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Chapter: Advanced Perspectives on Financial Engineering, Economic Modeling and Portfolio Optimization

WHEN FINANCIAL STRESS AND MONETARY POLICY INTERPLAY WITH ECONOMIC DYNAMICS IN THE EUROZONE: MULTIPLE SHOCKS EFFECTS

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Annotation. The aim of this paper is to examine the relationship between financial stress, as measured by the Composite Indicator of Systemic Stress (CISS), and macroeconomic variables, including GDP, inflation, unemployment and the ECB's monetary tools. Using a vector autoregression (VAR) model, we analyse euro area data over the period 1999 to 2023 to assess the dynamic influences and their relative strength. The study estimates impulse response functions (IRFs) and forecast error variance decomposition (FEVD) to interpret the effects of multiple shocks, including multiple shocks from 2020 onwards caused by the COVID-19 pandemic, the war in Ukraine, and the energy crisis. Our findings suggest that increased financial stress undermines the effectiveness of traditional ECB instruments such as the main refinancing operations, negatively impacts GDP and increases unemployment. The FEVD results indicate that financial stress accounts for a significant part of the variability in unemployment, suggesting that financial stress indirectly affects labour demand and investment. In addition, GDP shocks explain a large share of unemployment variability across the ten observation periods. The results underline the need for flexible monetary responses in times of crisis and provide deeper insights into how monetary policy, financial shocks, and economic determinants interact to optimise policy decisions. The paper fills a gap in empirical research by analysing financial stress over a longer period, during which several crises and multiple shocks have occurred since 2020, highlighting the importance of observing the interactions of selected variables in each period of the business cycle, especially in the period of multiple shocks.

Keywords: financial stress, monetary policy, vector autoregression model, impulse-response functions, eurozone.

JEL classification: E44, E52, E32, C32, G01.

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Introduction

External shocks have had a significant impact on inflation and economic activity, and the effects of these shocks exert an important pressure on financial markets. Although the series of multiple shocks after 2020 occurred a considerable time ago, the consequences and effects in the euro area continue to be evident in the form of higher inflation and the necessity for consolidation following challenging and burdensome years in both monetary and financial areas. The ongoing relevance and topicalitu of this issue warrant a deeper analysis. Researchers such as Costola and Iacopini (2023), Gomes-Pereira (2024), and Sleibi *et al*. (2023) have devoted significant research efforts to understanding the impact of financial stress on financial markets and the broader economy. We aim to uncover the effects of multiple shocks on important macroeconomic variables in the euro area. In particular, we focus on the causal relationship between financial stress and European Central Bank (ECB) monetary policy.

We fill a gap in the existing empirical research with a complex analysis of the relationship between financial stress in the euro area, as measured by the Composite Indicator of Systemic Stress (CISS), and monetary policy instruments. To the best of our knowledge, there are no papers that address a similar issue with the inclusion of a period of multiple shocks after 2020. Crises associated with multiple shocks have been an intense feature of national economies and integrations in recent years. An important tool with links to economic stability is the CISS, which includes 15 market-based measures of financial stress divided into five categories, according to ECB (2024), which have been discussed in detail by Hollo *et al*. (2012) and ECB (2023). The CISS combines risk signals from several financial market segments, including equity markets, bond markets, money markets and financial intermediaries. Unlike isolated indicators that measure individual market segments, the CISS provides a comprehensive view of systemic risks, allowing policymakers to anticipate and manage financial shocks more effectively. The experience of the 2008 financial crisis, the subsequent euro area debt crisis, and the series of multiple shocks since 2020 serves to underscore the significance of understanding the intricacies of financial markets and monitoring financial stress that can threaten macroeconomic stability. As pointed out by Gourinchas (2023), policymakers need to respond flexibly to new crises and seek appropriate measures and solutions; in order to ensure an orderly transition to a sustainable growth path.

The importance of our research lies in its capacity to identify changes in financial stress and related fluctuations in other macroeconomic variables that disrupt market stability, thus affecting the decisions of monetary authorities. The primary motivation and research question guiding this study is to investigate the effects of multiple shocks over the observation period on key macroeconomic determinants, including the CISS, and the implications of these shocks for economic stabilisation in the euro area. The relevance and importance of this issue is also highlighted by the experts at the Centre for Economic Policy Research (CEPR, 2024), who are working on the Financial Stress Index (FSI), through which they stress its fundamental importance in monetary policy at the international level.

The present analysis has been conducted on the basis of the research of Hollo *et al*. (2012), who introduced the CISS indicator, as well as by the work of Garcia *et al*. (2021) and Kremer (2015), who have discussed the role of non-standard monetary policy instruments in the context of financial stress. Our study includes data from 1999 to 2023, derived from twenty euro area countries. Through this data set, we uncover the interactions between the CISS, GDP, inflation, unemployment, main refinancing operations, and the EONIA rate at different stages of the business cycle. Our study differs from other authors' by the length of the period and the inclusion of phases of multiple shocks in recent years, triggered by previous crises in the euro area, which, in some ways, have occurred in isolation from the broader economy. Using a Vector Autoregression (VAR) model, we observe the interactions between the variables. Through impulse responses (IRFs) and forecast error variance decomposition (FEVD), we uncover responses of the researched variables to shocks over the time period and detect how variability of each variable is explained, which offers an important tool to interpret the results. In terms of policy implications, the paper investigates whether the relation between CISS and the researched variables is more pronounced when considering the period of multiple shocks in comparison to previous studies which did not consider them.

The paper is structured as follows. In the first section, we review the results of relevant empirical research. The second section describes all included macroeconomic variables and explain the applied method. In the third section, we report and interpret the results of VAR model, IRFs and variance decomposition. We discuss the obtained results and offer policy implications. The final section is the conclusions.

1. Literature Review

The relationship between systemic financial stress, macroeconomic performance and monetary policy has been, and continues to be, the focus of many studies in the euro area context. Several papers examine the asymmetric transmission of financial stress among the euro area Member States, such as Bartis (2021), as well as on the global scale, as explored by Liang *et al*. (2023) and the IMF (2024). CISS is an important tool in the monitoring of systemic risks within the Eurozone, which describes financial market vulnerabilities, especially during periods of increased stress. Several studies demonstrate its predictive power in forecasting macroeconomic downturns, also against other competing crisis indicators (Hollo *et al*., 2012; Figueres, Jarociński, 2020). By aggregating stress signals from many sectors, the CISS endows policymakers with a comprehensive vehicle to assess the propagation of financial shocks and forecast crises. De Grauwe *et al*. (2020) look at the transmission of financial stress and asymmetric shocks within the euro area. Using bond spreads and a vector autoregression (VAR) model, the study revealed that financial stress is not evenly distributed across countries. The results indicate that core countries, such as Germany, are less affected by financial stress from peripheral countries, such as Italy and Spain. This asymmetry highlights the limitations of a uniform approach to monetary policy in the euro area.

The complex interplay between financial stability and monetary policy in the Eurozone is explored by Mallick and Sousa (2013) and Garcia *et al*. (2021). To compare, Mallick and Sousa (2013) focus on the macroeconomic effects of financial stress and the role of ECB monetary policy during financial crises through VAR analysis. They find that although both conventional and unconventional ECB interventions mitigate the effects of financial stress, their effectiveness diminishes during periods of severe financial distress. These findings also suggest that the ECB's policy responses are limited by the heterogeneity of euro-area economies, especially during sovereign debt crises. Others, such as Beyer *et al*., 2023, emphasise the growing importance of fiscal policy mitigation in moderating the financial stress and growth of euro area Member States. Using a dynamic stochastic general equilibrium (DSGE) model, the results show that coordinated fiscal consolidation efforts together with monetary policy can help reduce inflationary pressures while promoting a more gradual tightening of monetary conditions. This is particularly beneficial for debt-laden countries because it reduces the risk of market fragmentation and accelerates economic recovery. In line with the above-mentioned studies, Garcia *et al*. (2021) address a similar issue through panel VAR models. Their results uncover that tighter monetary authorities improve financial stability by reducing asset bubbles and credit growth, but consequently, this may exacerbate financial risks during economic downturns by raising funding costs and reducing liquidity. Therefore, the authors highlight the complexity of monetary policy rebalancing as a tool for financial stability, especially when the financial cycle is in a downturn. This (non-linear) relationship between financial tensions and monetary policy points to the presence of a financial accelerator mechanism and tensions, which can amplify the effects of monetary interventions. Other authors, e.g. the IMF (2024), also address the propagation of systemic risk beyond the euro area.

The impact of financial conditions on growth risks in the euro area using quantile regressions is investigated by Figueres and Jarocinski (2020). The authors find that financial stress, as measured by the CISS, negatively affects output during crises in the euro area. In predicting these downside risks, the CISS outperforms other financial indicators such as equity volatility and bond spreads, underlining its importance for policymakers seeking to stabilise the economy. The interplay between financial stress, monetary policy, and macroeconomic indicators is an important part of the research, especially in the context of multiple shocks and systemic risk in the euro area. The role of the CISS in measuring financial stress and its transmission across countries, as well as the broader macroeconomic impact of shocks on the monetary union, has been increasingly highlighted in the literature (Costola, Iacopini, 2023; Polat, 2022). As with the use of the CISS to assess systemic risks in selected sectors, other authors (Cataldo *et al*., 2024; Hoque *et al*., 2024) create or utilise composite indicators in their studies in other sectors to consolidate multiple performance indicators. By integrating 38 sustainability indicators into a comprehensive assessment tool, Cataldo *et al*. (2024) create an indicator analogous to the use of the CISS in financial markets, thereby emphasising the significance and extensive applicability of composite indicators in analysing sector performance under conditions of stress and uncertainty.

Conversely, Szendrei and Varga (2023) adopt a quantile regression framework to capture the growth in risk in the euro area and highlights the importance of financial stress variables (such as GDP growth, bank bond spreads and retail credit spreads). Their findings uncover that several financial variables, particularly in the banking sector, explain different parts of the growth distribution, reinforcing the idea that the CISS is less effective at longer forecasting horizons in predicting euro area growth vulnerabilities. However, these findings contrast with previous studies, such as Figueres and Jarociński (2020), who highlight the effectiveness of the CISS in forecasting risks one year ahead, underlining the variability of forecasting power based on different methodologies. The role of monetary policy is also crucial in managing financial stress, especially when countries experience multiple, simultaneous shocks. Furthermore, Yao *et al*. (2023) examines cross-border interactions of financial stress using the CISS index for China, the US, and the Eurozone. The results show that financial stress in advanced economies exhibits stronger positive causality, while emerging markets (e.g., China) exhibit more uncertainty in their interaction with financial stress in advanced economies. This dynamic is even more pronounced during periods of extreme financial stress, such as during the global financial crisis or the COVID-19 pandemic.

