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EU CAPACITY TO BOLSTER AND STIMULATE RESEARCH AND INNOVATION: WHO IS THE LEADER IN DEVELOPMENT?

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Abstract:

This study investigates the role of innovation in attaining economic growth and development in the 27 EU Member States (EU-27). Our analytical approach employs advanced panel data econometric methods, including an autoregressive distributed lag (ARDL) model and data mapping analysis. Additionally, an interactive approach to regulatory quality was introduced to evaluate its influence on economic development. The results suggest that innovation significantly impacts economic development in both the long and short term. Empirical evidence indicates that the quality of regulatory frameworks is a main factor in shaping economic development in both the long and short terms. The main findings imply the need for countries to align their strategies with the effective integration of digital technologies and sustained innovation and further substantially invest resources in R&D capabilities to ensure robust economic progress. Among the countries examined, Sweden, the Netherlands, Finland, and Denmark exhibited the highest levels of innovation. Some nations, with significant economic potential, such as Romania and Bulgaria, tend to underinvest in R&D.

Key words: *innovation, R&D, economic growth*

1. Introduction

This study investigates the impact of R&D activities on economic progress within the European Union using an Autoregressive Distributed Lag modelling approach (ARDL). The pivotal role of R&D initiatives in bolstering the national economy is confirmed by many

European Union member states actively implementing initiatives to improve the quality of R&D activities (Anghelache et al., 2021). Existing discrepancies between EU member states in terms of government effectiveness, good public governance, efficient allocation of public funds, rational public spending, and sustained efforts to improve productivity and economic well-being (Houngbo et al., 2017) are essential elements for the economic evolution of the European Union (Drăcea et al., 2014). Investments in research and development play a decisive role in stimulating national growth, development and competitiveness (Gan et al., 2018). The European Union is made up of countries with heterogeneous economic structures, therefore, the need to analyse the impact of investments in research and development both on the state of economic development and society as a whole is noted. In addition, during the transition period, many countries in Central and Eastern Europe, including Romania, faced several significant challenges regarding reconfiguring their R&D activities (Sandu, 2010). However, neither the state's involvement nor the private sector's actions have strengthened research and development spending in the last decade (Albulescu & Turcu, 2022). This area was not considered essential because the research and development system was perceived as a financial strain rather than an economic growth-enabling resource (Radosevic & Auriol, 1999).

At the same time, the notion of globalisation is a concept that accelerates international competitiveness (Aničić & Nestorović, 2020). Moreover, globalisation represents an essential condition for all countries' economic and social development, and innovations lead to technology renewal and long-term economic and social benefits (Akcali et al., 2015). Hall (2006) argues that research and development activities are undertaken by entrepreneurs, companies, or individual institutional entities to generate novel or enhanced products and processes. Godin and Lane (2012) distinguished research as an academic domain, while they characterised development as an industrial domain. Moreover, according to the OECD, R&D indicates a country's efforts to drive innovation (Moffatt, 2013). These activities cover three areas of research: fundamental, applied and experimental development. Therefore, three primary allocative sources for investments in research and development were highlighted: the entrepreneurial environment, the state through its component institutions, and higher education institutions (Butum, 2017; Câmpeanu et al., 2014). Thus, the combination of these sources and the implementation of appropriate economic policies can constitute key elements in the development of a sustainable economy.

To examine the impact of these investments in detail, one needs to focus on the total amount allocated to them and how these sources shape economic progress at the national level among European Union member states by assessing their current state of economic development. At the same time, state involvement in this process can be perceived as the primary source of funding for these investments, representing a force that shapes and implements research and development activities (Sandu, 2014); thus, governments have increased their policy commitment to innovation, resulting in a significant impact on research and development spending levels, these actions are based on the effects of technological innovation on economic performance (Atkeson & Burstein, 2019). However, such a procedure risks extending research intensity and development beyond optimal levels (Yeh et al., 2010).

