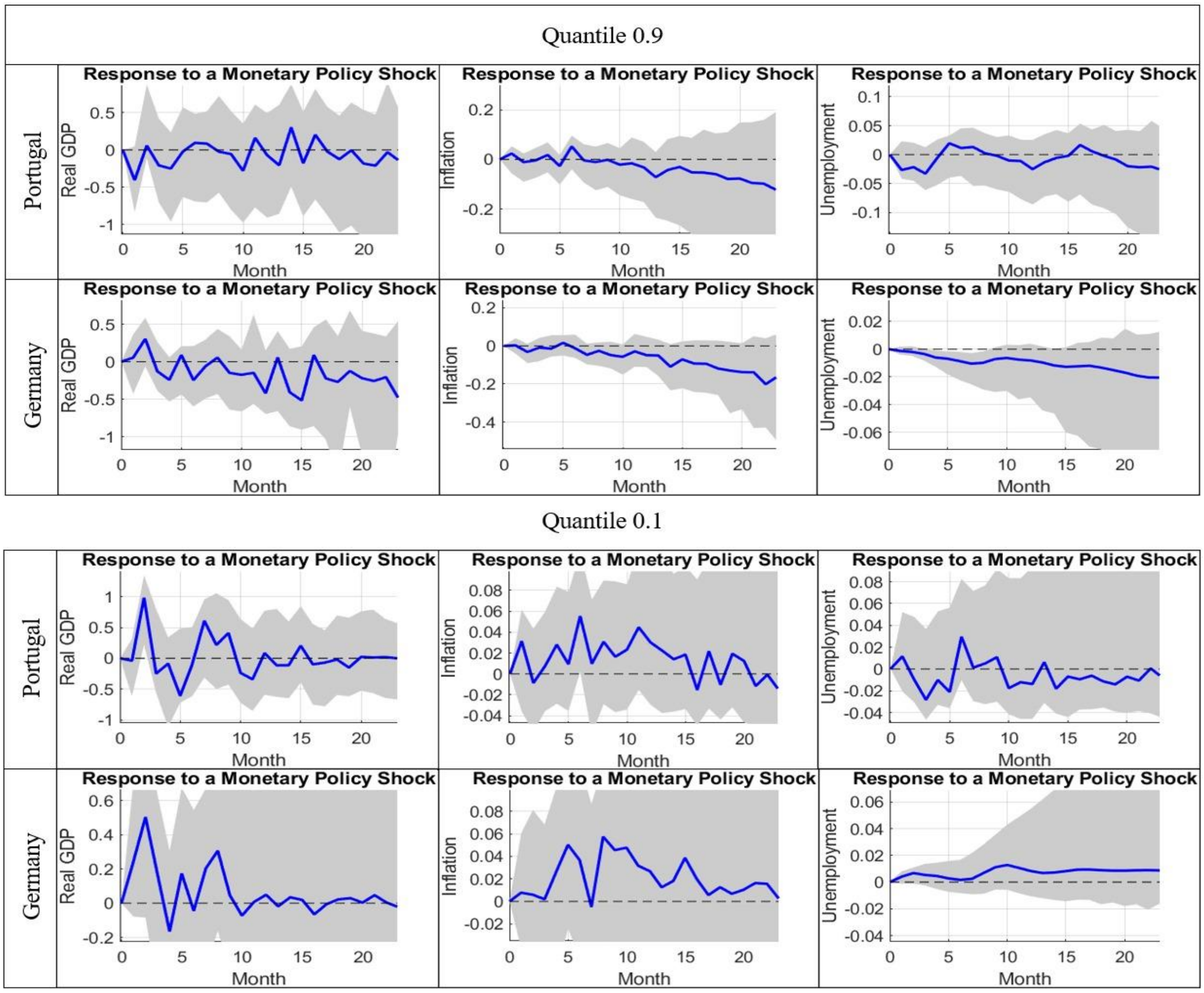

Figure 3 *QIRFs at the 0.1 and 0.9 Quantile to a One-Standard-Deviation Monetary Policy Shock for Portugal and Germany. Notes: The y-axis represents the response in percentage points. The x-axis represents the time horizon in months. Variables are in growth rates. The identification of monetary policy shocks follows the recursive approach. Shaded areas denote 95% confidence bands, calculated using 1,000 bootstrap repetitions.*

Figure 3 highlights significant differences between Portugal and Germany in their respective responses to monetary policy shocks across real GDP, inflation, and unemployment.

For real GDP, in expansionary states (0.9 quantile), Portugal exhibits an immediate negative response, stabilizing around zero by the 5th month, suggesting greater resistance to monetary tightening. In contrast, Germany experiences an initial slight positive response, known as "price puzzle", before declining more sharply and persistently, with effects peaking near the 15th month and stabilizing thereafter. In recessionary states (0.1 quantile), Portugal shows higher sensitivity characterized by larger magnitudes, greater volatility, and longer persistence, stabilizing around the 13th month. Germany shows similar responses but with smaller magnitudes, lower volatility, and quicker stabilization around the 10th month. For inflation, the findings further underscore Portugal's greater resistance to monetary shocks during expansionary states, with consistently lower magnitudes compared to Germany. However, in recessionary states, Portugal's inflation response becomes significantly more volatile, while Germany exhibits more stable dynamics. For unemployment, the responses differ significantly between Portugal and Germany across both high and low unemployment states, reflecting contrasting labor market dynamics. In Portugal, responses remain relatively similar across the two states, hovering near zero but becoming more volatile in low unemployment states. In Germany, the responses exhibit opposite patterns, increasing in low unemployment states and decreasing in high unemployment states. While Germany's responses show lower magnitudes and volatility, it displays greater persistence. These dynamics align with previous findings on recession and expansion behaviors. Moreover, this divergence underscores the critical role of labor market rigidities, with Portugal's higher rigidity limiting adaptability compared to Germany's more flexible labor market.

Overall, the findings reveal a consistent pattern in the responses of smaller economies with structural vulnerabilities, such as Portugal, compared to stronger economies like Germany. During expansionary states, smaller economies demonstrate greater resistance to monetary policy shocks, with less persistent but more volatile responses. In contrast, recessionary states reveal higher sensitivity in smaller economies, characterized by larger magnitudes, slightly prolonged persistence, and increased volatility. Regarding unemployment, smaller economies exhibit higher magnitudes and volatility but lack the persistence observed in stronger economies. Additionally, smaller economies have similar behavior across different unemployment states, while stronger economies exhibit opposite response signals between unemployment states, aligning with previous conclusions. These findings underscore the critical role of structural and institutional factors in shaping monetary policy actions.

