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Article

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Revista română de economie

The attractiveness of the research career in Romania in the European context

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***Abstract**: According to literature and, after all, to the economic rationale, the availability and quality of the human resources is a critical factor for vivid, flourishing and pervasive research, development and innovation (RDI) activities. Indeed, probably more than in many other social and economic areas, in the RDI sector, the human capital is hardly a fungible input. As research and innovation stand out as a prerequisite for economic growth, for higher competitiveness, as well as for the society's general welfare, the human resources in RDI become a very important asset for economic, social and environmental sustainability and resilience. This paper looks into the availability of the human capital for research, from the perspective of the attractiveness of the Romanian RDI system for the potential human resources. Drawing on literature, on qualitative analysis, and applying statistical tools such as autoregressive models built on panel data available for the EU countries, the authors identify and assess the relevance of the main factors considered most important for the capacity of a RDI system to attract and keep the most valuable human resources. They also draw a few strategic action lines that may boost the interest of the qualified individuals, for research and academic careers.*

***Keywords**: human resources in RDI; scientific research careers; doctorate holders careers*

***JEL**: O30, O38*

Introduction

The most recent European Union official reports draw attention on the low and descending level of the Romanian overall innovation performance. Even Bulgaria, the

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other EU modest innovator, has moved ahead, leaving Romania behind, the last among the EU countries, according to the Summary Innovation Index (SII) ranking (EC 2016).

Romania is also among the 7 EU member states that reported, between 2008-2015, a negative growth rate of the SII. Moreover, while the other 6 countries had a negative growth of up to 1%, for Romania, the decrease was 4.4%

The level and recent dynamics of the input indicators – such as the public and private expenditure on research, development and innovation (RDI) – are, also, not favourable, against the European average and the targets that Romania has assumed for 2020, in the National Strategy for RDI 2014-2020 and the Europe 2020 strategy (Sandu, Anghel, 2016).

In this context, for Romania and not only, the availability – in terms of quantity and quality – of the needed human resources for research and innovation activities, stands out as a key and critical input factor and premises for better prospects regarding the innovation performance, economic competitiveness and growth, and social development.

After a thorough literature review of the role and dynamics of the pool of human resources available for research, followed by a general overview on the human resources employed in the Romanian public, private and high education research sectors, the authors assess the impact of various factors considered important for the level of the attractiveness of the research system for the potential human capital. To this particular end, various autoregressive models were built on panel data retrieved for the EU countries. The last chapter summarizes the main conclusions and draws several lines of action of public policy that may increase the interest of the well qualified individuals in research, as well as the attractiveness of the RDI system.

Literature review

The development of the European Research Area (ERA), an endeavour aimed at strengthening and empowering the social and economic development of the European Union through a synergetic capitalization on available scientific resources, is met with multiple challenges, among which the availability of high quality human resources has stood out since onset. European Union official documents (Euorstat, 2000; EC, 2002; EC, 2010, etc.) as well as experts' scientific papers (Wiesel *et al.*, 2002; Zubieta, 2009; Fernandez-Zubieta and Ravel, 2011, etc.) have been warning about two main setbacks that the EU members and institutions need to tackle, as they mount as important obstacles to the achievement of the ERA.

On one hand, there was a generally acknowledged concern and anxiety regarding the lack of sufficient qualified people for scientific work, including researchers, S&T specialists, etc. necessary to form the critical scientific base required to successfully identify and exploit answers and solutions to the European societal demands. The other challenge regarded the deeply rooted barriers to the mobility of the RDI personnel between institutions, sectors and countries within the EU, which would limit the effectiveness of the research and innovation potential, capabilities and resources.

While the EU has lagged behind important world competitors with respect to the share of researchers in total active population, since the beginning of the 2000s the literature has drawn attention on the modest – even falling – interest of the young generation in pursuing advanced formal education in traditional sciences (such as mathematics, physics, etc.), engineering and technologic core fields (Zaman *et al.*, 2009). The young university graduates, in general, and the graduates in natural sciences, engineering and technology fields (SET), in particular, are the potential human resources for RDI, if the RDI system itself is able to attract and keep them in research. Besides, the ageing tendency of the population employed in SET sectors has been a constant along the last years in many EU member states, as in 15 of 28 countries, the share of the employees aged 25-34 has decreased and in 18 of 28 EU countries, the share of the older employees (aged 45-64) has increased since 2000.

On average, in the EU, the share of the people aged 25-34 in the total employees in natural sciences and technology (S&T) with tertiary education dropped by 3 p.p. (from 30.5% in 2000 to 27.5% in 2016), while the older employees (45-64 years) represented, in 2016, by 6 p.p more than in 2000 (38% in 2016 vs 32% in 2000).

Moreover, in order to achieve the target of 3% of GDP for the expenditure on research and development (R&D), set for 2020, the EU needs to attract at least 1 million more researchers to the figures in 2010 (EC, 2010).

In this context, the attractiveness of the research careers – in the academic, public or private research units has been set at the core of the EU 2020 Strategy and of the Innovation Union Flagship Initiative. Even prior to 2010, the European Commission invited all national and international stakeholders in research and innovation to adhere to a set of key principles regarding the recruitment, management as well as the conduct of researchers that may support and encourage people to undertake and pursuit highly effective and satisfying research careers: Science and Society Action Plan (2001); the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers (both adopted in 2005). Ensuring that researchers may be subject to the same obligations and rights in any European member state, the two last mentioned initiatives were meant to smooth up the path for ERA.

