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Article

Evaluation of the Impact of R&D on the Socio-Economic Development of EU Countries

Amfiteatru Economic Journal

Provided in Cooperation with:

The Bucharest University of Economic Studies

Suggested Citation: Ginevicius, Romualdas; Zemaitis, Eigirdas; Petraskevicius, Vladislavas (2022) : Evaluation of the Impact of R&D on the Socio-Economic Development of EU Countries, Amfiteatru Economic Journal, ISSN 2247-9104, The Bucharest University of Economic Studies, Bucharest, Vol. 24, Iss. Special Issue No. 16, pp. 1001-1013, <https://doi.org/10.24818/EA/2022/S16/1001>

This Version is available at:

<https://hdl.handle.net/10419/281685>

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EVALUATION OF THE IMPACT OF RESEARCH AND DEVELOPMENT ON THE SOCIO-ECONOMIC DEVELOPMENT OF EU COUNTRIES

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Please cite this article as:

Ginevičius, R., Žemaitis, E. and Petraškevičius, V., 2022. Evaluation of the Impact of R&D on the Socio-Economic Development of EU Countries. *Amfiteatru Economic*, 24(Special Issue No. 16), pp. 1001-1013.

DOI: [10.24818/EA/2022/S16/1001](https://doi.org/10.24818/EA/2022/S16/1001)

Article History

Received: 2 September 2022

Revised: 16 September 2022

Accepted: 28 September 2022

Abstract

Investment in R&D varies widely in EU countries, both in terms of its overall volume and the sources of investment, business, the state, and higher education institutions. To a large extent, the volume of investment depends on the state of economic development of the country. Economically developed EU countries are dominated exclusively by business investments, while investments in higher education play a limited role. This is because higher education institutions perform a large part of R&D together with businesses. In developing countries, investment in R&D is equally distributed between business, the state, and higher education institutions. This is because scientific business research opportunities are still limited in these countries. To adequately determine the impact of R&D investments on the economic development of countries, the overall size of R&D investment needs to be transformed in such a way as to assess its internal structure in which business and higher education institutions have the highest importance. Investments in R&D have a lower direct impact on a country's social development compared to the impact on economic development. This is because R&D affects economic development directly through technological innovations and social development indirectly through economic development.

Keywords: investment in R&D, countries' economic and social development, multi-criteria approaches.

JEL Classification: F63, F21, O11

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Introduction

In the context of the globalization, international competitiveness is an essential condition for the economic and social development of countries. In turn, competitiveness is driven by innovation. They are “born” by investments in R&D, so it is important, both in scientific and practical terms, to examine the factual situation. On the basis of this analysis, current trends can be revealed, and further ways to improve the efficiency of these investments can be foreseen.

The European Union is made up of the countries that differ in their economic situation, and it is therefore appropriate to analyse the impact of investment in R&D both on the state of economic and social development, depending on the state of economic development. Statistics show that there are three sources of investment in R&D – business, the state, and higher education institutions. In order to deepen the analysis of the impact of investments in R&D, it is appropriate to examine not only their overall amount, but also the impact of these sources on the economic development of countries, by assessing their state of economic development.

The state plays a crucial role in the development of R&D investments. Its involvement in this process could be seen in two ways: as one of the sources of these investments and as a force that shapes and implements R&D investment policies and promotes them by appropriate means.

Today, we see a situation in which the impact of R&D investments on the economic development of countries is analysed in most of the cases. On the other hand, too little attention is paid to the analysis of their impact on social development. Economic development is not an endpoint. Its main goal is the well-being of the country’s population, so the impact of investment in R&D on the social development of the country is important.

The possibilities for such analysis are limited by the fact that the social development of the country is a very complex phenomenon, represented by many different aspects. This complicates the formation of a system of indicators that adequately reflects its situation. Moreover, these indicators are multi-dimensional, varying in the different directions and have the different importance for the social development. In order to quantify the current situation, they need to be transformed in such a way that they can be combined into a single variable.

The aim of the article is the structural analysis of the state of investment in R&D in the European Union and a quantitative assessment of the impact on their economic and social development.

1. Review of literature

The subject of literature analysis is the relationship between investment in R&D and the economic and social development of countries. Most studies focus on their impact on economic development (Cameron et al., 2005; Kafouros, 2005; Bravo-Ortega and Marín, 2011; Cozzi, Giordani, 2011). The impact of both the overall and the individual sectors (private, public, and higher education) is analysed (Becker, 2015; Bilbao- Osorio and Rodríguez- Pose, 2004).