As elucidated by Hollo *et al*. (2012), the originators of the CISS index, the index is designed to measure periods of high stress in multiple sectors. It is therefore a reliable measure for understanding how financial market volatility can spill over into the real economy. The authors point to this index's significance and the interplay between macroeconomic variables such as GDP growth, unemployment or inflation in turbulent periods. In line with research on the CISS index, papers on the cross-country dependence of financial stress highlight the transmission mechanisms of shocks between countries. Studies which employ VAR models and GARCH analyses (Dovern and Roye, 2014; Yao *et al*., 2021) uncover that financial stress in core economies, such as the US or the euro area, significantly affects emerging and peripheral economies. The authors emphasise the systemic nature of financial crises, during which shocks are rapidly transmitted through integrated financial markets.

The propagation of systemic risk in interconnected financial markets is analysed by Farkhondeh Rouz *et al*. (2024) who use the above-mentioned CISS indicator and Granger causality tests, with a particular focus on Chinese financial markets. The results demonstrate how fluctuations in a single market, such as the foreign exchange market, can disseminate to other markets, including the bond and stock markets. This interconnectivity of financial markets underscores the pivotal role of systemic risk in undermining the stability of entire economic systems. While the authors concentrate on China, this analysis of risk spillovers is also pertinent to the euro area, where numerous shocks, including those of sovereign debt, are frequently transmitted across diverse financial sectors. The impact of external shocks to financial stress on Eurozone-wide sovereign yields is minimal, whereas the ECB's unconventional monetary policy plays a more decisive role in mitigating risks. This finding highlights the pivotal role of the ECB in stabilising sovereign debt markets through targeted interventions, even in the context of multiple, compounding financial shocks (see e.g. Nguyet Vu, Katsiampa, 2024; Creel *et al*., 2019; ECB, 2018; ECB, 2012).

The key role of the CISS in tracking the dynamics between financial stress and key macroeconomic indicators is highlighted by Kremer (2015) and Blot *et al*. (2019). Kremer (2015) uses the CISS variable in a Vector Autoregression (VAR) model, and examines the dynamic interactions between financial stress and basic but important macroeconomic variables, including inflation, output, and ECB monetary policy settings. The results show that the impact on inflation remains muted, while the financial stress captured by the CISS has a significant impact on monetary policy and output growth. Blot *et al*. (2019) examine the relationship between sovereign bond yields and financial stress, particularly during the European sovereign debt crisis. Their findings indicate that the ECB's asset purchase programmes, along with other unconventional monetary policies, play a pivotal role in mitigating financial stress. Furthermore, their research on multiple shocks and their transmission uncovers the significance of the interaction between financial sectors. The VAR analysis in the study includes variables such as GDP, inflation, the ECB's main refinancing rate, and the EONIA-MRO spread. Similarly to other research papers by Fortin (2023) and Blot *et al*. (2019), the results suggest that the CISS is a reliable predictor of output growth, while it leads to a significant reduction in GDP growth when financial stress is higher. Moreover, Kremer and Bolt (2016) highlight that the unconventional monetary policy of the ECB, represented by changes in the balance sheet (total assets), responds directly to changes in financial stress, while the conventional refinancing rate (MRO) responds indirectly through its impact on macroeconomic conditions.

The aforementioned studies provide expert insight into the interconnectedness of monetary policies, important macroeconomic variables, financial stability, financial stress and regulation in maintaining market equilibrium during turbulent and economically challenging periods associated with the emergence of crises. The authors' results confirm the continued need for a balance and an appropriate approach that considers not only the effective communication of central banks in market management but also the synergies between short-term economic stabilisation and long-term risks (see Polat, 2022; ECB, 2022).

2. Data

In the present paper, we examine the 20-euro area countries as a whole over the period from 1999 to 2023. The selected variables comprise a composite indicator of systemic stress, monetary policy rates, inflation, economic output, the unemployment rate and the ECB's total assets. These variables have been employed in empirical studies in various combinations and permutations to evaluate the interplay between financial stress and the macroeconomic context (ECB, 2023; Fortin *et al*., 2023; Foglia *et al*., 2022; Kremer, 2015). To guarantee consistency in the periodicity of each variable, some annual data (e.g.

GDP and total assets) has been interpolated to monthly frequencies. Through this interpolation process, we have ensured that all variables are aligned in a manner that facilitates the observation of dynamic relationships between them.

In our study, a select number of macroeconomic key indicators is utilised. The CISS indicator aggregates stress levels in different segments of the financial market, including the money market, bond market, stock market and financial intermediaries, and is obtained from the ECB's statistical data warehouse. The CISS has also been used for systemic risk assessment by other authors, such as Bacchiocchi and Dragomirescu-Gaina (2024), Škrinjarić and Croatian National Bank (2022), and Kabundi and Nadal De Simone (2022). Simulations based on a quantile VAR conducted by Chavleishvili and Kremer (2023) suggest that systemic stress is a major driver of the Great Recession, although the contribution to the pandemic crisis was relatively minor. Similarly, Skouralis and the European Systematic Risk Board (2021), employ a global vector autoregression (GVAR) model to monitor systemic risk in the euro area. The findings indicate that an increase in aggregate systemic risk results in a decline in output, with two-thirds of the response attributable to cross-country spillovers. In addition, a similar conclusion is reached by other authors in their respective articles (Fiorelli, Meliciani, 2019; Cerutti *et al.*, 2015).

The €STR rate is derived from actual overnight borrowing transactions and offers a more accurate benchmark for short-term interest rates. The short-term interest rate in the euro was obtained from the ECB database. The EONIA rate was abolished in 2022 and replaced by the €STR. Consequently, the conversion of €STR to EONIA was undertaken, as the EONIA rate is used for almost the entire period under study (ECB, 2024; Bacchiocchi, Dragomirescu-Gaina, 2024; ECB, 2022). The effects of monetary policy shocks in the euro area are also addressed in the research by Kabundi and Nadal De Simone (2022), conducted in the aftermath of the global financial crisis from 2008 to 2019. Through SFAVAR, they estimate responses to shocks that relate to bank vulnerabilities. Unconventional monetary policy appears to be more successful in raising output and inflation than conventional monetary policy. The aforementioned unconventional policy has an important role in economic and financial stabilisation, as interpreted by Fiorelli and Meliciani (2019), where they use the FAVAR model and the results show that the simultaneous implementation of two different policies is a 'powerful weapon' for the ECB. (Benito *et al.*, 2007).

Table 1. Descriptive Statistics (Original Data)

	Mean	Median	Std. Dev	Min.	Max.	Obs.
CISS	0.19	0.13	0.16	0.03	0.78	289
EONIA rate	1.31	0.71	1.70	- 0.58	4.39	289
MRO	1.54	1.00	1.51	0	4.75	289
HICP	93.48	94.08	11.13	73.76	121.03	289
GDP	11,387,839,9 35 210.3	11,360,232 789,931.2	864,375, 245,579.4	9,591,471 381,980.2	13,047, 026,323 802.7	289
UNEMPLOYMENT	9.15	9.02	1.43	6.59	12.10	289
TOTAL ASSETS	2,988,167.03	2,246, 184.08	2,287, 548.47	795,161.00	8,564,361.00	289

Notes: GDP and TOTAL ASSETS are measured in millions of euros (€). EONIA, MRO, and UNEMPLOYMENT are expressed as percentages (%). CISS and HICP are index values.

Source: own calculations.

In terms of the monetary policy analysis, the MRO rate sourced from the ECB database is employed. This rate is commonly used in studies on the impact of interest rates. To capture inflationary pressures, the

Harmonised Index of Consumer Prices (HICP) database from Eurostat is selected. We chose GDP data from the World Bank. The unemployment rate, a key indicator of labour market conditions, was taken from the AMECO database, and data on the ECB's total assets, which reflect the size of the central bank's balance sheet, were obtained from the ECB Statistical Data Warehouse from the Eurosystem's annual consolidated balance sheet. These indicators provide an overview of the impact of various monetary policy operations on the euro area financial system. The choice of the data is inspired by recent studies, e.g. ECB (2024), Bacchiocchi and Dragomirescu-Gaina (2024), Kabundi and Nadal De Simone (2022), Fiorelli and Meliciani (2019), and ECB (2018).

Table 1 presents the descriptive statistics for the full sample. The total number of observations (samples) is 289. The variables GDP or Total Assets have higher standard deviations, indicating a higher variability of the dataset, which may be related to multiple shocks, economic cycles or policy changes.

3. Methods

In this section, the methodology employed to achieve the objectives, i.e. to explore the relationships between the variables included in our dataset, is described. To capture the interdependencies between variables, we decided to apply a vector autoregression (VAR) model. The VAR model, introduced by Sims (1980), has become a fundamental tool of macroeconomic and financial analysis (Christiano *et al*., 1999).

The purpose of the paper is to ascertain the response of one variable to another, with consideration to time lags that can be obtained from the VAR model. The VAR model permits to estimate the relationship between two variables considering time lags: first, one variable is set as explanatory, and the second is explained; and then also inversely. This allows the identification of bi-directional effects.

This ability of VAR models increases its usefulness in empirical macroeconomic research. IRFs and FVEDs are also useful for understanding the transmission of shocks in the system, such as financial stress affecting inflation, unemployment and monetary policy measures, which are the focus of our study. (Stock, Watson, 2001).

Table 2. Descriptive Statistics (Original Data)

Variable	Transformation/Description
dCISS	logarithmic difference of the systemic risk index
dEONIA	logarithmic difference of EONIA
d2MRO	second difference of the MRO measure
d2HICP	second difference of the HICP
d2GDP	second difference of GDP
d2UNEMPLOYMENT	second difference of the unemployment rate
d2TOTAL_ASSETS	second difference of total central bank assets

Notes: ADF test results confirmed that the transformed series are stationary at the desired level (with p-values < 0.05 for all variables after appropriate differencing).

Source: own calculations.