According to the European Commission report in 2012 (EC, 2012) which gathered contributions and opinions from all stakeholders, from individual researchers, national and European institutions, to industrial respondents such as Volvo Technology, Philips or European Technology Platform, etc, ensuring the supply of well qualified and highly competent human resources for research and innovation stood out as the most important priority that needed urgent common efforts in order to achieve ERA, the economic competitiveness and development targets.

Increasing the attractiveness of the research career to the young generations, on one hand, and the interest of the brilliant professionals, researchers – EU and non-EU – in the available positions within the European Union, on the other, have citizens, therefore, been on the agenda of the policy makers and experts. To this end, numerous studies and reports have looked into the elements that are responsible for the level of attractiveness of a research career, as well as of the research jobs. The results of the quantitative and qualitative studies were carried, further, into designing well targeted and effective policy measures.

The main factors responsible for hampering the choice for a research career and for losing the best minds abroad, which were highlighted in early studies (EC, 2002; Wiesel *et al.*, 2002; EURAB, 2002; EC, 2007) and further confirmed, complemented and detailed in the literature (Zubieta, 2009; EC 2012a; Janger and Nowotny, 2013; Joynson and Leyser, 2015, etc.) are mainly related to: (a) the quality, availability and access to education and training for a productive and rewarding research career; (b) recruitment and career advancement policies; (c) remuneration and working conditions; (d) intensity of the linkages and cooperation between industry and academic research; (e) intersectoral, international mobility.

(a) The equitable and open access to a research career is firstly dependent on the early interaction of the young person with science and scientific subjects, in the primary, secondary and high school. Facilitating the access of the child's mind and interest to science through attractive, interactive and practice-oriented teaching methods, the introduction of SET curriculum and acquiring basic innovation literacy in the secondary school would be important instruments for preparing the young generation for entering a research career (EC 2002, EC 2012; Janger *et al.*, 2013, etc)

Further on, the undergraduate education does not always focus on students gaining and using basic research skills, which are a pre-requisite for taking research to an advanced level. Scholarships for undergraduate research projects, access of students to co-publishing with mentors may stimulate a deeper interest in research.

It has often been signalled that the doctoral schools across the EU do not provide the same quality training, and even more important, that they do not always equip the doctoral candidate with the needed research skills that would ensure professional independence and relevance on the global R&D stage (EC 2002, EC 2012, Janger *et al*, 2013; Fernandez-Zubieta and van Bavel, 2011, etc.). In an attempt to set a common reference base and framework for doctoral training, in 2011, the EC published "The seven principles of innovative doctoral training", which refer to excellence in research, interdisciplinarity, international and intersectoral networking, quality, etc.

(b) The allocation of human resources in research should be based on merit and excellence. Unfortunately, the general perception of the recruitment policies especially in the public research institutions across EU is negative, as they seem lacking in transparency (in vacancy advertisement and selection criteria), strategic orientation, unbiased and achievement-based selection. Moreover, once in the system, researchers often complain of lack of employment security (as the number and share of temporary contracts are increasing - Fernandez-Zubieta and van Bavel, 2011) and lack of career development opportunities.

(c) Inadequate infrastructure for carrying out high-quality research, a non-participatory management framework, low recognition and status generally related to the research profession (EC 2002, Janger *et al*. 2013, Fernandez-Zubieta and van Bavel, 2011), unclear career prospects, lack of access to permanent positions, to research project funding, unchallenging and less performant environment are amongst the main reasons regarding the working conditions, that draw potential valuable human resources away from research careers, along with the inadequate payment. Wages in R&D are generally lower than in other SET based career alternatives and the wages greatly vary within the EU, between countries and experience levels. It is worthing noting that in 2017, the European Commission announced a project for supplementing the income of researchers in countries with low wage levels. While supporting mobility, this project is meant to slow down brain drain from Est to West and to encourage high-quality human capital to choose countries with lower payment, such as Romania and Poland, where the payment level is a third of the Germany's or France's (Janger *et al*., 2013)

Nevertheless, the motivations and particularities of a person with a research-shaped mind structure seem to offset other economic considerations and criteria when deciding for a certain career path. Some authors argue that, while being relevant, the economic criteria play a less important role in choosing to become a researcher, as the work-related satisfaction seems to offset relative payment disadvantages Moreover, a working environment based on collaboration, openness and multidisciplinarity, which encourages creativity are very important, while high competition and tough selection criteria for funding or for employment lower creativity and quality, and discourage collaboration (Stephan, 1996; Stern 2004, Janger and Nowotny, 2013; Joynson and Leyser, 2015; Zaman *et al*., 2009)

(d) As compared to world competitors such as the USA, China or Japan, in EU the employment of researchers in the private sector has been considerably lower than in the public sector, and formal cooperation between the public and private sector researchers is relatively scarce (Janger and Nowotny, 2013). This would foster optimal commercialization of and, timely and innovatively capitalization on research results with direct impact on competitiveness and growth. Moreover, a strong cooperation between industry and academic /public sector research is critical to ensuring the match between the supply of human capital and research results on one hand, and the demands of industry, on the other hand (EC, 2012). Early involvement of industry partners in the education process, networking platforms, long-term partnerships, innovative clusters, intersectoral mobility programmes and PhD industrial programmes may strengthen and deepen the connectivity and cooperation between the public and private sectors.

