THE IMPACT OF QUALITY IN RESEARCH AND DEVELOPMENT ENVIRONMENTS ON ENTREPRENEURIAL ACTIVITY IN ROMANIA. A COMPARATIVE STUDY

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Abstract: *Research and development (R&D) efforts have a great impact on the performance of companies. However, the costs and time frame are difficult to anticipate. Evaluation of research and development (R&D) activity assumes many aspects related to the size of efforts and the quantification of their effects on entrepreneurial activity, which can be achieved by aggregating several economic indicators. The effectiveness of R&D can be regarded from various perspectives: the extent to which it supports the increase in company performance, the time frame in which such performance appears, and from the standpoint of the degree to which research activities uphold performance at its maximum efficiency point. This empirical research aims to conduct a comparative study at the Romanian level on the impact of research activity carried out within three reputable research environments: the private (business) environment, the government (public) environment, and the university environment. The study aims to differentiate between the results of these environments. This quantitative research has been carried out based on data processed by regression analysis extracted from three different sources and covers the time interval 2005-2022. The findings show that the research results referring to the private environment are visible in the current year, whereas the effects exhibit volatility in the following years. University environment research can be regarded as the most effective as it yields a subsequent constant increase of the effects on the entrepreneurial environment over the following three years subjected to analysis, while the measured intensity of its impact is clearly superior to that of the other research environments: private and governmental.*

Keywords: R&D expenditure; private environment research; university environment research; business environment; comparative study.
JEL Classification: M40; M20; O32; O30.

1.Introduction

R&D activities can have a major impact on the performance of companies, but they also imply a series of efforts whose costs and time frame are not easily anticipated.

It is difficult to estimate whether they will have a positive impact on the activity of companies and if so, what the latter could be. The side effects of R&D activities are difficult to assess and depend on the perspective from which the studies are conducted. Therefore, R&D expenditure can be assessed through efforts, specific inputs, such as the size of personnel involved in the research activity (Vtola and Eria, 2015), or the various effects it can trigger at the level of companies. The increase in productivity and added value, as performance indicators of companies, are results, effects, and known outputs that have been approached for several years (Minasian, 1962). Later, the number of innovations and patents has been included in the effects (Anselin, Varga, and Acs, 1997; Hall, Griliches, and Hausman, 1984). This aspect is also studied based on the area of activity of companies conducting R&D activities, such as pharmaceuticals (Minasian, 1962) and IT (House, Parks, and Lindstrom, 2014).

When companies are part of different areas of activity, the time frame in which the effects of R&D expenditure are visible varies (Lee and Choi, 2015; Griliches, 1979). On the other hand, the effectiveness of different research environments can differ if we refer to the principle of minimizing efforts and maximizing effects. This depends on the area of research the studies refer to: private (Fortune and Shelton, 2012; Schaeffler, 1977), public (Acosta, Coronado, and Romero, 2015; Aerts and Schmidt, 2008), or higher university education (Bonander et al., 2016; Moretti and Thulin, 2013).

Thus, although there are several studies germane to the topic of R&D, they approach issues unilaterally or narrowly. The objective of this study is to fill in such deficiencies and compare the impact of private, public, and university research environments from the point of view of the effort-effect ratio for R&D expenditure and its results, quantified at the company level. The study includes companies selected regardless of their areas of activity, therefore endowing the research results with significance. These aspects or variables included in the study are effort effect variables and will be divided into two categories. They will aim to measure the impact of the R&D effort (input variables) on innovation capacity, general entrepreneurial activity, company results, business excellence, and overall effects of R&D (output variables). The efforts (inputs) and the effects (outputs) will be represented by means of a complex of variables. Additionally, apart from the effort-effect ratio, which measures the results of R&D in space for the three research environments, the study also measures the intensity of the results of research activities in time as a temporal framework in which the effects are seen and maintained. From this perspective, the latter are quantified as an ability to ensure the stability in time of the effects of R&D. Finally, the study will establish which of the three research environments (private, public, and university) has the most effective R&D activity. This assessment will be twofold: spatial, relying on the effort-effect ratio as an instrument, and temporal, from the standpoint of the time frame in which the positive results of R&D are maintained in entrepreneurial activities.