Limitations

Despite the robustness checks conducted, limitations call for further consideration. Firstly, while QIRFs provide a richer perspective compared to standard IRFs by effectively capturing state-dependent and nonlinear responses, it comes with interpretability challenges. QIRF tend to exhibit higher volatility due to their quantile-specific nature, especially when analyzing extreme quantiles or smaller subsets of data, such as the tails of the distribution. Additionally, the use of monthly datasets can amplify these fluctuations. For instance, the volatility observed in some QIRFs, particularly in recessionary states, underscores the need for cautious interpretation of the results. While the focus is on the trends of the QIRFs, excessive variability can complicate the extraction of clear policy implications. Secondly, the study proxies the 0.1 and 0.9 quantiles to represent recessionary and expansionary states, respectively, this approach may oversimplify the complexities of real-world economic conditions. Exploring deeper quantiles, such as 0.05 or 0.95, could offer richer insights into extreme economic states. However, the limited number of observations in these tails introduces the risk of estimation bias. Thirdly, the use of SIR as the monetary policy indicator, while appropriate for the sample period, combines both conventional and unconventional monetary policy effects. This integration could leave policymakers uncertain about which tools, such as interest rate adjustments or quantitative easing, are more effective under different economic conditions.

To address this limitation, the study extends its analysis by disentangling conventional and unconventional monetary policy effects through a second model. In this framework, the MRO rate is used as a proxy for conventional monetary policy, while the ECB’s total assets capture unconventional measures, such as quantitative easing. The QIRFs from this model, presented in Figure 15 and Figure 16 in the appendix, demonstrate broadly similar dynamics to the primary analysis. Notably, in recessionary states, no significant differences emerge between the two policy types. However, in expansionary states, quantitative easing exhibits greater persistence, slightly higher magnitudes, and longer-term impacts, as expected. Despite this extension, the analysis introduces additional limitations. The ZLB remains a constraint, particularly for the quantile approach, as the clustering of observations around zero may bias the results, something that does not happen with the SIR approach. Moreover, using the ECB’s total assets as a proxy for quantitative easing, while common in the literature, may overlook other forms of unconventional policies. For these reasons, we recommend interpreting the findings from the second model with caution and primarily relying on the results from the first analysis.

Another limitation concerns the heterogeneity effects observed within the EA. While Portugal and Germany provide valuable contrasts due to their distinct structural and institutional characteristics, the findings may not generalize to other member states with differing economic structures. Structural factors, such as fiscal policy regimes and labor market flexibility, are highly specific to individual countries. For unemployment, in particular, the model may not fully capture these structural effects, potentially underestimating the extent of heterogeneity or the degree of convergence within the EA. Additionally, the Industrial Production Index (IPI), used as a proxy for real GDP, may be less representative for Portugal, given its relatively weak industrial sector. However, the IPI remains a widely used indicator in the literature and represents the best available measure for this analysis. In conclusion, while the results of this study are robust researchers and policymakers should be aware of these constraints.

Summary of Findings

The analysis of the QIRFs across the EA, Portugal, and Germany revealed several insightful findings of macroeconomic responses to monetary policy shocks. The results demonstrate that responses vary not only in magnitude but also in direction depending on the economic state. In expansionary states, a tightening of monetary policy results in a contraction of both real GDP and inflation, aligning with traditional expectations. However, in recessionary states, the findings reveal an unexpected increase in both real GDP and inflation following monetary tightening, diverging from conventional research, and raising critical questions about the underlying mechanisms. Additionally, the magnitude of the responses is notably smaller during recessions compared to expansions, and the shocks in expansionary states tend to exhibit greater persistence. This pattern is consistent across all analyzed regions, underscoring the asymmetrical effects of monetary policy. Regarding unemployment, the findings suggest that monetary policy exerts a stronger influence in low-growth environments compared to expansionary states. However, the overall impact remains low in both states, implying that factors such as labor market rigidity and structural issues play a more significant role in shaping unemployment dynamics. The study also uncovers significant heterogeneities across the EA. Countries with more pronounced structural issues exhibit higher volatility and greater magnitudes of response during recessions, suggesting heightened sensitivity to monetary policy shocks. Conversely, during expansions, these countries demonstrate some degree of resilience, with their responses. Larger, more industrialized economies appear to align more closely with the overall Euro Area dynamics, underscoring the divergence in monetary policy transmission mechanisms between structurally weaker and stronger economies. For a concise overview, Table 6 is provided in the appendix to facilitate a quicker review of the key findings.

Discussion

The contrasting responses of real GDP, inflation, and unemployment to monetary policy shocks in expansionary and recessionary states within the EA, Portugal and Germany raises several important questions about the mechanisms driving these outcomes. At the root of these distinctions lies a key challenge faced by policymakers: the dual effects of monetary policy announcements. Tightening policy is traditionally expected to reduce inflation and real GDP, known as monetary effect. However, markets also learn new information from these announcements, interpreting it as signals of the central bank's expectations for future economic conditions. For instance, an interest rate hike might suggest that the ECB anticipates strong future growth, which has the opposite impact as intended. To better understand these findings, this discussion addresses key questions arising from the study. Starting with the central finding of the study: Why monetary tightening leads to contractionary effects in expansions but counterintuitively stimulates real GDP and inflation during recessions. In expansionary states, resources are fully utilized, and demand-side pressures dominate. Higher interest rates increase borrowing costs, reducing consumption and investment, thereby contracting aggregate demand. This aligns with traditional monetary theory, such as the IS-LM framework, credit channels and the New Keynesian Phillips Curve, which show that reduced demand directly leads to lower output and inflation. Additionally, the gradual decline in inflation can be attributed to price stickiness (Rotemberg 1982), as firms are resistant to adjusting prices downward immediately, creating a persistent inflationary response. These findings are consistent with much of the existing literature, so our focus shifts to the counterintuitive effects observed during recessions. In recessions, the positive responses of real GDP and inflation to monetary tightening reflect a divergence from traditional expectations, suggesting that signaling and confidence effects dominate over traditional demand-side effects. Monetary tightening in recessions can signal central bank confidence in the economy's recovery potential, altering private sector expectations. Markets might question why the ECB would raise interest rates during periods of low or negative growth. This unconventional action can be interpreted as a signal of anticipated economic improvement, triggering a positive immediate reaction. Additionally, the credit channel may also support a role helping in recessions in this scenario, as tighter monetary policy can enhance bank profitability, increasing their capacity and willingness to lend. This alleviates credit constraints that are often related during downturns, promoting economic activity. Furthermore, higher interest rates yield better returns for investors, potentially stimulating the economy, especially when signaling effects dominate. The Neo-Fisherian hypothesis, Uribe (2018), suggests that higher nominal interest rates increase long-term inflation expectations through the Fisher effect. This encourages households and firms to spend and invest today to avoid future cost increases, a mechanism known as intertemporal substitution, thereby stimulating output and demand. This naturally raises the question of why signaling and confidence effects dominate in recessions and why the responses differ in magnitude. This divergence can be understood through the lens of economic slack and potential output. During recessions, when the economy operates far below its potential, the marginal benefits of improved expectations and credit access outweigh the dampening effects of higher borrowing costs. Traditional channels are weakened as agents, being more risk-averse and less willing to consume, are less sensitive to borrowing costs. Additionally, liquidity traps and subdued aggregate demand limit the capacity of monetary policy to significantly influence economic activity. In such contexts, the direct monetary effect is reduced, allowing signaling effects to outweigh conventional mechanisms. Conversely, in expansions, where resources are fully utilized and demand-side pressures are strong, traditional effects prevail. In this state, the channels are strong and more effective, so monetary tightening directly reduces overheating economies by suppressing demand, without any significant signaling component.