(e) International and intersectoral mobility is crucial for to improving economic competitiveness, as it spurs the development of professional RDI networks, of knowledge and technological transfer and information flows. It is apparent that facilitated shifting from fundamental research to industry associated with appropriate training programmes increases attractiveness of the SET career (Janger and Nowotny, 2013; Foray and Lissoni 2010)

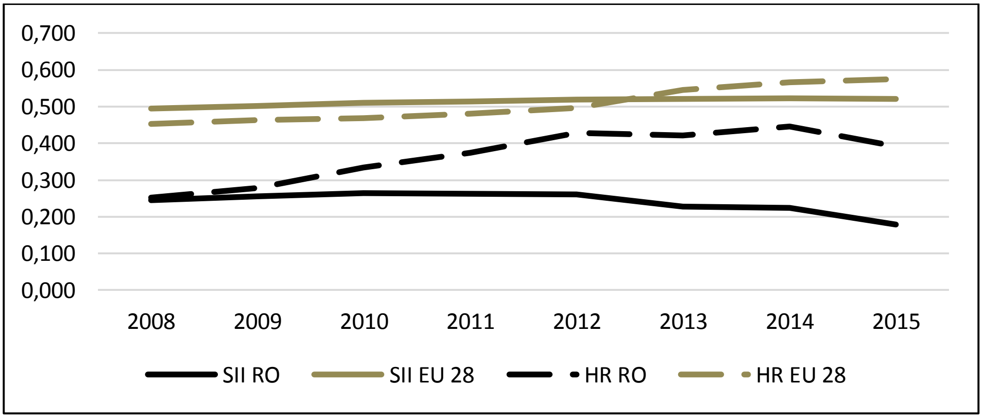
Human resources and scientific research and innovation in Romania

In Romania, the human resources for RDI have been rather scarce and, to a considerable extent, have failed to achieve their full potential effectiveness.

The current level may be, to considerable extent, the consequence of the post-revolution reforms and transformation that, even if well intended, have almost destroyed the RDI system. Its sudden and unprepared decentralisation and the privatisation of the oversized and numerous RDI units, the shift from public funding to uncertain, hard to access funding sources, etc., led to the disintegration and dissipation of research teams. Valuable, well trained and experienced researchers opted for switching careers, for undertaking some research activity in the private business sector, or, very often, for immigrating to countries where their assets have been capitalized upon (Sandu, 2016). Subsequently, the low payment, the relatively inadequate research infrastructure and the fragmentation of the RDI system, together with the low interest of the potential employers to invest in research and innovation have kept the potential human capital away from RDI activities. Currently, the human resources employment intensity in research and innovation is significantly lower than in any other European Country.

The Summary Innovation Index calculated and yearly released by the European Commission experts with the European Innovation Scoreboard report includes the Human Resources dimension, an input element for the overall innovation performance indicator (SII). Consisting of the number of new doctorate holders, the share of population that has completed tertiary education and the share of the youth with upper secondary degree, the subindex for HR had been on the rise from 2008 until 2012. After a sinuous and divergent to the EU28 evolution, the HR subindex dropped, in 2015, to a level slightly above the 2011 figures, dragging downward the SII, as well (Figure 1). Yet, it ranked Romania the last but one, the same position as in Union Innovation Scoreboard 2015.

Figure 1. The trends for the Human Resources Subindex and Summary Innovation Index. Romania vs EU 28 average



Source: EIS 2016 (EC, 2016).

The share of the tertiary educated in total population and the share of the upper secondary graduates in youth have improved since the last report, but to a minor extent, so that Romania lost one position regarding the second mentioned indicator and kept the last but one position regarding the first mentioned indicator. Yet, the number of new doctorate holders – the optimally equipped human capital for innovation and research, and, thus an indicator with maximum relevance regarding the pool of potential researchers, fell by 0.5 p.p and Romania lost 6 positions in the EU28 hierarchy (from the 12^{th} to the 18^{th}) in just one year.

The general pool of potential human capital, expressed by the indicator ”the population with tertiary education”, as a percentage in total active population (15-74 age group), doubled in the last 15 years, from 10.2 in 2002 to 20% in 2016. The gap compared to the EU28 average is the same as in 2002 (about 12 p.p.) and Romania ranks also the last in the EU, far below Bulgaria, for example, that ranks right below the EU28 average.

Regarding the share of scientists and engineers employed in S&T – which are also considered potential agents for innovation and research – the evolution has been more favourable, as it followed a relatively steady upward trend, reaching 5.9% in 2016, 1.1p.p below the EU average. Considering that, in 2005, the EU28 average was 1.8 times the Romanian level (2.5 as compared to 4.5), the improvement is significant and Romania has earned the 18th place in the EU, together with France and Spain.