The novelty of this study is mainly due to how we have approached the empirical analysis and how the research framework was created. The techniques and the advanced research methods applied, such as advanced panel data econometric methods, content analysis and comparative analysis, have facilitated a deeper understanding of the relationship between innovation and economic development in the European Union member states. This innovative approach allowed us to capture the obvious aspects, subtle interdependencies, and mutual influences, thus providing a broad and detailed perspective on the subject. Therefore, examining the total volume of R&D expenditures and investigating investments in fixed capital formation, government regulatory policies, the legislative framework, and the human resources involved in the R&D sector is essential. This comprehensive approach can provide a broader perspective on how the institutional environment and human resources can influence research and innovation success at the European Union (EU-27) level, with the potential to guide policy and investment strategies in directions that maximise positive impact on innovation and last but not least on economic development.

In this complex framework, the present study focuses on determining the influence of investments in research and development on economic growth, starting from the hypothesis that, from a certain level, R&D can negatively affect economic development. The empirical results align with the general equilibrium model, highlighting specific influences from R&D on GDP (Ulku, 2004; Fraumeni & Okubo, 2005; Wang et al., 2013; Sandu & Ciocanel, 2014).

The paper is organised as follows: Section 1 investigates the relationship between innovation, regulatory quality, and economic development while addressing allocative critiques of R&D spending and disparities among EU member states. Section 2 reviews the relevant literature, while Section 3 describes the data used in the study. Sections 4 and 5 describe the methodology and present the research findings. The conclusion is given in Section 6.

2. Literature review

Over the past years, the question of whether investment in research and development (R&D) positively impacts long-term growth has attracted attention. This study examines this relationship from the perspective of economic policy uncertainty in Europe, analysing the connection between R&D expenditures and gross domestic product per capita (GDP).

However, the scientific literature does not offer a general universal perspective of the effects of R&D on the progress of society (Herlinawati & Machmud, 2020; Singhai et al., 2021; Huang & Ren, 2010; Fayomi et al., 2018). Therefore, economic development refers to the sustained growth of a nation's economic output and improving its citizens' living standards. On the other hand, innovation involves exploring and creating new knowledge, technologies and products to improve economic performance (Lee, 2020). It is important to emphasise that technological innovations contribute significantly to long-term economic development (Jungmittag et al., 2004; Lipsey et al., 2005; Omri, 2020; Zhou, 2021). Furthermore, innovations that contribute to increasing productivity are fundamental to

improving the wealth of a nation (Ginevičius et al., 2022). Therefore, promoting innovations is complementary to guaranteeing employment, ensuring societal well-being, and improving the quality of life (Leta & Zemedkun, 2018). Thus, economic development and R&D are two fundamental aspects that underlie the progress of a nation (Freeman, 2004; Okokpujie et al., 2018).

The quality of regulation largely determines how R&D affects economic development. Thus, the quality of regulation plays a significant role in economic development, helping to create a favourable business environment, promoting investor confidence, and boosting innovation and competition (Assane & Grammy, 2003). Additionally, the quality of regulation ensures that businesses operate fairly and transparently, protecting consumer rights and promoting market efficiency, which is more important for economic development than increasing R&D spending (Ding et al., 2007). Thomas (2010) employed a series of global governance indicators to examine the implications of public administration and assess public governance concerning economic development. Dima (2016) found that establishing meaningful connections between governance and economic progress is theoretically challenging. However, Dima (2013) established correlations between good governance and economic output in the European Union. The study by Kondratenko et al. (2020) stated that a nation's level of innovation is positively associated with the efficiency and effectiveness of its government as well as the strength of the rule of law, based on an analysis of correlations using data from the Global Governance Indicator, Internal Research Expenditures and Development, the Global Index of Innovation and the Global Index of Sustainability Competitiveness.