The variation in response magnitudes is further reinforced by the heterogeneity within the EA. Larger economies, such Germany, with developed financial systems and more diversified production structures, exhibit stronger negative responses to monetary tightening in expansions due to the greater efficiency of monetary policy transmission channels. In contrast, smaller economies, such as Portugal, often face structural challenges that weaken these transmission mechanisms, resulting in less pronounced responses. These dynamics explain both the differences in magnitude of economic responses to monetary tightening and the potential for contrary responses between recessions and expansions. The findings on unemployment dynamics raise additional important questions: Why does unemployment respond more strongly to monetary policy during periods of low unemployment growth compared to periods of high unemployment growth, yet exhibit relatively low magnitudes overall? This disparity can be attributed to structural labor market rigidities. In periods of high unemployment growth, many firms have already implemented substantial layoffs, leaving little room for further reductions in labor demand. By contrast, during periods of low unemployment growth, firms have greater flexibility to adjust hiring and firing decisions in response to monetary policy changes, leading to a more pronounced impact on unemployment. The muted overall magnitude of these responses may stem from labor-specific rigidities that limit the influence of monetary policy on the labor market. Heterogeneity across countries further highlights these dynamics. Portugal, for instance, shows relatively uniform behavior across both high and low unemployment growth states, reflecting structural vulnerabilities and limited flexibility in its labor market. In contrast, Germany demonstrates more divergent responses, indicating greater resilience and adaptability, leading to expected outcomes. These differences underscore the role of labor market characteristics, such as wage stickiness, labor market sensitivity and hiring costs, in shaping the observed patterns and reinforcing the broader explanation.

Conclusion

This work project provides compelling evidence of the asymmetric effects of monetary policy. These effects manifest not only in the magnitude of the responses but also in their direction, producing outcomes contrary to traditional expectations. The findings are robust and consistently observed across EA countries, reinsuring the dynamic and state-dependent nature of monetary policy impacts. These results highlight the dangers of relying solely on mean analysis, as it hides the significant state-dependent dynamics of monetary policy. Furthermore, the research highlights pronounced heterogeneity within the EA, emphasizing that the impacts of monetary policy differ markedly across countries. These insights call for a rethinking of monetary policy design to account for these complexities.

Here are some practical implications for policymakers: During expansionary states, monetary effects dominate signaling effects, leading to the expected contraction in real GDP and inflation. However, the magnitude of these effects is larger than conventional mean-based analysis suggests. To avoid excessive economic slowdowns, policymakers should consider more moderate increases in interest rates to achieve their objectives without over-contracting the economy. In contrast, during recessionary states, signaling effects outweigh monetary effects, resulting in counterintuitive outcomes where monetary tightening can stimulate real GDP and inflation. In such scenarios, a simple reduction in interest rates might be insufficient and could even exacerbate contractionary pressures. Policymakers may need to lower interest rates more aggressively to ensure monetary effects dominate or, alternatively, leverage signaling effects by employing a counter-intuitive increase in rates. Regarding unemployment, the study indicates that monetary policy has limited effectiveness in addressing labor market issues due to its relatively small impact on unemployment rates. Other policy tools may be more suitable for addressing unemployment concerns. Additionally, the study reveals notable heterogeneity within the Euro Area. Smaller economies with structural problems, such as Portugal, exhibit higher sensitivity to monetary shocks during recessions and greater resilience during expansions, while larger economies like Germany follow more conventional dynamics, nevertheless asymmetries still occur. For instance, a targeted monetary policy aimed at helping smaller economies to converge should focus on mitigating signaling effects during recessions and ensuring proportionate responses during expansions to prevent overcorrections. These findings emphasize the importance of adopting a more comprehensive, state-aware approach to monetary policy. By incorporating asymmetry, state dependence, and regional heterogeneity into their frameworks, central banks can enhance the precision and effectiveness of their interventions, reinforcing economic stability and promoting sustainable growth across the EA.

Further Research

This study lays the groundwork for further exploration of the complex dynamics of monetary policy transmission across different economic states. The significant findings underscore the need for refining methodologies to better capture these state-dependent effects, such as through the Quantile Local Projections approach. While existing literature suggests that such approaches would yield consistent results, their application could validate and expand upon the insights presented here. Building on these findings, future studies could delve deeper into the transmission channels of monetary policy, focusing on the heterogeneous effects observed during recessions and expansions. Identifying which channels, such as credit, interest rate, or exchange rate mechanisms, are more effective in each economic state is crucial for designing more targeted and impactful policies. Additionally, a sectoral perspective could further enhance understanding of monetary policy's impact, particularly in critical areas such as finance, real estate, and energy. Among these, the energy sector, especially renewable energy, deserves special attention due to its important role toward sustainability. The Draghi (2024) report highlights the importance of substantial investments in renewable energy for the Euro Area's economic future. A deeper understanding of monetary policy's role in this sector could help direct investment flows more effectively and align monetary policy objectives with environmental goals. Such advancements would not only strengthen the resilience of the economic framework but also align with the broader sustainability agenda.

