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The Relationship between Sustainable Economic Growth, R&D Expenditures and Employment: A Regional Perspective for the North-West Development Region of Romania

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Abstract: The role of research and development (R&D) in economic growth has been intensively promoted by scholars and policy-makers of the last decades, emphasizing its impact on technological innovation, intensive and sustainable growth and economic revival. The R&D sector is considered a main driver in the fight against chronic underdevelopment, regional disparities, isolation and lack of socio-economic perspectives. Although the steady economic growth of Romania in the last 15 years continues to converge with the European Union's average, the regional disparities persisted and even deepened, the country still being considered a modest innovator, and resources allocated to research and innovation are far below the European level. In this paper, we aim to identify the existence, direction and duration of the relationship between economic growth, expenditure and employment in the R&D sector. We applied the Johansen cointegration test, the VECM model and Granger causality both at the county and component region levels during the 1995–2021 period. The results of our research reveal the consistency of these bidirectional relationships at the regional and sub-regional levels, especially in the long run. We also emphasize the importance of economic growth in supporting public and private efforts for R&D: the regions that can allocate more resources to research, development and innovation (RD&I) will benefit from the more reliable and long-run-oriented economic growth.

Keywords: regional economic development; research and development expenditures; innovation; Romania; North-West Region

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1. Introduction

Understanding the factors that determine economic growth has been a major and constant concern of scholars and policy-makers. Since the end of the 1980s, numerous theoretical and empirical studies have emphasized the role of technology as an essential factor for national and regional economic growth, based on seminal contributions through the New Growth Theory. The role of technological change in propelling economic growth [1], endogenous growth models [2,3], and technological diffusion and convergence [4] emphasize that the primary force driving growth is closely tied to technology. This can occur through its incorporation into labor [5], the expansion of the quantity of intermediate available goods [3], or an enhancement in the quality of the relationship between these inputs [6,7].

Implicitly, the support and adequate public and private funding of research and development (R&D) activities, together with an educated human capital, will drive and spread technological innovations, increase the competitiveness of companies, contribute to the modernization of economic structures, and will lead to the growth and prosperity of countries, regions and local communities. However, the growth of technological capital can also be achieved, apart from innovation, through imitation [8] or technological transfer [9]. Many developing countries, with an insufficient stock of knowledge, low-qualified human capital, and deficient institutional structures, have resorted to this second option to reduce the gaps and speed up economic development.

Despite the complexities, many states engage in R&D to foster domestic growth, produce competitive goods through independent efforts, decrease reliance on uncompetitive and unsustainable domestic resources [10], and stimulate competition and entrepreneurial spirit, etc. [11]. Reducing the technological gap requires the allocation of considerable resources and deep institutional transformations, but it is often noticed that either as a result of different allocations or due to other factors, regional development is not homogeneous.

Additionally, the rationale of our study is based on the fact that the regions of Central and Eastern Europe (including the regions of Romania) experience non-uniform rates of economic growth, which are more pronounced compared to other regions of the EU [12]. Thus, the benefits of development and modernization are unequally distributed in territorial, social and sectoral terms, thus aggravating urban–rural disparities and the decline of peripheral areas, leading to reduced investment in deprived areas that are further drained by the exodus of human capital to more prosperous countries and regions [10–12]. Investments in R&D could mitigate these imbalances, underlining the importance of choosing appropriate indicators to measure R&D efforts and their effects on economic growth [13]. Although there are several indicators that can capture the relationship between research, development, innovation and economic growth, namely *number of patents filed and trademarks, turnover from active R&D local units, number of projects for R&D activities*, it is only the *total expenditure on R&D* and *individuals employed in the R&D sector* that are available for a long enough time period on a national, regional (NUTS2) or sub-regional (NUTS3) level.

In this paper, we are interested in finding, for the case of Romania and some territorial administrative units (region and counties), if there is a positive correlation between R&D efforts (expressed by total expenditure on R&D and individuals employed in the R&D sector) and economic growth (Gross Domestic Product—GDP). The novelty of this study resides in enriching the national and regional perspectives, which have already been studied in the recent literature, with a sub-regional (county/NUTS 3) approach. The presence (or absence) and strength of this relationship can offer insights for decision-makers at various levels to incentivize R&D to stimulate growth. Alternatively, it may prompt a reassessment and adjustment of policies to bolster innovation and technological progress, supporting both regional and national economic prosperity.

The paper's structure is as follows: after this introduction, we provide a review of key contributions to the relationship between R&D expenditure and (regional) economic growth. Following that, we present the context of R&D and economic development in the Nord-West Region of Romania and selected counties, discuss the research methodology, present the main results, and conclude with a discussion. We end with conclusions and highlight the study's contribution to scientific knowledge on this topic, along with its main limitations.

2. Theoretical Overview

2.1. R&D and Economic Growth

Research and development support has a positive impact on economic growth [14,15], creating productive external effects [16] and emphasizing sustainable innovation impacts and spillover effects at the regional level [17,18]. According to Goel et al. [19], public R&D expenditures allocated at the central level are essential for economic growth, the causality being direct and positive in the long term [20], or even bidirectional [21], simulta-

neously driving the diffusion of innovation on a regional and sectoral scale and enhancing entrepreneurial initiatives [22].

While many recent studies establish a direct causal link between increased expenditure on R&D, innovation, education, and sustainable economic growth, closing gaps between countries and regions [23], numerous studies temper these optimistic claims and even question their existence or effectiveness.

Lichtenberg [24] and Park [25] admit the positive role of R&D expenditures in private sector growth, but their effect seems insignificant in the public sector [26], while other scholars, analyzing data from developed countries, are cautious about the existence of an obvious relationship between economic growth and R&D expenditures [27], or innovation [28,29] or, simply, the direction of causality between the variables cannot be determined [30]. The relationship between R&D expenditures and economic growth in developing countries is unconvincing [31], the effects are much smaller and uneven compared to developed countries [32], or weak in the short run but strong in the long run [33]. Even in OECD countries, although the R&D expenditures have a positive and significant effect on economic growth, the magnitude and duration of the effects are variable in the medium and long terms [21].

Understanding the motivations and sources of R&D in relation to regional economic growth is subject to two major explanations—the substitution and complementarity effects, but often, the real world shows that the two explanations are not mutually exclusive [34,35]. Public funding for R&D appears to be essential in increasing the R&D capabilities of firms and regions [36], but it does not greatly influence the commercialization and diffusion of innovations. The motivations of companies to get involved in research and innovation are, primarily, to increase profits and strengthen their market position [37], and this somewhat contradicts the objectives of governmental funding for R&D—to stimulate regional growth, reduce disparities and have a more "collective distribution" of the benefits [38–40].

Research in fundamental fields, which is perceived as riskier and less likely to produce practical results, is typically avoided by companies and instead becomes the responsibility of public authorities [41]. On the other hand, applied research with innovative potential is also of interest to the private sector, which suggests complementarity rather than substitutability; specifically, public spending in R&D complements private investment pre- and post-economic crisis [42]. However, it is controversial whether the increased public involvement in R&D will drive and encourage more private spending in R&D [35]. Somewhat, firms improve their own technological and innovation capabilities starting from the results of public investments in R&D [43], influencing productivity growth which, in turn, will be reflected in a greater share of production and GDP at sectoral and regional levels [41], or, in other words, the regions susceptible to (and equipped for) innovation are "capable of transforming a larger share of their own R&D into innovation and economic activity" [44] (p. 82).

2.2. R&D in the European Union and Romania

In the European Union (EU), member countries and regions have enacted public policies to support R&D, aiming for efficient public spending and the promotion of investments in innovation [45]. These policies also target private sector growth, employment [36], and the dynamism of small and medium-sized companies, utilizing local resources effectively. The EU's Regional Policy (Cohesion Policy—CP) has significantly backed public and private R&D investment, particularly in lagging regions, aiming to enhance regional competitiveness and diminish economic disparities. In the recent programming periods (from 2007 to the present), 25% to 30% of PC funds were allocated to R&D [40].

