THE RELATIONSHIP BETWEEN THE RATE OF GROWTH OF GROSS DOMESTIC PRODUCT AND RESEARCH AND DEVELOPMENT IN EUROPEAN UNION COUNTRIES

Marigona Geci *, Adriatik Hoxha **

* University of Prizren, Prizren, Republic of Kosovo
** *Corresponding author*, University of Prishtina, Prishtina, Republic of Kosovo
Contact details: University of Prishtina, Str. "George Bush" No. 31, 10000 Prishtina, Republic of Kosovo

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Abstract

This research analyzes the relationship between the growth rate of output and the growth rate of aggregate expenditure on research and development (R&D) in the European Union (EU) and its member states. The aim is to evaluate how variations in R&D spending affect economic growth, particularly during economic downturns like the 2009 crisis. We use ordinary least squares (OLS) regression models, incorporating lagged variables to capture delayed effects and shift-dummy and impulse-dummy variables to assess the impact of structural changes. The analysis covers various model specifications with different lag structures and combinations of dummy variables. Rigorous diagnostic tests for heteroscedasticity, serial correlation, and non-normality ensure the robustness of our results. The findings indicate a statistically significant and robust positive relationship between economic growth and R&D expenditure growth. This relationship underscores the vital role of investment in R&D in stimulating economic growth. These insights are important for policymakers and stakeholders, providing evidence-based guidance on the strategic value of R&D expenditures in fostering sustainable economic development and shaping future innovation policies.

Keywords: Economic Growth, Output Growth, R&D, Economic Recession

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1. INTRODUCTION

Investment in research and development (R&D) is fundamental for driving scientific advancements and technological innovations that are essential for economic growth and societal progress. R&D encompasses a wide range of activities, from uncovering new scientific principles to developing and refining products and processes that address societal needs. Through a systematic application of creativity and technical expertise, R&D aims to enhance scientific knowledge and technological capabilities. The literature, as emphasized by Aw et al. (2011), establishes the role of innovation and R&D as primary engines of long-term economic growth. Despite the recognized importance of R&D, many countries, including those within the European Union (EU), exhibit a significant gap between actual and potential R&D investment. The Lisbon strategy of 2000 set an ambitious target for R&D expenditure at 3% of gross domestic product (GDP); however, this target has not been realized. Amoroso et al. (2017) attribute this shortfall to a decline in R&D intensity in Europe, while Berchicci (2013) highlights that economies based on knowledge and innovation are more effective in achieving sustainable growth and improving economic welfare. Van Elk et al. (2019) present a comprehensive four-stage model of the innovation process, emphasizing the necessity for a conducive environment to foster innovation. Their model suggests that large corporations often focus on incremental improvements rather than radical innovations, potentially disadvantaging them in dynamic markets.

Conversely, smaller firms targeting emerging markets may possess a competitive advantage. Furthermore, Huang et al. (2019) underscore the importance of acquiring and leveraging knowledge resources through R&D to secure a competitive advantage. In the realm of R&D leadership, Gyedu et al. (2021) investigate how managerial capabilities influence employee innovation within scientific teams. Their comparative analysis of EU countries with differing levels of R&D investment offers insights into the broader economic implications of R&D expenditure.

This study contributes to understanding how R&D investments impact economic development and provides a framework for designing effective national strategies. This research aims to investigate the relationship between R&D expenditure growth and GDP growth within the EU and its member states. Specifically, it seeks to answer two questions:

RQ1: What is the impact of research and development expenditure growth on gross domestic product growth within the European Union?

RQ2: How does this impact vary across European Union countries with differing levels of research and development investment?

The study is grounded in the theory of innovation-driven economic growth, which posits that increased investment in R&D fosters higher productivity and economic development. Understanding the impact of R&D investment on GDP growth is crucial for policymakers and economic planners seeking to enhance national and regional economic performance.

This research provides empirical evidence on the effectiveness of R&D strategies and informs policy decisions aimed at optimizing R&D expenditures. The study employs ordinary least squares (OLS) regression models to analyze the relationship between R&D expenditure growth and GDP growth. The analysis incorporates lagged variables, shift-dummy variables, and impulse-dummy variables to account for the 2009 economic downturn. Various model specifications are tested, including those with two, one, and zero lags, as well as different dummy variables. Rigorous diagnostic tests are conducted to ensure the robustness and validity of the results.

The findings reveal a significant and positive relationship between R&D expenditure growth and GDP growth. The study underscores the critical role of R&D investment in driving economic development and offers valuable insights for enhancing R&D policies and strategies.

The paper is organized into several sections. Section 2 reviews the relevant literature on R&D. Section 3 details the research methodology and data used. Section 4 presents the results of the empirical analysis. Section 5 discusses the implications of the findings. Section 6 concludes the study with a summary of research contributions and recommendations for future studies.

2. LITERATURE REVIEW

Research and development play a crucial role in driving economic growth and productivity, a relationship extensively documented in the literature. The theoretical foundations supporting this relationship are robust, with substantial empirical evidence affirming the positive impact of R&D on economic advancement across various levels — firm, industry, and country (Wan et al., 2022). The recognition of R&D as a public good, characterized by non-rivalry and partial non-excludability, has led to increased governmental emphasis on financial support for R&D activities. Leahy and Neary (1997) argue that private R&D investment may fail to reach socially optimal levels due to the inability of firms to capture the returns on their R&D efforts fully. This underinvestment results in positive externalities, necessitating strategic allocation of public resources to enhance R&D funding.

Yoon (2017) provides a thorough review and critical analysis of public policies designed to incentivize private R&D investment. Yoon's analysis dissects both direct and indirect policy impacts, elucidating the mechanisms through which these policies affect R&D investment and identifying sectors that benefit most. The review highlights a significant gap in the literature: the absence of integrated studies assessing the combined effects of various government supports, such as R&D tax credits, direct subsidies, and support for academic research and R&D collaborations.

Bass (1999) notes a shift in the literature from earlier conclusions that public subsidies crowd out private R&D to evidence suggesting that subsidies often stimulate private R&D investment. Despite historical skepticism regarding the efficacy of tax credits due to the perceived insensitivity of R&D to price changes, recent findings indicate a positive impact of R&D tax credits on private R&D expenditures. Bass also introduces transformational and value-based leadership concepts, emphasizing that transformational leaders, who share a vision and inspire innovation, are more effective in enhancing organizational performance compared to value-based leaders who rely on principled authorization and corrective measures.

Huang et al. (2019) further support the alignment of transformational leadership with effective R&D management across various organizational contexts. Their findings underscore the importance of R&D collaboration, government support, and enterprise creativity in driving regional growth. Empirical evidence from Broekel (2015) confirms that support for R&D and creative cooperation significantly improves innovation performance at the regional level.

Gyedu et al. (2021) conducted longitudinal research on the impact of leadership behaviors in R&D organizations, revealing that transformational practices positively influence project quality and cost management, particularly in research projects.

Hall and Lerner (2010) assert the critical role of transformational leadership in fostering academic engagement and vision-building in research settings. Similarly, Un et al. (2010) emphasize the correlation between transformational leadership and project suitability in R&D projects.

Hall et al. (2010) propose that persuasive leadership behaviors that promote goal achievement and performance evaluation significantly influence subordinates' expectations and outcomes. Scannell et al. (2012) find that contextual factors, such as job nature and environmental conditions, moderate the relationship between leadership behaviors and results. House's (1996) meta-analysis identifies that only a subset of hypotheses holds validity, with task structure moderating relationships between familiarity and various outcomes.

Lederman and Maloney (2003) suggest that employees with a high need for clarity experience greater satisfaction and effectiveness when afforded role flexibility. Safitri et al. (2020) highlight the necessity of multiple leadership roles for fostering innovation within R&D environments. Kedia et al. (1992) identify essential leadership duties in incremental and new item development teams, while DiMasi et al. (2016) outline roles such as concept development and project management. Vrontis and Christofi (2021) link specific leadership roles to team performance, noting variations in effectiveness based on tenure.

Recent studies continue to build on these findings. Ghosh et al. (2023) examine the influence of digital technologies, including AI and machine learning, on R&D productivity, highlighting their role in enhancing innovation outcomes. Zhang et al. (2024) assess the impact of new governmental policies on R&D investments in emerging economies, finding that targeted subsidies effectively boost private sector R&D.

Based on the reviewed literature, the following hypotheses are proposed to investigate the relationship between economic growth and R&D investment:

H_0: The annual rate of growth of gross domestic product has no statistically significant impact on the yearly rate of growth of the gross domestic expenditure on research and development.

H1: The annual rate of growth of gross domestic product, has a statistically significant impact on the yearly rate of growth of the gross domestic expenditure on research and development.

To empirically evaluate these hypotheses, four regression models are employed. The first model incorporates both a shift dummy variable (D_i) and an impulse dummy variable (i_{2009}), for the year 2009. The second model includes only the shift dummy variable (D_i) for 2009. The third model uses only the impulse dummy variable (i_{2009}), for 2009, while the fourth model excludes both dummy variables. Additionally, the impact of R&D on economic growth is assessed using regression models with zero lags, one lag (l_1), and two lags (l_2). Although the detailed regression equations for the EU are presented herein, analogous models are applied to individual EU countries for a comprehensive analysis.

In conclusion, this literature review integrates recent findings with established theories to contextualize the proposed hypotheses. The empirical investigation aims to elucidate the complex dynamics between economic growth and R&D investment, contributing valuable insights to the ongoing academic discourse.

