THE IMPACT OF RESEARCH, DEVELOPMENT AND INNOVATION EXPENDITURES AND EMPLOYMENT ON ECONOMIC GROWTH. A PANEL DATA ANALYSIS THROUGHOUT ROMANIA'S MACRO-REGIONS

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Abstract: *This present study examines the causality between core elements of an economy, namely economic growth, employment levels in R&D sector, and research, development, and innovation (RDI) spending throughout Romania's macro-regions. RDI has a pivotal role when it comes to economic expansion, but its impact depends on several factors, including, but not limited to funding sources and regional disparities. While both public and private sources of investment in the field of RDI contribute to economic development, private funding tends to yield more efficient results, regardless of discussed timeframe, and thus its influence transcends local and regional economies and manages to develop cross-border relationships and dynamics. We have developed a panel data ARDL model for Romania, that reveals the significant impact on long and short run of research, development, and innovation spending on the economic growth as well as a long run impact of hirings in this sector on the economic growth.*

Keywords: *regional development; research and development; economic growth; spending levels*.

JEL Classification: *O0; O2; O3; O5.*

1. Literature review

Research, development and innovation (RDI) are to be considered as the cornerstone for the development and improvement of economies, regions and societies. Advancements regarding RDI translate into the development of knowledge, the process of satisfying a broader percentage of needs, wants and desires through the form of creating novel products, services and technologies (Solow R. M., 1956), (Szarowská, 2017). Countries and regions that manifest potent ecosystems targeting innovation manage to attract greater investment levels, improved quality of hirings and manage to at least maintain auspicious trade balances (European Commission, 2016; Wensheng, Kong, Shi, Boamah, & Tang, 2022). Apart from impacting regions and societies, companies (SME's and MNC's alike) must understand that the investments

and hirings for RDI purposes will entail improved business survival rates, whilst simultaneously protecting the companies from decreasing their revenue streams, maintain customer levels, and improve working conditions for employees (Cadar & Bădulescu, 2018). What is more, by comparison of regions, three distinctive elements always seem to arise when analyzing the reasons behind the advancements and the success of various regions, irrespective of size: the quality and productivity of institutions, effectiveness of the industry-academia-government partnership, and lastly, the presence of procedures, regulations and mechanism that promote the transfer of knowledge (Cooke, Gomez Uranga, & Etxebarria, 1997).

Even though there are numerous studies on the impact of RDI spending and RDI related employment upon economic growth, a straightforward consensus has yet to be achieved; even so, one point of consensus shows that even though the funding sources can be both private and public, out of the two, private sources of funding do manage to pose a higher impact and more greatly influence general growth levels (Sehleanu, Simuț , & Simuț, 2022).

The aspect regarding private sources for financing of RDI activities and employment further detail the imbalances that exist between regions, so much so, that it has become apparent and evident for authorities/lawmakers and the general population that investment levels across various regions from public sources are not sufficiently large or targeted. Even so, a somewhat paradoxical situation has arisen in recent years: even though the effect of private financing for RDI activities has better outcomes than public sources for financing less advanced EU regions have in fact attempted to increase their overall public expenditure on R&D; these public expenditures automatically mean higher GDP growth rates, given that technological improvements (one of the purposes of RDI investments) positively impact economic growth (Guadalupi, Tutore, Matricano, & Andreottola, 2013). Even so, differences between factor driven and efficiency driven economies (together with their respective regions) are not able (given the lack of resources) to maintain in the long run such RDI expenditures (Sehleanu, Simuț , & Simuț, 2022). But here again, the channeling or focusing of monetary and policy related efforts (specializing in a certain field or domain and maintaining constant investment levels in those specific areas) proves useful for such factor driven economies in order to diminish the imbalances that exist between countries and regions.

In the field of specialty literature, numerous studies that have been presented throughout the years have aimed to showcase the impact of the RDI spending and employment on economic growth. Given that each innovation cycle that humanity has gone through has a certain particularity, namely that each new cycle will last for a smaller period of time than the previous one (Jovanović, Dlačić, & Okanović, 2018), most of the published articles point out that adaptability is of key importance, regardless of country or of region. Table 1 is intended to highlight relevant studies and models, and their respective impacts on/correlation to economic growth, based on RDI spending and employment.