Moreover, a bidirectional link exists between innovation and economic progress (Dhanora, 2020; Zayas-Márquez & Jose, 2022), i.e. economies with highly developed technological capabilities tend to possess correspondingly sophisticated financial systems, and this relationship is often reciprocal (Hsu et al., 2019). Critical voices claim these expenses can be excessive and sometimes ineffective (Guellec & Van, 2003). Therefore, the specialised literature gives contradictory results; the idea that (R&D) has a positive impact on long-term growth is not always supported (Kaur & Singh, 2016; Alam et al., 2018; Wang & Liu, 2013). Additionally, there are concerns about misdirecting investment in areas that do not significantly impact economic development or improve the population's quality of life (Pellissier, 2008). Therefore, there is not always a direct correlation between R&D and economic development (Agezew, 2024; Sokolov, 2016). Theoretically, it is also uncertain whether R&D investment correlates with economic performance (Pellissier, 2008; Shen & Lin, 2017). Therefore, investments in research and development are not always positively related to economic development. In the theoretical phase, connecting research and development investments directly with the economic performances of EU member states is incorrect. Although investments in R&D resources, such as funding and personnel, can be linked to innovation outcomes (Shen et al., 2019), investments in R&D innovation do not necessarily translate into increased high-tech manufacturing, thus potentially undermining their ability to contribute to economic performance (Xiong et al., 2020). Therefore, it is appropriate to examine each set of causal links separately. Wu et al. (2020) suggest that the relationship between R&D investment and economic growth is not linear but rather varies depending on the level of R&D expenditure. In addition, R&D investments bear an inherent

element of uncertainty, as they may result in only moderate improvements to new production output or cost-cutting measures. Liao & Li (2024) investigated whether R&D activities consistently promote economic growth, hypothesising that the relationship between R&D and economic development may have an inflexion point, and excessive R&D investment could result in inefficient resource allocation. Blanco et al. (2016) reveal that evaluating the contribution of R&D initiatives to economic growth must be approached carefully, given the significant disparities in R&D investment and economic growth observed across nations. The argument indicates that using just R&D investment as a measure to evaluate a nation's research and development performance may prove ineffective.

Agrawal (2018) employed a set of global governance metrics to analyse the implications of public administration and assess public governance about economic growth. Liao and X. (2024) and Ersin et al. (2022) argue that there is a critical point or level below this threshold, and the impact of R&D on economic development presents limitations. The relationship between R&D and economic development is not linear, and there is a critical point below which the impact of R&D on economic development presents limitations (Sikdar & Mukhopadhyay, 2016). However, once this threshold is crossed, the positive effects of R&D on economic development are significant and positive. Furthermore, a minimum level is associated with the share of R&D expenditure required to stimulate economic growth and development (Coccia, 2009; Jones & Williams, 2000; Tarasyev & Watanabe, 2001). Additionally, the levels of R&D investment required to stimulate economic growth and development differ across countries and industries.

3. Methodology

The impact of regulatory quality of innovation on economic development requires separate consideration in the short and long term, and the ARDL limit testing method proposed by Pesaran et al. (2000), Kollias et al. (2008) and Su et al. (2021) suggested the Autoregressive Distributed Lag (ARDL) technique. Compared to traditional testing methods, the ARDL method presents several advantages. First, the sequence under examination does not need to be of the same order, whether I (0) or I (1). Secondly, it is sufficiently robust to accommodate a small sample size. Thirdly, the ARDL model can generate unbiased and efficient parameter estimates when the explanatory variables are endogenous. Lastly, this model facilitates the derivation of a dynamic Error Correction Model through a straightforward linear transformation, allowing the integration of short- and long-term effects (Wang et al., 2021).

The initial step was testing the time series' stationarity. If the sequence exhibits an I (0) or I (1) order of integration, the ARDL Bounds cointegration testing approach can be used using the framework of Equation (1) (Pesaran et al., 1999).

$$\Delta LnR\&D_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta LnR\&D_{t-1} + \sum_{1=0}^{n} \alpha_{2i}\, \Delta LnGDP_{t-1} + \sum_{i=0}^{n} \alpha_{ki}\, Control_{t-1} + \alpha_4 \Delta LnR\&D_{t-1} + \alpha_5 \Delta LnGDP_{t-1} + \alpha_m \Delta Control_{t-1} + \mu_i$$

The control variable is denoted as "Control", and the first-order difference term is represented as "1". The short-term dynamic relationship is captured by the parameters α_1, α_2, and α_{k1}. Additionally, the cointegration relationship between the variables is described by the parameters α_6, α_7, and α_m.