Yet, the Romanian RDI system employed, in 2014, the smallest share of researchers in active population, as compared to the EU28 countries (0.31%). Despite a significant increase of 0.09 p.p since 2000, the level in 2014 is still a third of the EU28 average (1.14%) and almost 7 times lower than the highest percentage, reported by Finland (2.12%). It is also important to note that even Bulgaria employed a higher share of the active population in research (0.53%), while Hungary, Poland, the Czech Republic and other East-European countries attracted more than double the Romanian percentage. These figures confirm the importance of our research objective and the need to understand what would keep the educated human capital away from research and what incentives may prove to towards raise the attractiveness of the RDI system on the labour market.

An important positive aspect regarding the human capital engaged in research and innovation, in Romania, is related to its relatively young age. While many European countries have signalled a tendency of ageing workforce in RDI, Romania can boast with the 11th position among the EU28 for the “share of the 25-34 age group employees” in total scientists and engineers. With a percentage of 31.3%, it ranks well above the EU28 average (27.7%).

Indeed, the interest in the SET among the Romanian youth (expressed as the share of graduates (ISCED 5-6) in Math, S&T in graduates of all fields) was slightly higher than the EU average (22.9% in 2012), as was of 24.8%, in 2012, a level that hasn’t been reached since 2003. Against the European broader landscape, the number of graduates (ISCED 5-6) in math, S&T per 1000 inhabitants aged 22-29, in Romania, continually increased during 2000-2009 (from 4.5% to 24%) when it fell by 6.8 p.p but still remained above the EU28 average. In 2012, Romania ranked the 9th among the EU28 countries.

To this relatively high youth employment intensity in RDI has probably contributed the design of the PNCDI programmes that aimed at attracting young researchers in the teams of European and national funded research projects (Zaman *et al*., 2009).

Therefore, though it may be explained with both the slower ageing rate for the Romanian population in general, and the capacity to attract young workers in ST, this is a certainly a strength that policy makers should capitalize upon for improving the research and innovation performance and contribution to the economic and social development.

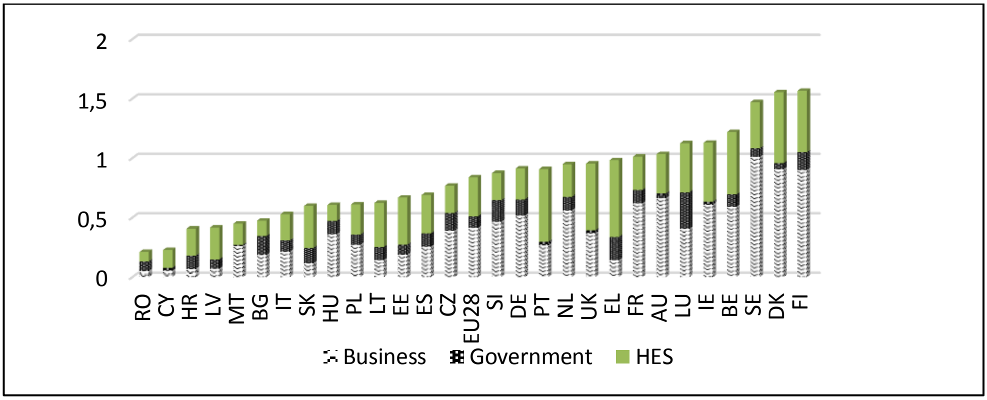
We cannot argue for the same conclusions regarding the researchers' age distribution. On one hand, the information is not available for all EU member states, nor for all sectors. On the other hand, though, among the 16 countries providing the age distribution of researchers employed in the government and higher education sectors, Romania ranks the 13th regarding the share of young researchers (25-34 age group) in total researchers (HC) and the percentage fell from 25.6% in 2008 down to 18.9% in 2014. Moreover, the interest in research among the youth, expressed by the number of researchers (employed in the Public Sector and Higher Education Sector) per 1000 tertiary educated population aged 35-34 sharply decreased since 2010, reaching 6.55 in 2013.

The capacity of the Romanian RDI system to secure the necessary workforce for research and innovation may also be described by a comparative analysis of the pool of available potential human capital, on one hand, and the effective employment intensity in research. Thus, while the trend of the share of tertiary educated population in total employed population was on the rise – yet, at the same pace with the EU28 average – the number of researchers per 1000 employed tertiary educated population (25-64 age group) steadily decreased, from 20 in 2004 to 11.74 in 2014. During 2004 – 2014, Denmark reported an increase from 31 to 45. Only Cyprus ranks lower than Romania and the gap with EU28 average was of 15 researchers per 1000 tertiary educated employees.

Regarding the effectiveness of employment in research, as displayed by the workforce distribution among the public, private and higher education sectors of research, it is apparent that Romania is not in a favourable position. It has been argued, in empiric and theoretic approaches, that high innovation and research performance is conditioned by a consistent engagement of the private sector in RDI (Figure. 2), as it is the private sector that needs to assume the role of developing, applying and turning to profit the research performed within or outside the sector.