Table 1 showcases the numerous facets through which employment and spending aimed at RDI are connected with economic growth, but more importantly, this table points towards the existence of bidirectional approach to the type of relationship that exists between RDI related employment and spending, and economic growth (for several regions, instances exist where not only is economic growth the direct results of spending and hirings related to RDI activities, but economies that manage to follow and

upward economic path also manage to do so by welcoming more investments targeted at RDI related activities)(Cooke, Gomez Uranga, & Etxebarria, 1997).
Even though the vast majority of economic literature is in favor of the idea that RDI spending and employment have a positive impact on economic growth, there are nonetheless several authors that have brought forth several critiques of these ideas (either through direct criticism of this view, or by challenging the limitations and inefficiency of RDI investment presented by those that consider this idea to hold water). Among the ideas that come as a critique aimed at the impact of RDI investments, one that has managed to gain numerous followers revolves around the notion according to which despite increased investments in innovation, technology (RDI in general terms), oftentimes a certain lag in measuring economic growth presents itself; these particular

Table 5. Key Economic Theories Linking RDI Spending, Employment, and Economic Growth

Economic Model or Theory	**General concept of the model or theory**	**RDI Spending Activity & Its Impact on Economic Growth**	**RDI-Related Employment & Its Impact on Economic Growth**
Endogenous Growth Theory	Knowledge accumulation and innovation are the key drives of long term oriented economic growth.	Increased RDI spending greatly impacts technological progress, and thus in turn it leads to sustained economic growth.	Employment in high-skill, RDI-intensive sectors not only does it enhance productivity, but it also reinforces GDP in the long run (Romer, 1986), (Lucas, 1988).
Schumpeterian Growth Model	The process of "Creative destruction" manages to replace old industries with newer and more novel ones, especially within innovation-driven sectors.	Increased RDI spending fosters business innovation, thus massively contributing to the process of industrial transformation/ development and GDP growth.	RDI-related employment fosters new industry creation; at the same time, situation where certain jobs for various outdated or old sector may be displaced (or destroyed altogether) (Schumpeter, 2003)
Capital-Skill Complementarity Model	RDI investments are usually prone to favor adaptable and skilled labor whilst widening wage gaps	RDI funding has as an effect an increase in the demand for advanced technology, reinforcing growth but at the same time, it also manages to increase inequality if not addressed properly at nationwide levels.	RDI employment mostly benefits high-skilled workers, potentially leading to job polarization across the various regions of nations, unions, trade zones (Krusell, Ohanian, Ríos-Rull, & Violante, 2000)
Triple Helix Model	Collaborations between various types of	Targeted RDI investments foster the creation and development of start-ups	RDI employment in science, tech, and academia have a

	stakeholders (universities, industry, and government representatives – both at local and national levels) drive innovation.	(potentially leading them to attain the level of unicorns), tech clusters (accelerators, hubs, technology parks), and industrial competitiveness, thus boosting GDP levels.	direct impact the regional economic development (Etzkowitz & Leydesdorff, 2000) .
Regional Innovation Systems	The economic impact of RDI varies across regions based on the regions' capacity to assimilate innovation.	RDI investment is one of the drivers of regional economic disparities, given that they tend to benefit high-tech hubs (which have proven their worth time and time again) whilst those hubs or regions that lag will show signs of struggling.	RDI employment is centered around innovation hubs and accelerators; thus, unemployment rates will be on the rise in regions that do not manage to keep up the pace (Cooke, Cooke, & Etxebarria, 2004)