If it is determined that the variables exhibit an integrative relationship, the next step is to examine the long-term association between the variables using the Autoregressive Distributed Lag (ARDL) model. The coefficient estimate in equation (1) is used exclusively to establish the existence of a long-run relationship, and the coefficient (2) is then used to estimate the long-run effect.

$$\Delta LnR\&D_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta LnR\&D_{t-1} + \sum_{1=0}^{n} \alpha_{2i}\, \Delta LnGDP_{t-1} + \sum_{i=0}^{n} \alpha_{ki}\, Control_{t-1} + \mu_i$$

The innovation process is influenced by the lagged value of R&D activities as well as the current or lagged values of independent variables. The coefficient α_{1i} represents the impact of the previous period's R&D levels on the current period. The coefficient α_{2i} reflects the long-term effect of changes in GDP on R&D. The coefficients α_{mi} capture the long-term effects of changes in control variables on R&D.

Another approach is to derive an autoregressive distributed lag Error Correction Model (ECM), equation (3) to investigate the short-term dynamics among the variables.

$$\Delta LnR\&D_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta LnR\&D_{t-1} + \sum_{1=0}^{n} \alpha_{2i}\, \Delta LnGDP_{t-1} + \sum_{i=0}^{n} \alpha_{ki}\, Control_{t-1} + ECM_{t-1} + \mu_i$$

The coefficients represent the immediate impact of the variables on R&D. The delay error correction factor, ECMt−1, denotes the speed of the economic system's self-adjustment.

4. Data and results

The data set was configured based on the primary evidence provided by the specialised literature and includes variables for the specific dimensions of the indicators of innovation, public governance, and economic development at the level of the member states of the European Union EU-27, from the period 2010-2022, this period covers the latest available data. To measure economic development, we used GDP per capita; this indicator was collected from the World Bank database, and the Regulation Quality was also collected through this database. Regulatory Quality (RQ) gives perceptions of the government's ability to launch and implement a set of sound policies and regulations that enable business climate development, expressed in scores. The indicator related to the dimension of innovation, namely research and development expenditure (R&D), was collected from the Eurostat database. The related research and development (R&D) expenditures are expressed as a percentage of GDP, including current and capital expenditures, and are provided on four levels: entrepreneurial environment, public sector, higher education and non-profit. Data were collected in tabular panel form. They went through an initial stage of statistical analysis

to be processed and then used in the econometric analysis. The descriptive statistics for the variables examined in this study are presented in Table 1.

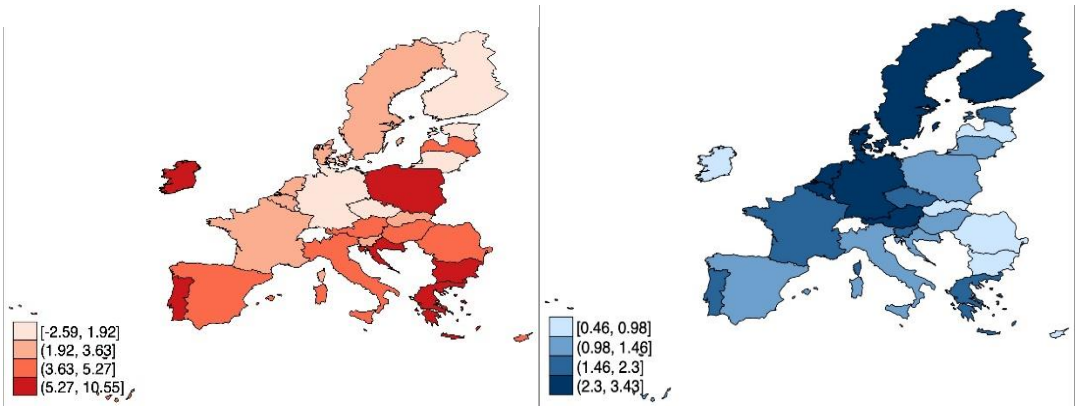
Table 1. Descriptive statistics of the analysed indicators

Variable	Median	Mean	Standard dev.	Min	Max	Skewness	Kurtosis	Jarque-Bera
R&D	1.3700	1.626	0.8909	0.3800	3.7100	0.5817	2.1076	31.447***
PIB	26822	34497	23491	6863.6	133711	1.7555	6.7494	385.89***
RQ	1.1241	1.139	0.4662	0.1352	2.0399	0.0133	1.9000	17.706**