The literature focuses on the effectiveness of R&D investments. Their impact on economic, financial, and social development is measured by the innovations generated, expressed in the amount of patents per million inhabitants (Table 1).

Table no. 1. R&D investment efficiency indicators

Source	R&D indicators	Innovation efficiency indicators
Sharma and Thomas (2008)	R&D expenditure, number of researchers, GDP	Patents, scientific publications
Cullman et al. (2009)	R&D expenditure (business, government, higher education, total), number of researchers	Patents
Hashimoto and Haneda (2008)	R&D expenditure	Patents, profit
Dočekalová and Bočková (2013)	R&D expenditure, R&D staff	Sales of R&D products
Thomas et al. (2011)	R&D expenditure	Patents, scientific publications
Kaihua and Mingting (2014)	R&D expenditure, R&D staff	Patents, High-tech value added, Sales, Patents

Source: created by authors

Table 1 shows that the result of the investment in R&D is innovation, expressed in patents, which are seen as an essential condition for the economic development of the country.

In the analysis of investment in R&D, literature sources pay special attention to countries and their governments. This is in part because they have pursued an ambitious R&D policy over the past decades to increase the impact of these investments on economic growth. These efforts can be divided into two groups. The first includes direct investment in R&D, the second is the promotion of these investments through appropriate measures, subsidisation, fiscal policies (Freire-Serén, 2001) etc. The literature highlights that these measures are more effective than direct investment (Becker, 2015). On the other hand, some literature suggests that increasing government investment in R&D stimulates economic growth (Chen and Liang, 2020; Freire-Serén, 2001; Xu et al., 2020; Brécard et al., 2006). Therefore, we see a certain contradiction between the two approaches. This could have been due to the lack of an assessment of the economic development situation of the countries. Some state investments in R&D may be in economically developed countries and other in developing countries. This depends on the potential and capacity of both business, higher education institutions and the state itself to turn this investment into innovation, i.e., economic growth innovation.

In the literature, analysing the role of the state in the development of R&D investments, much attention is paid to subsidisation and fiscal measures (Boeing et al., 2022). These measures are particularly important for encouraging investment activities for the business companies.

The literature also examines the impact of investment in R&D from three sources – business, state and higher education. The focus is on business investment policy. It is manifested in particular by an increase in corporate profits and thus by the impact on economic development (Lee, 2018).

The literature, which examines the impact of R&D investments on the economic development of countries, is based entirely on correlation-regressive analysis (Kaur and Singh, 2016).

The impact of R&D investments on the social development of countries is less analysed. This is to a large extent because today there is no established methodology acceptable for practical application. The country's social development is a complex phenomenon, which is reflected in a range of different aspects, even wider than economic development (Gedvilaitė, 2019). As a result, a large number of different indicators have been offered all the time (Chakravarty, 1976; Morris, 1979; Espina and Arechavala, 2013; UNDP, 2020; Annoni and Bolsi, 2020; Singh et al., 2020). Today's research is mostly based on the Human Development Index used in the United Nations Development Programme. On the other hand, it covers only a few indicators and therefore does not adequately reflect the social development of countries. The EU Social Development Index, which includes 12 sub-indices covering 54 factors, is much more complex (Annoni and Bolsi, 2020).

As a result, there is no unified system for quantifying the state of social development in different countries. In this situation, it is appropriate to refer to the dominant groups of factors proposed in the literature. In this respect, factors reflecting economic well-being, health protection, life expectancy, and housing conditions can be distinguished (Chakravarty, 1976; Morris, 1979; Annoni and Bolsi, 2020; Espina and Arechavala, 2013; UNDP, 2020). They cover the main aspects of social life and allow for a sufficient assessment of the state of social development of countries.

2. Research methodology

An analysis of literature sources has shown that investment in R&D is an essential condition for the economic and social development of countries. On the other hand, the extent of the impact depends to a large extent not only on the size of the investment but also on its internal structure. It may vary depending on the country's political, economic, legal, etc. situation. In order to determine the impact of adequate investments in R&D, first an analysis of the current situation is required. It allows the overall size of these investments to be assessed in such a way as to take account of the orientation of their internal structure in terms of their highest impact on the economic and social development of the countries.