Celli et al. [39] find that CP has had a positive and significant impact on regional economic growth in the EU over the last 15 years, confirming the previous results of Becker et al. [46] and Pellegrini et al. [47], but also, they find that many of the regions that invested additional funds in R&D did not experience higher economic growth compared to those regions that did not. Thus, Celli et al. [39] consider that increasing R&D expenditures in lagging regions does not have a significant effect on economic growth in the short term,

recalling here the negative or divergent influence of the lack of skilled labor, a critical number of firms generating ambitions and entrepreneurial spirit, institutional deficiencies and insufficient support for entrepreneurship [48,49], or in essence, the reduced and ineffective absorption capacity of funds dedicated to research, innovation and development (RD&I) [50]. The literature also shows that consistent investments in R&D do not have the same effect in less-developed regions [39]. On the one hand, this is explained by the lack of favorable circumstances (the ability to move from technological progress to innovation, the agglomeration of innovative firms, the quality of human capital, and the existence of innovative value chains) [45]; on the other hand, policies that are trying to compensate these disadvantages by providing significant incentives for R&D could overestimate the limited absorptive capacity of underdeveloped regions. This could eventually generate negative effects by discouraging economic recovery and growth [31–33,39]. Pop Silaghi et al. [26] argue that the impact of private R&D spending on economic growth in Central and Eastern European countries is much higher than the impact of public spending, and existing regional economic structures tend to influence this perception [51].

Due to the importance of the topic and the challenges and opportunities that followed Romania's accession to the European Union in 2007, the relationship between R&D, innovation and regional economic growth found a consistent reflection in the Romanian economic literature. Research has shown that, in conditions where other comparative advantages decrease, focus on innovation becomes inevitable [52–54]. However, hindered by low R&D funding, weak national–regional coordination of technology transfer support programs [55], and challenges in predictability and innovation diffusion [56], the contribution of RD&I to national and regional economic growth is unsatisfactory. The limited share of innovative companies and volatile innovation performance, concentrated in specific sectors [57] or spatial "pockets of excellence" [58], further underscores the lack of proportionality between R&D financing efforts and economic impact [52].

According to Dachin and Postoiu [59], innovation (supported by investments in R&D, education, and technology transfer) still does not generate regional economic development in Romania. However, at the sub-regional level (NUTS 3), a direct relation can be identified between investments in R&D and the GDP/capita level. Goschin [60] (p. 33) supports, however, the positive effect of R&D expenditures on regional economic growth in the period 1995–2010, and "the existence of stable regional characteristics that influence the economic growth patterns". Therefore, when formulating regional development policies, it is crucial to consider peculiarities and structural features [58,60], the specialization of local RD&I systems, university involvement in technology transfer, support for innovative entrepreneurship, and co-financing the acquisition of advanced technologies by companies [61]. Additionally, enhancing the integration of centers of excellence in research and innovation into international networks and value chains can transform them into service centers for other regions [58], thus aiding in the alleviation of regional disparities.

2.3. The Case of Romania in a Regional Approach

In 2020, the World Bank classified Romania (for the first time) as a country with a high income level [62]. Regarding GDP/capita (measured in purchasing power standard—PPS), Romania has been converging with the EU average, increasing from 44% in 2007 to 72% in 2020. However, persistent regional disparities, with the ratio between GDP/capita in the most prosperous and poorest regions of Romania being almost three times higher [63], remain a challenge.

In terms of investing in RD&I, Romania ranks at the bottom of the European Union. The RD&I system in Romania faces chronic challenges characterized by insufficient funding, fragmentation, and unpredictability [64]. Closing the gap in Romania's R&D system compared to the EU may take anywhere from 5 to 25 years, depending on the indicator [65].

As per the 2019 European Innovation Scoreboard (EIS), Romania ranks at the lowest position within the EU concerning innovation performance, having a country score of 20, and being considered as an emerging innovator. For example, the first three countries in

this ranking (Denmark, Sweden and Finland) have scores of above 130 points each [66]. For EU average levels, between 2015 and 2022 we can notice an increase in innovation performance of 9.9%; however, in Romania, performance has exhibited a downward trend in 2016–2018, and 2022. Notably, the most pronounced decline in performance in 2022 was observed in indicators such as Innovation Expenditures per Employee and Collaborative Initiatives among Innovative SMEs. These findings highlight a concerning pattern of decreasing performance in specific aspects of innovation, signifying potential challenges or areas requiring focused attention and strategic intervention. Ever since 2015, the most significant decreases in terms of innovation-related indicators refer to environment-related technologies, doctorate graduates and non-R&D innovation expenditures [67].

According to the NUTS classification for 2021, Romania is divided into 4 NUTS 1 macro-regions, NUTS 2 regions, and 42 NUTS 3 counties (including Bucharest) [68] (see Figure 1 below).

Figure 1. Romania' NUTS 2 region and component counties. Legend: 1—North-East Region, 2—South-East Region, 3—South Muntenia Region, 4—South West Oltenia Region, 5—West Region, 6—North-West Region, 7—Center Region, 8—Bucharest–Ilfov Region. Source: [69].

The strongest region throughout Romania (in terms of GDP/capita) is the capital region, namely the Bucharest–Ilfov Region, with over 25,400 EUR/capita, followed by the West Region (11,200 EUR/capita), Centre Region (10,600 EUR/capita) and North-West Region (10,400 EUR/capita) [70]. The innovation scores for each region are the following: Bucharest–Ilfov (59.5 points; rank within the EU: 199), North-East (35.8; 230), North-West (34.5; 232), West (32.6; 234) Center (25.7; 236), South (23.0; 237), South-West (19.8; 238), South-East (18.9; 239) [67].

In our analysis, we will look at the North-West Development Region (NW Region) and two (out of six) constituent counties, namely Cluj County and Bihor County (see Figure 1). Regarding Cluj County, out of a total county population of 741,000 inhabitants, the capital county, namely Cluj–Napoca, has a population of 307,000 individuals [70], it being the 2nd-largest city in Romania. Cluj–Napoca is by far one of the largest and most respected academic, cultural, industrial, and business centers in Romania, one of the main IT clusters in Romania. Regarding Bihor County (551,000 inhabitants), the county's capital city, Oradea is the 10th-largest city in Romania (221,000 inhabitants), and the second-biggest city of the NW Region, after Cluj–Napoca [70].

3. Data Analysis and Research Methodology

3.1. Data Analysis

In order to investigate the relationship between economic growth (expressed in current prices—million RON) (GDP) and the total expenditure on R&D (expressed in current prices—million RON) (EXP), and also the relationship between the economic growth (GDP) and the individuals employed in the R&D sector (full-time equivalent) (EMP), in Romania, in the NW Region, and in the two constituent counties (namely Cluj County and Bihor County), this analysis applies the Johansen cointegration test, the VECM model and Granger causality. The data utilized in this study have been sourced from the National Institute of Statistics (Romania) [70]. Given the limited availability and accessibility of data, this research focuses on the timeframe from 1995 to 2021. Table 1 presents the descriptive statistics for the dataset in Romania, the NW Region, Cluj County and Bihor County.

Table 1. The descriptive statistics of the variables—GDP, total expenditure on R&D (EXP) and individuals employed in the R&D sector (EMP).

Variables	Minimum	Maximum	Mean	Median	Std. Dev.	Skewness	Kurtosis
Romania							
GDP	7648.9	957,554	411,069.7	425,691.1	310,750.5	0.218027	−1.20984
EXP	577,148	9,528,718	3,278,001	2,786,830	2,086,427	1.444748	2.458032
EMP	26,171	60,939	36,003.36	32,507	9916.696	1.735055	1.718173
NW Region							
GDP	911.1	162,865.8	49,891.85	51,229	41,306.6	0.850533	0.707835
EXP	23,113	386,870	204,135.4	204,056	100,169.5	0.007063	−0.85062
EMP	1757	3919	2451.16	2352	554.2362	1.402258	1.863705
Cluj County							
GDP	266.9	66,861.55	18,912.54	18,265.7	16,965.97	1.067688	1.144931
EXP	16,400	332,665	165,766.9	176,353	82,750.57	−0.19194	−0.83136
EMP	1119	2436	1738.84	1790	388.459	−0.06118	−0.74113
Bihor County							
GDP	214.6	31,106.52	10,306.54	11,807.1	7841.948	0.629216	0.397997
EXP	574	76,026	10,121.72	5956	16,711.5	3.299811	11.14963
EMP	22	840	254.12	172	227.8661	0.964202	0.103342

Note: Std. Dev—standard deviation. Source: own elaboration based on data provided by the Romanian National Institute of Statistics [70].