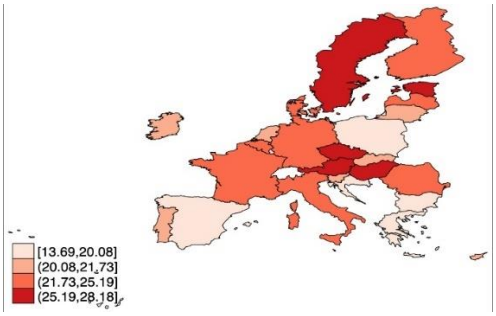
*** significance level 1%, ** 5%

Source: author's own work in Eviews 12

Table 1 provides a summary of the variables' descriptive statistics. The median R&D expenditure is 1.37%, representing a significant proportion; however, slight differences between the mean and median indicate the presence of asymmetry. The standard deviations for R&D and GDP suggest that they undergo significant changes over time. Skewness, distribution asymmetry, and positive values indicate that the variables have distributions that are shifted slightly to the right. The kurtosis, or flatness of the distribution, across all variables exceeds 1.5, indicating that the distributions deviate substantially from normality and have heavier tails than a normal distribution. In addition, The Jarque-Bera test suggests that the variables exhibit statistically significant departures from normality at the 1% level. Accordingly, the empirical analysis employed logarithmic transformations of the variables.



a) GDP per cap **b)** R&D



c) RQ

Figure 1. Mapping of the level of the indicators
Source: author's own work in Stata 18

To graphically represent the differences between the countries under analysis, we resorted to the data mapping technique at the level of 2022. Figure 1 illustrates the mapping of the dimensions of innovation and public governance, including development and societal well-being, from the perspective of the EU-27 member states. Stat 18 software allowed full customisation of the maps for each individual dimension. Detailed analysis of these maps revealed significant differences between EU member states.

The results highlight the following aspects: we note that in 2022, a higher level of GDP per capita was recorded (Figure 1a). With the highest GDP per capita about the EU-27 average, it was registered in Bulgaria, Poland, Ireland and Croatia. From the point of view of the quality of the regulation (Figure 1c) in 2022, we observe that the Nordic states such as Denmark, Finland and Sweden recorded the highest values, demonstrating a stable regulatory framework. In contrast, Bulgaria, Romania and Hungary are at the opposite pole, registering lower levels of regulatory quality. From the perspective of expenditure on research and development (Figure 1b), we observe a similar distribution of country groups for the three indicators, the highest values being recorded in Central, Northern and North-Eastern Europe, average values were recorded in Western and South-Western Europe, and the lowest values are recorded in Eastern and South-Eastern Europe. Therefore, following the analysis based on mapping, we can consider countries such as Finland, Denmark, Germany, Austria, Ireland and Sweden as models of good practice, at the opposite pole are countries such as Romania, Bulgaria, Hungary and Poland; these are countries which requires improvements in terms of the level of spending on research-development-innovation, the quality of regulation.

To examine the relationship between research-development-innovation spending and economic development, we used the ARDL (Autoregressive Models with Distributed Lags) methodology, taking into account the data available for the period 2010-2022 at the level of the European Union EU-27. This methodology ensures the accuracy and consistency of the results while also providing a deep understanding of the relationships between the studied variables. ARDL is a powerful tool for investigating causal relationships and making accurate statistical predictions. Thus, the long-term and short-term impact of the variables will be identified while evaluating the direction and significance of these relationships. Also, the ARDL method offers the possibility of controlling the variables.

The Autoregressive Distributed Lag does not necessitate that all components or sequences be integrated in the same order, but the order of integration of the variables mustn't exceed I (1). Pesaran suggested that the critical value of the F-statistic be computed based on the order of integration of the variables, which can be either I (1) or I (0).

If the sequence exceeds the critical value, the F-statistic used to assess the presence of a cointegration relationship will be invalid. This study employs the augmented Dickey-Fuller and LLC tests to determine the order of integration of the variables.

We used the ARDL model to determine the relationship between R&D spending and economic development in EU 27 countries. The unit root test was applied to check the stationarity of the variables. Table 2 presents the empirical results of unit root tests, ADF, LLC. The integration process exhibits the same order; the highest order is less than I (1), which fulfils the prerequisite requirement for the ARDL cointegration test.