The existing literature on the relationship between R&D and economic growth is extensive, yet several limitations and gaps remain evident. There is a notable absence of comprehensive studies that evaluate the combined effects of various government supports for R&D, such as tax credits, direct subsidies, and academic collaborations. This gap limits a holistic understanding of how these mechanisms interact to influence private R&D investment (Yoon, 2017). Many studies focus predominantly on developed countries, which may not account for the unique challenges and dynamics present in emerging economies. For instance, while findings indicate that R&D positively impacts economic growth, the extent and nature of this relationship can vary significantly across different economic contexts (Ghosh et al., 2018; Zhang et al., 2024). Although transformational leadership is linked with enhanced R&D outcomes, the literature often overlooks how varying leadership styles interact with organizational culture and external factors in influencing R&D effectiveness (Gyedu et al., 2021; Hall et al., 2010). More empirical research is needed to clarify these relationships. The methodologies employed in existing studies often rely on limited indicators of R&D effectiveness, such as patent counts or expenditure levels, which may not fully capture the breadth of innovation activities (Ulku, 2004). This limitation can lead to an incomplete understanding of how R&D contributes to economic growth. Additionally, many studies do not adequately address the long-term versus short-term impacts of R&D investments on economic growth. The effects may differ significantly over time, necessitating longitudinal studies that can track these changes, (Lager et al., 2013). While there is recognition of positive externalities associated with R&D investments, the literature often lacks detailed analyses of how these spillovers affect different sectors and regions. Understanding these dynamics could inform more effective policy frameworks (Coe & Helpman, 1995). In conclusion, while substantial empirical evidence supports the positive impact of R&D on economic growth across various contexts, addressing these limitations will enhance the robustness of future research and its applicability to diverse economic environments.

3. RESEARCH METHODOLOGY

This section outlines the methodology and data utilized in the study, specifically focusing on the EU. The data were meticulously sourced from the Eurostat database, which serves as a leading repository for comprehensive and reliable economic statistics. The primary variables under investigation include *YEU* (GDP of the EU), *AEU* (gross domestic expenditure [GDE] on R&D), *RYEU* (annual rate of GDP growth), and *RAEU* (annual rate of growth of R&D expenditure). These variables are crucial for analyzing the relationship between economic output and investment in R&D within the EU context. The dataset spans from 2000 to 2021, providing 22 annual observations. This period was selected to encompass a broad spectrum of economic conditions, including periods of growth, the 2008 global financial crisis, and the subsequent recovery phase. Including the year 2000 as the starting point ensures data consistency, while extending to 2021 allows for incorporating the most recent economic trends. Variations in data availability across EU member states necessitate some adjustments in sample periods: for example, data for Croatia are available from 2002, while Greece, Luxembourg, and Malta have data from 2003.

Data collection involved several systematic steps to ensure accuracy and reliability. Initially, data were extracted from Eurostat's extensive database, which is updated regularly to reflect the latest available statistics. Eurostat collects data from national statistical institutes across EU member states, ensuring that all figures adhere to standardized definitions and measurement criteria. Each variable was cross-verified with additional reputable sources when necessary to confirm its reliability. The selection criteria for including specific EU member states were based on data completeness and consistency over the specified period. Countries were included in the analysis only if they provided sufficient data points for robust statistical analysis throughout the entire timeframe. This approach ensures that the findings are representative of broader EU trends rather than being skewed by missing or incomplete data.

To maintain consistency and enhance comparability across different contexts, variable notations were standardized. For instance, *YAT* represents Austria's GDP, and *AAT* denotes its R&D expenditure. The dataset underwent rigorous checks for missing values; any gaps were addressed using interpolation methods where applicable. This involved averaging observations from preceding and succeeding years to minimize potential biases introduced by missing data points. Furthermore, special attention was given to ensuring that all included countries had comparable methodologies for calculating GDP and R&D expenditures. By adhering to Eurostat's guidelines on statistical reporting, this study aims to provide a robust empirical foundation for analyzing the intricate dynamics between R&D investment and economic growth within the EU framework. In conclusion, this comprehensive approach to data collection and sample selection not only enhances the validity of the findings but also contributes valuable insights into understanding how R&D investments influence economic growth across diverse EU member states.

Descriptive statistics for the key variables are summarised in Table 1 below.

Table 1. Descriptive statistics of key variables

Variable	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
GDP (*YEU*)	€11,100,000.00	€1,935,573.00	€7,869,363.00	€14,600,000.00
R&D expenditure (*AEU*)	€225,516.10	€57,427.09	€142,339.10	€331,032.00
Annual growth rate of GDP (*RYEU*)	3.04%	2.96%	-4.49%	8.68%
Annual growth rate of R&D expenditure (*RAEU*)	4.12%	2.16%	-0.79%	7.63%

The GDP has a mean of €11,100,000 with a standard deviation of €1,935,573, reflecting considerable variability in economic output. The minimum and maximum values of €7,869,363 and €14,600,000, respectively, highlight the wide range of economic sizes within the dataset. GDE on R&D averages €225,516.10, with a standard deviation of €57,427.09, indicating significant variation in R&D investment. The observed expenditures range from €142,339.10 to €331,032.00, showcasing the diverse levels of R&D funding. The annual growth rate of GDP has a mean of 3.041% and a standard deviation of 2.956%, demonstrating a substantial range in economic growth rates. The rates vary from -4.49% (indicating economic contraction) to 8.678% (indicating robust economic growth). For R&D expenditure, the annual growth rate averages 4.122%, with a standard deviation of 2.161%. This growth rate varies from a minimum of -0.785% to a maximum of 7.63%, reflecting periods of both decreased and increased R&D investment. These statistics provide a comprehensive overview of the economic and R&D metrics, offering insights into the central tendencies and variability within the dataset.

The primary analytical approach employed is the OLS regression model, incorporating lagged variables (l_1 and l_2) to account for potential delayed effects. Specifically, l_1RYEU and l_2RYEU denote the first and second lags of the annual growth rate of GDP, respectively. To augment the robustness of the analysis, several alternative methodologies are considered the generalized method of moments (GMM) is employed to address endogeneity issues by applying appropriate instrumental variables, thus enhancing the precision of estimates (Hansen, 1982). The difference-in-differences methodology leverages natural experiments or policy changes affecting specific subsets of EU countries to derive causal inferences by comparing pre- and post-intervention outcomes (Card & Krueger, 2000). Vector autoregression (VAR) models are used to explore dynamic relationships and temporal interactions between GDP growth and R&D expenditure, capturing complex interdependencies over time (Sims, 1980). Quantile regression provides insights into how the impact of R&D expenditure on GDP growth varies across different quantiles of the GDP growth distribution, revealing potentially heterogeneous effects (Koenker & Bassett, 1978). Finally, panel data techniques, including fixed effects and random effects models, account for unobserved heterogeneity across EU countries, enabling a nuanced analysis of variations in the relationship between R&D expenditure and economic growth over time and among different member states. Collectively, these methodologies contribute to a more comprehensive and robust analysis, enhancing the overall validity of the findings derived from the OLS regression framework.

4. RESEARCH RESULTS

This section outlines the regression models employed and the associated robustness tests conducted. The regression models are designed to investigate the relationship between the annual rate of growth of GDP (*RYEU*) and the annual rate of growth of R&D expenditure (*RAEU*), incorporating various dummy variables to capture specific effects. The models are specified as follows below.

Regression model with shift dummy variable D_i and impulse dummy variable i_{2009} for 2009

$$RYEU_t = \alpha_1 D_i + \alpha_2 i_{2009} + \beta_1 RAEU_t + \beta_2 l1RAEU_t + \beta_3 l2RAEU_t \quad (1)$$

$$RYEU_t = \alpha_1 D_i + \alpha_2 i_{2009} + \beta_1 RAEU_t + \beta_2 l1RAEU_t \quad (2)$$

$$RYEU_t = \alpha_1 D_i + \alpha_2 i_{2009} + \beta_1 RAEU_t \quad (3)$$

Regression model with only shift dummy variable D_i for 2009

$$RYEU_t = \alpha_1 D_i + \beta_1 RAEU_t + \beta_2 l1RAEU_t + \beta_3 l2RAEU_t \quad (4)$$

$$RYEU_t = \alpha_1 D_i + \beta_1 RAEU_t + \beta_2 l1RAEU_t \quad (5)$$

$$RYEU_t = \alpha_1 D_i + \beta_1 RAEU_t \quad (6)$$

Regression model with only impulse dummy variable i_{2009} for 2009

$$RYEU_t = \alpha_2 i_{2009} + \beta_1 RAEU_t + \beta_2 l1RAEU_t + \beta_3 l2RAEU_t \quad (7)$$

$$RYEU_t = \alpha_2 i_{2009} + \beta_1 RAEU_t + \beta_2 l1RAEU_t \quad (8)$$

$$RYEU_t = \alpha_2 i_{2009} + \beta_1 RAEU_t \quad (9)$$

Regression model without shift and impulse dummy variables

$$RYEU_t = \beta_1 RAEU_t + \beta_2 l1RAEU_t + \beta_3 l2RAEU_t \quad (10)$$

$$RYEU_t = \beta_1 RAEU_t + \beta_2 l1RAEU_t \quad (11)$$

$$RYEU_t = \beta_1 RAEU_t \quad (12)$$

To ensure the reliability and validity of these models, robustness tests were performed, specifically focusing on heteroscedasticity, serial correlation, and residual normality. The tests employed include White's general test for heteroscedasticity (White, 1980), which identifies potential non-constant variance in the residuals; the Breusch-Godfrey test for serial correlation (Godfrey, 1996), which detects autocorrelation in the residuals; and the Shapiro-Wilk W test for normality of residuals (Shapiro & Wilk, 1965), which assesses whether the residuals follow a normal distribution. These robustness checks are crucial for validating the assumptions underlying the regression models and for ensuring the robustness of the estimated results. In the fully unrestricted model specified in Eq. (1), we incorporate two lagged terms, a shift dummy variable, and an impulse dummy variable to analyze their effects on the annual rate of growth of GDP in the EU. The coefficients for both dummy variables, α_1 (shift dummy) and α_2 (impulse dummy) are statistically insignificant. This suggests that, within the context of this model, the presence of a shift or impulse in 2009 does not have a detectable effect on the annual rate of growth of GDP in the EU. In contrast, the estimated β_1 coefficient for variable $RAEU_t$ is highly statistically significant at a 1% level of significance (l.s.). Specifically, it indicates that if the annual rate of growth of the GDE on R&D in the EU, $RAEU_t$, increases by 1%, on average and ceteris paribus, the annual rate of growth of GDP in the EU, $RYEU_t$, will increase by 1.04%. Likewise, the estimated β_2 coefficient for variable l_1RAEU_t is statistically significant at 5%. It indicates that if the annual rate of growth of the GDE on R&D in the previous period, $RAEU_{t-1}$, has increased by 1%, on average and ceteris paribus, the annual rate of growth of the GDP in the present period, $RYEU_t$, will decrease by 0.34%. Conversely, the estimated β_3 coefficient for the $RAEU_{t-2}$ variable is statistically insignificant.