The remainder of this paper is organized as follows: the next section presents a brief literature review, while the following one presents the data used and displays the methodology, followed by a section dedicated to the presentation of empirical results. The last section concludes the paper.

2. Literature Review

The literature classifies R&D expenditure according to the environment in which it occurs: private, public, or university, while later studying the impact of each environment on companies, an impact quantified from various viewpoints.

Private company R&D expenditure and its impact on their performance

The impact of the efforts of private companies germane to R&D on their general performance has been largely studied in the dedicated literature. To evaluate results, indicators such as turnover, productivity, profitability, and other general quantitative performance indicators are frequently used. This topic is tackled by older and more recent studies.

First, Minasian (1962) found some evidence after using regression. According to this study, increasing R&D expenditure leads to productivity and finally to profitability based on outputs such as added value, productivity, labour and capital. Furthermore, it states that companies that spend more on R&D are not typically large. Later, Branch (1974) argued that there is a reciprocal relation between R&D and profits. Morbey and Reithner (1990) elaborated on the impact of R&D on the size of profit, i.e., amid rapid market growth, there is a negative correlation between the two variables. For the impact of R&D expenditure to be positive, the company must be in a strong position. Other studies mention a high level of profitability for highly innovative companies (Lu and Wang, 2024, Rađenović et al., 2023)

The conducting of R&D expenditure is closely related to patenting. This aspect is not diminished by situations in which the company is controlled by a majority shareholder, by the constant capacity to patent, or by the existence of history in matters of patenting for that particular company (Nie et al., 2023; Hall, Griliches, and Hausman, 1984).

In the case of companies conducting their activity in areas where it is necessary to have intensive research activities, the investments of companies in R&D are a source of above-average returns (Mittal and Mittal, 2024; Grabowski and Mueller, 1988). Then contradictory results appear, according to which there is no difference between the results of companies with high levels of R&D expenditure compared to those with none. Furthermore, companies in the first category exhibit, in exchange, higher returns volatility (Chan, Lakonishok and Sougiannis, 2001). The comparatives study conducted at international level reveals that the intensity with which R&D expenditure is reflected in the results of companies varies from one country to another (Fitz-Oliveira and Tello-Gamarra, 2024; Ding, Stolowy and Tenenhaus, 2007). Higher R&D expenditure is related to higher brand values and higher firm-level financial performance metrics (Peterson and Jeong, 2010).

In the pharmaceutical area, R&D expenses revealed increased returns, with a powerful impact on increasing performance (Fortune and Shelton, 2012). These findings are in line with others according to which R&D expenditure implies an increase in company profitability using the following items for the measurement of these outputs: returns on assets, returns on equity, capitalization, and cash flows (Boiko, 2022; Apergis and Sorros, 2014).). Additionally, studies that simultaneously measure the impact of R&D on profitability for various sectors of activity found

similarities between the positive conditioning of profitability, measured as return on assets, by R&D expenditure (House, Parks and Lindstrom, 2014).
Companies in the mining industry with R&D expenditure generate a significant increase in sales, by 4-11%, and in profits, by 4-13% (Rafiq, Salim and Smyth, 2016). The increase is larger in the case of older companies (Rafiq, Salim and Smyth, 2016; Fortune and Shelton, 2014). The positive impact of R&D expenditure is even more evident in the case of private companies than in public ones (Boeing, Mueller and Sandner, 2016). Furthermore, R&D expenditures and investments could improve innovation in the case of small and medium companies (Bigliardi et al., 2020).

Public-funded R&D expenditure and its impact on companies' performance
The performance of companies can also be supported by R&D expenditure. Public expenditure in R&D is approached only to a small extent in the dedicated literature (Soete et al., 2022; Levy, 1990).
The two sources of funding, public and private, may overlap when supporting a private company without creating a crowding-out effect on the part of one for the other (Aerts and Schmidt, 2008; David, Hall, and Toole, 2000). In the case of Latin America and the Caribbean, a complete crowding-out effect is encountered only in smaller companies (Hall, 2005). Other more recent studies (Marino et al., 2016) state that there is no crowding effect and no cumulative effect of public and private R&D expenditure.
Supporting public expenditure to finance R&D expenditure is necessary but does not necessarily lead to an increase in productivity (Acosta, Coronado and Romero, 2015). In the case of Germany, an empirical study has shown that public funding of R&D expenditure leads to an increase in innovation activities by approximately 4% (Almus and Czarnitzki, 2003). Later, contradictory results are found for the same country, revealing that the effectiveness of R&D expenses is equally consistent, regardless of their source: private or public (Hussinger, 2008).
In Spain, most companies that have benefitted from public funding for R&D expenditure would not have reached performance (González, Jaumandreu and Pazo, 2005). At the regional level, regardless of the field of activity, entrepreneurial efficiency is higher in regions where R&D is more public focused than average (Min et al., 2020)