Our procedure includes stationarity tests, model specification criteria, VAR model estimation, and subsequent impulse response functions (IRFs) and forecast error variance decomposition (FEVD). The methodology also includes various diagnostic tests to ensure model robustness and validity. Before estimating the VAR model, it was imperative to ascertain the stationarity of all-time series, which was done by using the Augmented Dickey-Fuller (ADF). The ADF test was conducted on log-transformed and differenced variables, if necessary, to ensure stationarity. In our case, the ADF test was performed for each variable in their differences (*Table 2*).

To determine the optimal number of lags, the following information criteria were employed: the Akaike information criterion (AIC), the Hannan-Quinn criterion (HQ), the Schwarz criterion (SC), and the finite prediction error (FPE). The result of AIC and FPE recommended for six lags, so the defined numbers of lags were applied in our VAR model, which was estimated using this selected lag length.

The general form of the VAR model for the seven variables with six lags is as follows:

$$\mathbf{Y_t = A_1Y_{t-1} + A_2Y_{t-2} + A_3Y_{t-3} + A_4Y_{t-4} + A_5Y_{t-5} + A_6Y_{t-6} + \varepsilon_t} \quad (1)$$

where:

$\boldsymbol{Y_t} = [dCISS_t, dEONIA_t, d2MRO_t, d2HICP_t, d2GDP_t, d2UNEMPLOYMENT_t, d2TOTAL\_ASSETS_t]$

$\boldsymbol{A_i}$: coefficient matrices for lag i

$\boldsymbol{\varepsilon_t}$**:** vector of innovations (errors)

Equation for $dCISS_t$:

$dCISS_t = \alpha_1 + \Sigma_1{}^6 \beta_1,i * dCISS_{t-i} + \Sigma_1{}^6 \beta_1,i * dEONIA_{t-i} + \Sigma_1{}^6 \beta_1,i * d2MRO_{t-i} + \Sigma_1{}^6 \beta_1,i * d2HICP_{t-i} + \Sigma_1{}^6 \beta_1,i * d2GDP_{t-i} + \Sigma_1{}^6 \beta_1,i * d2UNEMP_{t-i} + \Sigma_1{}^6 \beta_1,i * d2TOTAL\_ASSETS_{t-i} + \varepsilon_{1t}$

(2)

Equation for $dEONIA_t$:

$dEONIA_t = \alpha_2 + \Sigma_1{}^6 \beta_2,i * dCISS_{t-i} + \Sigma_1{}^6 \beta_2,i * dEONIA_{t-i} + \Sigma_1{}^6 \beta_2,i * d2MRO_{t-i} + \Sigma_1{}^6 \beta_2,i * d2HICP_{t-i} + \Sigma_1{}^6 \beta_2,i * d2GDP_{t-i} + \Sigma_1{}^6 \beta_2,i * d2UNEMP_{t-i} + \Sigma_1{}^6 \beta_2,i * d2TOTAL\_ASSETS_{t-i} + \varepsilon_{2t}$

(3)

Equation for $d2MRO_t$:

$d2MRO_t = \alpha_3 + \Sigma_1{}^6 \beta_3,i * dCISS_{t-i} + \Sigma_1{}^6 \beta_3,i * dEONIA_{t-i} + \Sigma_1{}^6 \beta_3,i * d2MRO_{t-i} + \Sigma_1{}^6 \beta_3,i * d2HICP_{t-i} + \Sigma_1{}^6 \beta_3,i * d2GDP_{t-i} + \Sigma_1{}^6 \beta_3,i * d2UNEMP_{t-i} + \Sigma_1{}^6 \beta_3,i * d2TOTAL\_ASSETS_{t-i} + \varepsilon_{3t}$

(4)

Equation for $d2HICP_t$:

$d2HICP_t = \alpha_4 + \Sigma_1{}^6 \beta_4,i * dCISS_{t-i} + \Sigma_1{}^6 \beta_4,i * dEONIA_{t-i} + \Sigma_1{}^6 \beta_4,i * d2MRO_{t-i} + \Sigma_1{}^6 \beta_4,i * d2HICP_{t-i} + \Sigma_1{}^6 \beta_4,i * d2GDP_{t-i} + \Sigma_1{}^6 \beta_4,i * d2UNEMP_{t-i} + \Sigma_1{}^6 \beta_4,i * d2TOTAL\_ASSETS_{t-i} + \varepsilon_{4t}$

(5)

Equation for $d2GDP_t$:

$d2GDP_t = \alpha_5 + \Sigma_1{}^6 \beta_5,i * dCISS_{t-i} + \Sigma_1{}^6 \beta_5,i * dEONIA_{t-i} + \Sigma_1{}^6 \beta_5,i * d2MRO_{t-i} + \Sigma_1{}^6 \beta_5,i * d2HICP_{t-i} + \Sigma_1{}^6 \beta_5,i * d2GDP_{t-i} + \Sigma_1{}^6 \beta_5,i * d2UNEMP_{t-i} + \Sigma_1{}^6 \beta_5,i * d2TOTAL\_ASSETS_{t-i} + \varepsilon_{5t}$

(6)

Equation for d2UNEMPLOYMENT$_t$:

d2UNEMPLOYMENT$_t$ = $\alpha_6 + \Sigma_1{}^6 \beta_6,i * dCISS_{t-i} + \Sigma_1{}^6 \beta_6,i * dEONIA_{t-i} + \Sigma_1{}^6 \beta_6,i * d2MRO_{t-i} + \Sigma_1{}^6 \beta_6,i * d2HICP_{t-i} + \Sigma_1{}^6 \beta_6,i * d2GDP_{t-i} + \Sigma_1{}^6 \beta_6,i * d2UNEMP_{t-i} + \Sigma_1{}^6 \beta_6,i * d2TOTAL\_ASSETS_{t-i} + \varepsilon_{6t}$

(7)

Equation for d2TOTAL_ASSETS$_t$:

d2TOTAL_ASSETS$_t$ = $\alpha_7 + \Sigma_1{}^6 \beta_7,i * dCISS_{t-i} + \Sigma_1{}^6 \beta_7,i * dEONIA_{t-i} + \Sigma_1{}^6 \beta_7,i * d2MRO_{t-i} + \Sigma_1{}^6 \beta_7,i * d2HICP_{t-i} + \Sigma_1{}^6 \beta_7,i * d2GDP_{t-i} + \Sigma_1{}^6 \beta_7,i * d2UNEMP_{t-i} + \Sigma_1{}^6 \beta_7,i * d2TOTAL\_ASSETS_{t-i} + \varepsilon_{7t}$

(8)

Once the VAR model has been estimated, we utlise IRFs and FEVDs to analyse the interrelationships between the variables to provide and extend insights into the transmission of shocks in the countries under study for selected determinants over time. We use IRFs to examine how a one standard deviation shock in dCISS (systemic financial stress) propagates through macroeconomic variables, inflation (d2HICP), output (d2GDP), unemployment (d2UNEMPLOYMENT), and monetary policy instruments, such as dEONIA and d2MRO. IRFs demonstrate how quickly and to what extent these variables respond to disturbances in systemic tensions.

It is anticipated that a positive shock to dCISS (representing increased financial stress) can impact GDP, inflation, and monetary policy variables over the forecast horizon (in line with other studies, such as Chavleishvili and Kremer (2023)). Our analysis aims to highlight not only the magnitude of these effects but also key economic outcomes providing crucial insights into macro-financial linkages in the euro area and the speed at which financial strains are transmitted to the economy. Through FEVD, the proportion of variability is revealed in each of the variables. Innovations in financial stress, monetary policy and other economic variables explain this share of variability. The two aforementioned analyses form the basis for the interpretation of the results, which also provide important implications for monetary policy authorities and for policymaking in the context of financial stress.

4. Results, Discussion, and Practical Implications

In accordance with the objectives of the study, an analysis of the results obtained from the estimated vector autoregression (VAR) model is undertaken. The selected model enables the acquisition of insights into the dynamic interactions between the specified variables and the identification of the impact that a shock, or multiple shocks, on one variable can have on other determinants. In order to facilitate a more accurate interpretation, the factors that play a pivotal role in the dynamics of the selected variables were identified. The results include the significance levels of individual coefficients, which facilitate a more robust assessment of the importance and reliability of the relationships between variables. This section presents a discussion and analysis of the model results, their interpretation, graphical representation, and evaluation from an economic and econometric perspective, with a particular focus on the value of specific relationships between them. The estimation results of the model are reported in *Table 3*.

The VAR model demonstrates the influence of systemic financial stress on macroeconomic variables, including inflation and GDP. The findings are consistent with the theory of financial cycles, as presented by the European Central Bank (ECB, 2017). The results of the vector autoregression (VAR) model are in line with the theoretical expectations and demonstrate that financial stress and interest rate fluctuations exert a considerable influence on real economic variables (such as GDP, HICP, and EONIA rate and unemployment in our VAR models). It is imperative that central bank regulation and subsequent actions are designed with these dynamics in mind in order to minimise the risks of financial crises and their negative effects on the real economy. The negative coefficient of the CISS on GDP indicates that elevated levels of financial stress are associated with a reduction in economic activity (β = -0.0001; *Table 3*). The findings of this study are supported by those of other researchers (e.g. Kremer, 2015), who have demonstrated that financial crises and financial market stress are linked to diminished investment and lower GDP growth. Financial stress can impede or influence access to credit, which may subsequently result in a reduction in consumption and, consequently, a negative impact on GDP. This mechanism is exacerbated during periods of heightened financial stress when the financial system is unable to efficiently allocate capital. Regarding the coefficients and the relationships between the variables, based on the results of the VAR model reported in *Table 3*, we created a graph with an overview of the positive and negative relationships between the variables (*Figure 1*).