Table 2. The unit root test

ADF			
Level			
	t-statistic	p-value	Conclusions
RQ	-0.04571	0.4818	unstable
GDP per capita	3.74509	0.999	unstable
R&D	- 1.21483	0.1122	unstable
In first difference			
RQ	-4.96688	0.0000	stable
GDP per capita	-6.94727	0.000	stable
R&D	-4.36584	0.000	stable
LLC			
Level			
	t-statistic	p-value	
RQ	-1.33387	0.0911	stable
GDP per capita	2.56936	0.9949	unstable
R&D	-4.55932	0.000	stable
In first difference			
RQ	-2.72884	0.0032	stable
GDP per capita	-9.73455	0.000	stable
R&D	-5.18750	0.000	stable

Source: author's own work in Eviews 12

Table 2 provides Augmented Dickey Fuller (ADF) and Levin Lin Chu (LLC) unit root test results. The empirical results show that all variables are stationary in the first difference, i.e. I (1). The results are significant at 1%, 5% and 10% level of significance and also have an order of integration of both I (1) and I (0). After testing for stationarity and confirming that all variables are stationary at the first difference, we estimate the ARDL-based model to examine the relationship in the long and short run. The outcomes of model information criteria, such as the Akaike Information Criterion (AIC), suggest the ARDL specification. The AIC, Schwarz Information Criterion (SIC), and Bounds test offer an approach for determining the optimal lag length of the Autoregressive Distributed Lag Error Correction Model (ARDL-ECM). The optimal lag order for each differenced component is identified as 2 (dependent variable) and 3 (regressors). The F-statistics obtained from the bounds testing can establish a cointegrating relationship, the findings are summarised in Table 3.

The F-statistics from the bounds testing approach suggest that the relationship between research and development (R&D) and gross domestic product (GDP) is cointegrated, as the F-statistics exceed the critical value at the 1% significance level, the long-term and short-term coefficients between these parameters can be estimated.

Table 3. Cointeger-test

Co-integration Bound						
	10%		5%		1%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Crit.value	2.63	3.35	3.1	3.87	4.13	5
F-stat	3.6517					

Source: author's own work in Eviews 12

Table 4 presents the results of long-term ARDL estimation. The elasticity coefficient of GDP per capita is 0.3606, which is not statistically significant. This suggests that in the long run, R&D investments cannot significantly contribute to the realisation of economic development goals. Fagerberg et al. (2010) have shown that incorporating innovation into the endogenous growth model of Romer and Howitt can result in the emergence of a development trap. This implies that disparities in economic development across countries are attributable to differences in the endogenous accumulation of knowledge. Thus, this theoretical approach suggests that long-term economic growth is largely contingent on the prevailing conditions for appropriability. Moreover, the theory suggests that larger economies are anticipated to be more innovative and gain greater benefits from innovation compared to smaller economies. As expected, R&D and RQ had a positive but statistically insignificant impact on economic development, suggesting no immediate returns on investment for economic growth. Görg and Strobl (2001), in a similar meta-study for a sample of both developed and developing nations, report that using panel data mostly yields negative or insignificant spillovers. Fagerberg and Verspagen (2002) suggest that the significance of innovation for economic development is increasing with time.

Table 4. Estimation of the Long-term ARDL model

Long Run				
Variable	Coefficient	Standard error	T-stat	Prob.
GDP per capita	0.360620	0.271786	1.326853	0.1854
RQ	0.258833	0.340365	0.760457	0.4475
C	-1.465604	1.208306	-1.212941	0.2260

Source: author's own work in Eviews 12

Table 5. presents the results of the short-term estimation. The elasticity coefficient for R&D per cap (−1) is -0.081, which is statistically significant. This demonstrates that R&D was slightly affected by the previous period. In turn, the GDP per cap elasticity coefficient (−1) is −0.029, which is statistically insignificant. Thus, we can observe a significant GDP per cap and R&D spending sensitivity compared to the previous period. At the same time, these results provide information on the impact of innovation on economic development. However, innovation has a significant impact on economic development, and the sensitivity of GDP (-2) per cap and R&D spending to changes in the economic environment indicates the need for an appropriate allocation of financial resources and the formulation of efficient approaches grounded in innovative principles. It is important to note that this negative relationship is not a universally valid rule; variations such as the economic context, government policies, industrial sector, and other factors can influence the stability of the model. Hasanov et al. (2018) and Liddle (2018) attest to these results. Moreover, these results also corroborate the theoretical justification.