Universities' R&D expenditure and its impact on companies' performance
Most studies conducted in the field conclude that the share of external R&D supplied by universities has a positive and significant effect on product innovation (Medda, 2020). However, considering published results, studies pertaining to the impact of R&D expenditure in universities on the economic environment exhibit mixed results. The first results stemming from cross-sectional studies conducted on certain geographical regions reveal intense positive correlations between research in the university environment and its impact on the private sector, from the standpoint of innovations (Anselin, Varga and Acs, 1997). Later, the hypothesis is confirmed that the results of university research prompt an increase in innovations and cost reduction (Woodward et al., 2006). The results of more recent research (Drucker, 2016) mention that the influence of university research through the increase in

production, entrepreneurship, and overall economic performance is felt within a 60-mile distance of university centers.

The concentration of international companies around universities can be considered a landmark of the effectiveness of research results that are put into practice in the economy (Moretti and Thulin, 2013). Mixed results are obtained in different studies, according to which the effectiveness of research results conducted in the university environment is not particularly visible from the point of view of growth and regional development (Bonander, et al., 2016). The explanation for this could be the fact that the research results and innovations achieved in a certain region are difficult to find in the evolution of businesses from that particular region, due to the mobility of personnel and companies (Rosen, 1979; Power and Malmberg, 2008).

Evaluation of the size of R&D activities is reflected primarily through R&D expenditure (Lehman, 2015). On the other hand, research performance indicators in education can include patent applications and the total number of R&D personnel and researchers (Vītola and Eriņa, 2015). The quality of human capital in universities is an aspect that has a strong influence on maintaining the competitiveness of the business environment in the region (Guerrero, Urbano and Fayolle, 2016). In Germany, Estonia and Lithuania, a regression study based on the Summary Innovation Index for 2010-2015 concludes that the number of researchers has a significant impact on increasing innovation (Svagzdiene and Jurate, 2016).

R&D expenditure and the time-lag effect (the effect over time)

The effect of R&D expenditure on the various economic indicators attained at the level of companies, considered in the dedicated literature, may be observed over time, during an interval of one or more years (Lee, 2020; Griliches, 1979). There is notable interest in studying this aspect in the dedicated literature and it is also the subject of older articles and more recent ones, albeit without high occurrence over time.

Some studies identify the impact of RD in a general way: short-term or long-term (Pazarzi and Sorros, 2018). Others more specifically quantify the time horizon in which the effect can be observed. R&D expenditure leads to an increase in profits and market value of shares within a 20-month interval since its inclusion in financial statements (Lev and Sougiannis, 1996). Later, it was found that the effects of R&D are noticeable in the following 7 years, although the highest increase in the result of exploitation is encountered during the first 3 years (Aboody and Lev, 2001).

More recent results support the idea that, albeit profitability is diminished in the year when it is implemented, the positive effect of R&D expenditure on the former becomes apparent after two years (Parcharidis and Varsakelis, 2007). In the global pharmaceutical industry, 25% of the effect of R&D expenditure is visible in patents in the following year, and its influence is perceived until the fifth year (Wang and Hagedoorn, 2014). The results are also confirmed by the Korean pharmaceutical industry, where the effect of R&D expenditure is visible until the fifth year (Lee and Choi, 2015).

3. Research Methodology

The beginning of the study is based on the consolidation, in a preliminary phase, of certain relevant variables leading to the objective assessment of the relation between efforts (inputs) and effects (outputs) pertaining to R&D expenditure at the level of the three representative environments: private, governmental/public and university.