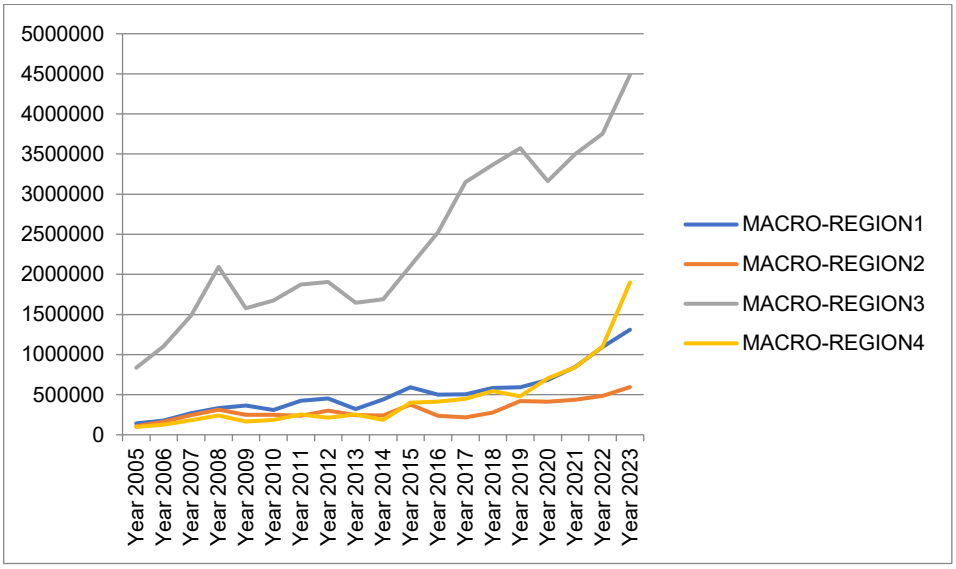
Source: own adaptation by the authors of multiple theoretical elements

results concerning productivity suggest that RDI investments do not always translate into immediate economic benefits due to inefficiencies, adoption delays, or misallocated or misused resources (Solow R., 1987). Another important critique has been brought forward by Zachariadis (2004); his study points to the fact that even though RDI has a positive impact on GDP growth in OECD countries, there is no uniform causal link (dependencies on elements such as education, infrastructure and diffusion of innovation being the ones that pose a broader impact on GDP growth). Other critiques noteworthy of mentioning include: subsidies targeting RDI investment and employment will result in the massive reliance of companies on public/government support (thus diminishing not only the opportunity of investing own funds towards RDI activities, but also decreasing the motional aspects behind conducting RDI activities) (Almus & Czarnitzki, 2003); the structure of research institutions and the involvements stemming from the private sector have a far greater impact on economic development that straightforward RDI spending and employment (Guellec & van Pottelsberghe de la Potterie, 2004); government intervention in innovation is often inefficient unless well-structured policies are in place, and as such, private sources for financing RDI related spending and employment and much rather preferred from an efficiency perspective (Mazzucato, 2013). Several critiques (of the many that exist) have been presented in the previous paragraph. As a commonality, most of these critiques point towards similar ideas, namely that a mere increase in RDI spending and hiring will not necessarily lead to economic improvements and growth except for the situation in which structural inefficiencies (private-public sector collaborations, increased adaptability to novel technology through educational programs and transfer of knowledge, and the quality of various institutions) are addressed and resolved.

2. Romanian national and regional context

According to the Nomenclature of Territorial Units for Statistics (NUTS), Romania is divided into 4 NUTS 1 macro-regions (macro-region 1, 2, 3 and 4), 8 NUTS 2 regions, and 42 NUTS 3 counties (including Bucharest)(EUROSTAT, 2021). A dataset released by the National Institute of Statistics in 2021 highlights that 10.7% of the active enterprises within Romania exhibit characteristics related to innovation, having manifested innovation regarding products, process or a combination of the two (Romanian National Institute of Statistics, 2023). For 2024 levels, Romania has had a GDP of 356.39 billion dollars (tradingeconomics.com, 2025), and during the last 10 years, the country has managed to advance 9 positions in terms of ECI (economic complexity index) positions worldwide (Hardvard Growth Lab, 2025), thus showcase the upward trend faced by the economy.In order to showcase the evolution of RDI related spending (expressed in thousands of RON) in the four Romanian macro-regions, the following graph is used:

Graph no. 1. Evolution of RDI spending (expressed in thousands of LEI) per Macro-region in the 2005-2023 timeframe in Romania