Analysis of the state of investment in R & D. The analysis requires an assessment of both the size and the qualitative structure of the R&D investment. Their size is provided by international statistical databases. It is expressed as a percentage of GDP (Eurostat, 2020). The qualitative structure can be assessed by weighting the individual R&D investments in their total volume:

$$K_{ji} = \frac{M_{ji}}{\sum_{i=1}^n M_{ji}} = \frac{M_{ji}}{I_{jb}}, \tag{1}$$

where K_{ji} is the weighting of the i – source of investment in R&D of country j in their total volume; M_{ji} – the size of i source of investment in R&D of country j as % of GDP; I_{jb} – total investment in R&D of j country, % of GDP; n is the number of R&D sources of investment ($n = \overline{1,3}$).

The R&D investment structure analysis based on formula (1), does not provide an overall qualitative picture. This can be done by considering the importance of each element for the economic development of the country (Hwang and Yoon, 1981):

$$P_1 + P_2 + P_3 = \sum_{i=1}^3 P_i = 1.0, \quad (2)$$

here P_i is the coefficient of the importance of the investment in R&D i source for the economic development of the country.

Based on (1) and (2) formulas, the qualitative structure of investments in R&D can be assessed as follows:

$$S_{jk} = \sum_{i=1}^n P_i \frac{M_{ji}}{\sum_{i=1}^n M_{ji}} = \sum_{i=1}^n P_i \frac{M_{ji}}{I_{jb}}, \quad (3)$$

this S_{jk} is the size reflecting the quality of the investment in the R&D structure of the country j .

The quantitative and qualitative sides of the investment taken separately in R&D do not yet reflect their overall impact on the economic development of the country, since even in its low condition, the structure of these investments may be good and vice versa. Their total size may be determined as follows:

$$\tilde{I}_{jb} = I_{jb} \cdot S_{jk}, \quad (4)$$

this \tilde{I}_{jb} is the size of the j country's investment in R&D, considering their quantitative and qualitative sides, as a percentage of GDP. I_{jb} total investment of country j , % of GDP.

Analysis of the impact of R&D investments on the state of economic development of countries. Based on I_{jb} , S_{jk} and \tilde{I}_{jb} values, the impact of R&D investments on the economic development situation of the countries can be determined. This can be done on the basis of the following correlation-regressive analysis models:

$$BVP = f(I_{jb}), \quad (5)$$

$$BVP = f(M_{ji}), \quad (6)$$

$$BVP = f(S_{jk}), \quad (7)$$

$$BVP = f(\tilde{I}_{jb}). \quad (8)$$

Analysis of the impact of R&D investments on the state of social development in the country. These investments affect the social development of the countries indirectly, based on the economic development initiated by them. On the other hand, it also makes sense to determine their direct impact.

In order to implement such an analysis, it is necessary to determine a variable that summarizes the state of social development of the country. Social development is a complex phenomenon, expressed in many different aspects. Diversity is represented by the fact that indicators that reflect them can be expressed in different dimensions; they are different in nature, i.e. some are maximising, others are minimising. Moreover, their relevance to the phenomenon is different. In such a situation, multi-criteria methods are well suited to their summarized representation. Their philosophy is reflected in the SAW method (Hwang and Yoon, 1981; Kraujalienė, 2019; Lisiński et al., 2020):

$$K_{SAWj} = \sum_{i=1}^n \omega_i \tilde{q}_{ji}, \quad (9)$$

here K_{SAWj} is the value of the SAW assessment of the state of social development of a country j ; ω_i – weight of i indicator ($\sum_{i=1}^n \omega_i = 1.0$); \tilde{q}_{ji} – normalised value for i indicator of country j .

Normalisation of indicator values as follows:

$$\tilde{q}_{ji} = \frac{q_i}{\sum_{i=1}^n q_i}, \quad (10)$$

here q_i is the primary value of i indicator of country j ; and n is the number of indicators ($i = 1, n$).

The system of indicators of the phenomenon under consideration may consist of both maximising and minimising indicators. Under the SAW method, their directions of change need to be aligned, i.e. transformed into either maximising or minimising. Maximisation can be done on the basis of the formula (Hwang and Yoon, 1981):

$$q_{ji}^{\max} = \frac{q_i^{\min}}{q_{ji}}, \quad (11)$$

the minimisation shall be carried out as follows:

$$q_{ji}^{\min} = \frac{q_{ji}}{q_i^{\max}}, \quad (12)$$

where q_{ji}^{\max} is the maximisation value of indicator i of country j ; the q_{ji}^{\min} same, minimising; q_i^{\max} – the highest value of indicator i of all available; q_i^{\min} the same, the least.