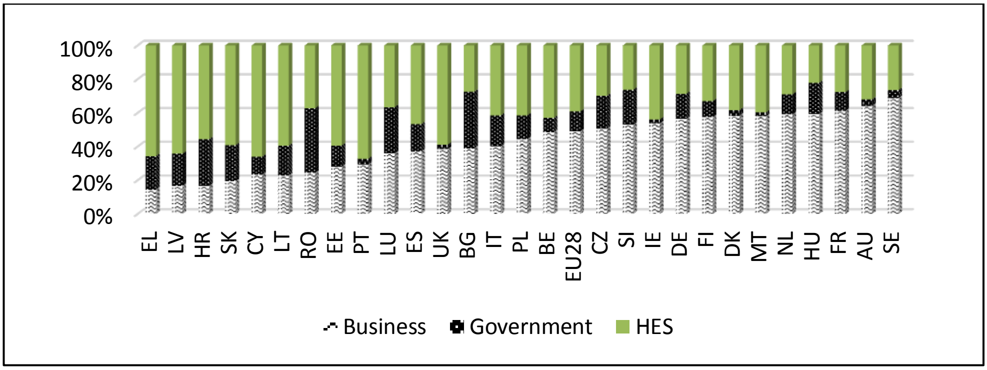
Figure 2. Employed researchers by sector of performance, 2015

a) The share of researchers in total employment[1]



Source*:* authors' processing of Eurostat data.

b) Researchers distribution by sector of performance



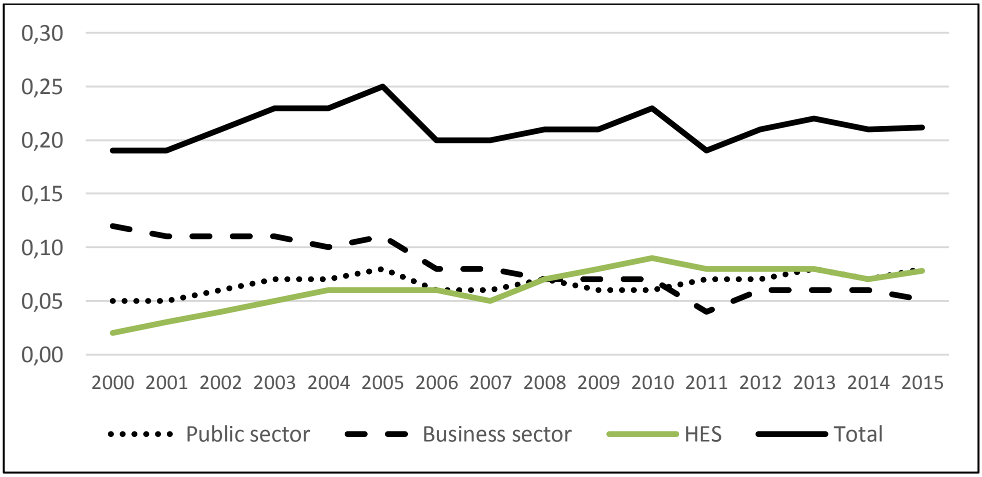
Source: authors' processing of Eurostat data.

Romania not only ranks the last by the share of employed population attracted in research activities, but also among the EU states with the smallest share of researchers employed in the business sector, in total researchers (Figure 3b).

[1] It measures the effective working time (Full Time Equivalent - FTE), not the number of individuals employed regardless of working hours (Head Count – HC).

Moreover, the private sector is the only sector that registered an almost steady downward trend regarding the share of researchers in total employment (Figure 3)

Figure 3. The share of researchers [1] in total employment, by sector of performance, Romania



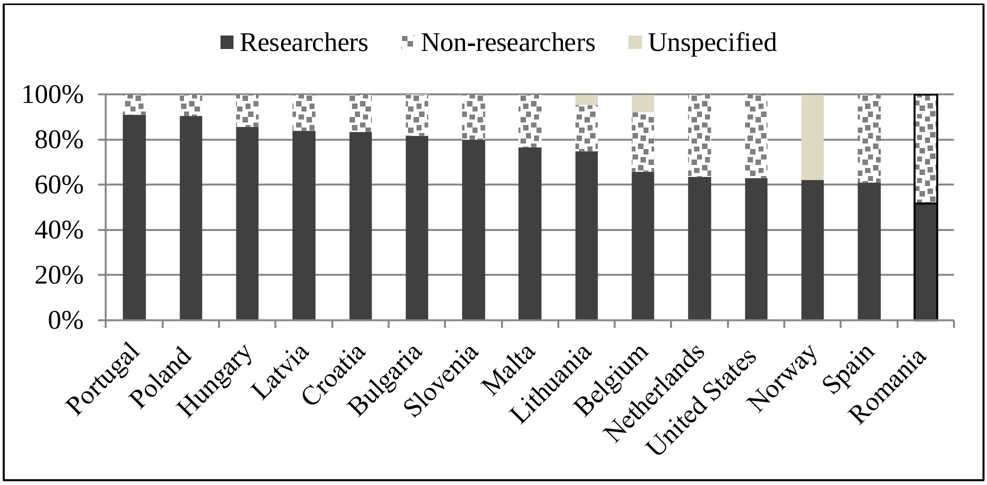
Source: Eurostat database processed by authors.