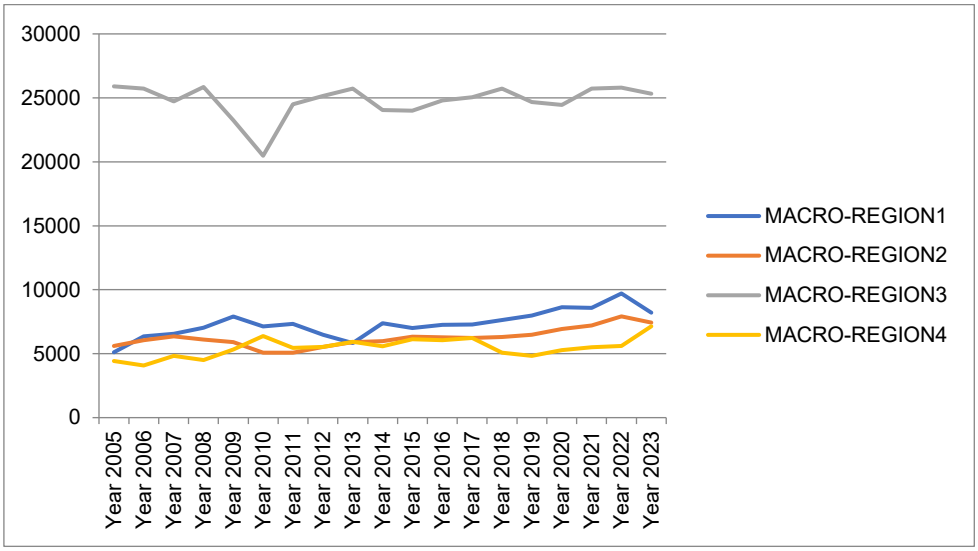


Source: Own adaptation by the authors based on data from the Romanian National Institute of Statistics database, section CDP104B (Romanian National Institute of Statistics, 2025), available online at https://insse.ro

Graph no. 1 highlights the dominance of Macro-Region 3 as opposed to the other regions of the country, also hinting at the concentration of certain urban/research centers and institutions which have developed over the year within this particular region. In general terms, all four regions have present solid growth over the analyzed period. Another conclusion that can be drawn from the table is the impact that certain disturbers (pandemics, trade wars, etc.) can have upon RDI spending throughout the

regions, and the recovery following times of economic downturn can be attributable (at least in part) to past investments made in the field on RDI.

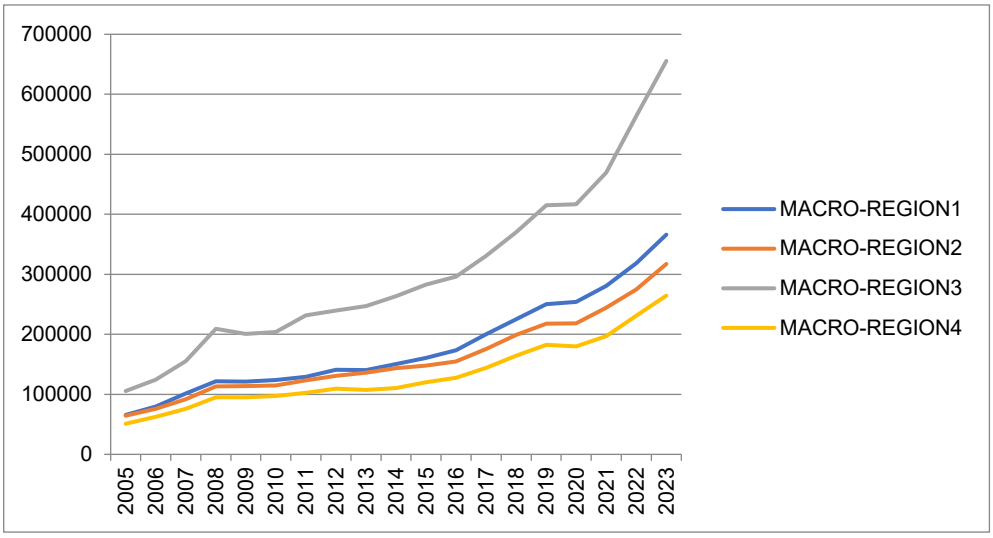
Graph no. 2. Hirings in RDI activities (expressed in number of individuals) per Macro-region in the 2005-2023 timeframe in Romania



Source: Own adaptation by the authors based on data from the Romanian National Institute of Statistics database, section CDP102E (Romanian National Institute of Statistics, 2025), available online at https://insse.ro.