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Appendix

DATA Treatment:

Table 1: **Data Sources, Transformations, and Descriptions**

Category	Variable	Transformation	Source
Model 1: Macroeconomic Variables (Endogenous)	Industrial Production Index (IPI) (base year = 2015) Sessonly adjusted	Log with first difference*100	EuroStat
	Harmonized Index of Consumer Prices (HICP) (base year = 2015) Sessonly adjusted	Log with first difference*100	EuroStat
	Unemployment Rate (%) Sessonly adjusted	First Difference	EuroStat
	Shadow Interest Rate (%)	First Difference	Jing Cynthia Wu's personal website
Control Variables (Exogenous)	Commodity Price Index (base year = 2015)	Log with first difference*100	UNCTAD
	Composite Indicator of Systemic Stress (CISS)	Not required	ECB Data Portal
Model 2: Addicional Variables	Main refinancing operations (MRO) (%)	First Difference	ECB Data Portal
	European Central Bank Total Assets (QE)	Log with first differences*100	ECB Data Portal
Roboustness Checks:	Shadow Short Rate (%)	First Difference	Dr Leo Krippner's personal website

The variables were extracted from their respective sources, as detailed in Table 1. Stationarity was tested using the Augmented Dickey-Fuller (ADF) test for all variables. The results indicated that all variables were non-stationary except for the CISS. To address the issue of non-stationarity, transformations were applied, including first differences and logarithmic transformations with first differences, as shown in Table 1. After performing the necessary transformations, stationarity tests were repeated, confirming that all variables had become stationary. Following the transformations, all variables were expressed in growth rates or first differences to ensure comparability and eliminate trends that could bias the estimation. The optimal lag length for the VAR model was determined using the Likelihood Ratio (LR) test, which, for example, identified an optimal lag for EA of 14 compared to the AIC that suggested a lag of 7 (Table 2). To ensure robustness, the presence of autocorrelation at the optimal lag was evaluated (Tables 3 and 4). If no autocorrelation was detected at the LR-optimal lag, the preceding lag was examined. In cases where no autocorrelation was found, the lower lag was selected to address overidentification concerns.

Table 2: **Optimal Lag Value (Euro Area)**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-349.682				.000153	2.56512	2.62727	2.7201
1	-249.881	199.6	16	0.000	.000084	1.97078	2.11579	2.33239*
2	-211.778	76.206	16	0.000	.000072	1.81403	2.0419	2.38227
3	-169.492	84.572	16	0.000	.00006	1.6276	1.93833*	2.40247
4	-143.787	51.409	16	0.000	.000056	1.55878	1.95237	2.54028
5	-129.494	28.586	16	0.027	.000057	1.57088	2.04734	2.75902
6	-104.685	49.618	16	0.000	.000053	1.50841	2.06773	2.90318
7	-82.5276	44.316	16	0.000	.000051*	$\boxed{1.46473*}$	2.10692	3.06614
8	-68.5314	27.992	16	0.032	.000052	1.47895	2.20399	3.28698
9	-56.5838	23.895	16	0.092	.000053	1.50769	2.31559	3.52236
10	-45.4194	22.329	16	0.133	.000055	1.54198	2.43275	3.76329
11	-34.7891	21.261	16	0.169	.000058	1.58006	2.55369	4.008
12	-18.3002	32.978	16	0.007	.000058	1.5766	2.63309	4.21117
13	1.11868	38.838	16	0.001	.000057	1.55235	2.6917	4.39355
14	14.9817	$\boxed{27.726*}$	16	0.034	.000058	1.56751	2.78972	4.61534
15	22.8286	15.694	16	0.475	.000062	1.62533	2.93041	4.8798

* optimal lag

Table 3: **Autocorrelation for LR criteria**

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	15.8871	16	0.46087
2	24.6033	16	0.07713
3	18.2822	16	0.30763
4	17.8602	16	0.33215
5	22.3272	16	0.13294
6	25.3729	16	0.06351
7	15.2895	16	0.50354
8	23.7716	16	0.09461
9	12.1158	16	0.73597
10	18.4529	16	0.29805
11	13.9104	16	0.60539
12	20.0823	16	0.21654
13	14.6932	16	0.54721
14	20.9990	16	0.17855

H0: no autocorrelation at lag order

Table 4: **Autocorrelation for AIC criteria**

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	19.4740	16	0.24485
2	31.8082	16	$\boxed{0.01059}$
3	20.5948	16	0.19462
4	21.4816	16	0.16073
5	23.7575	16	0.09494
6	24.1527	16	0.08622
7	26.0608	16	0.05318

H0: no autocorrelation at lag order

Cointegration among the variables was tested using the Johansen test, which indicated no cointegration, validating the use of a VAR model instead of a VECM.

Finally, the stability of the VAR model was confirmed by examining the eigenvalues, which all lay within the unit circle (Table 5), thereby ensuring the stability of the model.

Table 5: **QSVAR Stability (Euro Area)**

Eigenvalue stability condition

Eigenvalue	Modulus
-.9184551 + .2009802i	.940188
-.9184551 - .2009802i	.940188
.1582248 + .9253588i	.938789
.1582248 - .9253588i	.938789
.6561895 + .6675122i	.936033
.6561895 - .6675122i	.936033
-.9356986	.935699
-.6669139 + .6347514i	.920697
-.6669139 - .6347514i	.920697
-.284089 + .8741393i	.919144
-.284089 - .8741393i	.919144
-.8184855 + .4112738i	.916005
-.8184855 - .4112738i	.916005
.9077433 + .1021316i	.913471
.9077433 - .1021316i	.913471
.730669 + .5457838i	.912007
.730669 - .5457838i	.912007
-.03555751 + .9090592i	.909754
-.03555751 - .9090592i	.909754
.3479074 + .8388337i	.90812
.3479074 - .8388337i	.90812
-.09988888 + .9013107i	.906829
-.09988888 - .9013107i	.906829
-.5052404 + .7520042i	.905968
-.5052404 - .7520042i	.905968
.8765429 + .2242123i	.904764
.8765429 - .2242123i	.904764
.523815 + .7357448i	.903163
.523815 - .7357448i	.903163
.9017006	.901701
.4196686 + .7923288i	.896608
.4196686 - .7923288i	.896608
-.7336813 + .5052859i	.890844
-.7336813 - .5052859i	.890844
.7974961 + .3825805i	.884516
.7974961 - .3825805i	.884516
-.8725865 + .07508388i	.875811
-.8725865 - .07508388i	.875811
.8602503	.86025
.7407722 + .4341501i	.858621
.7407722 + .4341501i	.858621
.7407722 - .4341501i	.858621
-.4372018 + .7376766i	.857503
-.4372018 - .7376766i	.857503
.5805385 + .6066783i	.839693
.5805385 - .6066783i	.839693
-.721422 + .4240869i	.836839
-.721422 - .4240869i	.836839
-.01936746 + .7920842i	.792321
-.01936746 - .7920842i	.792321
-.2432518 + .746324i	.784966
-.2432518 - .746324i	.784966
-.5020449 + .582265i	.768818
-.5020449 - .582265i	.768818
.1552013 + .4982352i	.521848
.1552013 - .4982352i	.521848
-.5043258	.504326

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

This procedure was also applied for both Portugal and Germany.