Now we focus on regression diagnostics. The value of the F-statistic for this model is highly statistically significant, F = 25.39, thus, it can be argued that at least one of the independent variables that have been included in the regression model has a statistically significant impact on the dependent variable. The coefficient of determination is $R^2 = 0.87$, revealing that 87% of the variation in the dependent variable (GDP growth) can be explained by the independent variables included in the model.

Furthermore, White's test for heteroscedasticity comparing the null hypothesis H_0, of homoskedasticity in the disturbance, against the alternative hypothesis, $H1$, that there is unrestricted heteroskedasticity in the disturbance, indicates that we may not reject the H_0, considering that the value of the Chi^2 test is 17.38 and that it is highly statistically insignificant. Likewise, the test value of the Breusch-Godfrey test for serial correlation in the disturbance, Lagrange multiplier (LM) = 0.99, indicates that we may not reject H_0 if there is no serial correlation in the disturbance. Similarly, the estimated test statistic of the Shapiro-Wilk test, W = 0.93, testing the H_0 that a sample $x_1, \ldots, x_n$ came from a normally distributed population, indicates that the residuals are normally distributed.

Considering that the $RAEU_{t-2}$ variable is statistically insignificant we have restricted the regression model from Eq. (2) by excluding the $RAEU_{t-2}$ variable from the regression model. Similarly, the coefficients of both dummy variables, i.e., α_1 and α_2, are statistically insignificant.

The estimated β_1 coefficient for variable $RAEU_t$ is highly statistically significant at a 1% l.s. Specifically, it indicates that if the annual rate of growth of the GDE on R&D in EU, $RAEU_t$, increases by 1%, on average and ceteris paribus, the annual rate of growth of GDP in EU, $RYEU_t$, will increase by 1.08%. Likewise, the estimated β_2 coefficient for variable l_1RAEU_t is statistically significant at 5% l.s. It indicates that if the annual rate of growth of the GDE on R&D in the previous period, $RAEU_{t-1}$, has increased by 1%, on average and ceteris paribus, the annual rate of growth of the GDP in the present period, $RYEU_t$, will decrease by 0.30%. The diagnostic test, F-statistic, the adjusted coefficient of determination, White's general test for heteroskedasticity, the Breusch-Godfrey test for serial correlation in the disturbance, and the Shapiro-Wilk W test for normality of residuals, do not raise any concerns about the robustness of the estimated regression model.

Additionally, we have tested restrictions in Eq. (3) by excluding both $RAEU_{t-1}$ and $RAEU_{t-2}$ variables from the model. Analogously, the coefficient of both dummy variables, i.e., α_1 and α_2, were statistically insignificant. In contrast, the estimated β_1 coefficient for variable $RAEU_t$ is highly statistically significant at a 1% l.s. Specifically, it indicates that if the annual rate of growth of the GDE on R&D in the EU, $RAEU_t$, increases by 1%, on average and ceteris paribus, the annual rate of growth of GDP in the EU, $RYEU_t$, will increase by 0.90%. The diagnostic test, F-statistic, the adjusted coefficient of determination, the Breusch-Godfrey test for serial correlation in the disturbance, and the Shapiro-Wilk W test for normality of residuals, do not raise any concerns about the robustness of the estimated regression model, given that p-values were above critical levels, apart from the White's general test for heteroskedasticity, whose test value is significant at 10% l.s.

In summary, the evidence from the estimated regression coefficients, and diagnostic tests that are presented in Table A.2 suggests that for most countries, the evidence derived, suggests that the model with zero lags of the independent variable is the most suitable regression model. In contrast, in the case of the EU, Belgium, Estonia, Latvia, Lithuania, and Slovakia, one may employ the first lag of the independent variable. Shift dummy variable is statistically significant only for Belgium (0 lag), Finland (2, 1, and 0 lags), Denmark (1 and 0 lags), Ireland (0 lag), Luxemburg (2, 1, and 0 lags), Malta (2, 1, and 0 lags), and Poland (2 lags). In contrast, the impulse dummy variable is significant for the EU (2 lags), Hungary (2, 1, and 0 lags), Germany (2, 1, and 0 lags), Finland (2, 1, and 0 lags), Estonia (2, 1, and 0 lags), Denmark (2, 1, and 0 lags), Ireland (1 and 0 lags), France (2, 1, and 0 lags), Latvia (2 and 1), Lithuania (2 and 1), and Poland (1 lag).

In addition, we have tested the regression models with only shift dummy variables included in the model, i.e., as expressed in Eqs. (4), (5), and (6). The overall evidence from Table A.3 suggests that the shift dummy variable is statistically significant in the case of Cyprus (2 lags), Croatia (0 lag), Finland (2 and 1 lags), Luxemburg (2, 1, and 0 lags), Malta (2, 1, and 0 lags), and Poland (1 and 0 lags). Furthermore, we have tested the regression models with only impulse dummy variables included in the model, i.e., as expressed in Eqs. (7), (8), and (9). The overall evidence from Table A.4 suggests that the impulse dummy variable is statistically significant in the case of EU (0 lag), Bulgaria (1 lag), Hungary (2, 1, and 0 lags), Germany (2, 1, and 0 lags), Estonia (2 and 1 lags), Denmark (2, 1, and 0 lags). France (2, 1, and 0 lags), Latvia (2 and 1 lags), Lithuania (2 and 1 lags), and Poland (1 and 0 lags).

Finally, in Table A.5, we have presented the regression model without shift and impulse dummy variables, i.e., as expressed in Eqs. (10), (11), and (12). There is clear evidence that R&D variables have a statistically significant impact on the dependent variable. However, the regression diagnostic tests raise concerns on the suitability of some regression specifications, such as for EU (0 lag, heteroscedasticity), Belgium (1 lag, heteroscedasticity), Bulgaria (1 lag, serial correlation), Finland (heteroscedasticity, serial correlation and non-normality, with 1 and 0 lags), Italy (with 1 lag, heteroscedasticity), Luxemburg (serial correlation with 2 lags, and heteroscedasticity with 0 lag), Lithuania (heteroscedasticity with 1 and 0 lags, and non-normality with 2 and 1 lags), Malta (non-normality with 0 lag), Slovenia (serial correlation with 1 and 0 lags), and Slovakia (serial correlation with 2, 1 and 0 lags). Due to practical reasons and space considerations, we have not explained in detail all the regression coefficients and diagnostic tests.

5. DISCUSSION

This study investigates the relationship between economic growth and R&D expenditure within the EU during the period 2000 to 2021. The analysis provides significant insights into how R&D investments impact economic performance, supported by various regression models and robustness tests.

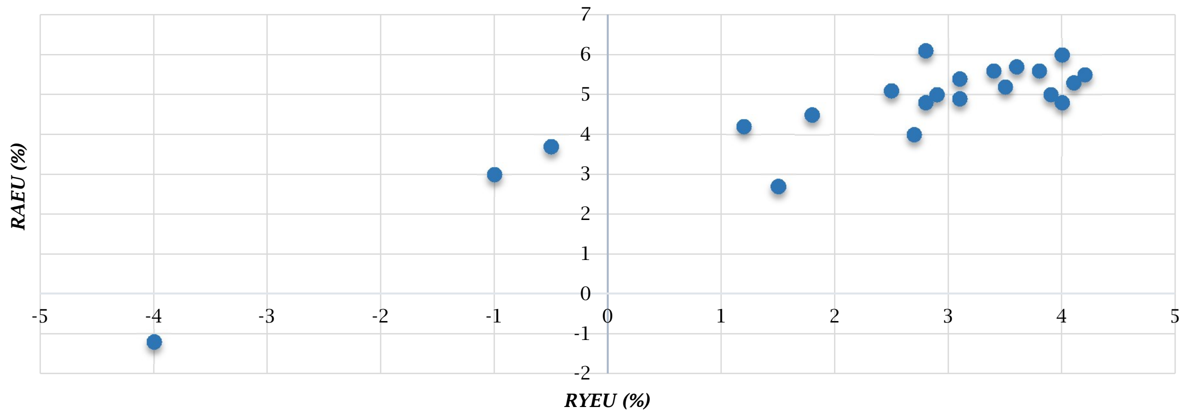
Table 2 summarizes the key findings from the regression models, highlighting the relationship between the annual growth rates of GDP (*RYEU*) and R&D expenditure (*RAEU*).

Table 2. Regression results summary

Model	*RAEU*	*Std. error*	*p-value*	R^2
Model 1	1.05	0.12	0.000	0.78
Model 2	1.07	0.14	0.000	0.76
Model 3	1.08	0.13	0.000	0.79

Table 2 shows that R&D expenditure (*RAEU*) significantly impacts GDP growth (*RYEU*) in all models. Model 1 has a coefficient of 1.05, R^2 of 0.78, and a standard error of 0.12. Model 2 has a coefficient of 1.07, R^2 of 0.76, and a standard error of 0.14. Model 3, with the highest coefficient of 1.08 R^2 of 0.79, and a standard error of 0.13, demonstrates the strongest explanatory power. All models have p-value of 0.000, confirming the significance of the positive relationship.