According to descriptive statistics, EXP and EMP variables in Cluj County exhibit negative skewness, while in all other cases, the variables show positive skewness. In terms of kurtosis, most variables demonstrate low kurtosis, except for the EXP variable in Bihor County. To test for the presence of outliers, we used the interquartile range (IQR) and applied winsorized estimators to replace extreme values with percentiles, in particular trimmed minimum and maximum values. The application of logarithmic transformation to the variables was employed to address issues related to asymmetry and achieve a more symmetrical distribution of the data. The outcomes revealed a decrease in both variance and asymmetry. To facilitate interpretation and address heteroscedasticity issues, we transformed the variables using natural logarithms, denoted as follows: LGDP—natural logarithm of GDP, LEXP—natural logarithm of total expenditure on R&D and economic growth, and LEMP—natural logarithm of individuals employed in the R&D sector (full-time equivalent).

3.2. Methodology and Research Hypotheses

In examining the time series, we have started from the hypothesis that the observed series are stationary. According to the literature, the majority of time series fail to meet the condition of stationarity, attributed to the numerous changes that occur in the economic environment. To assess the relationship and the causality among the three picked variables in Romania, the NW Region, and two constituent counties, the initial step involved examining the stationarity of all variables. Following this, cointegration tests were conducted to identify a long-run equilibrium relationship among the variables. The third step involved the testing of causality between these variables.

The analysis starts by investigating the stationarity of the following variables: economic growth (LGDP), total expenditure on R&D (LEXP) and individuals employed in the R&D sector (LEMP). In order to test the stationarity, we have used the Augmented Dickey–Fuller test [71]. The null hypothesis of the ADF test is the presence of a unit root, indicating non-stationarity. The alternative hypothesis is the absence of a unit root, implying stationarity. The ADF test involves estimating an autoregressive model of the form:

$$\Delta Y_t = \delta Y_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta Y_{t-j} + \alpha + \beta t + u_t \quad (1)$$

where: Y_{t-1}—the lagged dependent variable, ΔY_{t-j}—the lagged differenced values; u_t is the error term; the coefficients δ, γ, α, and β are the initially estimated coefficients.

To assess the existence of cointegration between the selected variables, we will employ the method introduced by Johansen and Juselius [69], which involves testing the null hypothesis of non-cointegration. Starting from this procedure, we will use the following two tests: the Maximum Eigenvalue test and the likelihood ratio (LR) tests, specifically the Trace test (LRtr) [72,73]. As stated by Engle and Granger [74], when there is cointegration between time series, a long-run effect exists, preventing the time series from diverging.

To explore the long-term equilibrium relationship among the LGDP, LEXP and LEMP variables, we will employ the Johansen cointegration test. Following the results obtained from the Johansen–Juselius cointegration tests, we can determine the suitability levels by applying the vector error correction model (VECM). Following the normalization of the cointegrating vector in order to estimate the error correction model (ECM) of the dynamic structure, we obtain [73]:

$$y_t = \alpha_1 + \beta_1 x_t + \varepsilon_t \quad (2)$$

where: y_t—is the dependent variable, x_t—is the independent variable, α_1, β_1—the coefficients, ε_t—the aleatory variable. The error correction term can be obtained from the abovementioned equation, providing valuable insights into the adjustment process of the variables over time (Equation (1)):

$$EC_t = y_t - \alpha_1 - \beta_1 x_t \quad (3)$$

Thus, the equation becomes:

$$\Delta y_t = a_0 + \delta EC_{t-1} + \sum a_{1j} \Delta y_{t-j} + \sum a_{2j} \Delta x_{t-j} + u_t \quad (4)$$

A negative and significant coefficient of the EC shows that any short-term association between the dependent and independent variables will yield a consistent long-run relationship between them [75].

Based on the literature review, i.e., GDP, EXP and EMP, we have formulated and examined the following six hypotheses in the case of Romania, the NW Region, Cluj County and Bihor County:

H1a: *A long-run equilibrium defines the relationship between economic growth (GDP) and total expenditure on R&D (EXP).*

H1b: *A long-run equilibrium defines the relationship between economic growth (GDP) and individuals employed in the R&D sector (EMP).*

H2a: *A unidirectional relationship exists between economic growth (GDP) and total expenditure on R&D (EXP).*

H2b: *A unidirectional relationship exists between economic growth (GDP) and individuals employed in the R&D sector (EMP).*

H3a: *A bidirectional relationship exists between economic growth (GDP) and total expenditure on R&D (EXP).*

H3b: *A bidirectional relationship exists between economic growth (GDP) and individuals employed in the R&D sector (EMP).*

4. Results and Discussion

In most instances, economic variables tend to be non-stationary. Therefore, our initial step involves examining the stationarity of the variables under consideration. In Table 2, we have presented the results of the Augmented Dickey–Fuller (ADF) test for the three analyzed variables.

Table 2. Stationarity test of data series.

	LGDP (*p*-Value)		**LEXP (*p*-Value)**		**LEMP (*p*-Value)**	
	Level	**First Diff**	**Level**	**First Diff**	**Level**	**First Diff**
Romania I(1)	−0.749 (0.869)	−1.705 (0.082)	−2.741 (0.230)	4.778 (0.004)	−1.575 (0.772)	−3.855 (0.031)
NW Region I(1)	−1.225 (0.938)	−3.194 (0.002)	−2.775 (0.219)	−4.725 (0.005)	−2.054 (0.543)	−5.065 (0.002)
Cluj County I(1)	−1.242 (0.940)	−3.081 (0.003)	−1.027 (0.914)	−5.418 (0.000)	−0.344 (0.549)	−6.259 (0.000)
Bihor County I(1)	−1.149 (0.930)	−3.112 (0.003)	−0.032 (0.662)	−6.570 (0.000)	−1.285 (0.177)	−7.556 (0.000)

Note: *p*-values are in ( ) and the optimal lag length is determined based on Akaike, Schwarz and Hannan–Quinn information criteria. Source: own elaboration using Eviews 12.

The ADF test results indicate that, following the first difference, the null hypothesis is rejected for nearly all variables, considering a significance level of p-value < 0.05. However, in the case of Romania's LGDP variable, the null hypothesis is only rejected when considering a significance level of p-value < 0.10 after the first difference. Therefore, it can be inferred that all variables exhibit a unit root. Since the time series become stationary after the first difference, it is established that these are integrated of order one, I(1). Given that, in our case, all the variables share the same order of integration I(1) at the 10% significance level, the condition to be cointegrated is respected. To evaluate the presence of cointegration among the chosen variables, we will utilize the approach introduced by Johansen and Juselius.

The results (Table 3) show the rejection of the null hypothesis suggesting a no-cointegration relationship among the variables at the 5% significance level. Thus, we accept the alternative hypothesis that suggests the presence of at least one cointegration equation between the LGDP and LEXP, respectively, between the LGDP and LEMP in the Romanian economy, the NW Region, and the Cluj and Bihor Counties. The two tests

used in the cointegration analysis suggest that the set of time series has an error correction representation that reflects the long-run adjustment mechanism.

Table 3. Cointegration test by Johansen and Juselius.