Methodology specification

Cholesky decomposition:

The Cholesky decomposition imposes a recursive structure on the system by transforming the reduced-form residuals $\boldsymbol{u_t}$ into structural shocks $\boldsymbol{\varepsilon_t}$ as follows:

$$\boldsymbol{u_t} = \boldsymbol{B\varepsilon_t} \tag{3}$$

where $\boldsymbol{B}$ is a lower triangular matrix obtained from the decomposition of the covariance matrix $\boldsymbol{\Sigma}$ such that $\boldsymbol{\Sigma} = \boldsymbol{BB'}$ and $\boldsymbol{\varepsilon_t}$ are the mutually uncorrelated structural shocks, $\boldsymbol{\varepsilon_t} \sim (\boldsymbol{0}, \boldsymbol{I})$.

The triangular structure of $\boldsymbol{B}$ imposes a causal ordering among the variables, which determines the contemporaneous response of each variable to the shocks. In this analysis, the ordering follows the assumed hierarchy of macroeconomic variables, where monetary policy shocks are identified last.

The lower triangular matrix $\boldsymbol{B}$ can be explicitly written as:

$$\boldsymbol{B} = \begin{bmatrix} \boldsymbol{b_{11}} & \boldsymbol{0} & \boldsymbol{0} & \dots & \boldsymbol{0} \\ \boldsymbol{b_{21}} & \boldsymbol{b_{22}} & \boldsymbol{0} & \dots & \boldsymbol{0} \\ \boldsymbol{b_{31}} & \boldsymbol{b_{32}} & \boldsymbol{b_{33}} & \dots & \boldsymbol{0} \\ \vdots & \vdots & \vdots & \ddots & \boldsymbol{0} \\ \boldsymbol{b_{n1}} & \boldsymbol{b_{n2}} & \boldsymbol{b_{n3}} & \boldsymbol{b_{n4}} & \boldsymbol{b_{nn}} \end{bmatrix} \qquad (\boldsymbol{4})$$

This structure ensures that shocks to a variable affect only itself contemporaneously and variables ordered after it, while earlier variables remain unaffected.

Robustness checks:

Given the use of alternative variables, models, and sample periods, the underlying data process was repeated for each robustness check. This can lead to changes in the optimal lag structure for each estimation.

1. Alternative Shadow Interest Rate Measure: Krippner Shadow Short Rate

The following QIRFs are derived from a QSVAR (14) estimated over a 24-month horizon with 95% confidence bands, calculated using 1,000 bootstrap repetitions. While both frameworks (Wu-Xia and Krippner's Shadow Short Rates) are well-suited for analyzing periods on the Zero Lower Bound (ZLB), their results may diverge when the ZLB is not restrictive. This divergence stems from Krippner's model being more flexible in capturing a broader range of yield curve behaviors, along with differences in their underlying assumptions, methodologies, and potential input data. Despite these differences, the asymmetry in the results is evident: Figures 4 and 5 illustrate a clear directional contrast, with the 0.9 quantile showing a negative response and the 0.1 quantile exhibiting a positive response. This reinforces the presence of asymmetry in the system's dynamics.

Figure 4: **QIRF for Euro Area with SSR as Monetary Policy Indicator: Quantile 0.9**

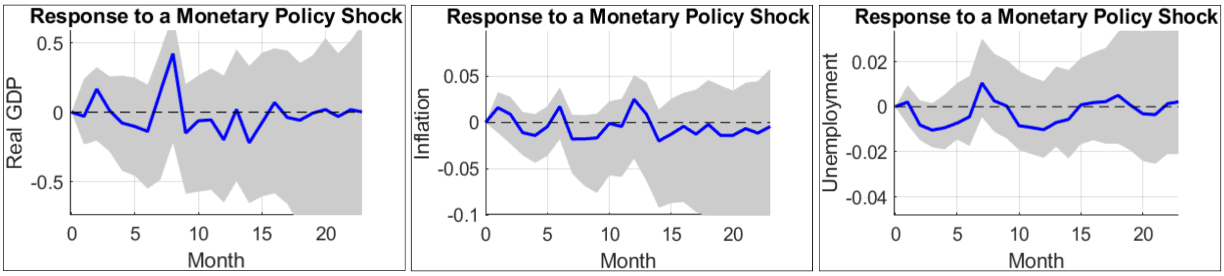
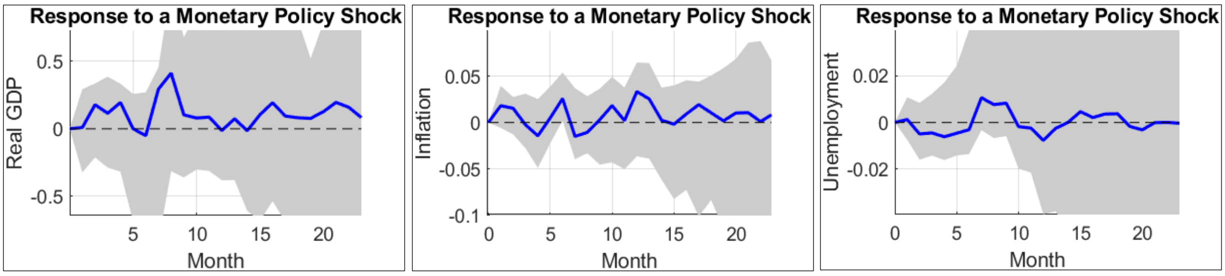


Figure 5: **QIRF for Euro Area with SSR as Monetary Policy Indicator: Quantile 0.1**



2. Alternative Cholesky Ordering

The following QIRFs are derived from a QSVAR (14) estimated over a 24-month horizon with 95% confidence bands, calculated using 1,000 bootstrap repetitions. Note that the Shadow Interest Rate (SIR) is ordered last, with unemployment, real GDP, and inflation preceding it, as reflected in the left-to-right visualization.