Table 3. Significant Relationships between Selected Variables from the VAR Model

Dependent Variable	Independent Variable	Coefficient	Std Error	tValue	pValue	Significance
dCISS	dCISS.l4	-0.1535	0.0644	-2.3852	0.0179	*
dCISS	d2HICP.l4	14.6229	6.5811	2.2220	0.0273	*
dCISS	d2GDP.l4	-453.8674	223.3971	-2.0317	0.0434	*
dCISS	dEONIA.l5	-0.5857	0.2991	-1.9582	0.0514	.
dEONIA	d2MRO.l1	0.5861	0.1344	4.3605	0.0000	***
dEONIA	d2MRO.l2	0.7961	0.1452	5.4824	0.0000	***
dEONIA	d2HICP.l2	3.5426	1.5274	2.3194	0.0213	*
dEONIA	d2MRO.l3	0.8150	0.1614	5.0500	0.0000	***
dEONIA	d2UNEMPLOYMENT.l3	33.2076	19.7672	1.6799	0.0944	.
dEONIA	dCISS.l4	-0.0253	0.0148	-1.7111	0.0884	.
dEONIA	d2MRO.l4	0.5340	0.1708	3.1274	0.0020	**
dEONIA	d2MRO.l5	0.5889	0.1716	3.4328	0.0007	***
dEONIA	d2UNEMPLOYMENT.l5	-30.2607	13.7680	-2.1979	0.0290	*
dEONIA	d2TOTAL_ASSETS.l5	1.7175	0.8399	2.0448	0.0420	*
dEONIA	d2UNEMPLOYMENT.l6	37.5294	13.6038	2.7588	0.0063	**
d2MRO	d2MRO.l1	-0.2859	0.0672	-4.2525	0.0000	***
d2MRO	d2HICP.l1	1.6599	0.7327	2.2654	0.0244	*
d2MRO	d2MRO.l2	-0.3756	0.0726	-5.1710	0.0000	***
d2MRO	dEONIA.l3	0.0620	0.0337	1.8382	0.0674	.
d2MRO	dEONIA.l4	-0.0936	0.0346	-2.7075	0.0073	**
d2MRO	d2MRO.l4	-0.3928	0.0854	-4.5983	0.0000	***
d2MRO	d2MRO.l5	-0.2084	0.0858	-2.4282	0.0160	*
d2MRO	d2HICP.l5	1.3691	0.7699	1.7782	0.0767	.
d2HICP	d2MRO.l1	0.0136	0.0060	2.2740	0.0239	*
d2HICP	d2HICP.l1	0.1650	0.0650	2.5389	0.0118	*
d2HICP	dCISS.l3	0.0013	0.0007	1.9184	0.0563	.
d2HICP	d2UNEMPLOYMENT.l6	-1.5482	0.6035	-2.5654	0.0110	*
d2GDP	dCISS.l1	-0.0001	0.0000	-2.5193	0.0125	*
d2GDP	d2HICP.l1	0.0056	0.0030	1.8500	0.0656	.
d2GDP	d2GDP.l1	0.1618	0.0827	1.9555	0.0518	.
d2GDP	dCISS.l2	-0.0001	0.0000	-2.3748	0.0184	*
d2GDP	d2GDP.l2	0.7882	0.0831	9.4809	0.0000	***
d2GDP	d2GDP.l3	0.3693	0.1097	3.3669	0.0009	***
d2GDP	d2UNEMPLOYMENT.l3	-0.0927	0.0411	-2.2562	0.0250	*
d2GDP	d2GDP.l5	-0.1518	0.0794	-1.9119	0.0572	.
d2GDP	d2UNEMPLOYMENT.l5	0.0593	0.0286	2.0721	0.0394	*
d2GDP	d2GDP.l6	-0.4064	0.0793	-5.1284	0.0000	***

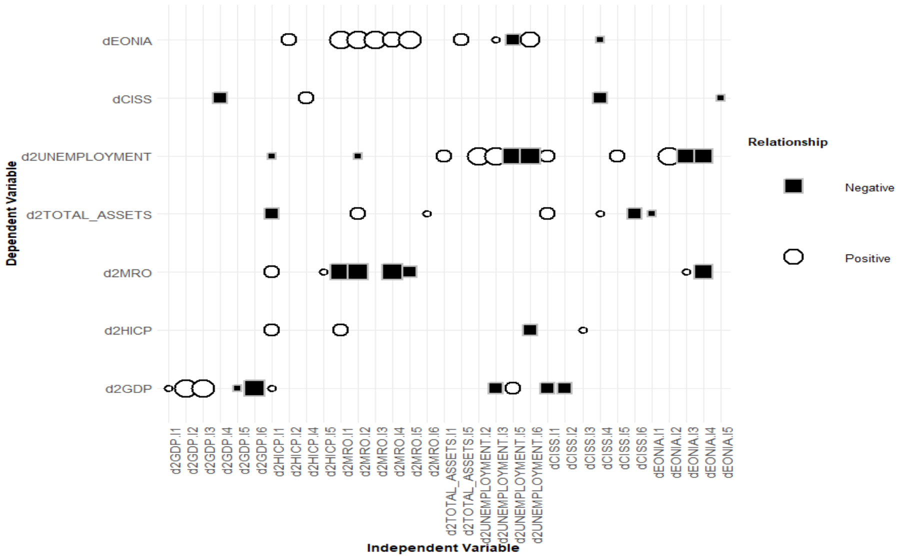
Table 3 (*continuation)*. Significant Relationships between Selected Variables from the VAR Model

Dependent Variable	Independent Variable	Coefficient	Std Error	tValue	pValue	Significance
d2UNEMPLOYMENT	dCISS.l1	0.0002	0.0001	2.0557	0.0410	*
d2UNEMPLOYMENT	d2HICP.l1	-0.0126	0.0075	-1.6879	0.0928	.
d2UNEMPLOYMENT	d2TOTAL_ASSETS.l1	0.0107	0.0042	2.5492	0.0115	*
d2UNEMPLOYMENT	dEONIA.l2	0.0014	0.0003	4.2001	0.0000	***
d2UNEMPLOYMENT	d2MRO.l2	-0.0014	0.0007	-1.8762	0.0619	.
d2UNEMPLOYMENT	d2UNEMPLOYMENT.l2	0.8203	0.0760	10.7913	0.0000	***
d2UNEMPLOYMENT	dEONIA.l3	-0.0010	0.0003	-2.9145	0.0039	**
d2UNEMPLOYMENT	d2UNEMPLOYMENT.l3	0.6010	0.1008	5.9597	0.0000	***
d2UNEMPLOYMENT	dEONIA.l4	-0.0010	0.0004	-2.8648	0.0046	**
d2UNEMPLOYMENT	dCISS.l5	0.0002	0.0001	2.3504	0.0196	*
d2UNEMPLOYMENT	d2UNEMPLOYMENT.l5	-0.2583	0.0702	-3.6773	0.0003	***
d2UNEMPLOYMENT	d2UNEMPLOYMENT.l6	-0.4286	0.0694	-6.1758	0.0000	***
d2TOTAL_ASSETS	dCISS.l1	0.0029	0.0012	2.3306	0.0207	*
d2TOTAL_ASSETS	dEONIA.l1	-0.0092	0.0054	-1.7255	0.0858	.
d2TOTAL_ASSETS	d2HICP.l1	-0.2632	0.1169	-2.2508	0.0254	*
d2TOTAL_ASSETS	d2MRO.l2	0.0269	0.0116	2.3223	0.0211	*
d2TOTAL_ASSETS	dCISS.l4	0.0022	0.0012	1.8997	0.0587	.
d2TOTAL_ASSETS	dCISS.l6	-0.0026	0.0012	-2.1321	0.0341	*
d2TOTAL_ASSETS	d2MRO.l6	0.0256	0.0137	1.8593	0.0643	.

Notes: the number of observations is 289, and the number of variables in each VAR equation is seven. Robust standard errors are reported in the table. The correlation matrix did not indicate any multicollinearity between variables. The VAR model was estimated with six lags selected based on the Akaike Information Criterion (AIC) and the Final Prediction Error (FPE). Significance symbols. , *, **, and *** denote statistical significance at the 10% ($p < 0.10$), 5% ($p < 0.05$), 1% ($p < 0.01$), and 0.1% ($p < 0.001$) levels, respectively.

Source: own calculations.

The results of the model and the individual relationships between macroeconomic variables show that the CISS exhibits a strong negative effect on GDP, while a similar relationship also emerges between the CISS and the EONIA rate (*Table 3* and *Figure 1*). The estimated coefficients in *Table 3* reveal that lagged CISS has a significant negative impact on future values of CISS. The results may be indicative of self-correcting dynamics in financial stress, as high CISS values in one period may lead to a decrease in stress in a later period. The negative relationship between the CISS and GDP in the euro area is in line with financial and business cycle theory (Dovern, Roye, 2014), which suggests that periods of financial stress cause a reduction in investment and economic activity. Multiple shocks or financial crises are directly related to an increase in the CISS and are therefore often accompanied by a decline in demand, investment or consumption, leading economies into a period of recession. We observe a strong positive relationship between CISS and lagged inflation (*Table 3* and *Figure 1*), which represents a rise in financial stress preceded by a rise in inflation rate. This result is related to the course of the financial cycle, where higher inflation is associated with uncertainty in markets and rising tensions between supply and demand, contributing to an increase in risks in several sectors, including the banking sector. It is the banking sector's ability to maintain market and funding stability that is threatened by high inflation and its associated risks. In times of financial crises, such as the global financial crisis of 2008 or the multi-shock period of 2020–2022, these relationships have manifested themselves in declining GDP, rising inflation and rising unemployment or higher indebtedness of countries. In times of increased financial stress, monetary and fiscal authorities and regulators need to take appropriate measures to minimise these negative impacts. Kremer (2015) similarly finds that CISS has a strong negative impact on GDP, confirming our results and the link between financial stress and reduced investment in the euro area. Even though Dovern and Roye (2014) concur, Garcia *et al*. (2021) stress that this relationship is non-linear, with stronger effects during periods of extreme financial volatility. On the one hand, our results suggest a stronger relationship between financial stress and inflation, which may be caused by the inclusion of the period even from multiple shocks after 2019. On the other hand, Kremer finds that the relationship between financial stress and inflation is milder in earlier periods, but his time series did not include the aforementioned multiple shocks.



Note: the bigger the symbol is, the higher (stronger) the relation, i.e. the higher the value of the estimated regression coefficient, between the given dependent and independent variable is.

Source: created by the authors.

Figure 1. **Relationships between Dependent and Independent Variables in Estimated VAR Models**

A strong relationship between the EONIA rate and the other researched variables was identifed. We observe a very strong and significant long-run positive relationship between the EONIA rate and MRO (*Table 3* and *Figure 1*). When MRO increases, the EONIA rate or €STR increases, as well. This effect persists even after several time periods (lag 1 to lag 5). Rising rates reduce the availability of liquidity, which is associated with a decline in credit activity, a reduction in investment and, consequently, a slowdown in economic growth. This finding is of practical relevance to policymakers because it confirms that the monetary policy transmission mechanism through the MRO is effective in influencing short-term interest rates, but it also takes time to take full effect.