The coefficient of elasticity of Regulation Quality is positive. These findings attest to the importance of investments and an effective regulatory framework in promoting economic development objectives. States that do not develop effective strategies and appropriate R&D allocations may face stagnation or limited growth in meeting economic development objectives; these objectives can be achieved if R&D expenditures are constantly financed and do not fluctuate significantly over time. Thus, a critical point associated with R&D can be stated: determining the optimal level of resources and funding assigned to research and development (R&D) is essential for political decision-makers to drive innovation and economic growth. While economic theory suggests that market economies tend to under-provide innovation due to the public goods nature of knowledge, empirical evidence supports the notion that targeted policy interventions can address this market failure (Bloom et al., 2019). Furthermore, evidence indicates that, in the short term, policies such as direct public funding for R&D can be effective levers for stimulating innovation, in the long term, increasing the supply of human capital is likely to be a more sustainable strategy (Mazzucato, 2015).

Table 5. Short-term estimation results of ARDL

Short-run estimation results of ARDL				
Variable	Coefficient	Standard error	T-stat	Prob.
R&D (-1)	-0.081841	0.021499	-3.806673	0.0002
GDP per cap (-1)	0.029514	0.024092	1.225059	0.2214
RQ	0.021183	0.028319	0.748019	0.4550
GDP per cap (-2)	0.495616	0.040252	12.31295	0.0000
ECM (-1)	-0.081841	0.021321	-3.838476	0.0001
C	-0.119947	0.106000	-1.131572	0.2586
R^2	0.354639			

Source: author's own work in Eviews 12

In addition, additional model validation tests were performed, including checking the autocorrelation of residuals and tests of model specification. These additional tests confirmed the robustness and accuracy of the model in terms of long-run equilibrium and cointegration of the variables. Moreover, the analyses based on our equilibrium model indicated that the cointegration relationships are significant, thus supporting the validity of the results. It is essential to emphasise the importance of the CUSUM and CUSUMSQ tests (Figure 2.), they provide the credibility of the results obtained from the time series model (long and short-term estimates), they also provide the coefficients of the ARDL model, which are stable, and they do not deviate from the limit interval, raising the validity of the model.

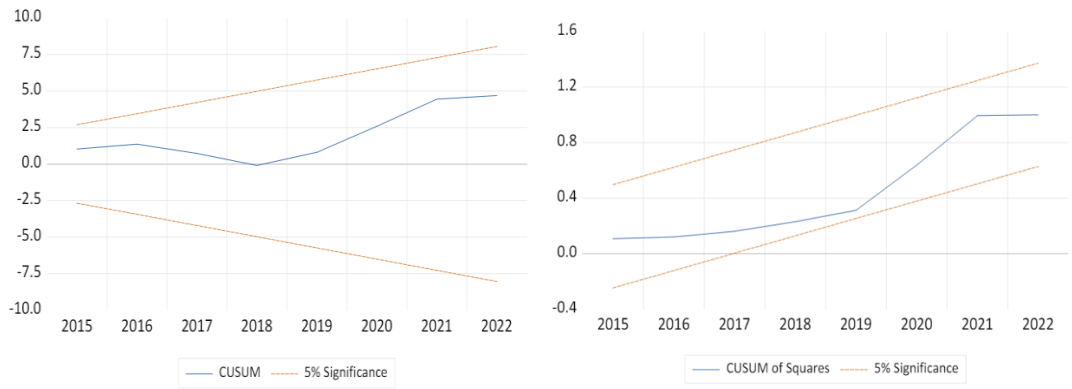


Figure 2. CUSUM and CUSUMSQ
Source: author's own work in EViews 12

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This study uses a robust methodology, namely Robust Least Squares regression, for robustness checks. The results of the robustness check, presented in Table 6, support

our primary findings. The outcomes suggest that R&D and regulatory quality increase GDP per capita significantly (Jalilian et al., 2007) (Silberberger & Königer, 2016). The study finds a strong positive link between Regulatory Quality, R&D and GDP per capita, indicating that countries with higher-quality regulations tend to invest more in R&D and experience more significant economic growth. This aligns with the notion that an effective regulatory regime fosters economic development, particularly in developing nations.