Series	Hypothesized No. of CE(s)		Trace Statistic	Max-Eigen Statistic	Critical Value (0.05)	
					Trace	Max-Eigen
Romania (total)						
LGDP/LEXP	None	H_0: r = 0	41.93 **	34.66 **	25.87	19.38
	At most 1	H_0: r ≤ 1	6.82	6.82	12.51	12.51
LGDP/LEMP	None	H_0: r = 0	43.96 **	38.76 **	20.26	15.89
	At most 1	H_0: r ≤ 1	5.20	5.20	9.16	9.16
NW Region						
LGDP/LEXP	None	H_0: r = 0	30.73 **	21.28 **	25.87	19.38
	At most 1	H_0: r ≤ 1	9.45	9.45	12.51	12.51
LGDP/LEMP	None	H_0: r = 0	39.36 **	33.16 **	25.87	19.38
	At most 1	H_0: r ≤ 1	6.19	6.19	12.51	12.51
Cluj County						
LGDP/LEXP	None	H_0: r = 0	32.79 **	22.68 **	25.87	19.38
	At most 1	H_0: r ≤ 1	10.10	10.10	12.51	12.51
LGDP/LEMP	None	H_0: r = 0	37.10 **	32.37 **	25.87	19.38
	At most 1	H_0: r ≤ 1	4.72	4.72	12.51	12.51
Bihor County						
LGDP/LEXP	None	H_0: r = 0	29.53 **	19.40 **	25.87	19.38
	At most 1	H_0: r ≤ 1	10.13	10.13	12.51	12.51
LGDP/LEMP	None	H_0: r = 0	20.91 **	18.70 **	15.49	14.26
	At most 1	H_0: r ≤ 1	2.20	2.20	3.84	3.84

Note: ** denotes significance (at the 5% significance level); r denotes the number of cointegrated vectors. Source: own elaboration using Eviews 12.

Considering the results obtained after testing the cointegration between the variables, we can state that long-run relationships exist between them. Therefore, in order to examine the relationship between these variables, we can apply a vector error correction model (VECM). The long-run relationship between economic growth (LGDP) and total expenditure on R&D (LEXP), respectively between economic growth (GDP) and individuals employed in the R&D sector (EMP) for one cointegrating vector, is presented in Table 4.

Based on the findings provided in Table 4, we can argue that in the case of Romania, the causal effect of the LGDP on the LEXP and on the LEMP variables is significant in the long run. This conclusion is supported by the statistically significant nature of the estimated adjusted coefficients (p-value > 0.05). More than that, the negative sign of these coefficients indicates that a long-run equilibrium characterizes the relationship between the LGDP and LEXP variables, respectively, between the LGDP and LEMP. Regarding the long-run causal effect of the LEXP and the LEMP variables on the LGDP, the presence of negative values suggests a long-run equilibrium in the relationship between these variables. In the case of the causal effect of the LEXP on the LGDP, the causality is significant in the long run only for the 10% significance level, as the value of the t-statistics is greater than 1.3160, while in the case of the causal effect of the LEMP on the LGDP, significance in the long run is observed at both the 5% and 1% significance levels. At the sample level, the short-run coefficients suggest convergence from LGDP to LEXP and, likewise, from LEMP to LGDP. Therefore, at the sample level, we can state that if the GDP at Romania's level increases by one unit, the total expenditure on R&D at the Romanian level will increase by 0.026 units, while if the number of individuals employed in the R&D sector increases by one unit, the GDP will increase by 0.127 units. In terms of the short-run causal results of LGDP on

the LEMP and of LEXP on the LGDP, the results suggest divergence and non-significant coefficients. As such, the results confirm hypotheses H1a and H1b in the case of Romania.

Table 4. The results of VECM estimation by the OLS method.

Causality Direction	Error Correction Term (ECT) [t-Statistics]	Short-Run Coefficient [t-Statistics]	Lag Coefficient [t-Statistics]	R-Squared	F-Statistic
Romania					
LEXP → LGDP	−0.033 * [−1.380]	−0.808 [−0.706]	−0.047 [−0.200]	0.103	0.708
LGDP → LEXP	−0.167 *** [−7.729]	0.026 [0.822]	−0.279 ** [−1.804]	0.878	45.924 ***
LEMP → LGDP	−0.087 *** [−2.216]	0.127 [0.853]	0.194 [0.965]	0.377	3.835
LGDP → LEMP	−0.125 *** [−7.700]	−0.199 [−0.945]	−0.277 ** [−1.819]	0.867	65.723 ***
NW Region					
LEXP → LGDP	−0.379 *** [−2.478]	0.977 * [1.430]	0.114 [0.599]	0.258	2.207
LGDP → LEXP	−0.154 *** [−4.944]	0.075 * [1.669]	0.010 [0.062]	0.784	23.060 **
LEMP → LGDP	−0.082 [−1.022]	0.432 * [1.725]	0.057 [0.289]	0.155	1.163
LGDP → LEMP	−0.171 *** [−4.677]	0.296 ** [1.868]	0.097 [0.488]	0.755	19.609 **
Cluj County					
LEXP → LGDP	−0.356 *** [−2.062]	−0.617 [−0.970]	0.002 [0.013]	0.208	1.664
LGDP → LEXP	−0.174 *** [−5.459]	0.100 *** [2.271]	−0.063 [−0.409]	0.814	27.837 **
LEMP → LGDP	−0.017 [−0.580]	−0.149 [−0.408]	−0.244 [−1.224]	0.176	1.356
LGDP → LEMP	−0.123 *** [−3.866]	0.057 [0.471]	−0.044 [−0.197]	0.690	14.116 **
Bihor County					
LEXP → LGDP	−0.291 ** [−1.820]	1.471 [0.713]	−0.232 [−1.070]	0.269	2.332
LGDP → LEXP	−0.202 *** [−4.942]	0.009 [0.583]	0.061 [0.365]	0.759	19.984 **
LEMP → LGDP	−0.093 [−1.038]	0.181 [0.172]	−0.494 *** [−2.495]	0.342	3.301
LGDP → LEMP	−0.175 *** [−4.783]	0.029 [0.876]	0.039 [0.225]	0.751	19.116 **

Note: *, **, *** denote significance at the 10%, 5% and 1% confidence levels. Source: authors' estimates using Eviews 12.

The causal effect of the LGDP on the LEXP and on the LEMP variables in the case of the NW Region is significant in the long run, with the estimated adjusted coefficients demonstrating statistical significance. This is evident as the t-statistics value is greater than 1.708 for the 5% significance level and 2.060 for the 1% significance level. Also, the negative sign of these coefficients implies the existence of a long-run equilibrium in the

association between the LGDP and LEXP variables, respectively between the LGDP and LEMP. Regarding the long-run causal effect of the LEXP and the LEMP variable on the LGDP, we can also observe negative values that presuppose a long-run equilibrium in their relationship. The causal effect of the LEMP on the LGDP is not statistically significant in the long run, with t-statistics below 1.3160. On the other hand, the causality of LEXP on LGDP is significant in the long run at both the 5% and 1% significance levels. The results confirm hypotheses H1a and H1b only partially in the case of the NW Region. The short-run coefficients indicate convergence from LGDP to the LEXP, from LGDP to the LEMP, and also from the LEMP to LGDP, respectively from LEXP to LGDP. Thus, the results confirm hypotheses H2a and H2b in the case of the NW Region.

In the case of Cluj County, the causal effect of the LGDP on the LEXP and on the LEMP variables is significant in the long run, with the estimated adjusted coefficients demonstrating statistical significance. This is evident as the value of t-statistics is greater than 1.708 for the 5% significance level and 2.060 for the 1% significance level. The negative sign of these coefficients shows that a long-run equilibrium defines the relationship between the LGDP and LEXP variables, as well as between the LGDP and LEMP. Regarding the long-run causal effect of the LEXP and the LEMP variable on the LGDP, we have also observed negative values, which presuppose a long-run equilibrium in their relationship. The causal effect of the LEMP on the LGDP is not significant in the long run as the value of t-statistics is lower than 1.3160 for the 10% significance level. In the case of the causal effect of the LEXP on the LGDP, the causality is significant in the long-run for the 5% and 1% significance levels. Therefore, the results confirm hypotheses H1a and H1b only partially in the case of Cluj County. Convergence from LGDP to the LEXP is suggested by the short-run coefficients. Therefore, we can state that if GDP at Cluj County's level increases by one unit, the total expenditure on R&D at Cluj County's level will increase by 0.10 units. Thus, the results confirm only the H2a hypothesis.