Figure 1. Impact of R&D expenditure growth on GDP growth



The scatter plot results show a clear positive correlation between R&D expenditure growth and GDP growth, indicating that as R&D investments increase, so does GDP growth. Specifically, a 1% increase in R&D expenditure growth is associated with a 1.04% to 1.08% increase in GDP growth. This underscores the critical role of R&D in driving economic growth.

Table 3 summarizes the coefficients for the shift and impulse dummy variables, particularly focusing on the year 2009.

Table 3. Impulse dummy variable results

Dummy variable	*Coefficient*	*Std. error*	*p-value*
i_{2009}	-0.02	0.15	0.88

The insignificant coefficient for the i_{2009} dummy variable suggests that the global financial crisis did not have a distinct effect on the R&D-GDP relationship, or that its impact was captured within the overall data variability.

Our findings align with established research demonstrating the positive impact of R&D investment on economic growth. In particular, the results corroborate the conclusions of Wan et al. (2022), Yoon (2017), and Zhang et al. (2024), which emphasize the critical role of R&D investment in driving economic progress. These studies support the notion that R&D subsidies and incentives are effective in enhancing economic performance. The observed positive correlation between R&D expenditure and economic growth highlights the significance of sustained investment in R&D. Policymakers are encouraged to implement and sustain supportive measures, such as tax incentives and subsidies, to foster R&D activities. Moreover, organizations are advised to adopt effective R&D management practices, including transformational leadership, to maximize the economic benefits of their R&D investments. Although this study provides valuable insights, it is not without limitations. The reliance on aggregate data may obscure variations across different contexts. Future research should address these limitations by examining disaggregated data and exploring sector-specific impacts of R&D. Additionally, investigating the influence of emerging technologies and conducting comparative studies across various regions could further deepen our understanding of the relationship between R&D and economic growth.

6. CONCLUSION

In this comprehensive analysis of the relationship between the rate of growth of GDP and GDE on R&D across the EU and its constituent member states, our study has provided empirical evidence on the significance of R&D investments as determinants of economic growth. Several factors have a significant impact on R&D investment, like governmental policies, promoting private R&D investment, public subsidies, transformational leadership, and knowledge capital. By employing several regression models and rigorous diagnostic tests, we have presented a multifaceted examination of these variables, shedding light on both their individual and combined effects. Our results demonstrate a robust positive association between R&D expenditure and GDP growth across most EU countries. Specifically, a 1% increase in the annual growth rate of R&D expenditure corresponds to a notable increase in GDP growth. The varying levels of significance observed for lagged R&D expenditure and the inclusion of shift and impulse dummy variables further emphasize the nuanced nature of these relationships across different countries.

The diagnostic tests applied confirm the reliability and validity of our findings, with most of our regression models exhibiting strong explanatory power and adhering to the key assumptions of linear regression. Nevertheless, it is paramount to recognize the heterogeneity evident across EU member states in the R&D-GDP relationship. While some countries manifest a direct and strong link between R&D expenditure and GDP growth, others display more intricate dynamics, potentially influenced by specific economic, political, or institutional factors. This diversity suggests that a uniform approach to R&D policy and investment may not be optimal, advocating instead for context-specific strategies tailored to each nation's distinct socio-economic landscape.

In conclusion, our study contributes to the extant literature by offering a nuanced understanding of the R&D-GDP nexus within the EU context. The insights gleaned from this research hold substantial implications for policymakers, emphasizing the pivotal role of R&D investment as a strategic instrument for fostering sustainable economic growth. As future avenues, subsequent research could delve deeper into the country-specific determinants of this relationship, further elucidating the underlying mechanisms and potential policy implications in a more granular manner. In addition, examination of the relationship between output growth and R&D, using panel data analysis, that has not been conducted in this study, may certainly provide more comprehensive results on the relationship between these two variables. Likewise, examining the relationship between output growth and various components of R&D, like R&D of the business enterprise sector, government sector, higher education, or private non-profit sector, would certainly provide a clearer picture of the relationship between the variables. Unfortunately, the greatest challenge to doing that would still be the unavailability of data for various components of R&D for all the countries of the EU.

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APPENDIX

Table A.1. List of variables

Variable	*Definition*
YEU	GDP at market prices, annual data, current prices, million euro.
AEU	GDE on R&D (GERD), annual data, all sectors, million euro.
RYEU	Annual rate of growth of GDP at market prices, annual data, current prices, million euro.
RAEU	Annual rate of growth of the GDE on R&D (GERD), annual data, all sectors, million euro.
l_1RYEU	First lag (l_1) of the annual rate of growth of GDP at market prices, annual data, current prices, million euro.
l_1RAEU	First lag (l_1) of the annual rate of growth of the GDE on R&D (GERD), annual data, all sectors, million euro.
l_2RYEU	Second lag (l_2) of the annual rate of growth of GDP at market prices, annual data, current prices, million euro.
l_2RAEU	Second lag (l_2) of the annual rate of growth of the GDE on R&D (GERD), annual data, all sectors, million euro.

Table A.2. Regression models with shift dummy variable *D* and impulse dummy variable *i* (Part 1)

Country	*Lag*	D_i	i_i	$RAEU_t$	l_1RAEU_t	l_2RAEU_t	*F-stat*	*Adj. R²*	*White*	*BG*	*SW*
		α_1	α_2	β_1	β_2	β_3			*Chi²*	*LM*	*Wald*
EU	2	-0.54	-2.16	1.04***	-0.34**	0.09	25.39***	0.87	17.38	0.99	0.93
	1	-0.49	-2.08	1.08***	-0.30**	n/a	36.29***	0.88	12.69	0.35	0.93
	0	-0.77	-4.00**	0.90***	n/a	n/a	43.36***	0.86	10.59*	0.83	0.91*
AT	2	0.56	-3.17	0.41**	0.15	-0.05	9.71***	0.70	18.08	1.62	0.90**
	1	0.56	-3.52	0.36***	0.14	n/a	13.98***	0.72	16.12*	1.67	0.89**
	0	0.86	-2.43	0.42***	n/a	n/a	18.15***	0.71	15.91***	2.26	0.95
BE	2	-0.97	0.30	0.80***	-0.45***	0.15	14.94***	0.79	18.86	2.33	0.97
	1	-0.73	-0.79	0.63***	-0.14	n/a	7.75***	0.57	17.87**	2.84*	0.97
	0	1.37***	-1.34	0.55***	n/a	n/a	10.91***	0.59	7.08	1.24	0.96
BG	2	-3.38	-8.11	0.28*	0.20	0.33**	4.83***	0.50	13.58	1.83	0.96
	1	-0.34	-7.40	0.34**	0.24	n/a	4.22**	0.39	11.11	4.23**	0.97
	0	1.59	-5.39	0.39**	n/a	n/a	4.32**	0.32	6.26	6.11**	0.97
HU	2	-0.37	-14.22**	0.42***	0.00	0.18*	6.98***	0.61	18.01	0.80	0.76***
	1	-0.11	-14.05**	0.44***	0.14	n/a	10.51***	0.66	14.74*	0.04	0.9**
	0	0.30	-13.36**	0.51***	n/a	n/a	17.26***	0.70	7.73	0.10	0.95
CY	2	-0.96	-5.85	0.22	0.09	0.14	4.27**	0.46	18.89	0.24	0.89**
	1	-0.66	-4.66	0.21	0.19	n/a	5.4***	0.47	11.84	0.12	0.93
	0	-0.38	-6.29	0.37***	n/a	n/a	7.21***	0.47	4.29	0.28	0.95
HR	2	-0.82	-3.47	0.37**	-0.06	0.21	1.76	0.18	16.89	0.27	0.96
	1	0.28	-2.01	0.35**	-0.03	n/a	2.08	0.19	12.88	1.39	0.94
	0	0.13	-2.34	0.36**	n/a	n/a	3.33**	0.27	11.18**	1.41	0.95
DE	2	1.04	-4.51**	0.56***	-0.15	0.07	21.18***	0.84	17.47	2.51	0.91*
	1	1.31*	-4.56***	0.57***	-0.14	n/a	29.77***	0.85	14.52	1.58	0.92
	0	0.84	-5.20***	0.55***	n/a	n/a	38.47***	0.84	8.85	2.37	0.91**
CZ	2	-1.50	-6.32	0.58***	-0.07	0.17	6.4***	0.59	14.17	2.59	0.90*
	1	-1.11	-4.62	0.61***	0.03	n/a	9.04***	0.62	9.01	2.08	0.93
	0	-1.28	-3.96	0.66***	n/a	n/a	14.35***	0.66	8.99	2.43	0.93
FI	2	2.28***	-8.27**	0.46**	-0.03	0.05	8.70***	0.67	12.77	4.39***	0.84***
	1	2.30***	-8.16**	0.47***	0	n/a	12.64***	0.70	8.35	4.91***	0.85***
	0	2.27***	-8.09***	0.51***	n/a	n/a	17.33***	0.70	1.41	3.88***	0.87***
EE	2	2.75	-20.07***	0.21**	0.11	0.08	8.67***	0.67	17.2	0.73	0.86**
	1	3.12	-20.13***	0.22***	0.16**	n/a	11.37***	0.67	7.8	1.71	0.91*
	0	3.60	-16.99**	0.31***	n/a	n/a	12.45***	0.62	8.04	1.73	0.89**
DK	2	1.80*	-10.72**	0.21	0.15	0.17	5.97***	0.57	7.68	0.00	0.69***
	1	2.18**	-11.15***	0.19	0.26	n/a	7.94***	0.58	3.97	0.93	0.72***
	0	2.49***	-8.68***	0.35***	n/a	n/a	10.66***	0.58	2.54	0.60	0.78***
IE	2	5.54*	-18.47*	0.41	0.19	0.01	3.65**	0.41	12.52	0.11	0.73***
	1	5.30*	-18.49**	0.45*	0.21	n/a	5.55***	0.48	4.95	0.14	0.73***
	0	5.65**	-17.94**	0.56**	n/a	n/a	7.73***	0.49	2.55	0.11	0.81***
FR	2	-0.54	-7.47***	1.17***	-0.05	0.11	14.62***	0.78	18.79	1.82	0.95
	1	-0.12	-7.20***	1.15***	-0.10	n/a	18.54***	0.78	18.02**	1.82	0.96
	0	0.02	-7.10***	0.99***	n/a	n/a	25.1***	0.77	17.58***	0.41	0.97
IT	2	-0.64	-4.65	0.77***	-0.43**	0.30	5.77***	0.56	16.94	6.66***	0.96
	1	-0.18	-3.26	0.82***	-0.28*	n/a	7.15***	0.55	15.65*	0.41	0.94
	0	-0.35	-4.06	0.63***	n/a	n/a	9.19***	0.54	2.02	1.20	0.91*
LU	2	3.95***	-8.26*	0.44**	0.26*	0.12	8.33***	0.67	12.1	4.44**	0.97
	1	4.10***	-7.87*	0.48***	0.27*	n/a	10.56***	0.68	7.49	3.57*	0.98
	0	4.38***	-6.90	0.52***	n/a	n/a	10.68***	0.62	9.42*	1.83	0.94
LV	2	0.55	-19.76**	0.2***	0.24***	0.10*	15.32***	0.79	12.71	0.95	0.95
	1	1.09	-19.92**	0.19**	0.28***	n/a	15.99***	0.75	6.77	1.27	0.95
	0	1.64	-12.31	0.3***	n/a	n/a	6.8***	0.45	1.98	1.79	0.89**
LT	2	0.74	-18.34***	0.37***	0.16	0.14	15.36***	0.79	11.43	0.67	0.74***
	1	1.07	-15.89**	0.39***	0.22**	n/a	18.79***	0.78	10.87	0.84	0.73***
	0	1.70	-12.70*	0.5***	n/a	n/a	9.12***	0.72	8.75	0.16	0.81***
MT	2	6.57***	-8.05	0.27	0.15	0.32	8.35***	0.67	17.28	4.12**	0.94
	1	6.97***	-7.03	0.38**	0.18	n/a	8.71***	0.63	8.58	3.94**	0.93
	0	7.88***	-7.02	0	n/a	n/a	7.30***	0.50	1.30	0.00	0.63***
SI	2	1.95	-8.03	0.25*	0.00	0.00	1.86	0.18	17.97	3.88**	0.94
	1	1.74	-9.05	0.25*	0.06	n/a	2.68*	0.25	11.71	5.12**	0.97
	0	1.82	-8.05	0.28**	n/a	n/a	4.35**	0.32	9.83*	4.90**	0.95