Given the values for K_{SAW} of all analysed countries, it is possible to determine the impact of R&D investments on the social development situation of the countries:

$$K_{SAW} = f(I_b). \quad (13)$$

An R&D investment study was carried out based on the methodology set out above.

3. Empirical research

Analysis of the state of investment in R&D. The international statistical databases provide information on the countries' investments in R&D in several respects – determines their overall size, as well as investments from individual sources – business, state, and higher education institutions. In all cases, they are expressed as a percentage of GDP. It shows that the countries invest differently in R&D (Table 2).

Table no. 2. Differences in investment in R&D between EU countries in 2019

Investment in R&D, % of GDP											
common			business			the States			higher education institutions		
Max	min	ratio	Max	min	ratio	Max	min	relationship	Max	min	ratio
3.39	0.48	7.06	2.33	0.28	8.32	0.43	0.01	43.0	1.0	0.06	16.67

Source: compiled by authors based on Eurostat, 2020

Several preliminary conclusions can be drawn from Table 2. Firstly, EU countries pay very unequal attention to R&D development; second, business investment prevails; thirdly, the role of the State in R&D development is limited.

The quantitative side of the investment in R&D is estimated based on formula (1). The results of the calculations are given in Table 3. Its directionality is determined on the basis of formula (3). The weights of investment in R&D sources are determined based on an expert survey. They were distributed in this way: business investment 0.5, public investment 0.15 and higher education institutions 0.35. The transformed values of investment in R&D, evaluating both their quantity and the quality of their structure, are determined based on formula (4). The results of the calculations are given in Table 3.

Table no. 3. State of investment in R&D by the European Union countries

Verse No.	Country	Investment in R&D, % of GDP				R&D investment structure, unit shares			S_{jk}	\tilde{I}_j
		com- mon	busi- ness	the states	higher education institutions	busi- ness	the states	higher education institutions		
1	Belgium	3.16	2.33	0.28	0.53	0.737	0.089	0.1677	0.441	1.393
2	Bulgaria	0.83	0.56	0.21	0.06	0.675	0.253	0.0723	0.401	0.333
3	Czechia	1.93	1.19	0.31	0.42	0.617	0.161	0.2176	0.409	0.789
4	Denmark	2.93	1.84	0.09	1.	0.628	0.031	0.3413	0.438	1.284
5	Germany	3.17	2.18	0.43	0.55	0.688	0.136	0.1735	0.425	1.347
6	Estonia	1.63	0.87	0.17	0.58	0.534	0.104	0.3558	0.407	0.664
7	Ireland	1.23	0.91	0.05	0.27	0.740	0.041	0.2195	0.453	0.557
8	Greece	1.28	0.59	0.29	0.39	0.461	0.227	0.3047	0.371	0.475
9	Spain	1.25	0.7	0.21	0.33	0.560	0.168	0.2640	0.398	0.497
10	France	2.19	1.44	0.27	0.44	0.658	0.123	0.2009	0.418	0.915
11	Croatia	1.08	0.53	0.2	0.35	0.491	0.185	0.3241	0.387	0.418
12	Italy	1.46	0.92	0.18	0.33	0.630	0.123	0.2260	0.413	0.603
13	Cyprus	0.71	0.31	0.05	0.27	0.437	0.070	0.3803	0.362	0.257
14	Latvia	0.64	0.17	0.12	0.35	0.266	0.188	0.5469	0.352	0.226
15	Lithuania	0.99	0.43	0.2	0.36	0.434	0.202	0.3636	0.375	0.371
16	Luxembourg	1.18	0.64	0.28	0.26	0.542	0.237	0.2203	0.384	0.453
17	Hungary	1.48	1.11	0.15	0.21	0.750	0.101	0.1419	0.440	0.651
18	Malta	0.57	0.35	0.01	0.21	0.614	0.018	0.3684	0.439	0.250
19	Netherlands	2.18	1.46	0.12	0.6	0.670	0.055	0.2752	0.439	0.958
20	Austria	3.13	2.2	0.23	0.68	0.703	0.073	0.2173	0.438	1.373
21	Poland	1.32	0.83	0.02	0.47	0.629	0.015	0.3561	0.441	0.583
22	Portugal	1.4	0.73	0.07	0.56	0.521	0.050	0.4000	0.408	0.572
23	Romania	0.48	0.28	0.15	0.05	0.583	0.313	0.1042	0.375	0.180
24	Slovenia	2.05	1.51	0.28	0.24	0.737	0.137	0.1171	0.430	0.881
25	Slovakia	0.83	0.45	0.16	0.21	0.542	0.193	0.2530	0.389	0.323
26	Finland	2.8	1.84	0.23	0.71	0.657	0.082	0.2536	0.430	1.203
27	Sweden	3.39	2.43	0.15	0.8	0.717	0.044	0.2360	0.448	1.518