Regarding Bihor County, we can argue that the long-run causal impact of LGDP on both the LEXP and LEMP variables is substantial, with the estimated adjusted coefficients being statistically significant. The relationship between the LGDP and LEXP variables, as well as between the LGDP and LEMP, is defined by a long-term equilibrium, as indicated by the negative sign of these coefficients. Regarding the long-run causal effect of the LEXP and the LEMP variables on the LGDP, negative values are also observed, presupposing a long-run equilibrium characterizing the relationship between these variables. As concerns the causal effect of the LEMP on the LGDP, the causality is not significant in the long run as the value of t-statistics is lower than 1.3160 for the 10% significance level, while in the case of the causal effect of the LEXP on the LGDP, the causality is significant in the long run for the 5% and 1% significance levels. Therefore, the results confirm hypothesis H1a, whereas it confirms H1b only partially in the case of Bihor County. The short-run coefficients indicate convergence from the LGDP to the LEXP, from LGDP to the LEMP, from LEXP to the LDP and from the LEMP to the LGDP, but only at the sample level. Thus, the second hypothesis cannot be confirmed. Regarding R-squared, in the case of Bihor County, we notice that the highest intensity of the correlation is found in the case of models that have as an independent variable the GDP (R-squared = 0.75). Thus, we can say that at the sample level, GDP influences to a large extent both the total expenditure on R&D and the individuals employed in the R&D sector. We could not say the same thing if GDP were considered as the dependent variable. Thus, according to the results, we can say that GDP influences these two variables to a much greater extent than these two influence GDP.

We have also checked the quality of the residual, namely: the homoscedasticity, the autocorrelation, and the normal distribution. Table 5 presents the test values and *p*-values associated with the three hypotheses on the residuals listed above.

Table 5. Residual Analysis.

Models Based on Causality Direction	Null Hypothesis—The Errors Are Homoscedastic ARCH LM (*p*-Value)	Null Hypothesis—The Errors Are Independent Breusch Godfrey LM (*p*-Value)	Null Hypothesis—The Errors Are Normally Distributed Jarque-Bera (*p*-Value)
Romania			
LEXP → LGDP	18.95 (0.39)	6.92 (0.13)	0.36 (0.83)
LGDP → LEXP	18.95 (0.39)	6.92 (0.13)	0.24 (0.88)
LEMP → LGDP	23.15 (0.18)	4.37 (0.35)	0.73 (0.69)
LGDP → LEMP	21.91 (0.23)	6.69 (0.15)	0.23 (0.89)
NW Region			
LEXP → LGDP	20.15 (0.32)	3.21 (0.52)	3.64 (0.16)
LGDP → LEXP	14.78 (0.67)	4.31 (0.36)	2.72 (0.25)
LEMP → LGDP	15.44 (0.63)	3.80 (0.43)	0.31 (0.85)
LGDP → LEMP	15.44 (0.63)	3.80 (0.43)	0.86 (0.64)
Cluj County			
LEXP → LGDP	18.56 (0.41)	3.17 (0.52)	3.55 (0.16)
LGDP → LEXP	10.87 (0.89)	3.52 (0.47)	2.32 (0.31)
LEMP → LGDP	24.48 (0.13)	11.56 (0.02)	0.91 (0.63)
LGDP → LEMP	24.48 (0.13)	11.56 (0.02)	0.93 (0.62)
Bihor County			
LEXP → LGDP	14.28 (0.71)	6.31 (0.17)	0.97 (0.61)
LGDP → LEXP	9.51 (0.94)	2.19 (0.70)	0.61 (0.73)
LEMP → LGDP	11.68 (0.86)	4.89 (0.29)	1.57 (0.45)
LGDP → LEMP	11.68 (0.86)	4.89 (0.29)	1.58 (0.45)

Source: authors' estimates using Eviews 12.

According to the results presented in Table 5, we can affirm that the null hypothesis is accepted for all three residual tests. This implies that the validity of the representation of residuals in all four estimated models for Romania, the NW Region and Bihor County is confirmed, as the associated probabilities exceed the 5% threshold (p-value > 0.05). Consequently, the accurate representation of the residuals in the estimated models is verified. In the case of Cluj County, the probabilities associated with the values of the first test and the third test are higher than the 5% threshold, so the null hypothesis is accepted, while in the case of the autocorrelation, the values of this test are higher than the 5% threshold, but only in the case of the first two models (LGDP and LEXP). Thus, as regards the LGDP and LEXP variables, it can be affirmed that the null hypothesis is accepted for all three residual tests, confirming the accurate representation of the residuals in the estimated models.

The cointegration test results indicate the presence of a long-run, stable equilibrium among total expenditure on R&D and economic growth, respectively, among individuals employed in the R&D sector and economic growth. This implies a causal relationship between the variables, including GDP and R&D sector variables (LEXP and LEMP), in at least one direction. In order to find this causality, we employed the Granger causality test. Figure 2 illustrates both the long-run Granger causality from the exogenous variables to endogenous variable and the one-way short-run Granger causality.

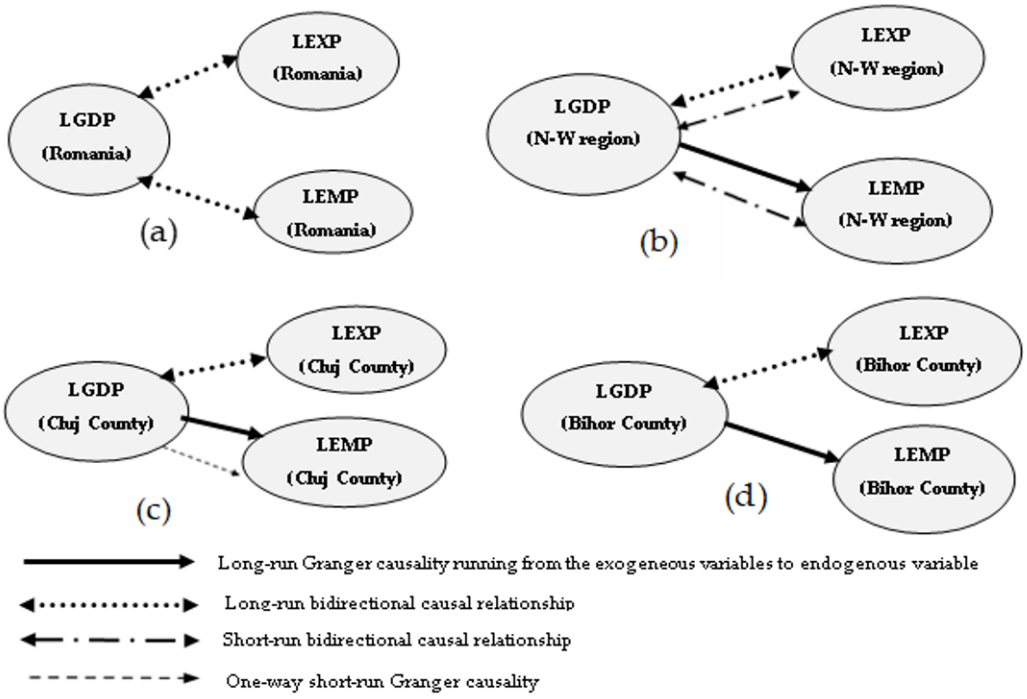

Figure 2. The Granger causality relationship between economic growth (GDP), total expenditure on R&D (EXP) and individuals employed in the R&D sector (EMP) in Romania (**a**), in the NW Region (**b**), in Cluj County (**c**) and in Bihor County (**d**). Source: authors' contribution.