Figure 6: **QIRF for Euro Area: Quantile 0.9**

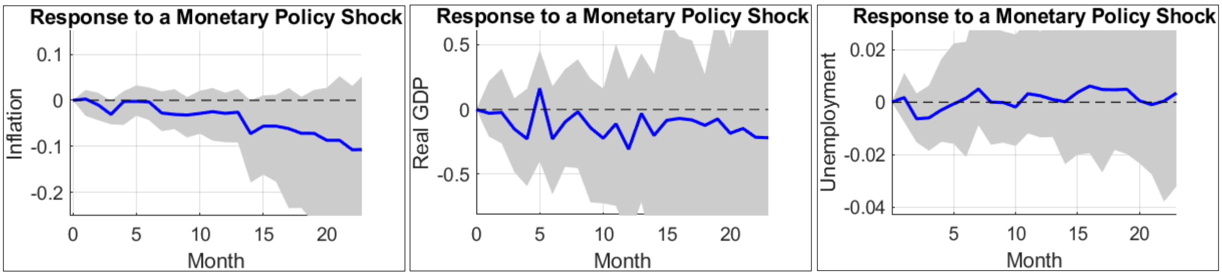
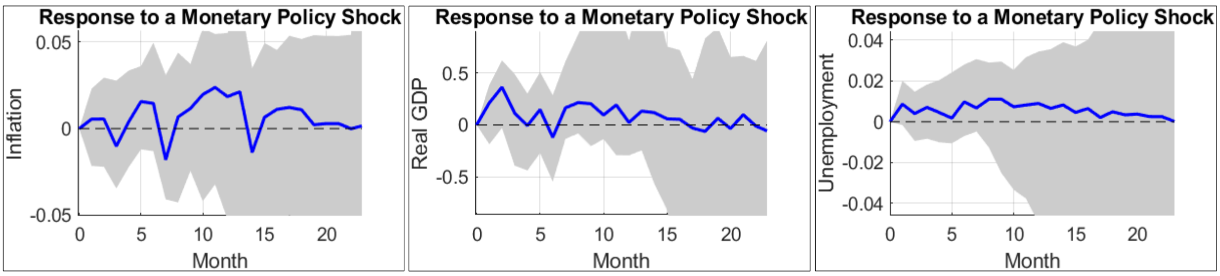


Figure 7: **QIRF for Euro Area: Quantile 0.1**



3. Pre-COVID QIRF

The following Quantile Impulse Response Functions (QIRFs) are derived from a QSVAR (11) model estimated over a 24-month horizon with 95% confidence bands, calculated using 1,000 bootstrap repetitions. The sample period is restricted to the timeframe from January 1999 to December 2019.

Figure 8: **Pre-COVID QIRF for Euro Area: Quantile 0.9**

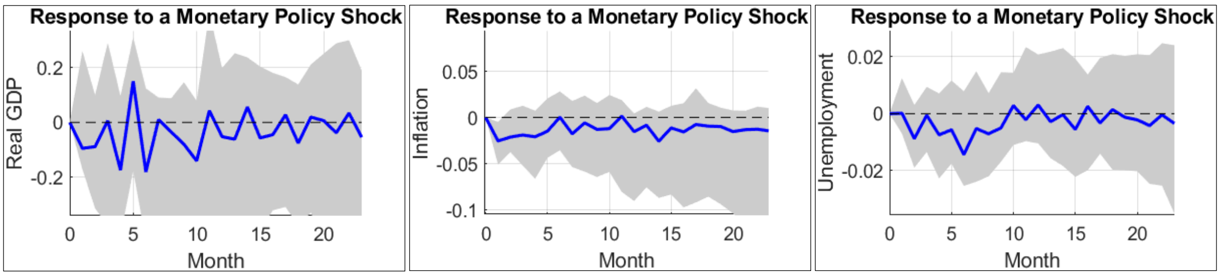
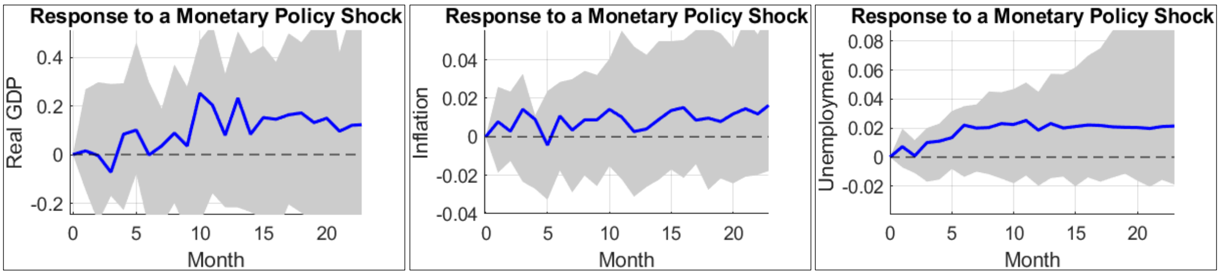


Figure 9: **Pre-COVID QIRF for Euro Area: Quantile 0.1**



4. Reduced Lag Structure

The following QIRFs are derived from a QSVAR (14) estimated over a 24-month horizon with 95% confidence bands, calculated using 1,000 bootstrap repetitions.

10 lags

Figure 10: **QIRF for Euro Area with 10 lags: Quantile 0.9**

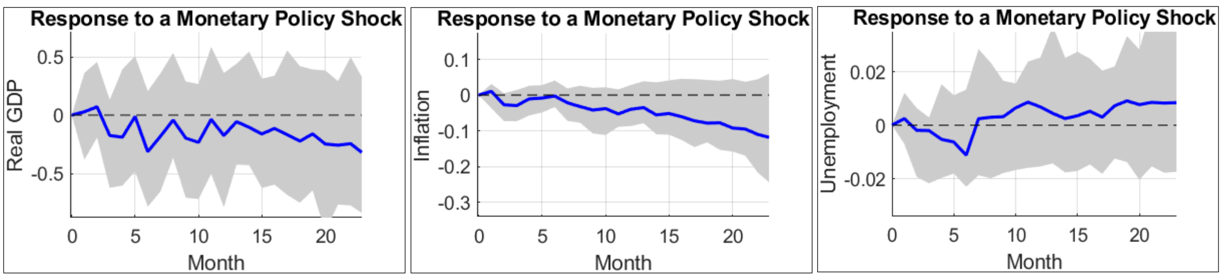
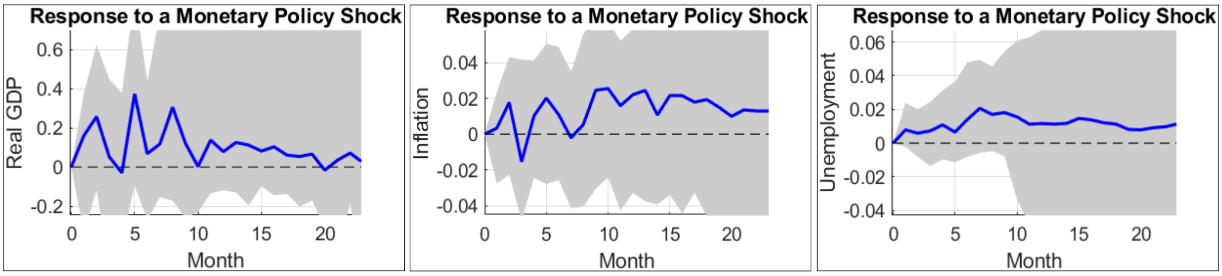