Table A.2. Regression models with shift dummy variable *D* and impulse dummy variable *i* (Part 2)

Country	Lag	D_i	i_i	$RAEU_t$	l_1RAEU_t	l_2RAEU_t	F-stat	Adj. R^2	White	BG	SW
		α_1	α_2	β_1	β_2	β_3			Chi^2	LM	Wald
NL	2	-0.44	-3.45	0.24	0.13	0.27	2.94*	0.34	15.47	1.65	0.85
	1	-0.20	-3.26	0.36	0.21	n/a	3.36**	0.32	8.62	1.78	0.87**
	0	0.28	-3.33	0.46**	n/a	n/a	4.8**	0.35	8.01	2.42	0.89**
PL	2	-3.68*	-9.21*	0.63***	0.09	0.01	20.28***	0.84	13.12	0.41	0.95
	1	-3.58**	-9.96**	0.6***	0.12	n/a	25.87***	0.83	10.23	0.58	0.95
	0	-2.89*	-7.58	0.65***	n/a	n/a	30.75***	0.81	2	0.62	0.94
RO	2	1.40	-7.61	0.5***	0.06	0.13	21.94***	0.85	18.01	0.22	0.96
	1	1.81	-2.55	0.52***	0.11	n/a	25.3***	0.83	15.38*	0.51	0.96
	0	1.66	2.41	0.6***	n/a	n/a	34.94***	0.83	15.45	0.35	0.96
SK	2	-4.44	-6.71	0.33**	0.30**	0.12	3.11**	0.36	10.01	11.20***	0.92
	1	-3.27	-5.43	0.37***	0.28**	n/a	3.78**	0.36	9.94	10.52***	0.97
	0	0.24	-3.07	0.32**	n/a	n/a	2.83*	0.21	12.32**	11.74***	0.93
ES	2	0.26	0.76	0.87***	-0.20	-0.15	8.69***	0.67	11.6	1.46	0.97
	1	0.26	-0.80	0.75***	-0.24	n/a	12.03***	0.69	7.9	1.22	0.96
	0	0.39	-3.56	0.56***	n/a	n/a	16.93***	0.69	2.06	1.30	0.96

*Note: The regression equations are as follows: a) the model with two lags (l_2), shift dummy variable D, and impulse dummy variable i, is expressed as in Eq. (1); b) the model with one lag (l_1), shift dummy variable D, and impulse dummy variable i, is expressed as in Eq. (2); and c) the model with zero lags (l_0), shift dummy variable D, and impulse dummy variable i, is expressed as in Eq. (3). BG — Breusch-Godfrey test, SW — Shapiro-Wilk W test, AT — Austria, BE — Belgium, BG — Bulgaria, HU — Hungary, CY — Cyprus, HR — Croatia, DE — Germany, CZ — Czechia, FI — Finland, EE — Estonia, DK — Denmark, IE — Ireland, FR — France, IT — Italy, LU — Luxembourg, LV — Latvia, LT — Lithuania, MT — Malta, SI — Slovenia, NL — the Netherlands, PL — Poland, RO — Romania, SK — Slovakia, ES — Spain. *, **, *** Indicate significance at the 10% (p < 0.10), 5% (p < 0.05), and 1% (p < 0.01) levels, respectively.*

Table A.3. Regression models with shift dummy variable *D* (Part 1)

Country	Lag	D_i	i_i	$RAEU_t$	l_1RAEU_t	l_2RAEU_t	F-stat	Adj. R^2	White	BG	SW
		α_1	α_2	β_1	β_2	β_3			Chi^2	LM	Wald
EU	2	-0.61	n/a	1.12***	-0.41**	0.06	30.83***	0.86	16.56	0.00	0.95
	1	-0.62	n/a	1.15***	-0.37***	n/a	46.94***	0.87	11.52	0.02	0.95
	0	-1.25*	n/a	0.95***	n/a	n/a	49.92***	0.82	8.69*	0.12	0.98
AT	2	0.45	n/a	0.49***	0.12	-0.12	11.49***	0.69	17.25	0.65	0.94
	1	0.29	n/a	0.41***	0.09	n/a	16.62***	0.70	14.61*	0.88	0.98
	0	0.60	n/a	0.43***	n/a	n/a	26.38***	0.71	13.25**	1.56	0.98
BE	2	-0.93	n/a	0.8***	-0.45***	0.15	19.98***	0.80	18.02	2.26	0.96
	1	-0.87	n/a	0.65***	-0.15	n/a	10.91***	0.60	17.92**	2.83*	0.96
	0	-1.30	n/a	0.57***	n/a	n/a	16.98***	0.60	6.74	1.14	0.97
BG	2	-3.68	n/a	0.29*	0.18	0.32**	5.61	0.49	13.49	2.25	0.94
	1	-0.68	n/a	0.34**	0.21	n/a	5.37	0.40	8.93	3.74*	0.98
	0	1.19	n/a	0.39**	n/a	n/a	6.47	0.34	5.66	5.13**	0.97
HU	2	-1.85	n/a	0.49***	-0.01	0.18	4.35**	0.41	13.33	0.99	0.94
	1	-1.41	n/a	0.5***	0.11	n/a	8.44***	0.53	7.41	0.35	0.92
	0	-0.91	n/a	0.53***	n/a	n/a	17.34***	0.61	6.67	0.08	0.94
CY	2	-1.31***	n/a	0.18	0.14	0.11	4.97***	0.46	18.46	0.82	0.92
	1	-1.00	n/a	0.18	0.22	n/a	7.00***	0.47	11.35	0.53	0.94
	0	-0.78	n/a	0.36***	n/a	n/a	9.73***	0.45	4.24	1.37	0.96
HR	2	-1.02	n/a	0.4**	-0.10	0.21	2.30	0.23	15.65	0.15	0.93
	1	0.14	n/a	0.36**	-0.05	n/a	2.94*	0.24	13.02	1.13	0.92
	0	-0.12***	n/a	0.37	n/a	n/a	5.21**	0.31	11.41**	1.08	0.94
DE	2	0.75	n/a	0.64***	-0.26*	0.09	17.17***	0.77	15.4	0.06	0.98
	1	1.08	n/a	0.66***	-0.25*	n/a	25.44***	0.79	12.51	0.14	0.98
	0	0.14	n/a	0.63***	n/a	n/a	32.4***	0.75	4.38	0.07	0.95
CZ	2	-1.95	n/a	0.63***	-0.1	0.14	7.72***	0.59	15.1	0.69	0.95
	1	-1.53	n/a	0.65***	0	n/a	12.19***	0.63	9.12	0.63	0.96
	0	-1.71	n/a	0.67***	n/a	n/a	21.92***	0.67	8.14*	1.01	0.95
FI	2	1.82**	n/a	0.71***	-0.33	-0.01	7.02***	0.56	15.9	3.38*	0.93
	1	1.80**	n/a	0.71***	-0.33*	n/a	10.85***	0.60	14.74*	3.65*	0.93
	0	1.63*	n/a	0.54***	n/a	n/a	12.79***	0.53	2.73	2.44	0.97
EE	2	1.18	n/a	0.26***	0.07	0.08	5.80***	0.50	16.78	2.1	0.96
	1	1.51	n/a	0.27***	0.12	n/a	8.46***	0.53	8.37	2.04	0.95
	0	2.08	n/a	0.33***	n/a	n/a	12.97***	0.53	5.72	2.11	0.92*
DK	2	1.71	n/a	0.37*	-0.31	0.28	3.55**	0.35	8.24	0.09	0.91*
	1	2.11*	n/a	0.37*	-0.10	n/a	4.36**	0.33	7.73	0.00	0.98
	0	1.93*	n/a	0.31**	n/a	n/a	7.63***	0.39	1.77	0.00	0.98
IE	2	4.39	n/a	0.55	0.17	-0.16	2.88*	0.28	8.55	0.33	0.88**
	1	3.98	n/a	0.46*	0.17	n/a	4.66**	0.35	6.15	0.48	0.90**
	0	4.26	n/a	0.56**	n/a	n/a	7.7***	0.39	3.39	0.33	0.83***
FR	2	-0.66	n/a	1.02***	-0.24	0.22	6.97***	0.56	18.55	0.44	0.96
	1	-0.33	n/a	1.08***	-0.18	n/a	10.38***	0.58	14.22*	0.08	0.98
	0	-0.32	n/a	0.91***	n/a	n/a	17.11***	0.61	6.55	0.21	0.98
IT	2	-0.79	n/a	0.84***	-0.41*	0.18	5.86***	0.51	15.68	2.95*	0.95
	1	-0.44	n/a	0.86***	-0.32*	n/a	8.77***	0.54	14.62*	0.66	0.95
	0	-0.70	n/a	0.65***	n/a	n/a	11.88***	0.51	1.42	1.04	0.93
LU	2	3.39**	n/a	0.47**	0.23	0.08	7.76***	0.60	7.49	0.07	0.97
	1	3.51**	n/a	0.5***	0.24	n/a	10.82***	0.62	2.64	0.00	0.98
	0	3.83***	n/a	0.53***	n/a	n/a	13.55***	0.58	6.83	0.01	0.96