The pool of human capital with the highest potential, capacity and interest in research and innovation is compounded of the Ph.D. According to the Eurostat database and the European Innovation Scoreboard (EC, 2016), it seems that the number of new doctorate holders per 1000 young population (25-34) still ranks Romania relatively favourably (the 18th in the EU28), despite a downward trend (from 2 in 2012, to 1.9 in 2013 and 1.4 in 2014). Yet, the number of new doctorate graduates in S&T per 1000 population decreased at a higher rate (0.7 in 2013 to 0.5 in 2014), to the benefit of other sciences (arts, social sciences and humanities).

It is worth mentioning that, according to an OECD report (Auriol *et al.*, 2013) that looked into the doctorate career development of 14 EU countries, Romania held the smallest share of doctorate holders working as researchers, as well (Figure 5a). Moreover, 75% of the doctorate holders working as researchers were employed in the higher education sector (Figure 5b), which may confirm the hypothesis that the research activity may represent, to most of the doctorate holders, a "must have" adjacent to the academic career rather than a career priority in itself.

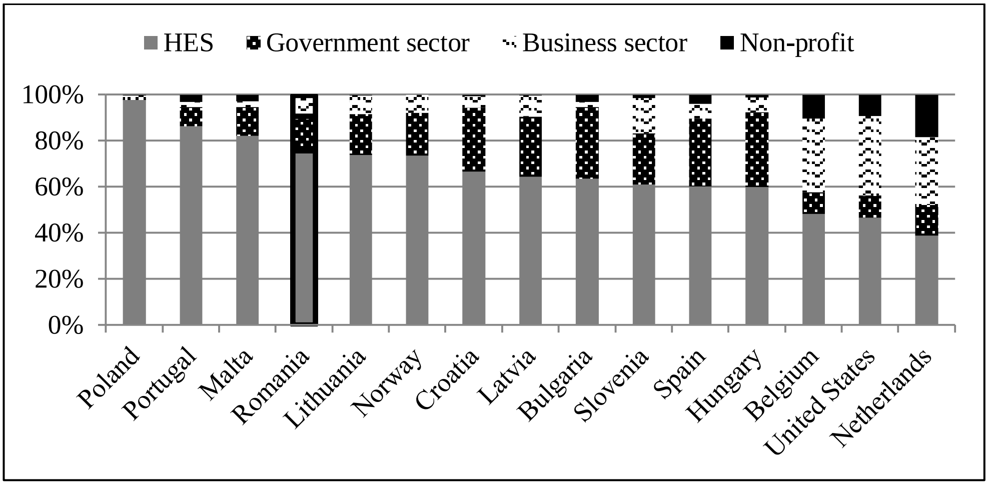
Figure 4. Doctorate holders working as researchers by sector of employment (2009)

a) *Percentage of doctorate holders working as researchers*



Source: Auriol *et al.*, 2013.

b) Doctorate holders working as researchers by sector of employment



Source: Auriol *et al.*, 2013

The same document reported (in the business and government sectors), a negative difference in annual earnings between the doctorate holders working as researchers and the doctorate holders that do not undertake research activities. This may partially account for the lack of interest in research among the most educated and capable. Only in the higher education sector the difference is positive, which is plainly explained by the mandatory character of the research activity associated to a developing academic career.

Methodology

In order to understand what keeps the qualified human capital outside the RDI private or public sector, we identified several potential factors and tested them, through relevant proxy indicators, in simple and multiple autoregressive panel linear regression models, controlling for fixed or random temporal and spatial effects.

The general model equations can be written as follows:

$$Y_{it} = \beta_0 + \sum_j \beta_j X_{jit} + \beta_{j+1} Y_{it}(-1) + e_{it,}$$ where i = 1,..., N, t = 1,....,T and j = 1, 2,

- Y_{it} is the observed dependent variable for the EU state *i* in year *t*: most often, the share of university graduates that are employed as researchers – in total or per sector of performance, if the model is built for the whole RDI system or for just on sector (public, business or higher education sectors);
- X_{jit} is the independent *j* variable observed for the statistic unit „i" (EU state) in year „t", which could be: the Gross Expenditure on Research and Development (GERD), labour costs of R&D or capital expenditure on R&D, in PPS, per capita, in total or per sector of performance; the Summary Innovation Index (SII); the GDP/capita (PPS);
- β_0 is the intercept shared by all cross-sectional units
- e_{it} represents the error term

Considering the similarities in the behaviour of the human resources in different but interconnected socio-economic contexts, we used the panel data for the EU countries between 2000 and 2014 or 2015, according to each indicator data availability, in order to raise the relevance and reliability of the econometric models.

The autoregression model allows for testing for, and outlining, the self-dependent and inertial character of the attractiveness of the national RDI system for the human resources. Also, integrating the dependent variable itself with a one year lag (Y(-1)) among the predictors, allows for isolating the observed independent variable and for controlling the simultaneous factors that are not included in the model. Moreover, the autoregressive model ensures that the residuals in the regression equation are independent, thus nullifying the hypothesis of errors auto-correlation. Indeed, the Durbin-Watson statistic test rendered values higher or close to 2, in each model.

Based on the literature (Fernandez-Zubieta and van Bavel, 2011; EURAB, 2002 etc) and experts' opinions, we considered, as potential factors triggering the attractivity of the RDI system to the potential researchers, the following:

- the level of development, importance and endowment of the research and innovation sector in an economy, in the private and public sectors;
- the performance level of the RDI system and, respectively,
- the general stage of economic development.