The findings reveal the existence of a long-run bidirectional Granger causality between Romania's total expenditure on R&D (R&D) and economic growth, respectively, between Romania's individuals employed in the R&D sector and economic growth. Therefore, Romania's economic growth is the cause of Granger's development of the Romanian R&D sector, i.e., national economic growth can promote the long-run development of the total expenditure on R&D and of the individuals employed in the R&D sector. We also can state that, in the long run, Romania's total expenditure on R&D and the individuals employed in the R&D sector in Romania are the cause of Granger's development of Romania's economic growth. The results confirm the first two hypotheses, H1a and H1b, and the last two hypotheses, H3a and H3b.

According to Figure 2, we can argue that in the NW Region, there is a long-run unidirectional Granger causality between total expenditure on R&D and economic growth. According to Figure 2, we can argue that in the NW Region, there is a long-run unidirectional Granger causality only from economic growth to individuals employed in the R&D sector and a long-run bidirectional Granger causality between Romania's NW Region's total expenditure on R&D and economic growth. Also, we find evidence of a long-run bidirectional Granger causality between Romania's NW Region's total expenditure on R&D and economic growth. In the short run, we have identified a bidirectional causal relationship between Romania's NW Region's total expenditure on R&D and economic growth, respectively, between Romania's NW Region's individuals employed in the R&D sector and economic growth. The results confirm hypotheses H1a, H2b—only from GDP to individuals employed in the R&D sector, H3a and H3b.

Regarding Cluj County, the results indicate the existence of a long-run bidirectional causal relationship between the GDP and the total expenditure on R&D. Also, we have identified a long-run unidirectional Granger causality between the individuals employed in the R&D sector in Cluj County and the economic growth of this county. Thus, we can conclude that the economic growth of Cluj County is the cause of Granger's development of the Cluj County R&D sector, i.e., the economic growth can promote the long-run development of total expenditure on R&D and individuals employed in the R&D sector. However,

the existence of the long-run influence of individuals employed in the R&D sector on economic growth is doubtful. In the short run, we have identified a unidirectional causal relationship between GDP and individuals employed in the R&D sector. The results thus confirm hypothesis H3a, while hypothesis H3b cannot be confirmed.

Regarding Bihor County, it is notable that a long-run bidirectional Granger causality was found only in the case of GDP and the total expenditure on R&D, while in the case of individuals employed in the R&D sector, we have found a long-run unidirectional Granger causality from GDP to this indicator. Thus, the economic growth of Bihor County is the cause of Granger's development of the Bihor County R&D sector. What is more, we can affirm that the total expenditure on R&D from Bihor County is the cause of Granger's development of Bihor County GDP but only in the long run. The results confirm hypothesis H3a.

As can be seen from Table 6, several hypotheses were confirmed. In general, the influence of GDP growth on total expenses and, respectively, on employment in the R&D sector is stronger than the effect of these two variables on GDP, in the case of Romania, the Cluj and Bihor Counties. As such, we can assume that regions with higher or better-performing GDP levels may attract more public funds and private investments in RD&I compared to other regions, where GDP levels are low. However, the influence that these two variables (total R&D expenditures and employment) have on regional development is also noteworthy, and regions already advanced and equipped for research and innovation will go further and attract more human and material resources than other less-developed regions.

Table 6. Results of testing the hypotheses.

Hypothesis	Romania	NW Region	Cluj County	Bihor County
H1a	confirmed	confirmed	confirmed	confirmed
H1b	Confirmed	partially confirmed	partially confirmed	partially confirmed
H2a	not confirmed	not confirmed	not confirmed	not confirmed
H2b	not confirmed	partially confirmed	partially confirmed	partially confirmed
H3a	confirmed	confirmed	confirmed	confirmed
H3b	confirmed	confirmed	not confirmed	not confirmed

Source: authors' elaboration.

The main limitations of the research consist in the incomplete number of factors influencing the relationship between the R&D sector and GDP, as well as the specific focus of findings, limited to a single Romanian region and two component counties. Another limitation of the study may be that it overshadows the role of other factors that shape economic growth (socio-economic policies, sectoral particularities, variations in economic structures, innovation and technology diffusion, entrepreneurship).

Another limitation of our study is its focus on the efforts dedicated to innovation (i.e., expenditure and employment in R&D activities) and not the actual results generated by these efforts (for instance, the number of patents filed and trademarks, turnover of innovative local units, the number of projects for R&D activities, etc.). Therefore, R&D expenditure does not capture the actual introduction of new products, services or processes, i.e., "expenditures will not necessarily produce outcomes in terms of output" [13] (p.18) and can hide or roughly approximate other inputs, for example: product design, market analysis, initial staff training, experiments. However, the indicators investigated by us are suitable for the analysis of long-term series and therefore useful for identifying a relationship with the relevant macroeconomic indicators, such as the evolution of GDP. In other words, the output indicators (patents and trademarks, turnover, etc.) are more suitable for medium-term analyses, at the micro- and meso-economic levels, but with more limited relevance for long time series.

Moreover, our analysis could not consider the level of autonomy in directing public R&D expenditure at the county and regional levels, given that the development regions in Romania are not administrative units and do not have formal powers for RD&I. Therefore, in future studies, we intend to extrapolate these results to other time periods or regional and national contexts but also other R&D-related indicators that were not addressed in the present investigation.

5. Conclusions and Implications

For over three decades, experts have emphasized the vital role of technological development, especially in RD&I, in fostering economic growth. The goals of national economic growth are closely linked to regional development, particularly in less-resource-endowed, peripheral, or isolated areas. Scholars have identified challenges such as a shortage of skilled labor, insufficient innovative firms, a lack of entrepreneurial spirit, insufficient infrastructural investments or unfavorable market dynamics, along with the inefficient use of RD&I funds, hindering regional prosperity and individual well-being.

Our research considered the analysis of the relationship between economic growth (expressed by GDP) and expenditure and employment in the R&D sector during the 1995–2021 period, running the Johansen cointegration test, the VECM model and Granger causality at the level of Romania and a component region. For a better understanding of these connections, we also deepened the analysis at the level of two counties in this region, engaged in innovative and sustainable technological development in the last two decades.

Our research findings support the existence of a long-run bidirectional Granger causality between Romania's total expenditure on R&D and employment in this sector, and economic growth, respectively. We can also state that, in the long term, Romania's total R&D expenditures and employment directly influence the country's economic growth.

At the regional level, the economic growth registered in the NW Region is the cause of the Granger development of the total R&D expenditures in the long run. Reciprocally, the NW Region's R&D expenditures support regional economic growth. In the short run, we also identified a bidirectional causality relationship between the NW Region's total R&D expenditure and economic growth. In the case of R&D employment in the NW Region, there is a short-run Granger causality relationship to economic growth but not vice versa.

For Cluj County, economic growth supports the long-run development of R&D expenditures and employment in this sector. However, the impact of R&D sector employment on economic growth is uncertain in the long run. Short-run causality exists between GDP and R&D sector employment. In Bihor County, there is a long-run bidirectional Granger causality between GDP and total R&D expenditures, while a long-run unidirectional causality exists between GDP and R&D sector employment. Total R&D expenditures drive the long-run development of Bihor County's GDP.

Our results are consistent with previous research on the favorable role of R&D on economic growth [24,25], stimulating innovation and economic recovery [28,29].

Previous studies [31–33] suggested that the effects of R&D spending on economic growth are weaker in developing countries; we observed that a similar pattern exists within a single county. Specifically, regions and counties that are better endowed in human and investment capital, and that are better prepared for innovation, tend to display a stronger, long-run link between R&D spending and employment and, respectively, economic growth.

Adapting RD&I policies to the national and regional specificities and comparative advantages can significantly contribute to economic growth. The relationships identified in our paper are, mainly, long-run relationships, and, consequently, our paper should act as a guide for both legislators and the business sector to multiply and potentiate the positive long-lasting effects of present-day decisions. The authorities must pay attention not only to the R&D allocation (from the state budget or from EU or private funds) but also to their intensity, duration and correct orientation towards technological and innovative sectors. Also, our study emphasizes the importance of the quality of governance and the increase in regional competencies, regarding public funding of research in fundamental fields, in

parallel with the stimulation of private investments in applied research, profitable in the short term. Finally, theoretical studies and practical actions must consider the propagation at the national level of the results recorded in those regions that allocate greater public and private resources to research and innovation, the alignment of different R&D priorities and strategies at the national, sectoral and regional levels.