Table A.3. Regression models with shift dummy variable *D* (Part 2)

Country	Lag	D_t	i_t	$RAEU_t$	l_1RAEU_t	l_2RAEU_t	F-stat	Adj. R^2	White	BG	SW
		α_1	α_2	β_1	β_2	β_3			Chi^2	LM	Wald
LV	2	-1.33	n/a	0.28***	0.21**	0.11	11.86***	0.70	16.27	1.33	0.95
	1	-0.77	n/a	0.27***	0.24***	n/a	14.16***	0.66	11.71	0.46	0.96
	0	0.39	n/a	0.35***	n/a	n/a	9.41***	0.44	1.45	1.63	0.97
LT	2	-0.79	n/a	0.51***	0.11	0.07	10.49***	0.67	16.23	1.42	0.90**
	1	-0.58	n/a	0.51***	0.16	n/a	16.19***	0.70	16.84**	1.47	0.87**
	0	0.27	n/a	0.56***	n/a	n/a	22.71***	0.67	14.98***	1.36	0.92*
MT	2	6.03***	n/a	0.3	0.12	0.28	8.88***	0.64	17	3.94**	0.95
	1	6.44***	n/a	0.4**	0.15	n/a	10.54***	0.61	8.56	5.15**	0.92
	0	7.34***	n/a	0	n/a	n/a	10.08***	0.49	0.77	0.21	0.59***
SI	2	1.63	n/a	0.26*	-0.09	0.04	1.84	0.15	17.81	2.85*	0.95
	1	1.44	n/a	0.27**	-0.03	n/a	2.60*	0.19	12.88	4.16**	0.95
	0	1.23	n/a	0.28**	n/a	n/a	4.92**	0.27	8.33*	4.74**	0.97
NL	2	-1.24	n/a	0.31	0.17	0.27	3.51**	0.35	15.7	0.52	0.92
	1	-0.91	n/a	0.43**	0.24	n/a	4.31**	0.33	8.12	0.56	0.94
	0	-0.28	n/a	0.52**	n/a	n/a	6.90***	0.36	8.07*	0.88	0.89**
PL	2	-4.13*	n/a	0.69***	0.04	-0.01	20.36***	0.80	11.4	0.00	0.95
	1	-4.35**	n/a	0.66***	0.07	n/a	26.63***	0.79	8.02	0.00	0.95
	0	-3.90**	n/a	0.69***	n/a	n/a	41.27***	0.79	1.16	0.21	0.93
RO	2	1.03	n/a	0.55***	0.03	0.10	27.39***	0.85	15.37	0.28	0.97
	1	1.61	n/a	0.54***	0.09	n/a	35.54***	0.84	11.63	0.38	0.96
	0	1.88	n/a	0.59***	n/a	n/a	54.83***	0.84	13.25	0.46	0.96
SK	2	-4.74	n/a	0.35**	0.29**	0.10	3.86**	0.38	8.83	8.78***	0.93
	1	-3.69	n/a	0.38***	0.27**	n/a	5.09**	0.38	9.14	8.63***	0.96
	0	-0.06	n/a	0.33**	n/a	n/a	4.41**	0.24	12.22**	8.68***	0.91*
ES	2	0.31	n/a	0.85***	-0.18	-0.14	11.61***	0.69	8.25	1.41	0.97
	1	0.20	n/a	0.77***	-0.27	n/a	16.99***	0.71	4.08	1.10	0.96
	0	0.11	n/a	0.57***	n/a	n/a	24.62***	0.69	1.99	0.72	0.95

*Note: The regression equations are as follows: a) the model with two lags (l_2) and shift dummy variable D is expressed as in Eq. (4); b) the model with one lag (l_1) and shift dummy variable D is expressed as in Eq. (5); and c) the model with zero lags (l_0) and shift dummy variable D is expressed as in Eq. (6). BG — Breusch-Godfrey test, SW — Shapiro-Wilk W test, AT — Austria, BE — Belgium, BG — Bulgaria, HU — Hungary, CY — Cyprus, HR — Croatia, DE — Germany, CZ — Czechia, FI — Finland, EE — Estonia, DK — Denmark, IE — Ireland, FR — France, IT — Italy, LU — Luxembourg, LV — Latvia, LT — Lithuania, MT — Malta, SI — Slovenia, NL — the Netherlands, PL — Poland, RO — Romania, SK — Slovakia, ES — Spain. *, **, *** Indicate significance at the 10% ($p < 0.10$), 5% ($p < 0.05$), and 1% ($p < 0.01$) levels, respectively.*

Table A.4. Regression models with impulse dummy variable *i* (Part 1)

Country	Lag	D_t	i_t	$RAEU_t$	l_1RAEU_t	l_2RAEU_t	F-stat	Adj. R^2	White	BG	SW
		α_1	α_2	β_1	β_2	β_3			Chi^2	LM	Wald
EU	2	n/a	-2.30	1.03***	-0.36**	0.04	32.38***	0.87	11.61	0.04	0.93
	1	n/a	-2.37	1.04***	-0.32**	n/a	48.99***	0.88	9.03	0.00	0.93
	0	n/a	-4.74***	0.82***	n/a	n/a	62.07***	0.85	11.65***	0.03	0.86***
AT	2	n/a	-2.97	0.41***	0.17*	-0.03	12.46***	0.71	14.44	1.87	0.94
	1	n/a	-3.09	0.39***	0.15*	n/a	18.92***	0.73	11.17*	1.61	0.94
	0	n/a	-1.53	0.46***	n/a	n/a	25.87***	0.73	7.07*	2.47	0.98
BE	2	n/a	-0.11	0.77***	-0.48***	0.11	19.14***	0.79	16.85*	3.16*	0.96***
	1	n/a	-1.24	0.59***	-0.17	n/a	10.78***	0.59	17.22***	2.88*	0.97
	0	n/a	-2.25	0.46***	n/a	n/a	16.41***	0.59	5.27	1.58	0.95
BG	2	n/a	-8.84	0.24	0.15	0.25*	5.62***	0.49	6.57	3.97**	0.95
	1	n/a	-7.52***	0.33***	0.23***	n/a	5.96***	0.43	9.39	4.08**	0.97
	0	n/a	-4.30	0.44***	n/a	n/a	6.54***	0.35	5.39	4.23**	0.97
HU	2	n/a	-14.51***	0.41***	0	0.18*	9.31***	0.64	15.01	0.66	0.75***
	1	n/a	-14.14***	0.44***	0.14	n/a	14.88***	0.68	6.31	0.04	0.89**
	0	n/a	-13.07**	0.51***	n/a	n/a	27.25***	0.71	6.77	0.07	0.95
CY	2	n/a	-6.47	0.2	0.08	0.14	5.49***	0.49	10.59	0.03	0.90*
	1	n/a	-5.16	0.2	0.18	n/a	7.51***	0.49	6.68	0.02	0.94
	0	n/a	-6.55	0.36***	n/a	n/a	11.34***	0.50	3.68	0.14	0.94
HR	2	n/a	-4.10	0.34**	-0.07	0.19	2.32	0.24	15.83	0.34	0.97
	1	n/a	-1.72	0.35**	-0.02	n/a	*2.97	0.25	7.75	1.29	0.94
	0	n/a	-2.17	0.36***	n/a	n/a	5.30**	0.31	3.34	1.32	0.96
DE	2	n/a	-4.26**	0.59***	-0.10	0.17	25.38***	0.84	6	4.72**	0.90*
	1	n/a	-4.16**	0.66***	-0.03	n/a	32.12***	0.82	2.54	2.93*	0.91*
	0	n/a	-4.43***	0.65***	n/a	n/a	53.26***	0.83	2.74	2.88*	0.91**
CZ	2	n/a	-7.35	0.54***	-0.07	0.13	8.10***	0.6	9.08	3.51*	0.87**
	1	n/a	-5.70	0.58***	0.02	n/a	12.42***	0.63	6.14	2.47	0.93
	0	n/a	-5.39	0.62***	n/a	n/a	21.86***	0.67	4.77	3.03*	0.93
FI	2	n/a	-5.18	0.56**	-0.14	0.10	4.88**	0.45	13.64	8.93***	0.92*
	1	n/a	-4.80	0.58**	-0.09	n/a	7.44***	0.49	14.65**	9.88***	0.9**
	0	n/a	-5.76*	0.55***	n/a	n/a	12.67***	0.53	14.44***	8.74***	0.89**
EE	2	n/a	-17.62**	0.24***	0.12	0.10	9.85***	0.65	11.52	1.15	0.92
	1	n/a	-17.16**	0.25***	0.17**	n/a	13.19***	0.65	10.54	2.26	0.96
	0	n/a	-13.18*	0.35***	n/a	n/a	15.7***	0.58	4.27	1.86	0.95
DK	2	n/a	-10.49**	0.24	0.19	0.26	5.63***	0.49	5.81	0.00	0.87**
	1	n/a	-10.94**	0.21	0.39*	n/a	6.39***	0.45	1.6	2.14	0.90**
	0	n/a	-6.81**	0.47***	n/a	n/a	7.89***	0.40	2.52	1.71	0.95