Evaluation of expenditure (inputs) for Romania has been achieved through the inclusion in the study of seven aspects, collected between 2005 and 2022 inspired by Eurostat data (the body calculating statistical information for the institutions of the European Union) for input variables germane to R&D (OECD, 2002) taken from the Frascati Manual (2002). They have been divided into three environments: private (PRIV), governmental (GOV), and university (UNIV). Input variables include R&D expenditure (Lehman, 2015; OECD, 2002), grouped based on origin criteria (self-funding or not) and destination criteria (labour force or capital expenses). Furthermore, variables pertaining to the number of researchers have been included, to quantify the size of the efforts in matters of R&D expenditure (Vītola and Eriņa, 2015; OECD, 2002).

The results and effects (outputs) of the R&D activity have been quantified based on two different sources. The first is the National Council for Small and Medium-Sized Enterprises of Romania (CNIMMPR), founded in 1992, which represents the interests of SMEs at national and international level. Some data have been synthesized from the annual reports of this institution, published between 2005 and 2022, pertaining to a yearly average number of 1.158 companies. The output variables have been broken down according to percentage intervals of 0%, 1-5%, 6-10%, 11-20%, 21-50%, respectively, above 51%.

The second source of output variables to evaluate the effect of R&D expenditure is the Global Competitiveness Report (GPR), issued by the World Economic Forum (WEF) for Romania published between 2005 and 2019. The variables have been analysed starting from two criteria: the accumulated points (score) and the position in the ranking of the countries in the Global Competitiveness Index (GCI), comprised in the annual Global Competitiveness Report (GPR) issued by the World Economic Forum (WEF) between 2005 and 2019. Output variables reflect the research results from the standpoint of the evolution of profitability and other financial indicators (Drucker, 2016; House, Parks and Lindstrom, 2014; Peterson and Jeong, 2010; Schoeffler, 1977; Minasian, 1962), of patenting and innovation (Acosta, Coronado and Romero, 2015; Almus and Czarnitzki, 2003; Hall, Griliches and Hausman, 1984), and of the contribution of investments in R&D to turnover (Fortune and Shelton, 2012; Ding, Stolowy and Tenenhaus, 2007; Grabowski and Mueller, 1988). We have considered detailing output variables encountered at the level of companies, depending on their age (Rafiq, Salim and Smith, 2016; Fortune and Shelton, 2014). From these sources, the variables presented in Table 1 have been selected to lay the basis of the study.

The statistical calculation of inputs and outputs has been achieved through multiple regression analysis of the two categories of variables, followed by the calculation of the coefficients of multiple correlation r of each input variable with each output

variable, so that each output variable would be evaluated through the lens of all input variables.

The coefficients of multiple correlations r have then been aggregated by using simple arithmetic mean, a procedure utilized in the economic field to emphasise basic tendency (Jacquier, Kanee and Marcus, 2003). To calculate the arithmetic mean, only those coefficients of correlation r are considered which indicated an intensity reasonable level of the connection between input and output variables. Thus, we have considered the 0.60 value threshold as satisfying, as it indicates a significant intensity connection at an average level. The possibility of obtaining significant negative values of the coefficient of multiple correlation r which is due to the decrease in input and to the decrease in outputs for measuring R&D activity in Romania, is excluded, since in the 2015-2022 period subjected to analysis, increasing trends have been found in all cases, for all input variables. The noticed efforts around R&D in Romania were on the increase in all three fundamental research environments included in the study: private, governmental and university.

Table 1: Variables description

	R&D Input patterns (considered for each environment individually: private (PRIV), governmental/public (GOV) and university (UNIV)	**Measurement unit**	**Source**
1	R&D expenditure from all financing sources	Euro/inhab	Eurostat
2	R&D expenditure from self-financing sources	Euro/inhab	Eurostat
3	R&D expenditure with labour costs	Euro/inhab	Eurostat
4	R&D expenditure with capital (land, buildings)	Euro/inhab	Eurostat
5	R&D expenditure with capital (instruments, equipment)	Euro/inhab	Eurostat
6	Number of researchers in full time equivalent	Number	Eurostat
7	Number of researchers in full time equivalent in total employment	%	Eurostat
	R&D Output patterns	**Measurement unit**	**Source**
1	Type of innovations (none, products, technologies, managerial approach, human resources innovations)	%	CNIMMPR
2	Intensity of investments in innovation	%	CNIMMPR
3	Share of innovation in investments made by 10-15-year-old companies	%	CNIMMPR
4	Share of innovation in investments made by companies older than 15 years	%	CNIMMPR
5	Investments in innovation of the largest companies	%	CNIMMPR
6	Share of turnover of revenues from innovation of 10-15-year-old companies	%	CNIMMPR
7	Share of turnover of revenues from innovation of companies older than 15 years	%	CNIMMPR
8	Share of turnover of revenues from innovation of the largest companies	%	CNIMMPR
9	Share of over 20% of turnover from innovation	%	CNIMMPR