Apart from RDI related spending, the four Macro-Regions of Romania have also had significant hiring surge related to RDI activities. Graph no. 2 aims to detail the evolution of such hirings throughout Romania, expressed in individuals. During the analyzed timeframe, Macro-Region 3 does manage to dominate the regions of the country, again pointing towards the existing infrastructure, and the existence of productive research centers, actively involved in development activities. Even though such concentration is beneficial for the respective regions (and it does assist when averaging for country levels), but the distribution of hiring highlights an important imbalance that exists within the country, not only in terms of RDI spending (as shown previously in Graph 1), but also in terms of RDI related hirings. The reasons behind such hirings within this specific region consider (but are not limited to) the following: the capital city of the country is included within this region, strong partnerships between the industry-academia-government, concentration of research centers, and concentration of headquarters of multinational corporations.

Graph no. 3. Evolution of GDP (millions of LEI) per Macro-region in the 2005-2023 timeframe in Romania



Source: Own adaptation by the authors based on data from the Romanian National Institute of Statistics database, section CON103 (Romanian National Institute of Statistics, 2025), available online at https://insse.ro

During the period 2005–2023, the evolution of GDP in Romania's NUTS 1 regions reflected the country's general economic trends, with variations between developed and less developed regions. In 2022, Romania's GDP was 286.4 billion euros, registering an increase of 18.7% compared to 2021. As seen in Graph 3, Macroregion 3 of Romania — which includes the regions of Sud-Muntenia and București-Ilfov — has the highest GDP compared to the other Macroregions mainly due to the dominant economic weight of the capital city, Bucharest, and its surrounding area. Bucharest alone generates over 25% of Romania GDP alone and this is due to a developed service sector, the high concentration of multinational companies and foreign investments. Macroregion 3 also concentrates the industrial powerhouse – mainly the oil refinery from Ploiesti, automotive industry (Mioveni) as well as several energy production plants.

3. Data and methodology

We will analyze the impact of RDI expenditures as well as hirings in RDI activities on the regional economic growth measured by the nominal GDP, using a panel data approach. A panel model refers to a statistical framework that is used to analyze how the selected variables influence the economic growth of countries or regions over time; it allows for the analysis of multiple regions over multiple time periods, capturing both cross-sectional (across entities) and time-series (over time) variations. We have collected annual data from the Romanian National Institute of Statistics for the following

variables: hirings in RDI activities, RDI expenditures and GDP in the 4 Romanian Macro-regions during the last 19 years (2005 – 2023). We will develop an ARDL **panel data model for the GDP in Romania,** using **R&D (Research and Development) spendings** and hirings in RDI activities as explanatory variables across regions and over time. The Bounds Test proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) was used to investigate the cointegration between the variables. Units root tests (Dickey Fuller (1979), Phillips and Perron (1988) and Levin and Lin and Choo (2002)) were employed for the variables in order to identify the integration order of each. Multicollinearity between the dependent variables will be checked using variance inflation factor (VIF) test.
We will employ the Hausmann test (1978) to indicate if the fixed effects model or the random effects model is appropriate. Then we will estimate the parameters of an ARDL(p,q,q,...q) model that can be written as follows:

$$y_{it} = \sum_{j=1}^{p} \delta_j y_{i,t-j} + \sum_{j=0}^{q} \beta'_{ij} X_{i,t-j} + \varphi_i + e_{it} \quad (1)$$

where y_{it} is the dependent variable, X_{it} is a k x 1 vector of independent variables, δ_j is the coefficient of the lagged dependent variable, β'_{ij} is a k x 1 coefficient vector , φ_i is the unit specific fixed effects, $i = \overline{1,N}$, $t = \overline{1,T}$, p and q are optimum lag orders and e_{it} is the error term. Dumitrescu Hurlin (2012) causality test will be employed to detect causal relationship between the variables across the panel.