Furthermore, VAR results uncover a positive relation between the lagged Total Assets and EONIA (β = 1.7175; *Table 3*). This relationship can be interpreted to mean that rising interest rates increase the value of total assets, especially in times when markets are forced to look for safer investment opportunities. This dynamic is particularly relevant in times of economic shocks and increased volatility in financial markets. The relationship between lagged CISS and unemployment is positive and significant (β = 0.0002; *Table 3*), confirming that an increase in systemic financial stress leads to an increase in unemployment. Typically, during periods of rising financial stress, banking institutions and monetary authorities adjust their lending conditions and economic agents find it more difficult to access finance. In such periods, investment falls and there are job losses, and thus changes in the unemployment rate. In such situations, this unemployment effect is often seen as a direct consequence of financial shocks. The relationship between lagged inflation (lag 1) and unemployment proves to be significant and negative (β = -0.0126, *Table 3*). This result is consistent with the concept of the Phillips curve and Combes and Lesuisse (2022), which describes the inverse relationship between inflation and unemployment, especially in the context of new knowledge during the entry into the EMU. In times of higher inflation, there is a higher demand for labour, which leads to a fall in unemployment. However, this relationship may not be linear and may vary depending on monetary policy and market expectations. In times of more pronounced inflation shocks or pressures, this relationship may be distorted, suggesting the need for further research to examine non-standard labour market conditions. It should be pointed out that the significance of the relationship in other lags is not confirmed by our model results, which may be related to the fact that the relationship may not be as reliable over longer time horizons, mainly due to factors such as inflation expectations and structural changes in the economy.

The lagged relationship between unemployment and total assets provides interesting and important implications for the monetary area. The relationship between unemployment and the ECB's total assets is described by the positive and significant coefficient of lagged total assets (Total Assets; see the results in *Table 3*), which indicates that the growth of assets on the ECB's balance sheet leads to an increase in unemployment, which can be attributed to expansionary monetary measures, including quantitative easing (QE). Under QE, the ECB purchases large volumes of bonds and other securities, thereby increasing the amount of liquidity in the banking system and supporting the availability of credit. In this way, the ECB creates conditions for economic growth and a reduction in unemployment. However, given our results and the positive relationship between the ECB's total assets and the unemployment rate, it can be speculated whether the ECB is expanding its assets precisely at times when the economy is in trouble, which is reflected in a simultaneous rise in unemployment (see the positive coefficient between Total Assets and unemployment in *Table 3*). This situation is usually associated with periods of crisis, such as a financial crisis or a pandemic, when the ECB reacts by buying assets to stabilise the financial markets and support liquidity in the system. Despite expansionary measures and a less frequent situation, unemployment may rise due to structural problems in the economy or due to lagged effects of monetary policy on the real economy, which is in line with Scherer (2022). This may be the reason for the observed positive relationship, which indicates that the ECB is increasing its assets at a time when the economy is vulnerable, and the unemployment rate rises at these times.

The relationship between the other variables and the dependent variable of total assets can be classified as complex and dynamic depending on the lags (*Table 3*). Financial stress with lags (1 and 4) has a positive impact on the ECB's total assets which may be caused by the fact that a short-term increase in financial stress leads the ECB to increase the amount of assets in order to respond to this stress with an expansionary monetary policy and to stabilise the market. However, at lag 6, we observe a negative relationship between the aforementioned variables suggesting that the persistent financial stress has an impact on reducing the value of the ECB's assets. This effect can be explained by the fact that, in the long run, financial stress may lead to liquidity constraints and to a shift of capital to safer assets. This may lead to a reduction in the value of the riskier securities held by the ECB, given the long-term use of some risky instruments, which may lead to a reduction in their effectiveness and a deterioration in confidence in the financial markets.

In terms of the relationship between the researched variables and the dependent variable MRO, we highlight a significant relationship between MRO and EONIA rate and a positive relationship with HICP

(*Table 3*). This relationship between inflation and MRO is consistent with classical monetary policy theory. Higher inflation leads to an increase in refinancing operations as the central bank tries to provide sufficient liquidity in the market while controlling inflationary pressures. This is closely linked to the other dependent variable, inflation, which is a key monetary policy objective and has important implications for consumer prices, wages, and economic stability. The results demonstrate a link between inflation and the main refinancing operations, as well as between unemployment, which brings us back to their inverse relationship, to the objectives of the monetary authorities, and to the prevention against overheating of the economy. GDP is a key indicator of economic growth and economic performance, and several significant relationships between GDP and other variables in our model have been identified in the present study. A negative relationship with CISS (l1) leads to a decline in GDP (*Table 3*). This effect is consistent with studies on financial crises (Xie *et al*., 2024; Eichengreen *et al*., 2024; Halmai, 2021), which argue that in periods of high financial stress, investment declines, leading to a slowdown in economic growth. In practice, policies to reduce financial stress (e.g. bank bailouts) are critical to sustaining GDP growth in times of crisis. At the same time, a negative relationship with unemployment (l3) has an undesirable impact on GDP (*Table 3*), where higher unemployment means lower consumption and investment, which ultimately limits economic growth. Our findings highlight the importance of policies aimed at reducing unemployment to promote economic growth.

The IRFs and the decomposition of forecasting errors are also estimated. The IRFs reported in figures 2–8 present responses of selected macroeconomic and financial variables to shocks based on key indicators. Based on the IRFs for shocks to each variable, we determine how these shocks affect other key variables in the model. This analysis reveals the complex transmission mechanisms in the euro area, in particular through ECB monetary policy, financial stability, and macroeconomic outcomes.

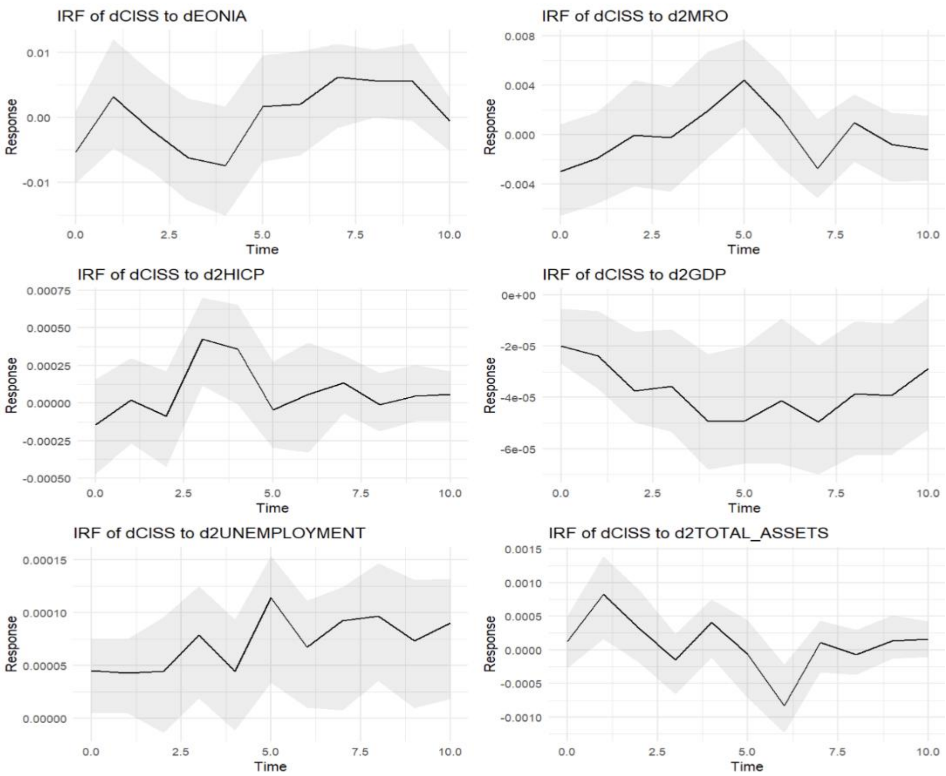


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Figure 2. **IRFs of CISS Shocks on Key Variables**

The impulse responses to financial stress shocks (*Figure 2*) show that the increase in financial stress negatively affects GDP and unemployment. The response of GDP to shocks in the CISS is significantly negative, suggesting that increased financial stress constrains economic activity and reduces economic growth. Consistent with our expectations, the response of unemployment to CISS shocks is accompanied by a gradual increase. Financial turbulence and systemic stress lead to higher uncertainty and a decline in the supply of jobs. CISS shocks influence the EONIA and MRO, too. It should be noted that the persistence of shocks is most pronounced for unemployment, where the effect persists beyond period 10. On the contrary, for GDP and total assets, the response is close to zero in the long run, indicating temporary effects.