Source: made by authors, according to Eurostat, 2020

Analysis of the impact of R&D investments on the state of economic development of the country. It is based on formulas (5) to (8). The results of the calculations are given in Table 4.

Table no. 4. Results of correlation-reflective analysis of the impact of R&D investments on the economic development of the European Union countries

Correlative-regressive model	Regression equation	Value of correlation coefficient <i>r</i>	Significance of the Student Criteria	
			actual	critical
$BVP = f(I_b)$	$BVP = 11.979I_b + 6.7068$	0.84	2.588	1.714
$BVP = f(I_v)$	$BVP = 15.209I_v + 10.675$	0.67	6.874	1.714
$BVP = f(I_q)$	$BVP = 211.46I_q^2 - 58.101I_q + 33.22$	0.26	1.258	1.711
$BVP = f(I_H)$	$BVP = 36.397I_H^2 + 16.312I_H + 12.292$	0.74	5.397	1.711
$BVP = f(\tilde{I}_b)$	$BVP = 10.226\tilde{I}_b^2 + 9.5062\tilde{I}_b + 13.314$	0.85	7.850	1.714

Source: created by authors

Table 4 shows that the total investment in R&D has a significant impact on the economic development of the countries. Equally significant investments are made by business and higher education institutions. As was the case, less efficient public investment could be expected. Both business and higher education institutions invest in R&D are risk-related, so they take it with responsibility. The risk and responsibilities of the responsible persons of the relevant authorities of the government are significantly lower, so investments do not always provide the desired result.

A deeper analysis makes it possible to highlight the structural trends of the investment in R&D depending on the level of economic development achieved in the countries. For that, all the countries were divided into two conditional groups depending on the level of investment in R&D and the level of their individual sources. Grouping is based on the formula (14):

$$L = \frac{I_i^{\max} - I_i^{\min}}{2}, \tag{14}$$

where L is the size of the grouping interval; I_i^{\max} – the highest value of the first source of investment from all countries concerned; I_i^{\min} the same, the lowest value.

The results of the analysis are shown in Table 5.

Table no. 5. Investment trends in R&D depending on the state of economic development of the European Union

State of Economic Development of the Countries	Investments in R&D					
	business		government		higher education institutions	
	small	large	small	large	small	large
Low	X			X		X
High		X	X		X	

Source: created by authors

Table 5 shows that the structural trends in investment in R&D depend heavily on the level of economic development achieved in the country. In countries where it is high, business exclusively invests in R&D. The role of the state here is very small. The limited role of higher education investment in those countries can be explained by their close cooperation with business.

These trends have not yet been established in economically developing countries, as the business opportunities are not yet so high. Therefore, we see a situation where both businesses, the state, and higher education institutions are investing in R&D on an equal footing.

Analysis of the impact of R&D investments on social development in the country. As stated above, investments in the social development of R&D are indirectly affected by their positive impact on economic development. However, it also makes sense to determine their direct impact. This requires, in particular, the establishment of a system of indicators reflecting social development. The following five indicators were selected on the basis of literature: life expectancy, unemployment, health expenditure, disposable income, and housing conditions (Towards a system of social and demographic statistics, 1975; Gedvilaitė, 2019; Chakravarty, 1976; Morris, 1979; Singh et al., 2021; UNDP, 2020; Annoni and Bolsi, 2020; Espina and Arechavola, 2013) (see Table 6).