The attitude and interest of the public policy makers and private companies in research and innovation, as engines of higher competitiveness and socio-economic development, are plainly revealed by the propensity for investment in RDI in both the public and private sectors. The budget allotted to RDI reflects, on one hand, the compensation and remuneration level for the employee and, on the other hand, how properly equipped and endowed the research and innovation infrastructure is. These two elements may be responsible for the satisfaction the researchers expect and get from working in the RDI, and thus, for their interest in searching employment in these activities.

As indicators, we selected, for this first factor, the GERD (in PPSs per capita) by type of expenditure and by funding source. Thus, we gathered data on the total expenditure, as well as on the expenditure on the workforce for RDI, and with the investment in capital for R&D. Moreover, we gathered and processed data on the total expenditure, as well as on the three main funding sources: the private sector, the public budget and the higher education sector.

In literature, one important reference indicator for the performance of RDI – the second factor considered in our analysis - is *the Summary Innovation Index* (SII), yearly calculated and provided by EU experts. We also referred to this indicator and included it in our econometric models for this specific factor.

For the last factor, the general level of economic and social development, we selected the GDP per capita (in PPS).

Except for the SII, all data was drawn from Eurostat database. The SII is provided in the European Innovation Scoreboard published in 2016 (EC, 2016) and previous years.

These indicators were integrated as independent, predictive variables in single and multiple regression equations that were built for the whole RDI system and for distinct main sectors of performance – the public, the private and the higher education sectors. The main findings are concisely presented in the following chapter.

The most relevant indicator that we considered as proxy for the attractiveness of the RDI activities to the potential human resources – the phenomenon whose causality we have sought to test in this paper – is “the share of researchers in total university graduates” of a country.

Instead of the share of researchers / total personnel in RDI in the employed population we opted for this indicator,, as the dependent variable in most of our models, as the actual pool of potential researchers – the active vector of RDI – are university graduates. Thus, the higher the attractiveness of the system to the potential human resources, the higher the share of university graduates that have chosen a researcher career. However, one should be careful when interpreting the results, as, in a case of a demand-driven labour market, where supply dynamics are just a feedback to demand variation, this indicator may not reflect the interest of the university graduates for research, but, on the contrary, the appetite, openness, and absorbing capacity of the business and public sector for research and researchers.

We also should be aware of reverse causality, as, for example, a change in the dependent variable (the share of researchers in total university graduates) brings forth some similar fluctuation in the RDI labour costs (an independent variable, in our models). To avoid this bias, we tested the models with one-year lag for the “labour costs with R&D” indicator, as well.

Results and discussions

The panel data regression models applied to the whole RDI system, regardless of the performing sector, tested, as predictive variables, the “gross expenditure for R&D per inhabitant” (PPSs), which was further differentiated by the funding sector and the type of expenditure; the SII; and the GDP per capita (also, in PPS_EU28). The dependent variable, in these models, is “the share of researchers in total university graduates”.

It is important to mention that, except for some models for which the Hausman test and the redundant fixed effects test confirmed mixed effects (temporal random effects and cross-sectional fixed effects), the equations generally tested for fixed temporal and spatial effects. All models have also confirmed historical dependence, as all coefficients for Y(-1) are highly significant (p=0.0000)

The unifactorial autoregressive model with the total GERD as independent variable rendered a statistically significant coefficient (p=0.0013) (Table 1, model 1). Yet, the impact is less important than expected.

When differentiating the gross expenditure for R&D by the funding source, it is apparent that only the private investment may induce an increase in the interest in RDI among the potential labour force. In the two-factor regression equation, the coefficient of the public expenditure on R&D is negative and not statistically significant (Table 1, model 2). This lack of correlation may be explained either by the fact that, in some cases, in contrast with the private sector, higher public funding for research – performed especially in the public sector, too – does not automatically involve creating more jobs, nor significantly better working conditions or generally higher pay. Indeed, in most national RDI systems, the public RDI sector is less market driven and oriented than the private one.

When further testing the influence, on the share of university graduates that chose a researcher career, of the public and private expenditure, taking into account also the type of cost (for labour or capital) it seems, also, that only the private investment in the RDI capital, and only the private expenditure for labour make a significant impact on the dependent variable. In both multiple regression equations, where the predictive variables are – beside the dependent variable at one-year lag - the public and private expenditure for labour and, respectively, the public and private expenditure ON capital, only the indicators with data for the private sector displayed a statistically significant coefficient (models 3 and 4).

Differentiating between the two main types of cost with the RDI activities – labour costs and capital expenditure (PPS per capita) – we see that both variables are statistically significant, in the simple and, also, multiple autoregressive equations (models 5, 6, 7).

In order to avoid the reverse causality bias (when more research jobs trigger higher labour costs), we introduced the „labour costs" indicator with one-year lag. Analysing the change in the share of researchers in the potential labour force pool, that comes up one year after an increase in the total private/public expenditure on the human resources in the RDI, would avoid the bias that may spur from the inherent increase in the labour costs concurring with a higher number of employed researchers. In the simple autoregressive models where the independent variable is the total, the public and, respectively, the private labour costs for RDI, only the total labour costs and the labour costs assumed by the business economic sector are significant factors, but with a much less important impact than in the models with no temporal lag (Table 1, models 8,9).