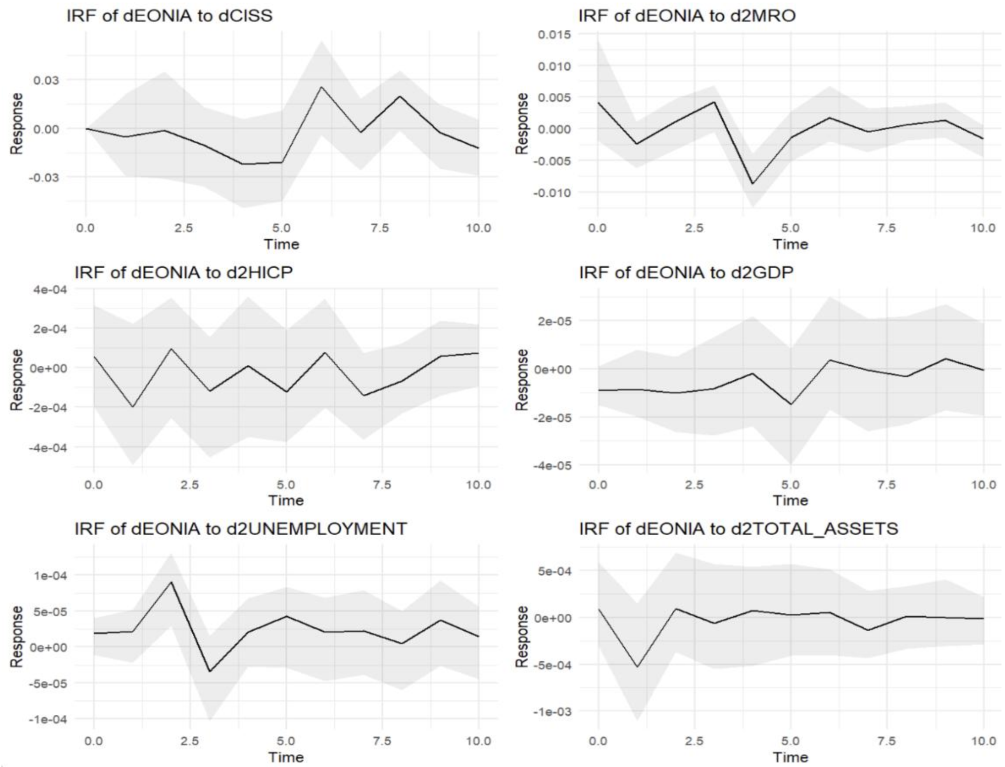

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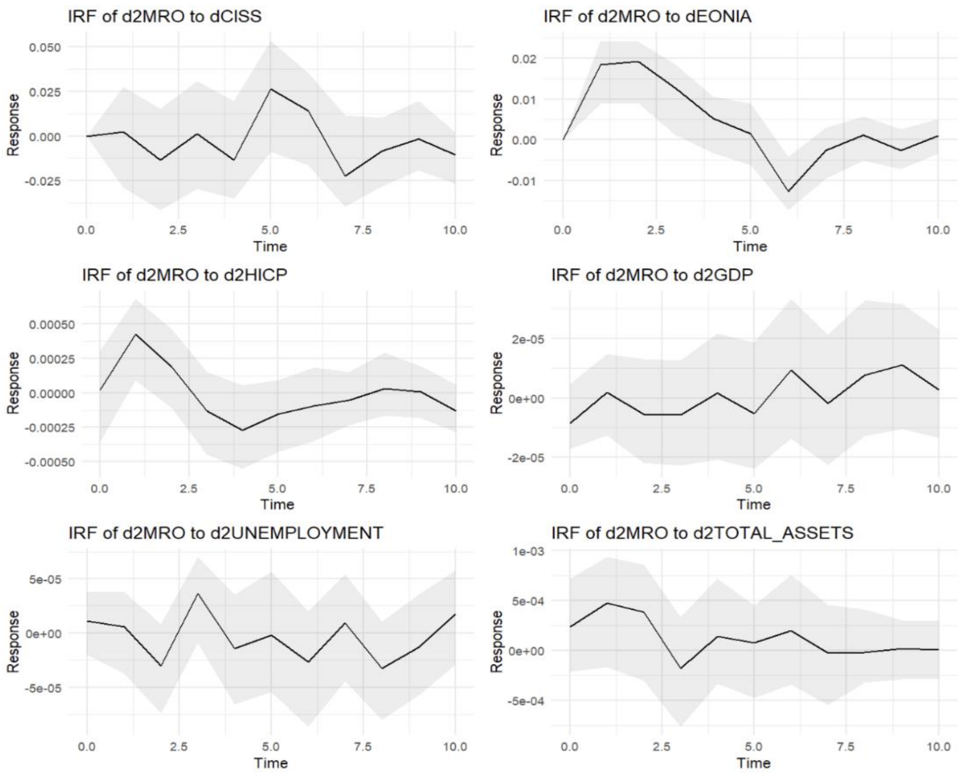
Figure 3. **IRFs of EONIA Shocks on Key Variables**

Regarding the shocks to the EONIA rate (*Figure 3*), the responses of GDP and unemployment are mixed. The response to shocks to the HICP is minimal, suggesting that shocks to the EONIA have a limited impact on inflation in the short term. The CISS rises modestly, suggesting that higher interest rates may cause some volatility in financial markets. Interestingly, the response of inflation to the EONIA shocks is modest. The response to EONIA shocks is most persistent for MRO and HICP, while the responses for total wealth and unemployment are more short-lived and dissipate more rapidly.

With regard to MRO shocks (*Figure 4*), the highest persistence is observed for the HICP. In the case of MRO shocks, which reflect changes in the volume of ECB refinancing operations, there is a significant response in EONIA, where shocks lead to an increase in short-term interest rates. Our findings are consistent with the ECB strategies consisting of refinancing operations to stabilise interest rates and liquidity in the banking sector.



Source: created by the authors.

Figure 4. **IRFs of MRO Shocks on Key Variables**

Figures 5–8 report additional IRFs for selected variables. As illustrated in *Figure 5A (Appendix 1)*, the responses of IRFs to HICP shocks are examined. *Figure 6A* demonstrates the responses of IRFs to GDP shocks. *Figure 7A* presents the responses of IRFs to unemployment shocks. The responses of IRFs on ECB total assets shocks are reported in *Figure 8*.

GDP responds negatively to HICP shocks (*Figure 5A*), which may indicate that rising inflation reduces real demand and economic growth. Inflation shocks lead to a stronger response in the CISS, where the response stabilises in the medium term. However, GDP responses have longer term persistence. In addition, the persistent impact of inflation is noticeable in the MRO and total assets, where responses remain significant after ten periods. Responses to shocks to GDP (*Figure 6A*) stabilise after five to seven periods in many variables, e.g. HICP. Financial stress and unemployment respond more strongly, but over extended periods the response flattens out. The impulse response functions of unemployment shocks exert a significant impact on all selected variables (*Figure 7A*). The effects are most notably observed in the MRO and the HICP. GDP responds strongly and negatively to unemployment shocks. *Figure 8A* indicates shocks to total assets, showing the strongest response in the first five periods following which the responses stabilise. Financial stress and GDP respond more slowly, with a gradual return to equilibrium over a longer time horizon

The FEVD results (*Figure 9*) provide insights into the relative influence of individual variables on changes in the dependent variables in the models. The extent to which each of the variables contributes to the prediction error of the individual variables over a horizon of 10 periods ahead is highlighted through the utilisation of FEVD. The findings of the present study demonstrate that the variance of the selected variables is often explained by the variable itself, but the influence of other factors, such as financial stress, interest rates or GDP, increases over time. The estimation results identify a number of interesting findings that point to dominant and strong relationships between the variables. CISS significantly affects its own variance. Even after 10 periods, FEVD suggests that about 85% of the variability of dCISS is explained by its own shocks. Financial stress is largely autonomous and highly persistent, with shocks to this variable persisting over the longer term. Over time, shocks from EONIA and ECB total assets become more significant, although their contribution is still smaller compared to internal and systemic stress, respectively. Interest rate shocks and expansionary monetary policy can contribute to the allevation or the increase of financial stress, but their impact is relatively smaller. EONIA is largely self-explanatory. Interestingly, MRO becomes an important factor, explaining up to approximately 19% of the variability in EONIA. This suggests a stronger link between ECB liquidity operations and interbank rates. Thus, it can be posited that financial stress is gradually becoming one of the factors where financial stress shocks can affect short-term interest rates in response to financial instability

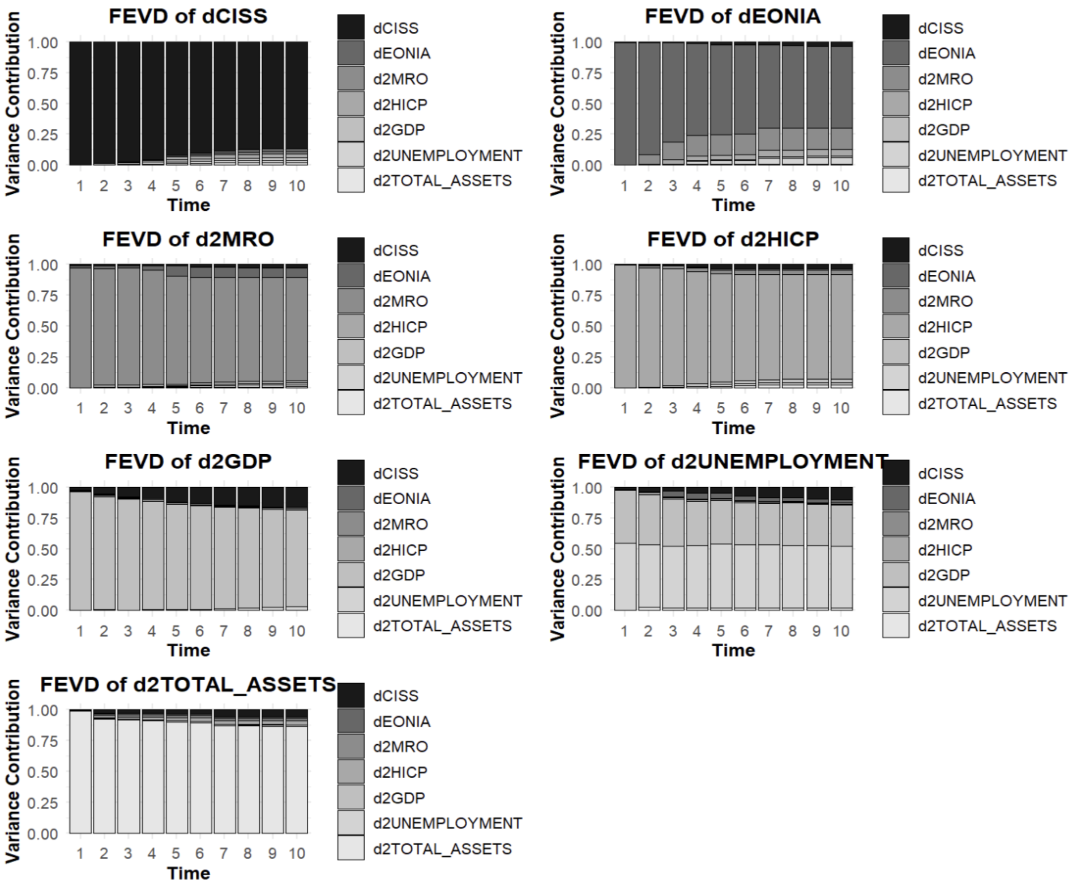


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Figure 9. **FEVD for Macroeconomic Variables**

Regarding the MRO, it has been determined that more than 80% of the variability (even after 10 periods) is explained by its own shocks. As these operations are a direct monetary policy instrument and are relatively stable, this result is in line with our expectations. The EONIA affects the variability of the MRO in the long run. This result confirms the relationship between ECB operations and interbank interest rates, where higher interest rates often imply a need for more liquidity through refinancing operations. The EONIA and the CISS also contribute to the variability of the MRO, implying that changes in interest rates and financial stress have some impact on the ECB's decision-making on monetary operations. In periods of stress, the volume of refinancing operations may be increased to stabilise the market. Besides, the MRO and total ECB assets contribute to the variability of the HICP. This finding implies that monetary policy influences inflation through MRO operations and asset purchases. FEVD uncovers impact of the shocks from EONIA and GDP on inflation. The results point to the fact that short-term interest rates and economic growth are important factors that influence inflation.