Table A.4. Regression models with impulse dummy variable *i* (Part 2)

Country	Lag	D_t	i_t	$RAEU_t$	l_1RAEU_t	l_2RAEU_t	F-stat	Adj. R^2	White	BG	SW
		α_1	α_2	β_1	β_2	β_3			Chi^2	LM	Wald
IE	2	n/a	-14.98	0.5	0.30	0.09	3.01	0.30	4.81	0.45	0.90*
	1	n/a	-14.64	0.58**	0.31	n/a	5.08**	0.38	3	0.38	0.91*
	0	n/a	-13.21	0.75***	n/a	n/a	7.44***	0.72	0.87***	0.11	0.98
FR	2	n/a	-7.53***	1.13***	-0.09	0.07	18.59***	0.79	17.37*	0.69	0.96
	1	n/a	-7.23***	1.14***	-0.11	n/a	26.19***	0.79	16.83***	1.47	0.96
	0	n/a	-7.09***	0.99***	n/a	n/a	39.73***	0.79	15.66***	0.41	0.97
IT	2	n/a	-4.85*	0.74***	-0.43**	0.25	7.33***	0.57	13.99	3.40*	0.95
	1	n/a	-3.41	0.81***	-0.29*	n/a	10.08***	0.58	14.18**	0.28	0.94
	0	n/a	-4.38	0.61***	n/a	n/a	14.31***	0.56	1.92	0.80	0.90**
LU	2	n/a	-4.97	0.49**	0.31	0.21	4.40**	0.43	10.13	7.59***	0.98
	1	n/a	-4.07	0.57***	0.33*	n/a	5.50***	0.43	9.36	6.38**	0.97
	0	n/a	-2.55	0.63***	n/a	n/a	5.76**	0.35	11.3**	3.63*	0.90*
LV	2	n/a	-19.01***	0.21***	0.24	0.11*	20.38***	0.80	9.11	0.87	0.95
	1	n/a	-18.42**	0.2***	0.28	n/a	22.12***	0.76	5.46	1.12	0.96
	0	n/a	-9.96	0.32***	n/a	n/a	10.41***	0.47	0.57	1.67	0.91*
LT	2	n/a	-17.57***	0.38***	0.16	0.15*	20.23***	0.80	7.4	0.46	0.78***
	1	n/a	-14.58**	0.42***	0.23**	n/a	25.81***	0.79	13.66**	0.37	0.77***
	0	n/a	-10.49*	0.54***	n/a	n/a	28.44***	0.72	11.84***	0.01	0.84***
MT	2	n/a	-2.57	0.36	0.23	0.46	2.25	0.22	10.82	2.39	0.96
	1	n/a	-0.57	0.54*	0.28	n/a	1.99	0.14	6.37	1.80	0.96
	0	n/a	0.86	0.02	n/a	n/a	0.02	-0.11	1.92	5.56**	0.61***
SI	2	n/a	-7.00	0.27*	0.03	0.04	1.98	0.17	7.06	4.32**	0.98
	1	n/a	-8.30	0.28**	0.09	n/a	3.18	0.25	4.74	5.63**	0.95
	0	n/a	-6.50	0.32***	n/a	n/a	5.66**	0.31	4.49	4.94**	0.98
LV	2	n/a	-3.86	0.21	0.11	0.26	3.91**	0.38	14.2	1.82	0.84***
	1	n/a	-3.46	0.34**	0.20	n/a	4.75**	0.36	5.57	1.83	0.86***
	0	n/a	-3.02	0.49***	n/a	n/a	7.56***	0.38	6.12	1.90	0.89**
LT	2	n/a	-10.23	0.57***	0.03	-0.08	20.84***	0.81	9.36	3.64*	0.91
	1	n/a	-12.07**	0.52***	0.04	n/a	26.83***	0.79	7.29	3.31*	0.90**
	0	n/a	-10.89**	0.56***	n/a	n/a	39.7***	0.79	2.48	3.05*	0.900**
MT	2	n/a	-6.04	0.52***	0.05	0.14	27.82***	0.85	13.92	0.25	0.97
	1	n/a	0.07	0.54***	0.1	n/a	33.18***	0.83	11.12*	0.58	0.96
	0	n/a	4.56	0.61***	n/a	n/a	52.10***	0.83	2.57	0.38	0.97
SI	2	n/a	-8.01	0.29**	0.21*	0.04	3.34**	0.33	4.85	12.09***	0.96
	1	n/a	-7.38	0.31***	0.22*	n/a	4.65**	0.35	2.96	12.12***	0.97
	0	n/a	-2.82	0.33***	n/a	n/a	4.48**	0.25	1.13	10.21***	0.93
NL	2	n/a	1.09	0.88***	-0.22	-0.14	11.56***	0.69	6.91	1.42	0.97
	1	n/a	-0.46	0.76***	-0.25	n/a	16.93***	0.71	4.67	1.18	0.96
	0	n/a	-3.16	0.57***	n/a	n/a	26.45***	0.71	1.51	1.23	0.95
PL	2	n/a	-4.97	0.49**	0.31	0.21	4.40**	0.43	10.13	7.59***	0.98
	1	n/a	-4.07	0.57***	0.33*	n/a	5.50***	0.43	9.36	6.38**	0.97
	0	n/a	-2.55	0.63***	n/a	n/a	5.76**	0.35	11.3**	3.63*	0.90*
RO	2	n/a	-19.01***	0.21***	0.24	0.11*	20.38***	0.80	9.11	0.87	0.95
	1	n/a	-18.42**	0.2***	0.28	n/a	22.12***	0.76	5.46	1.12	0.96
	0	n/a	-9.96	0.32***	n/a	n/a	10.41***	0.47	0.57	1.67	0.91*
SK	2	n/a	-17.57***	0.38***	0.16	0.15*	20.23***	0.80	7.4	0.46	0.78***
	1	n/a	-14.58**	0.42***	0.23**	n/a	25.81***	0.79	13.66**	0.37	0.77***
	0	n/a	-10.49*	0.54***	n/a	n/a	28.44***	0.72	11.84***	0.01	0.84***
ES	2	n/a	-2.57	0.36	0.23	0.46	2.25	0.22	10.82	2.39	0.96
	1	n/a	-0.57	0.54*	0.28	n/a	1.99	0.14	6.37	1.80	0.96
	0	n/a	0.86	0.02	n/a	n/a	0.02	-0.11	1.92	5.56**	0.61***

*Note: The regression equations are as follows: a) the model with two lags (l_2) and impulse dummy variable i is expressed as in Eq. (7); b) the model with one lag (l_1) and impulse dummy variable i is expressed as in Eq. (8); and c) the model with zero lags (l_0) and impulse dummy variable i, is expressed as in Eq. (9). BG — Breusch-Godfrey test, SW — Shapiro-Wilk W test, AT — Austria, BE — Belgium, BG — Bulgaria, HU — Hungary, CY — Cyprus, HR — Croatia, DE — Germany, CZ — Czechia, FI — Finland, EE — Estonia, DK — Denmark, IE — Ireland, FR — France, IT — Italy, LU — Luxembourg, LV — Latvia, LT — Lithuania, MT — Malta, SI — Slovenia, NL — the Netherlands, PL — Poland, RO — Romania, SK — Slovakia, ES — Spain. *, **, *** Indicate significance at the 10% ($p < 0.10$), 5% ($p < 0.05$), and 1% ($p < 0.01$) levels, respectively.*

Table A.5. Regression models without shift dummy variable *D* and impulse dummy variable *i* (Part 1)