10	Rank in the Global Competitiveness Index for Innovation (GCII) according to the World Economic Forum (WEF)	Rank, Score	WEF
11	Innovation capacity	Rank	WEF
12	Quality of scientific research institutions	Rank	WEF
13	Public acquisitions of advanced technologies	Rank	WEF
14	Availability of scientists and engineers	Rank	WEF
15	Number of patents achieved	Number	WEF
16	Number of patents applied	Rank	WEF
17	Turnover from innovation as percentage from all companies' turnover	%	WEF

Source: *Processing performed by authors*

The calculation methodology used to aggregate the values of multiple regression correlation coefficients is presented below (Formula 1):

$$AM_r(t_x)_{\alpha_a} = \frac{\sum_{i=1}^{l} r_{i_{poz}} + \sum_{j=1}^{m} r_{j_{neg}}}{n} \quad (1)$$

Where,

- $AM_r(t_x)_{\alpha_a}$ - value of arithmetic mean AM of all n values of regression correlation coefficients calculated for correlation coefficient r, where $|r| \geq 0.60$, resulting from multiple regression, of the temporal series of lag t_x, where x is the lag level (the level of dephasing of the variables measuring inputs, respectively outputs), whilst $x = \overline{-3,0}$ and $AM_r(t_x)_{\alpha_a} \in [-1;1]$;
- α_a – the environments for which the impact of research activities is comparatively evaluated, where a can successively represent the private, governmental, and higher education institutions environment.
- $r_{i_{poz}}$ - positive values of correlation coefficients r_i calculated for the relation between inputs and outputs in multiple regression, where $i = \overline{1,l}$;
- $r_{j_{neg}}$ - negative values of correlation coefficients r_j calculated for the relation between inputs and outputs in multiple regression, where $j = \overline{1,m}$;
- Total number of variables n considered for calculated values of the correlation coefficient r where $l, m \leq n$, $n = l + m$.

The greater the value of the arithmetic mean calculated aggregately, the greater the intensity of the positive relation between the input and output variables of R&D expenditure in Romania. The significance will be that an increase in inputs supports to an even greater extent the increase in outputs as the value of the arithmetic mean is approaching the maximum level which can be 1. The results obtained provide a double perspective: spatial (comparing the three fundamental research areas: the private environment, the governmental one, and higher learning institutions, for the same time frame), and temporal (the extent to which the intensity of the connection for each of the three fundamental areas lasts, persists over time).

Therefore, the research activity will be even more effective and present in the entrepreneurial activity conducted in the business environment and, implicitly, in

practice, as the value of the arithmetic mean for each fundamental level will be, firstly, large, and secondly, registered more quickly and having more permanence in time over the following years. The calculation of the value $AM_r(t_x)_{\alpha_a}$ from these three points of view will reveal the best-performing area of research of the three that have been selected: the private environment, the governmental one, and higher learning institutions.

4. Results and Discussions

By taking into account the correlation coefficients considered to be significant (when $|r| \geq 0.60$, for the data analysed stemming from the time frame 2005 – 2022), the calculation of impact on the entrepreneurial environment is ensured only for those variables where we have found a high level of intensity of the correlation, as it results from the table below (Table 2). In the first year, considering a zero-time delay, the values are generally lower for all research environments. The values noticed an increasing trend until the fourth year since the R&D expenses were implemented for the three research environments subjected to analysis.
In the case of the private (business) environment, the effects are seen earlier since the year in which R&D expenses are made and are felt throughout the years considered for the study.