FEVD further reveals that the shocks from the CISS have a significant impact on the variability of GDP. It can be observed under condition of increased financial stress, which has an adverse effect on economic activity. Although GDP is affected by the EONIA rate and unemployment, their impact is relatively small. This suggests that financial conditions and labour market shocks are important but less dominant factors, in comparison to financial stress.

The results of the FEVD reveal that Unemployment is partly self-explained at approximately 50%. Interestingly, GDP starts to contribute significantly to the variance of unemployment and explains more than 33% of the variance after 10 periods. This suggests strong links between GDP shocks and unemployment, and a conclusion that economic growth (or its slowdown, stagnation) has a direct impact on the labour market. The CISS explains about 10% of the variation in unemployment. This finding would suggest that increased financial stress affects the labour market indirectly through reduced investment and labour demand during financial crises. The significant impact of GDP and total assets shocks from the ECB on unemployment highlights the importance of monetary policy for the labour market. In the event of the economic growth increase, GDP shocks reduce unemployment. At the same time, expansionary monetary policy through asset purchases can help to reduce unemployment. The CISS, with regards to unemployment, illustrates a significant impact which is related to rising unemployment rates in periods of financial stress. Understandably, the ECB's total assets are strongly explained by its own shocks (up to 86%) given the direct control of central banks over asset purchases.

Table 4. Summary of Key Relationships and Coefficients from the VAR Model

Relationship	Direction	Lags	Significance	Coefficient (β)
CISS -> CISS	-	4	significant	-0.1535
CISS -> Inflation	+	4	significant	14.6229
CISS -> GDP	-	4	significant	-453.8674
CISS -> EONIA	-	5	marginal	-0.5857
CISS -> Unemployment	+	1	significant	0.0002
EONIA -> MRO	+	1	highly significant	0.5861
EONIA -> Inflation	+	2	significant	3.26
EONIA -> MRO	+	3	highly significant	0.8150
EONIA -> Unemployment	+	3	marginal	33.2076
EONIA -> CISS	-	4	marginal	-0.0253
Total Assets -> EONIA	+	5	significant	1.75
Unemployment -> GDP	-	3	significant	-0.0927

Notes: negative vs. Positive relationships: the Direction column indicates whether the relationships are positive (+) or negative (-), showing if a variable increases or decreases after one unit increase in the independent variable.

Source: own calculations.

These results of FEVD help to observe the transmission mechanisms of monetary policy-that is, how shocks to interest rates affect inflation or economic growth through interbank rates and refinancing operations. This tool can be important in calibrating monetary policy measures. The responses of unemployment, inflation and GDP to different types of shocks were estimated and observed through FEVD for the purpose of the promotion of economic growth through the actions of monetary and fiscal authorities. The results of this study provide deeper insights into how monetary policy, financial shocks, and economic determinants interact to optimise policy decisions. *Table 4* summarises the most important results that highlight the relationships between variables from the VAR models.

The FEVD results are consistent with the findings of previous studies. Kremer (2015) shows a significant role of financial stress in relation to monetary policy in the euro area. Consistent with our results, he finds that the impact of CISS on inflation is milder compared to output growth. Our results confirm that changes in the unemployment rate and GDP growth occur when financial stress changes in the euro area, thereby causing countries to experience a decline in economic performance during periods of crisis. *Table 5* provides a concise summary of the key relationships between variables, as identified by the IRFs and FEVD analyses.

Table 5. Summary of Key Relationships from IRFs and FEVD

Relationship	IRF Highlights	FEVD Contribution to Variability
CISS -> GDP	Strong negative impact on GDP, persistent over time.	Low contribution of CISS to GDP variability.
CISS -> Unemployment	Gradual increase in unemployment following CISS shock.	CISS explains significant portion of unemployment.
CISS -> EONIA	Initial drop in EONIA, followed by stabilisation.	CISS explains small part of EONIA variability.
MRO -> GDP	Short-term positive effect on GDP, weakens over time.	MRO explains moderate portion of GDP variability.
Inflation -> GDP	Inflationary shocks reduce GDP growth in medium-term.	Inflation explains considerable part of GDP variability.
EONIA -> MRO	Significant positive effect on MRO in the short term.	EONIA explains a substantial part of MRO variability.
Unemployment -> GDP	Higher unemployment decreases GDP in medium-term.	Unemployment explains large portion of GDP variability.
GDP -> Inflation	Positive relation between GDP and inflation over time.	GDP moderately explained by inflation shocks.
Total Assets -> GDP	Total assets negatively affect GDP in the long run.	Total assets moderately contribute to GDP variability.

Notes: the combination of IRF and FEVD results offers a deeper understanding of how the euro area economy responds to multiple shocks.

Source: own calculations.

However, while Kremer (2015) observes a relatively lower response of inflation to financial stress, our results suggest a somewhat stronger impact of monetary shocks on inflation, which may be related to the inclusion of multiple shocks from 2020 onwards. These shocks have amplified inflationary pressures through supply chain disruptions and increased market uncertainty and other government and health constraints globally. The results of the present study are, to an extent, consistent with the results by Mallick and Sousa (2013), who highlight the complex relationship between financial stress and monetary policy. They find that ECB interventions help stabilise markets, but their effectiveness declines during severe financial crises, i.e. a conclusion that is also reflected by our estimations. In our results, we show that during periods of heightened financial stress, the response of GDP and unemployment to monetary policy shocks is stronger, highlighting the importance of unconventional monetary measures.

The findings of Garcia *et al*. (2021), which indicate that tighter monetary policy exacerbates financial risks, are consistent with other studies. However, our analysis does not show a significant worsening of financial stress. On the contrary, our data suggest that the ECB's efforts are quite effective in mitigating some of the adverse effects, such as on unemployment and GDP growth. The overall consistency but also the differences between our results and those in the literature can be explained by the inclusion of multiple shocks, such as the COVID-19 pandemic, other shocks, and geopolitical tensions, which are not included in previous studies. These events are likely to have influenced the dynamics between financial tensions, monetary policy and economic performance in the euro area.

Conclusions

The paper aims to test macroeconomic responses to financial stress and monetary policy, providing a comprehensive overview of the interplay between key macroeconomic variables. Inspired by research by Hollo *et al*. (2012) and Kremer (2015), we assess the role of the CISS index in influencing macroeconomic performance. More specifically, the interaction between the CISS, GDP, inflation, unemployment, MRO, and the EONIA is examined. The analysis covers the euro area consisting of 20 Member States, during the period from 1999 to 2023. We estimate different variants of Vector Autoregression (VAR) models, Impulse Response Functions (IRFs), and Forecast Error Variance Decomposition (FEVD) to obtain a detailed presentation of the relationship between the variables and to uncover macroeconomic responses to shocks among the researched variables.

The paper fills the gap in recent empirical research by analysing the selected variables over a longer period, including years marked by significant shocks, especially since 2020, e.g. the COVID-19 padenmic, war in Ukraine, and energy crisis. The pandemic caused a deep economic slump and immediately increased financial stress. As mentioned by the ECB President Christine Lagarde (2021) in the *2020 Annual Report*, the pandemic and other sharp external shocks caused the largest contraction in the world economy since the Great Depression. This has also significantly affected economic activity in the euro area.

The VAR model findings demonstrate significant connections between the observed variables. We find a significant negative impact of CISS on GDP, indicating that elevated levels of financial stress are associated with reduced economic activity. Concurrently, we observe a positive relationship between CISS and inflation. At the same time, a rising CISS distorts the EONIA rate and the transmission mechanisms of the ECB's monetary policy. Higher levels of financial stress restrict consumers' and firms' access to credit, leading to a reduction in consumption and investment and, ultimately, a fall in GDP.

FEVD results highlight the role of financial stress, GDP, and unemployment in explaining the majority of their own variability, but the impact of other instruments, including EONIA and MRO, increases over time. More than 33% of the variability in unemployment is explained by GDP after 10 periods. The results discussed in this study highlight the critical interaction between monetary policy and financial stability during periods of economic stress.

IRFs reveal a positive shock in financial stress that causes negative effects on economic performance, impacts the labour market, and leads to an increase in unemployment. Shocks to the CISS also negatively affect the ECB's traditional monetary policy tools, suggesting that financial stress limits their effectiveness.

This study contributes in demonstrating the adverse effects of crises and financial stress on the economy and its agents. The results show that systemic financial stress, as measured by the CISS, constrains GDP growth, increases unemployment, and undermines the effectiveness of the ECB's traditional monetary policy tools. The paper extends existing empirical research with an analysis of financial stress over a longer period during which several crises and multiple shocks have occurred since 2020 simultaneously. Our results underline the importance of estimated interactions of selected variables over the whole period including the period with multiple shocks. This permits us to extend the well-known and established facts. To our best knowledge there is no study considering the data during the period (till year 2023) of multiple shocks.

Unlike previous research (Kremer *et al.*, 2015), our results suggest a stronger relationship between financial stress and inflation in the period of multiple shocks after 2019. More specifically, Kremer finds that the relationship between financial stress and inflation is milder in earlier periods, but his time series do not include the multiple shocks. Moreover, in our results, we show that during periods of heightened financial stress, the response of GDP and unemployment to monetary policy shocks is stronger, highlighting the importance of unconventional monetary measures.

Regarding the suggestions for future research, our analysis uses a VAR model, which enables the estimation of the relationship between two variables with time lags, identification of bi-directional effects, and estimation of IRF after 1% shock and FEVD capturing decomposition of variability of each variable in the model. However, this approach may overlook non-linear relationships during extreme events. Therefore, in future research non-linear models could possibly better capture dynamics during crises, while also augmenting the selected variables with unconventional instruments to observe their interactions with financial stress. Additionally, future research could focus on individual euro area countries and examine differences between core and peripheral euro area nations. Nevertheless, the CISS (Composite Indicator of Systemic Stress) is not available for individual countries, only aggregated data for the whole euro area are available. The publicly available values of CISS are more relevant and verified. However, in the future, we would aspire to estimate CISS at the country level through our own calculations (using the value of stocks, bonds, and other financial indicators), as it could shed more light on individual country relations. Therefore, the results obtained in the present paper provide a basis for further research.