The novelty of this article resides in identifying the relationship between economic growth, expenditure and employment in the R&D sector in Romania, focusing on a specific development region (i.e., the Northwest Region) and two of its constituent counties. Additionally, we aimed to investigate whether the long-run or short-run relationship, as well as the causality identified at the national level in Romania, applies to the analyzed regions and, specifically, to the examined counties.

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References

1. Solow, R. A Contribution to the Theory of Economic Growth. *Q. J. Econ.* **1956**, *70*, 65–94. [CrossRef]
2. Romer, P. Increasing Returns and Long-Run Growth. *J. Political Econ.* **1986**, *94*, 1002–1037. [CrossRef]
3. Romer, P. Endogenous Technological Change. *J. Political Econ.* **1990**, *98*, 71–102. [CrossRef]
4. Barro, R.; Sala-I-Martin, X. Technological Diffusion, Convergence and Growth. *J. Econ. Growth* **1997**, *2*, 1–26. [CrossRef]
5. Lucas, R. On the Mechanics of Economic Development. *J. Mon. Econ.* **1988**, *22*, 3–42. [CrossRef]
6. Grossman, G.; Helpman, E. *Innovation and Growth in the Global Economy*; MIT Press: Cambridge, MA, USA, 1991.
7. Aghion, P.; Howitt, P. A Model of Growth through Creative Destruction. *Econometrica* **1992**, *60*, 323–351. [CrossRef]
8. Segerstrom, P. Innovation, Imitation, and Economic Growth. *J. Political Econ.* **1991**, *99*, 807–827. [CrossRef]
9. Fernandez, N.; Martinez-San Roman, V.; Sanchez-Robles, B. R&D and Growth in the Spanish Regions, 1995-2007—An Empirical Approximation. *Int. J. Bus. Soc. Sci.* **2012**, *3*, 22–31. [CrossRef]
10. Ma, J.; Ahn, Y.-G.; Lee, M.-K. The Interactive Influence of Institutional Quality and Resource Dependence on Regional Economic Growth: Evidence from China's Resource-Based Provinces. *Sustainability* **2022**, *14*, 6173. [CrossRef]
11. Archibugi, D.; Filippetti, A.; Frenz, M. The Impact of the Economic Crisis on Innovation: Evidence from Europe. *Technol. Forecast. Soc.* **2013**, *80*, 1247–1260. [CrossRef]
12. Smętkowski, M. Regional Disparities in Central and Eastern European Countries: Trends, Drivers and Prospects. *Eur.-Asia Stud.* **2013**, *65*, 1529–1554. [CrossRef]
13. Taques, F.H.; López, M.G.; Basso, L.F.; Areal, N. Indicators used to measure service innovation and manufacturing innovation. *J. Innov. Knowl.* **2021**, *6*, 11–26. [CrossRef]
14. Wang, E. R&D Efficiency and Economic Performance: A cross Country Analysis Using the Stochastic Frontier Approach. *J. Policy Model.* **2007**, *29*, 345–360. [CrossRef]
15. Kuo, C.-C.; Yang, C.-H. Knowledge Capital and Spillover on Regional-Economic Growth: Evidence From China. China Economic Review. *China Econ. Rev.* **2008**, *19*, 594–604. [CrossRef]
16. Rodríguez-Pose, A.; Crescenzi, R. Research and Development, Spillovers, Innovation Systems, and the Genesis of Regional Growth in Europe. *Reg. Stud.* **2006**, *42*, 51–67. [CrossRef]
17. Sarpong, D.; Boakye, D.; Ofosu, G.; Botchie, D. The Three Pointers of Research and Development (R&D) for Growth-Boosting Sustainable Innovation System. *Technovation* **2003**, *122*, 102581. [CrossRef]

18. Wang, M.; Choi, B. An Analysis of the Impact of International R&D Spillovers and Technology Innovation in China. *Sustainability* **2023**, *15*, 1968. [CrossRef]
19. Goel, R.; Payne, J.; Ram, R. R&D Expenditures and US Economic Growth: A Disaagrgated Approach. *J. Pol. Model.* **2008**, *30*, 237–250. [CrossRef]
20. Bravo-Ortega, C.; Garcia Marin, A. R&D and Productivity: A Two Way Avenue? *World Dev.* **2011**, *39*, 1090–1107. [CrossRef]
21. Ildırar, M.; Özmen, M.; İşcan, E. The Effect of Research and Development Expenditures on Economic Growth: New Evidences. In Proceedings of the International Conference on Eurasian Economies, Kaposvár, Hungary, 29–31 August 2016.
22. Amaghouss, J.; Ibourk, A. Entrepreneurial Activities, Innovation and Economic Growth: The Role of Cyclical Factors. Evidence from OECD Countries for the Period 2001–2009. *Int. Bus. Res.* **2013**, *6*, 153–162. [CrossRef]
23. Woo, Y.; Kim, E.; Lim, J. The Impact of Education and R&D Investment on Regional Economic Growth. *Sustainability* **2017**, *9*, 676. [CrossRef]
24. Lichtenberg, F. *R&D Investment and International Productivity Differences*; NBER Working Paper No. 4161; NBER Working Paper Series; NBER: Cambridge, MA, USA, 1991. [CrossRef]
25. Park, W. International Spillovers of R&D Investment and OECD Economic Growth. *Econ. Inq.* **1995**, *33*, 571–591. [CrossRef]
26. Pop Silaghi, M.; Alexa, D.; Jude, C.; Litan, C. Do Business and Public Sector Research and Development Expenditures Contribute to Economic Growth in Central and Eastern European Countries? A Dynamic Panel Estimation. *Econ. Model.* **2014**, *36*, 108–109. [CrossRef]
27. Sylwester, K. R&D and Economic Growth. *Knowl. Technol. Policy* **2001**, *13*, 71–84. [CrossRef]
28. Ulku, H. *R&D, Innovation and Economic Growth: An Emprical Analysis*; IMF Working Paper, W/P/04/185; IMF: Washington, DC, USA, 2004.
29. Ulku, H. R&D, Innovation, and Growth: Evidence From Four Manufacturing Sectors in OECD Countries. *Oxf. Econ. Pap.* **2007**, *59*, 513–535. [CrossRef]
30. Goel, R.; Ram, R. Research and Development Expenditures and Economic Growth: A Cross-Country Study. *Econ. Dev. Cult. Chang.* **1994**, *42*, 403–411. [CrossRef]
31. Samimi, A.; Alerasoul, S. R&D and Economic Growth: New Evidence from Some Developing Countries. *Aust. J. Basic Appl. Sci.* **2009**, *3*, 3464–3469.
32. Inekwe, J. The Countribution of R&D Expenditures to Economic Growth in Developing Countries. *Soc. Indic. Res.* **2015**, *124*, 727–745. [CrossRef]
33. Gumus, E.; Celikay, F. R&D Expenditure and Economic Growth: New Empirical Evidence. *Margin J. Appl. Econ. Res.* **2015**, *9*, 205–217. [CrossRef]
34. Coccia, M. Public and Private R&D Investments as Complementary Inputs for Productivity growth. *Int. J. Technol. Policy Manag.* **2010**, *10*, 73–91. [CrossRef]
35. Salvekar, S. R&D Expenditure and Economic Performance: A Regional German Panel Analysis. Master's Thesis, Jönköping University, Jönköping, Sweden, 2020.
36. Beise, M.; Stahl, H. Public Research and Industrial Innovations in Germany. *Res. Policy* **1999**, *28*, 397–422. [CrossRef]
37. Harhoff, D. R&D Spillovers, Technological Proximity, and Productivity Growth—Evidence From German Panel Data. *Schmalenbach Bus. Rev.* **2000**, *52*, 238–260. [CrossRef]
38. Moutinho, R.; Au-Yong-Oliveira, M.; Coelho, A.; Pires Manso, J. The Role of Regional Innovation Systems (RIS) in Translating R&D Investments Into Economic and Employment Growth. *J. Technol. Manag. Innov.* **2015**, *10*, 9–23. [CrossRef]
39. Celli, V.; Cerqua, A.; Pellegrini, G. Does R&D Expenditure Boost Economic Growth in Lagging Regions? *Soc. Indic. Res.* **2021**. [CrossRef]
40. European Commission. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. European Structural and Investment Funds 2014–2020, Brussels, Belgium. 2021. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0213 (accessed on 17 November 2023).
41. Guellec, D.; Van Pottelsberghe De La Potterie, B. The Impact of Public R&D Expenditure on Business R&D. *Econ. Innov. New Technol.* **2003**, *12*, 225–243. [CrossRef]
42. Rehman, N.U.; Hysa, E.; Mao, X. Does public R&D complement or crowd-out private R&D in pre and post economic crisis of 2008? *J. Appl. Econ.* **2020**, *23*, 349–371. [CrossRef]
43. David, P.; Hall, B.; Toole, A. Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence. *Res. Policy* **2000**, *29*, 497–529. [CrossRef]
44. Rodríguez-Pose, A. Innovation Prone and Innovation Averse Societies. Economic Performance in Europe. *Growth Chang.* **1999**, *30*, 75–105. [CrossRef]
45. Bronzini, R.; Piselli, P. The Impact of R&D Subsidies on Firm Innovation. *Res. Policy* **2016**, *45*, 442–457. [CrossRef]
46. Becker, S.; Egger, P.; von Ehrlich, M. Going NUTS: The Effect of EU Structural Funds on Regional Performance. *J. Public Econ.* **2010**, *94*, 578–590. [CrossRef]
47. Pellegrini, G.; Terribile, F.; Tarola, O.; Muccigrosso, T.; Busillo, F. Measuring the Effects of European Regional Policy On Economic Growth: A Regression Discontinuity Approach. *Pap. Reg. Sci.* **2013**, *92*, 217–233. [CrossRef]