Country	Lag	D_t	i_t	$RAEU_t$	l_1RAEU_t	l_2RAEU_t	F-stat	Adj. R^2	White	BG	SW
		α_1	α_2	β_1	β_2	β_3			Chi^2	LM	Wald
EU	2	n/a	n/a	1.11***	-0.44***	0.00	41.4***	0.86	10.07	0.13	0.96
	1	n/a	n/a	1.11***	-0.42***	n/a	69.31***	0.87	8.38	0.42	0.96
	0	n/a	n/a	0.81***	n/a	n/a	83.24***	0.8	11.16***	0.43	0.97
AT	2	n/a	n/a	0.49***	0.14	-0.10	15.92***	0.70	11.41	0.74	0.95
	1	n/a	n/a	0.42***	0.11	n/a	26.07***	0.71	10.53*	0.82	0.99
	0	n/a	n/a	0.47***	n/a	n/a	52.5***	0.71	3.58	1.75	0.99
BE	2	n/a	n/a	0.77***	-0.48***	0.11	27.22***	0.81	15.33*	3.16*	0.96
	1	n/a	n/a	0.6***	-0.19	n/a	16.83***	0.61	16.53***	2.85*	0.97
	0	n/a	n/a	0.45***	n/a	n/a	32.64***	0.60	4.47	1.39	0.98
BG	2	n/a	n/a	0.24*	0.12	0.23*	6.77***	0.48	5.74	3.69*	0.96
	1	n/a	n/a	0.33**	0.19	n/a	8.47***	0.43	6.6	3.81*	0.97
	0	n/a	n/a	0.43***	n/a	n/a	13.26***	0.37	4.29	4.09**	0.97

Table A.5. Regression models without shift dummy variable *D* and impulse dummy variable *i* (Part 2)

Country	Lag	D_t	i_t	$RAEU_t$	l_1RAEU_t	l_2RAEU_t	F-stat	Adj. R^2	White	BG	SW
		α_1	α_2	β_1	β_2	β_3			Chi^2	LM	Wald
HU	2	n/a	n/a	0.42***	-0.04	0.16	5.61***	0.42	11.23	0.74	0.95
	1	n/a	n/a	0.46***	0.10	n/a	12.67***	0.54	3.69	0.21	0.92*
	0	n/a	n/a	4.41	n/a	n/a	35.68***	0.62	4.41	0.05	0.94
CY	2	n/a	n/a	0.15	0.14	0.10	6.54***	0.47	9.79	0.28	0.91*
	1	n/a	n/a	0.16	0.21	n/a	10.62***	0.49	6.63	0.24	0.95
	0	n/a	n/a	0.34***	n/a	n/a	19.93***	0.47	4.04	0.87	0.95
HR	2	n/a	n/a	0.37**	-0.11	0.18	3.16*	0.28	7.48	0.20	0.95
	1	n/a	n/a	0.37***	-0.04	n/a	4.70**	0.29	2.47	1.10	0.93
	0	n/a	n/a	0.37***	n/a	n/a	11.02***	0.35	1.93	1.06	0.94
DE	2	n/a	n/a	0.66***	-0.22*	0.16	23.42***	0.81	7.32	0.04	0.97
	1	n/a	n/a	0.72***	-0.15	n/a	35.12***	0.77	3.26	0.1	0.96
	0	n/a	n/a	0.64***	n/a	n/a	68.00***	0.76	0.19	0.05	0.96
CZ	2	n/a	n/a	0.59***	-0.09	0.09	9.99***	0.59	8.88	0.81	0.95
	1	n/a	n/a	0.62***	-0.03	n/a	18.20***	0.63	5.34	0.67	0.96
	0	n/a	n/a	0.62***	n/a	n/a	42.69***	0.67	4.06	1.11	0.96
FI	2	n/a	n/a	0.72***	-0.33	0.05	5.81***	0.43	15.54*	7.00***	0.91*
	1	n/a	n/a	0.72***	-0.29	n/a	10.09***	0.48	16.28***	7.61***	0.90**
	0	n/a	n/a	0.57***	n/a	n/a	18.34***	0.45	12.21***	5.61**	0.93
EE	2	n/a	n/a	0.27***	0.07	0.09	8.04***	0.53	12.64	2.23	0.97
	1	n/a	n/a	0.28***	0.13	n/a	12.88***	0.54	7.62	2.21	0.96
	0	n/a	n/a	0.35***	n/a	n/a	25.26***	0.54	4.98*	2.16	0.94
DK	2	n/a	n/a	0.40*	-0.26	0.37*	3.76**	0.30	6.05	0.02	0.97
	1	n/a	n/a	0.40*	0.03	n/a	4.01**	0.23	3.62	0.63	0.92
	0	n/a	n/a	0.41***	n/a	n/a	9.76***	0.29	1.41	0.54	0.95
IE	2	n/a	n/a	0.60	0.26	-0.06	2.94*	0.23	4.79	1.13	0.95
	1	n/a	n/a	0.57**	0.26	n/a	5.68**	0.32	3.28	1.19	0.94
	0	n/a	n/a	0.71***	n/a	n/a	11.86***	0.34	0.77	0.58	0.97
FR	2	n/a	n/a	0.97***	-0.28	0.18	9.46***	0.57	10.87	0.40	0.98
	1	n/a	n/a	1.05***	-0.21	n/a	16.26***	0.60	3.69	0.37	0.98
	0	n/a	n/a	0.86***	n/a	n/a	35.48***	0.62	1.29	0.2	0.98
IT	2	n/a	n/a	0.80***	-0.41*	0.12	7.73***	0.52	15.56*	1.37	0.95
	1	n/a	n/a	0.83***	-0.33**	n/a	13.54***	0.56	12.29**	0.40	0.95
	0	n/a	n/a	0.60***	n/a	n/a	23.34***	0.52	2.08	0.53	0.93
LU	2	n/a	n/a	0.51**	0.29	0.18	5.62***	0.43	10.12	3.98**	0.97
	1	n/a	n/a	0.57***	0.31	n/a	8.15***	0.44	9.33*	3.06*	0.96
	0	n/a	n/a	0.62***	n/a	n/a	11.85***	0.38	10.64***	2.16	0.90*
LV	2	n/a	n/a	0.28***	0.20***	0.10	16.29***	0.71	14.59	1.32	0.96
	1	n/a	n/a	0.27***	0.24***	n/a	22.26***	0.68	11.64**	0.47	0.96
	0	n/a	n/a	0.35***	n/a	n/a	19.76***	0.47	0.41	1.61	0.97
LT	2	n/a	n/a	0.50***	0.11	0.06	14.71***	0.68	15.23*	1.34	0.88**
	1	n/a	n/a	0.50***	0.15	n/a	25.51***	0.71	15.77***	1.34	0.86***
	0	n/a	n/a	0.56***	n/a	n/a	47.73***	0.69	14.04***	1.38	0.92*
MT	2	n/a	n/a	0.37	0.22	0.44	3.14*	0.26	10.13	2.12	0.96
	1	n/a	n/a	0.54*	0.28	n/a	3.18*	0.19	5.42	1.66	0.96
	0	n/a	n/a	0.02	n/a	n/a	0.04	-0.05	0.54	5.53**	0.46***
SI	2	n/a	n/a	0.27*	-0.06	0.07	2.20	0.16	5.48	3.57*	0.93
	1	n/a	n/a	0.29**	0	n/a	3.60**	0.21	4.18	4.79**	0.98
	0	n/a	n/a	0.31***	n/a	n/a	9.35***	0.28	3.62	5.05**	0.98
NL	2	n/a	n/a	0.24	0.10	0.24	4.63**	0.36	13.77	0.57	0.89**
	1	n/a	n/a	0.36**	0.19	n/a	6.54***	0.36	4.86	0.65	0.93
	0	n/a	n/a	0.49***	n/a	n/a	14.44***	0.39	5.62*	0.98	0.88**
PL	2	n/a	n/a	0.63***	-0.04	-0.11	21.97***	0.77	5.53	0.63	0.94
	1	n/a	n/a	0.57***	-0.05	n/a	28.78***	0.74	4.7	0.37	0.93
	0	n/a	n/a	0.57***	n/a	n/a	59.65***	0.74	0.32	1.28	0.92*
RO	2	n/a	n/a	0.55***	0.03	0.11	37.82***	0.85	11.2	0.32	0.97
	1	n/a	n/a	0.54***	0.10	n/a	52.70***	0.84	6.87	0.56	0.96
	0	n/a	n/a	0.60***	n/a	n/a	105.89***	0.83	1.59	0.65	0.96
SK	2	n/a	n/a	0.30	0.18*	0.02	4.23**	0.34	3.87	8.29***	0.96
	1	n/a	n/a	0.31***	0.19*	n/a	6.69***	0.36	2.00	9.41***	0.96
	0	n/a	n/a	0.33***	n/a	n/a	9.27***	0.28	0.29	8.41***	0.91*
ES	2	n/a	n/a	0.85***	-0.19	-0.13	16.34***	0.71	6.37	1.35	0.96
	1	n/a	n/a	0.78***	-0.26	n/a	26.86***	0.72	3.33	1.09	0.96
	0	n/a	n/a	0.57***	n/a	n/a	51.78***	0.71	1.36	0.71	0.94

*Note: The regression equations are as follows: a) the model with two lags (l_2), without shift dummy variable D and impulse dummy variable i is expressed as in Eq. (10); b) the model with one lag (l_1) without shift dummy variable D and impulse dummy variable i is expressed as in Eq. (11); and c) the model with zero lags (l_0) without shift dummy variable D and impulse dummy variable i is expressed as in Eq. (12). BG — Breusch-Godfrey test, SW — Shapiro-Wilk W test, AT — Austria, BE — Belgium, BG — Bulgaria, HU — Hungary, CY — Cyprus, HR — Croatia, DE — Germany, CZ — Czechia, FI — Finland, EE — Estonia, DK — Denmark, IE — Ireland, FR — France, IT — Italy, LU — Luxembourg, LV — Latvia, LT — Lithuania, MT — Malta, SI — Slovenia, NL — the Netherlands, PL — Poland, RO — Romania, SK — Slovakia, ES — Spain. *, **, *** Indicate significance at the 10% ($p < 0.10$), 5% ($p < 0.05$), and 1% ($p < 0.01$) levels, respectively.*