Figure 11: **QIRF for Euro Area with 10 lags: Quantile 0.1**



12 lags

Figure 12: **QIRF for Euro Area with 12 lags: Quantile 0.9**

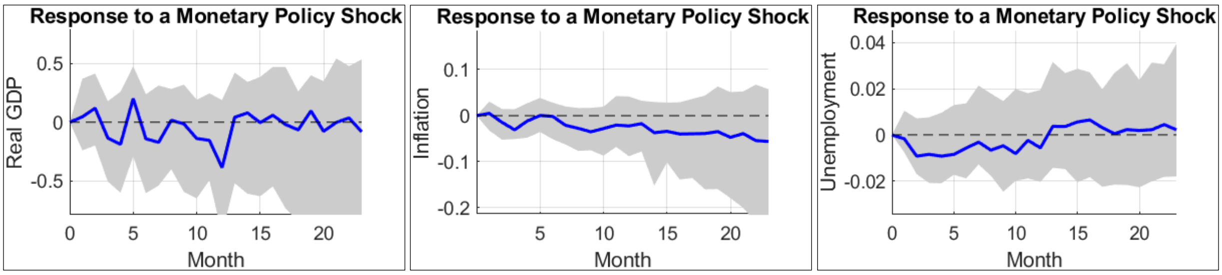
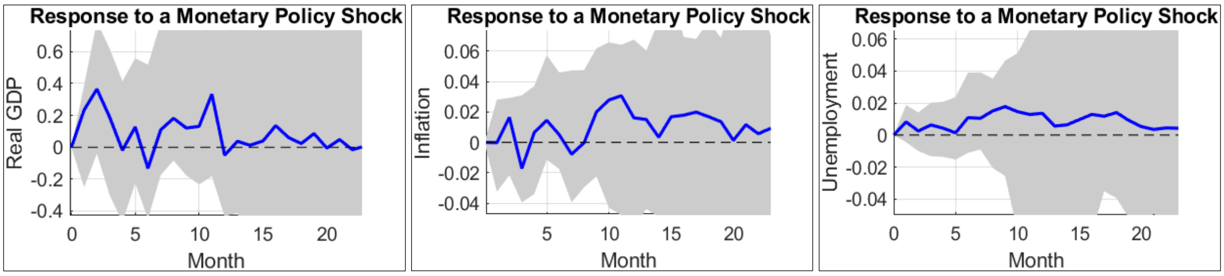


Figure 13: **QIRF for Euro Area with 12 lags: Quantile 0.1**



5. Excluding Unemployment from the Model

The following QIRFs are derived from a QSVAR (13) estimated over a 24-month horizon with 95% confidence bands, calculated using 1,000 bootstrap repetitions.

Figure 14: **QIRF for Euro Area excluding Unemployment: Quantile 0.9**

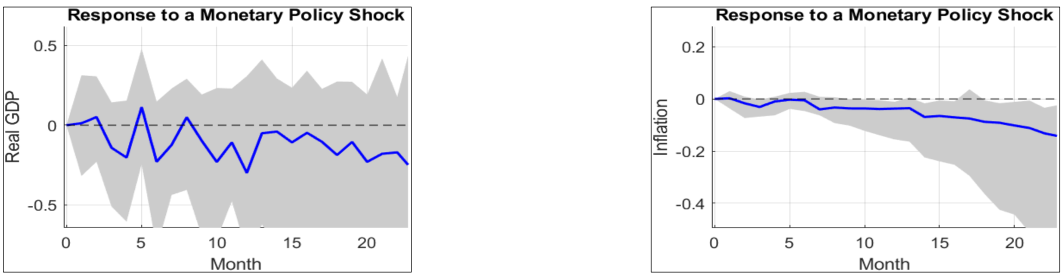
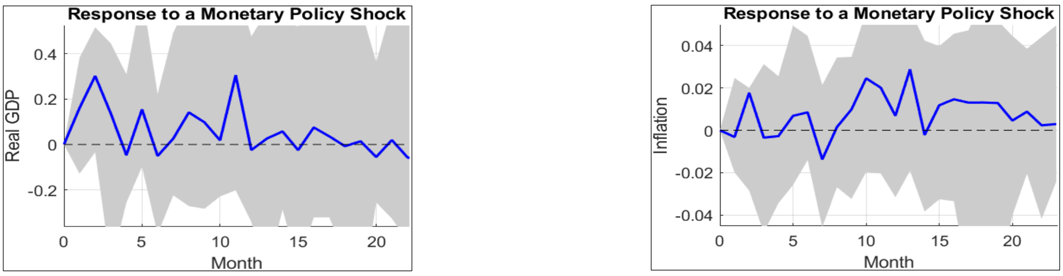


Figure 15: **QIRF for Euro Area excluding Unemployment: Quantile 0.1**



Unconventional and Conventional Monetary Policy Shock

The following QIRFs are derived from a QSVAR (13) model estimated over a 24-month horizon with 95% confidence bands, calculated using 1,000 bootstrap repetitions. Note that a tightening monetary policy shock, represented by an increase in the Shadow Interest Rate, reflects a dual mechanism: higher interest rates and reduced quantitative easing (QE). Therefore, we anticipate opposing responses in this analysis. For example, QE shocks are typically associated with positive effects, while MRO shocks often generate negative responses, going with the 0.9 quantile. However, our findings suggest that at the 0.1 quantile, a QE shock should have a negative response, while an MRO shock leads to a positive response, likely due to signaling effects. As we can see, these dynamics are evident in Figure 16 and 17.