48. Fratesi, U.; Perucca, G. EU Regional Development Policy and Territorial Capital: A Systemic Approach. *Pap. Reg. Sci.* **2019**, *98*, 265–281. [CrossRef]
49. Kijek, T.; Kijek, A.; Matras-Bolibok, A. Club Convergence in R&D Expenditure across European Regions. *Sustainability* **2022**, *14*, 832. [CrossRef]
50. Becker, S.; Egger, P.; von Ehrlich, M. Absorptive Capacity and the Growth and Investment Effects of Regional Transfers: Regression Discontinuity Design with Heterogeneous Treatment Effects. *Am. Econ. J.-Econ. Policy* **2013**, *5*, 29–77. [CrossRef]
51. Bilbao-Osorio, B.; Rodriguez-Pose, A. From R&D to Innovation and Economic Growth in the EU. *Growth Chang.* **2004**, *35*, 434–455. [CrossRef]
52. Diukanova, O.; Chioncel, M. *A GDP Impact Evaluation of R&D Investments in Romania Using the CGE Model Rhomolo*; JRC Working Papers on Territorial Modelling and Analysis No. 10/2021; European Commission: Seville, Spain, 2021; JRC126690.
53. Ur Rehman, N.; Hysa, E. The effect of financial development and remittances on economic growth. *Cogent Econ. Financ.* **2021**, *9*, 1932060. [CrossRef]
54. Badulescu, D.; Cadar, O. Romania: Many Entrepreneurs But Few Innovators. *Ann. Univ. Oradea Econ. Sci.* **2016**, *XXV*, 465–475.
55. Serbanica, C.; Pupinis, M. *PSF Review of the Romanian R&I System—Background Report*; Publications Office of the European Union: Luxembourg, 2021; Available online: https://data.europa.eu/doi/10.2777/38334 (accessed on 19 December 2023).
56. Chioncel, M. Analysis of the Factors That Obstruct the Diffusion of Innovation in Romania. 2017. Available online: https://uefiscdi.gov.ro/resource-821136-analysis-of-the-factors-that-obstruct-the-diffusion-of-innovatio.pdf (accessed on 11 November 2023).
57. Diaconu, M.; Vilcu, A. Business Innovation Activity in Romania: The Main Trends and Weaknesses. *Procd. Soc. Behv.* **2018**, *238*, 157–166. [CrossRef]
58. Șerbănică, C. Territorial Innovation Patterns in Romania. Future Pathways for Smart Specialization. *Transylv. Rev. Adm. Sci.* **2021**, *62*, 153–175. [CrossRef]
59. Dachin, A.; Postoiu, C. Innovation and Regional Performance in Romania. *Theor. Appl. Econ.* **2015**, *2*, 55–64.
60. Goschin, Z. R&D as an Engine of Regional Economic Growth in Romania. *Rom. J. Reg. Sci.* **2014**, *8*, 24–37.
61. Herte, D.A.; Dianu, D.; Ciucos, M.; Badulescu, D.; Badulescu, A. SMEs and Innovation in The European Context. *J. Innov. Manag. Small Medium Enterp.* **2021**, 238722. [CrossRef]
62. The World Bank. Romania. Overwiew. 2023. Available online: https://www.worldbank.org/en/country/romania/overview (accessed on 10 November 2023).
63. Eurostat. Gross Domestic Product (GDP) at Current Market Prices by NUTS 3 Regions. 2023. Available online: https://ec.europa.eu/eurostat/databrowser/product/page/nama_10r_3gdp (accessed on 11 November 2023).
64. Chioncel, M.; Del Rio, J.C. *RIO Country Report 2017: Romania*; Publications Office of the European Union: Luxembourg, 2018; ISBN 978-92-79-81280-4. [CrossRef]
65. Goschin, Z.; Sandu, S.; Goschin, G.G. How Soon Could Romania Close the R&D Gaps against EU-28. *Proc. Econ. Financ.* **2015**, *22*, 160–167. [CrossRef]
66. Hollanders, H.; European Commission. *European Innovation Scoreboard 2019*; Publications Office of the European Union: Luxembourg, 2019.
67. European Commission; Directorate-General for Research and Innovation; Hollanders, H.; Es-Sadki, N. *Regional Innovation Scoreboard 2023—Regional Profiles Romania*; Publications Office of the European Union: Bruxelles, Belgium, 2023; Available online: https://data.europa.eu/doi/10.2777/70412 (accessed on 18 December 2023).
68. Eurostat, NUTS—Nomenclature of Territorial Units for Statistics. 2021. Available online: https://ec.europa.eu/eurostat/web/nuts/background (accessed on 20 November 2023).
69. Ministry of Regional Development and Housing (Romania). The Urban Dimension of Romania's Cohesion Policy Regional Operational Programme 2007–2013. Available online: https://slideplayer.com/slide/4762639/ (accessed on 20 November 2023).
70. National Institute of Statistics (Romania). Tempo Online. Domains. 2022. Available online: http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table (accessed on 2 November 2023).
71. Dickey, D.; Fuller, W. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *J. Am. Stat. Assoc.* **1979**, *74*, 427–431. [CrossRef]
72. Johansen, S.; Juselius, K. Maximum Likelihood Estimation and Inference on Cointegration—With Application to the Demand for Money. *Oxf. Bull. Econ. Stat.* **1990**, *52*, 169–210. [CrossRef]
73. Andrei, T.; Bourbonnais, R. *Econometrie*, 2nd ed.; Economica Publishing: Bucharest, Romania, 2017; ISBN 978-973-709-812-2.
74. Engle, R.; Granger, C. Co-Integration and Error Correction: Representation, Estimation and Testing. *Econometrica* **1987**, *52*, 251–276. [CrossRef]
75. Greene, W.H. *Econométrie*, 7th ed.; Pearson Education France: Paris, France, 2021; ISBN 9782744054402.