4. Results

The data collected for the 3 variables in our model were taken in log, in order to eliminate the trend. Stationarity tests indicated that all the 3 variables in log are integrated of order 1, that is I(1). The Bounds Test proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) confirmed the cointegration between the chosen variables. This means that the correlation between these variables is not a short-lived one, but a permanent one, and one that can be recovered every time there is a perturbation.
We have chosen to estimate a regional fixed effect ARDL model. The estimators of the short run and long run parameters of model are presented in Table 2.
The model reveals that in the short-run, the variables with a significant impact on the regional development measured by the GDP are the lagged GDP, 2 period lagged hirings in RDI activities as well as one and two period lagged RDI expenditures. As regards the long-run results, all variables taken into account have a positive and statistically significant impact on the economic growth measured by GDP - RDI expenditures as well as hirings in RDI activities. The error correction term from the long run representation is statistically significant at the 0.01 level and its negative sign confirms the correct specification of the model.

Table 2. Panel ARDL model estimations

	Long-run coefficients			Short-run coefficients	
Variable	**Coefficient**	**P - stat**	**Variable**	**Coefficient**	**P- stat**
LGEMPL	0.182623***	0.0003	COINTEQ01	-0.813112***	0.0031
LGRDE	0.515715***	0.0000	D(LGGDP(-1))	0.502322**	0.0319

			D(LGEMPL)	0.108778	0.3943
			D(LGEMPL(-1))	0.040235	0.6485
			D(LGEMPL(-2))	0.154746*	0.0662
			D(LGRDE)	-0.171848	0.2783
			D(LGRDE(-1))	-0.276877***	0.0016
			D(LGRDE(-2))	-0.099422***	0.0067
			C	5.400101***	0.0042
			@TREND	0.021515***	0.0004

***Coefficient is significant at the 0.01 level (2-tailed). ** Coefficient is significant at the 0.05 level (2-tailed). *Coefficient is significant at the 0.1 level (2-tailed).
Source: Authors' calculation using Eviews 10

The analysis of the cross section results on short run has revealed the same situation across the 4 macroregions. In addition, in macroregion 3 the results reveal a short run correlation between the hirings in RDI activities and the regional GDP. The diagnostic tests were employed in order to confirm that the model is a valid one. The Jarque Bera test for normality confirmed the normality of the errors of the model. There are several causality tests that are used in the literature, the most known being the Granger (1969) test as well as the Dumitrescu and Hurlin (2012) test. The **Dumitrescu-Hurlin causality test** is a **panel data** version of the **Granger causality test**, used to detect causal relationships between variables across a panel of individuals (macroregions – in our case) over time.

Table 3. Dumitrescu Hurlin causality test results

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
LGGDP does not homogeneously cause LGEMPL	2.04144	0.96430	0.3349
LGEMPL does not homogeneously cause LGGDP	2.21850	1.15667	0.0474
LGRDE does not homogeneously cause LGGDP	3.15277	2.17168	0.0299**
LGGDP does not homogeneously cause LGRDE	3.93269	3.01900	0.0025***

** Coefficient is significant at the 0.05 level (2-tailed). ***Coefficient is significant at the 0.01 level (2-tailed). Source: Authors' calculation using Eviews 10

The causality test confirmed a feedback causality between the economic growth and RDI expenditures. As regards the impact of hirings in RDI activities on the economic growth, there is only a unilateral causality between the as hirings in RDI activities and the economic growth.

Conclusions and discussions

The impact of **R&D investment** on **regional economic growth** is a widely studied topic in economics, often explored through the lens of innovation-driven growth theories. Most studies find that higher RDI correlates with higher regional GDP per capita and

productivity growth. Theory reveals a spatial heterogeneity; effects are stronger in regions with good infrastructure, skilled labor, and existing innovation ecosystems. Macroeconomic policies should promote RDI in lagging regions in order to reduce inequality and encourage cooperation between government, firms as well as universities. A good labor mobility, partnerships, and infrastructure would encourage the spread of innovation benefits. The **impact of R&D hiring on regional economic growth** is a more specific way to assess the link between innovation and development that focuses on the **human capital** dimension - how employing researchers, scientists, and technical staff influences a region's economy. Skilled workers in R&D generate knowledge, innovation, and problem-solving capacity that drive **productivity** and **technological advancement**. Employees hired into R&D roles often collaborate, publish, or move between firms—helping diffuse innovation across the region. A larger R&D workforce can signal the presence of an innovation-friendly ecosystem, attracting further investment and startups. R&D staff may launch spin-offs or startups, contributing directly to regional job creation and economic diversification.

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