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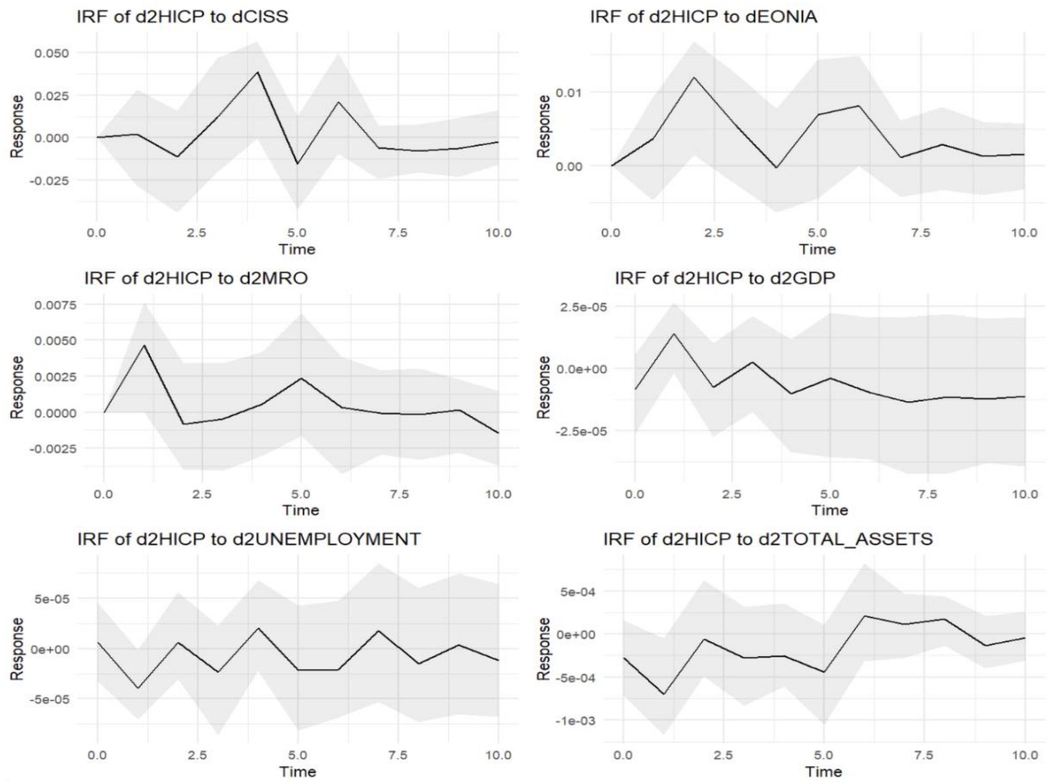
FINANSINĖS ĮTAMPOS IR PINIGŲ POLITIKOS SUSIPYNIMAS SU EKONOMINE DINAMIKA EURO ZONOJE: DAUGELIO SUKRĖTIMŲ POVEIKIS

Patrik Zihala, Marianna Sinicakova, Veronika Sulikova

Santrauka. Straipsnyje analizuojamas finansinės įtampos ir makroekonominių kintamųjų ryšys euro zonoje, daugiausia dėmesio skiriant kelių sukrėtimų laikotarpiui. Pasitelkus vektorinės autoregresijos (VAR) modelį ir remiantis 1999–2023 m. duomenimis, nagrinėjama sisteminės finansinės įtampos (CISS), BVP, infliacijos, nedarbo ir ECB pinigų politikos priemonių sąveika. Empiriniai rezultatai atskleidė, kad padidėjusi finansinė įtampa neigiamai veikia ekonominį aktyvumą, silpnina tradicinių pinigų politikos priemonių veiksmingumą ir žymiai prisideda prie nedarbo kintamumo. Impulso ir atsako funkcijos (IRF) modelio taikymas patvirtino, kad finansinės įtampos sukrėtimai lemia BVP mažėjimą ir infliacijos didėjimą, o jų poveikis laikui bėgant išlieka. Prognozės paklaidų variacijos dekompozicija (FEVD) leidžia pabrėžti finansinės įtampos, nedarbo ir kitų pagrindinių kintamųjų svarbą aiškinant bendrą ekonomikos kintamumą ir skatina akcentuoti būtinybę toliau tirti jų poveikį įvairiose verslo ciklo fazėse. Išvadose pateikiama naujų įžvalgų apie finansinių sukrėtimų perdavimo dinamiką ekonominėje ir pinigų sąjungoje, siūlomas empirinis pagrindas tolesniems finansinio stabilumo ir ekonominės politikos tyrimams, kai vienu metu vyksta keli sukrėtimai.

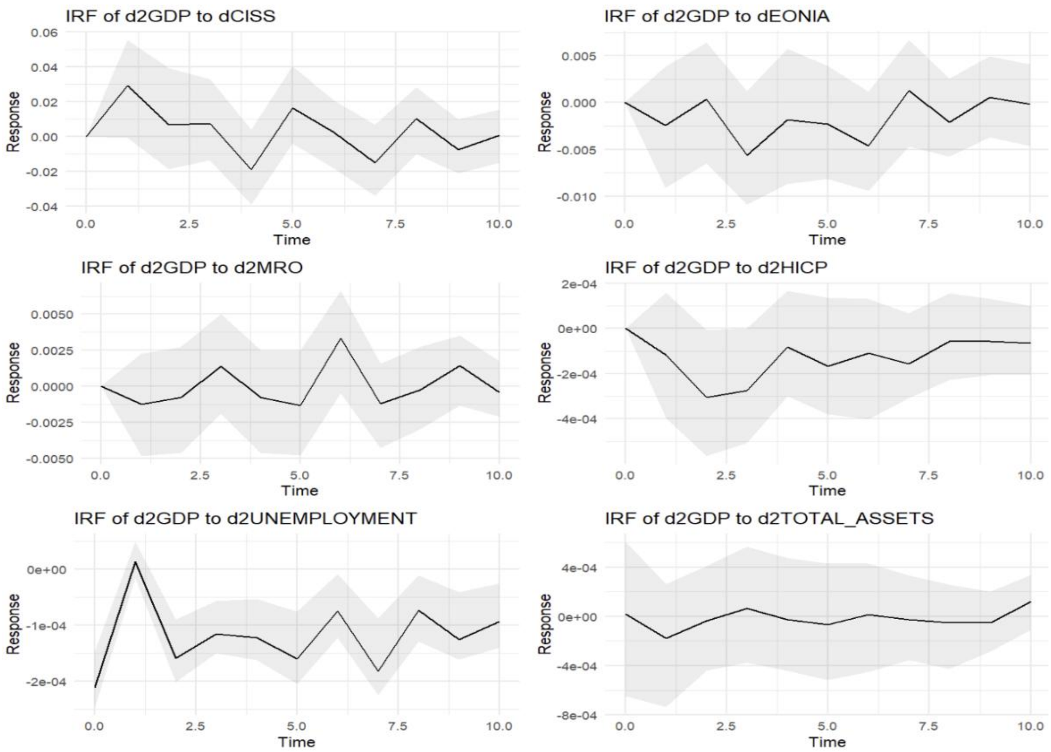
Reikšminiai žodžiai: finansinė įtampa; pinigų politika; vektorinės autoregresijos modelis; impulso ir atsako funkcijos; euro zona.

Appendix 1



Source: own results.

Figure 1. **IRFs of HICP Shocks on Key Variables**

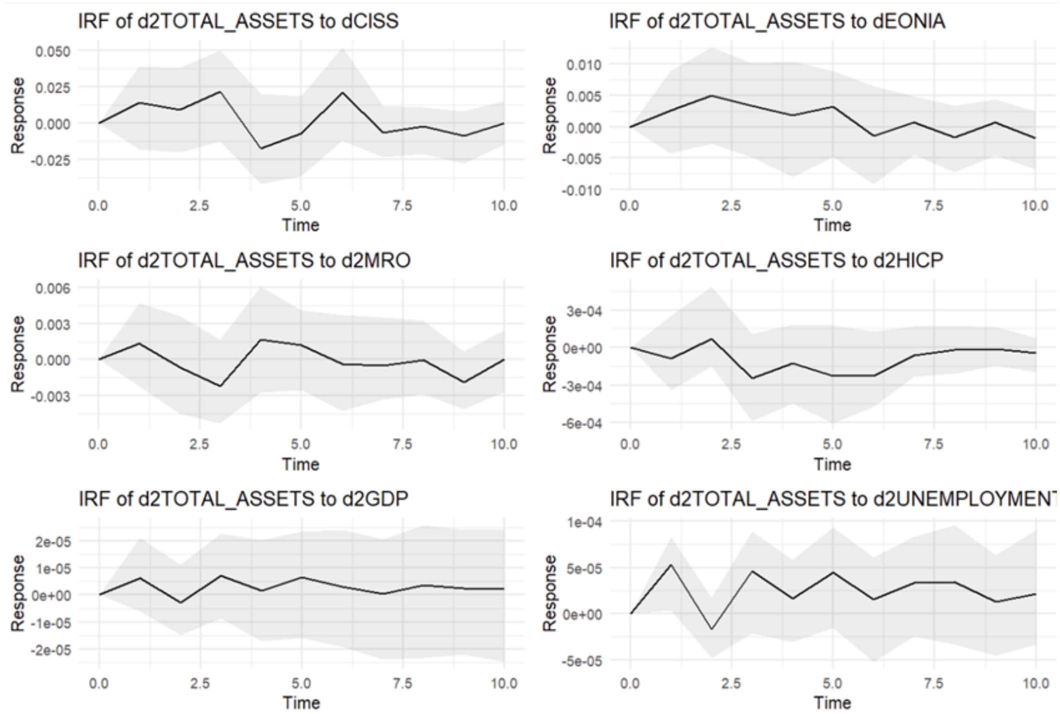


Source: own results.

Figure 2. **IRFs of GDP Shocks on Key Variables**

Source: own results.

Figure 3. **IRFs of Unemployment Shocks on Key Variables**



Source: own results.

Figure 4. **IRFs of Total Assets Shocks on Key Variables**