Table 2: Measuring time impact on entrepreneurial activity, based on lags, of expenses made by research environments in the period 2005 - 2022

Research environments	**Evolution of intensity in the current year and the following three years, for variables with a correlation intensity more than 0.6**			
	lag 0	**lag 1**	**lag 2**	**lag 3**
	2022	**2023**	**2024**	**2025**
Private (business) environment	0,17	0,38	0,21	0,68
Governmental (public) environment	-0,49	-0,52	-0,60	0,67
University environment	-0,52	-0,41	0,32	0,72

Source: Processing performed by authors

For the private environment, the results are in line with the studies conducted by Rađenović et al (2023), Wang and Hagedoorn (2014) and Lev and Sougiannis (1996). In the third year, one notices a slight decrease of effects, whose maximum level of 0.72 will be reached in the fourth year, when the intensity level reaches a significant value as it crosses the standard threshold of 0.60.
For the two remaining research environments, the situation is somewhat different from that of the private environment. The effects of R&D expenses are visible much

later: for the governmental (public) environment, in the fourth year, while for the university environment slightly earlier, in the third year, albeit the maximum intensity in the last (fourth) year is relatively identical to that in the private (business) environment. In the first two-three years, the increase in R&D efforts from the standpoint of effective expenditure and the number of personnel involved in research activities has no positive impact on entrepreneurial activity. On the contrary, one notices in this period that there is an almost significant negative correlation of close values in each of the two environments. What is certain, however, is that research in the university environment yields effects one year earlier that in the governmental (public) environment (Lee, 2020, Pazarzi and Sorros, 2018).

Another aspect to be considered is that in the case of the university environment, it could be observed throughout the three years a constant increase in intensity of the effects for the entrepreneurial environment, while for the private (business) and governmental (public) environments, there is significant volatility of research results in the second and third years.

For all three environments, the impact of research is at its maximum in the fourth year since the R&D endeavours, albeit in the private (business) environment, the effects are visible earlier. In the fourth year, the intensity of the correlation measured through regression analysis is relatively identical, which means that the effectiveness of research for the three environments is identical and quite high. If the maximum intensity of the results is encountered in the third year since the endeavours, excluding the year when R&D expenses were made, the results are in line with Abody and Lev (2001) for all three research environments.

5.Conclusions

The study conducts, at the level of Romania, a comparative evaluation of the effectiveness of research activities in three environments: private (business), governmental (public) and university. The evaluation is performed starting from the effort-effects ratio, which generates a complex study by including multiple variables for efforts (inputs) and effects (outputs). This aspect is capable of furthering unilateral studies in the dedicated literature which rely on a low number of variables. The results of the research may be viewed from two perspectives: the spatial and the temporal. The spatial perspective refers to static comparison (for the same time frame) of the results of R&D in the three research environments included in the competition. From a temporal viewpoint, we have resorted to a comparison of the evolution of the results of research for the three environments over time: in what time frame they become visible in entrepreneurial activity, how intense and durable the effect on company performance is. The study is based on data collected from three different sources, for an 18-year period, specifically 2005 – 2022. In the future, this research may continue by further extending the temporal series, to the extent that data sources publish information in the following years. This aspect enables the study results to be tested considering a longer time frame.

The research results add to the dedicated literature by mentioning the different impacts of research endeavours on the entrepreneurial environment, depending on where the research activity takes place. The findings show that research conducted

in the private (business) environment is visible in company activity as of the current year (Wang and Hagedoorn, 2014; Lev and Sougiannis, 1996). The research conducted in the governmental and university environments is visible after a longer time frame of three years (Abody and Lev, 2001). However, in the private environment, there is volatility regarding the evaluation of effects for the third year after R&D efforts have been implemented. The university environment exhibits a constant and increasing evolution of the impact of R&D on the business environment. All three research environments achieve maximum effectiveness in the third year since the implementation of R&D endeavors (Lee, 2020; Pazarzi and Sorros, 208; Abody and Lev, 2001). Therefore, although the effects are noticeable later, research in the university environment can be regarded as the most effective, as it exhibits a subsequent positive and constant evolution of the effects on the entrepreneurial environment during the following three years subjected to analysis, while the measured intensity of impact is clearly superior to that of the other two research environments: private (business) and governmental (public).

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