Table no. 6. European Union countries' social development indicators for 2019

Verse No.	Country	Indicators of social development in the country					Importance of the state of social development
		life expectancy	unemployment (maximum)	expenditure on health care	annual income of the population, euro	housing conditions	
1	Belgium	81.75	0.385	10.66	3321	77.6	0.0440
2	Bulgaria	74.91	0.465	7.13	825	53.1	0.0289
3	Czech	79.13	1.000	7.83	1509	47.8	0.0387
4	Denmark	81.2	0.426	10.00	3993	66.6	0.0460
5	Germany	80.94	0.645	11.7	3120	42.3	0.0442
6	Estonia	78.5	0.455	6.73	1599	38.6	0.0313
7	Ireland	82.3	0.435	6.68	4075	91.7	0.0460
8	Greece	81.94	0.116	7.84	1488	40.7	0.0284
9	Spain	83.49	0.145	9.13	2424	35.3	0.0335
10	France	83.58	0.244	11.06	3324	65.5	0.0421
11	Croatia	78.42	0.313	7.00	1295	78.3	0.0313
12	Italy	83.2	0.202	8.67	2536	47.2	0.0351
13	Cyprus	80.98	0.286	7.01	2879	72.1	0.0378
14	Latvia	75.24	0.313	6.58	1257	34.0	0.0273
15	Lithuania	76.13	0.313	7.00	1062	40.5	0.0273
16	Luxembourg	82.45	0.308	5.37	6036	62.4	0.0501
17	Hungary	76.02	0.606	6.35	830	71.9	0.0314
18	Malta	82.6	0.606	8.21	2502	42.8	0.0389
19	Netherlands	82.01	0.667	10.13	3507	74.8	0.0475
20	Austria	81.79	0.465	10.43	3689	53.3	0.0446
21	Poland	77.86	0.625	6.45	1274	55.2	0.0327
22	Portugal	80.68	0.313	9.53	1713	54.4	0.0336
23	Romania	75.46	0.541	5.74	692	67	0.0292
24	Slovenia	81.28	0.455	8.52	2046	71.5	0.0372
25	Slovakia	77.47	0.357	6.96	1389	51.5	0.0302
26	Finland	81.79	0.328	9.15	3264	65.4	0.0411
27	Sweden	82.96	0.333	10.87	3183	52.9	0.0414

Source: compiled by authors, based on Eurostat 2020, OECD 2022

From (9) the formula is clear that, in addition to the values of the indicators, it is also necessary to know their importance for the economic development of the country. It was established on the basis of expert assessments. After the coherence of the expert opinions, the following results were received (Table 7).

Table no. 7. National Social Development Indicators Weights

Indicators	Life expectancy	Unemployment	Expenditure on health care	Annual disposable income of the population	Housing conditions	Total
Weights of indicators	0.32	0.13	0.16	0.28	0.11	1.0

Source: written by authors

The multi-criteria assessment of the state of social development in EU countries is based on formulas (9) to (12). The results of the calculations are given in Table 6.

Given the size \tilde{I}_b and K_{SAW} the (13) formula, it is possible to determine the direct impact of investments in R&D on the social development of countries. The following results were obtained (Table 8).

Table no. 8. Results of correlation-reflective analysis of the impact of R&D investments on social development in European Union countries

Correlative-regressive model	Regression equation	Value of correlation coefficient r	Significance of the Student Criteria	
			actual	critical
$K_{SAW} = f(\tilde{I}_b)$	$K_{SAW} = -0.0038\tilde{I}_b^2 + 0.0173\tilde{I}_b + 0.0274$	0.64	4.211	1.711

Source: created by authors

The results given in tables 5–8 allow a number of conclusions to be drawn. First, investment in R&D has a sufficiently strong positive impact on the social development of countries. Secondly, compared to the impact on economic development, it is lower because investments in the R&D countries have a direct impact on the economic development and social development indirectly due to economic development.

Conclusions

Despite the importance of R&D investments for economic and social development, the size of R&D investments varies across the European Union. Their internal structure also differs: in some countries, only business investments are predominant, in others – both business, state and higher education institutions. The correlation-regression analysis confirmed the very strong positive impact of overall investment in R&D on the economic development of the countries. On the other hand, the effects of their individual structural components are different. Economically developed EU countries are dominated by business investment and are almost equally distributed between business, state and higher education institutions in developing countries. This is because business research opportunities are still limited in these countries. The low role of higher education institutions in economically developed countries

may be due to the high degree of cooperation with business and, therefore, their contribution through business investment in R&D.

In order to adequately determine the impact of R&D investments on the economic and social development of countries, the overall size of R&D investments needs to be transformed in such a way as to assess the orientation of their internal structure, i.e., giving the highest importance to the business and higher education institutions.

The lower impact of R&D investments on the social development of the countries compared to economic development can be explained by the fact that its economic development is directly affected and its social development indirectly, due to economic development.

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