Figure 16: **QIRF for Euro Area with: Conventional and unconventional monetary policy at the 0.9 Quantile**

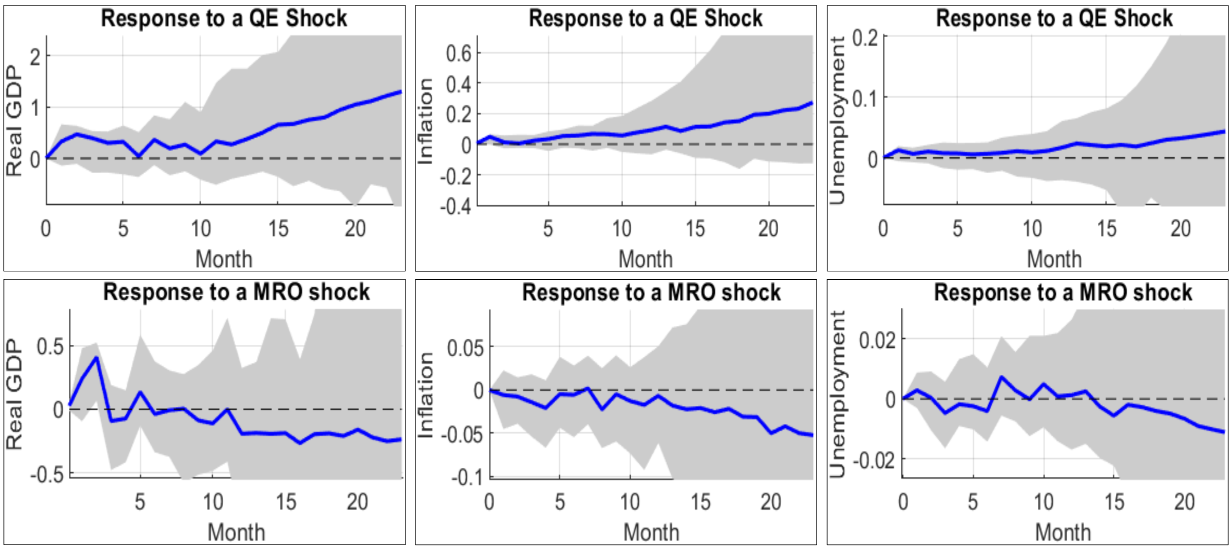
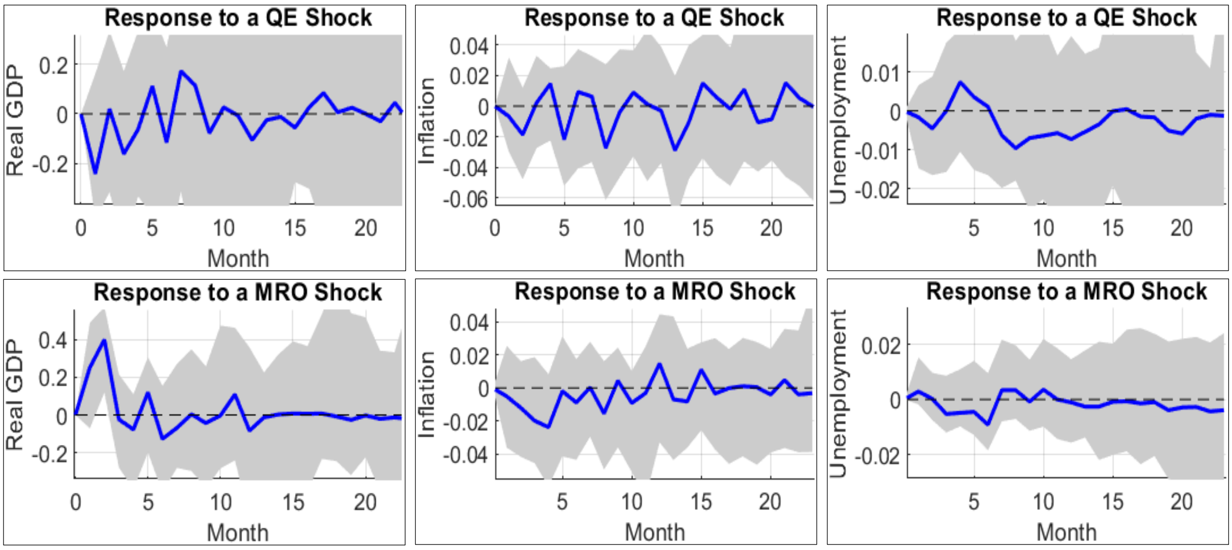


Figure 17: **QIRF for Euro Area with: Conventional and unconventional monetary policy at the 0.1 Quantile**



Summarized Findings Table

Table 6: **Key Results Overview: Euro Area, Portugal and Germany**

State	Euro Area	Portugal	Germany	Key findings
Expansion states (0.9 Quantile)	**Real GDP:** Contraction peaking at -30 bps by month 12.	**Real GDP:** Decline, but with shorter persistence; stabilizes near zero by month 10.	**Real GDP:** More persistent contraction; initial "price puzzle" effect; peaks at -15 bps by month 15.	Traditional monetary tightening dynamics: Smaller economies show more resistance to the effects, while larges economies exhibit more persistent responses.
	Inflation: Gradual decline, stabilizes at -10 bps by month 20.	**Inflation:** Declines gradually with lower magnitudes.	**Inflation:** Larger and stable decline.	
	Unemployment: Minimal effect, peaks at +1.5 bps by month 7.	**Unemployment:** Rigid labor market, muted response.	**Unemployment:** Persistent decline with low magnitude,	
Recessions states (0.1 Quantile)	**Real GDP:** Immediate increase, peaks at +35 bps within 3 months; stabilizes near zero by month 15.	**Real GDP:** Highly sensitive and volatile; stabilizes by month 13.	**Real GDP:** Increase, but with smaller magnitudes; stabilizes faster by the month 10.	Counterintuitive responses: Signaling effects explain increases in recessions. Smaller economies experience greater volatility and magnitudes, while larger economiesare more stable and adjust quicker.
	Inflation: Gradual positive response, peaks at +2 bps by month 13.	**Inflation:** Significant increase with high volatility.	**Inflation:** Stable increase, less volatile than Portugal.	
	Unemployment: Continuos increase, peaks at +1 bps by month 9.	**Unemployment:** Continued muted response across states, with highier volatility.	**Unemployment:** Persistent increase with low magnitude; less volatile than Portugal.	