Table 6. Robust Least Squares

Variable	Coefficient	Standard error	T-stat	Prob.
R&D	0.491883	0.039609	12.41847	0.0000
RQ	0.462992	0.047312	9.786035	0.0000
C	4.353614	0.010078	431.9933	0.0000
Robust Statistics				
R-squared	0.510245		Adjusted R-squared	0.507431
Rw-squared	0.692481		Adjust Rw-squared	0.692481
Akaike info criterion	456.2143		Schwarz criterion	468.2412
Deviance	8.129299		Scale	0.134308
Rn-squared statistic	518.3410		Prob	0.0000

Source: author's own work in Eviews 12

5. Conclusion

This research explores the influence of R&D and Regulatory Quality (RQ) on GDP per cap in the European Union states (EU27) from 2010 to 2022. Our observation is that R&D, along with Regulatory Quality, has a significant impact on economic growth.

The unit root properties of each variable were examined using the Augmented Dickey-Fuller and Levin-Lin-Chu tests. The cointegration relationship was confirmed through the bound testing approach. To analyse the long-run and short-run relationships among the variables, including R&D, RQ and GDP, an Autoregressive Distributed Lag Model (ARDL) was employed. The findings indicate a positive association between innovation and economic growth. Conversely, innovation and regulatory quality were found to be positively linked with economic growth. Furthermore, the long-run coefficients for the model are higher than the short-run coefficients.

Our results evidence a positive association between GDP per capita and the explanatory variable, R&D and RQ. However, for the quality of the regulation, the coefficients

are positive, which implies that the quality of the regulation can influence the allocation policies of the funds intended for the R&D sector, and these, in turn, can affect economic growth. These findings underscore the importance of innovation in economic growth. A practical regulatory framework can stimulate R&D, contributing to GDP growth. At the same time, economic development and innovation have a positive and negative relationship in the short run. In the long term, innovation can contribute to economic development goals. Several factors can influence the relationship between economic growth and innovation, including the level of research and development spending. Countries that invest more in R&D tend to have a more robust connection between economic growth and innovation. Also, government policy significantly influences this relationship. Implementing government measures that support innovation and stimulate technology transfer can contribute to GDP growth.

The main findings at the EU member state level indicate, on the one hand, that several countries, including Croatia, Greece, Slovakia, Bulgaria, Malta, Cyprus, Portugal, Estonia, Poland, and Romania, require substantial improvements in all three dimensions analysed. On the other hand, some nations rank among the highest in funding research and development, such as Sweden, the Netherlands, Finland and Denmark, showcasing that research and development activity has been successfully adopted in these countries. This research methodology highlighted the discrepancies between EU member states regarding economic development potential and the importance of research and development activity. This study complements previous studies on this topic by providing new evidence and implications of R&D spending on each EU member state's economic development potential. However, several states, such as Romania and Bulgaria, continue to present a low level in terms of the adoption and implementation of R&D expenditures, which can be explained by the fact that the R&D process is perceived as an expense rather than a sustainable investment. The technological capabilities of advanced and less advanced nations serve as pivotal factors in accounting for divergences in economic growth. One prerequisite for technological progress is research and development. Initiatives and strategies focused on R&D contribute to economic expansion and advancement. Based on the results of the research study, a series of political guidelines and recommendations can be developed, such as: (i) EU states show a significant need to improve and strengthen the way of allocating expenses for research and development; (ii) the approach of strategies aimed at improving the quality of public sector through research and development activity leading to increased economic performance. Thus, the results of the scientific research recommend that all governments throughout the EU develop specific policies and adapted strategies to increase opportunities for public and private level support to adopt technological processes and stimulate economic performance. Moreover, the present scientific research can be helpful to decision-makers in the field of public policies, both from the perspective of identifying support solutions for the implementation of innovative processes and the efficient allocation of expenses for the research-development sector.

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