Moreover, in the multiple autoregressive equation (Table 1, model 10) where the public and private labour costs with RDI – with one-year lag – are predictive variables, the model does render significant coefficients only for the private expenditure on labour.

When differentiating between labour costs and capital expenditures, the temporal lag highly decreased the value of the coefficient for the "labour costs" variable in the simple autoregressive panel data equations,. Yet, after introducing the temporal lag in the two-variable autoregressive model, the coefficient of the labour costs was significant and almost ten times the value of the same indicator entered without the temporal lag, while the capital expenditure indicator has not rendered a significant coefficient.

When the expenditure on capital is considered, only the raise in private investment on RDI infrastructure and capital brings forth an increase in the labour force engaged in the research activities. The "public expenditure on RDI capital" variable presents a statistically non-significant coefficient (Table 1, model 11).

Neither the SII nor the GDP are significant predictive variables ($p<0.05$) in the simple panel autoregressive models (Table 1, models 12,13). When considering a higher probability interval ($p<=0.1$), the Summary Innovation Index becomes significant (Table 1, model 14). Yet, one-year lag for the SII variable brings the probability for the SII coefficient under the significance threshold of 0.05 and its value remains high.

It is important to note that, in the simple panel data autoregressive models where the dependent variable is the percentage of total personnel employed in R&D in the total labour force, both predictive variables are significant. While the GDP indicator exerts a small influence, an increase of the innovative performance level induces a considerably higher level of attractiveness of the RDI sector to all human resources involved in research and development.

The three main RDI sectors of performance display certain features that may determine different behavioural responses at the same attractivity factors for the potential human resource. The motivations for an individual to choose a research career in the business economic sector would very often be essentially distinct from the incentives other individuals may find in the opportunity to go for a researcher career in the higher education sector, or in the public sector.

Therefore, in order to differentiate the analysed phenomenon between the specific contexts in each performing sector, we tested the same main models presented above, by sector: the private, public and higher education sectors. The dependent variables, in every set of autoregressive panel data equations, are "the share of researchers employed in the public/private/higher education sector in the total university graduates", while the predictive variables are the gross expenditure with RD, the labour costs, the capital expenditure – (PPS/inhabitant) in each of the three sectors of performance, the GDP (PPS/inhabitant) and the Summary Innovation Index.

The total gross expenditure on R&D in a sector is a significant predictive factor for each sector's attractiveness the human capital, but it's impact is the highest in the higher education sector (about ten times the coefficient in the public sector) (Table 2, models

1-3). This may be due to the fact that a university teaching career and research intrinsically overlaps.

The autoregressive equations with “labour costs” and “capital expenditures” as predictive variables rendered significant coefficients for both indicators, in all sectors (Table 2, models 4-6). It is interesting, that in the public and higher education sectors, increasing the financial infusion for R&D infrastructure is negatively and significantly correlated with the share of researchers employed in those sectors, in the total university graduates. That may be an argument for the hypothesis that, (maybe except for the business economic sector), this segment of the labour market is demand-driven. While more and better research opportunities may attract more potential researchers, there is no available employment, as funding for R&D has already been directed to investment in R&D capital. Moreover, one may even need to dispense with what seems a surplus of human capital. In other words, the availability of financial resources and the priorities of employers, and not the interest of the potential employee, is the key factor that eventually determines the human resources dynamics in the R&D sector. Yet, higher funds for human resources in R&D increases employment in research, which may be a token of higher attractiveness for available human capital or, as well, a higher demand for it.

Within none of the three main R&D sectors the general level of economic development seems to have a significant impact on the employment intensity. It may not directly determine an increase in the share of researchers in the total university graduates, due either to higher attractiveness of the R&D activity, or to higher demand for labour (Table 2, models 7-9).

However, the quality of innovation system does seem to make a difference by the interest in research among the university graduates, especially in the business economic sector, and in the higher education sector. Entered with one-year temporal lag, the SII proves a significant predictive variable in all simple autoregression panel data models applied to each R&D performing sector (Table 2, models 10-12).

Conclusions, main limitations and future research

Our research looked into several potential factors that may raise the attractiveness of the research and innovation activity to the human capital, assuming the premises that the scarcity of competent human resources may trigger lower innovation performance, economic competitiveness and growth. The factors considered were the expenditure on R&D (expressed in GERD, by type of expenditure and funding source), the RDI system performance (represented by the Summary Innovation Index) and the general economic development level (GDP/capita).

Following our statistical analysis performed with simple or multiple autoregressive equations with panel data, it seems that the general level of investment in research and development is positively and significantly determining the share of university graduates who chose a research career and got employed as researchers. This significant causal relationship is tested and confirmed also in each of the three R&D sectors. Yet, its weigh is rather small.

When differentiating between types of R&D expenditures – on either labour or capital – the labour costs importance is higher than the investment in capital. In the equations tested on each R&D sector of performance, the variable “labour costs” is significantly influencing the share of researchers employed in that particular sector, in all university graduates. At the same time, the investment in capital was significantly but negatively correlated with the dependent variable in the *public* and the *higher* education sectors, and positively affected the share of university graduates that got employed as researchers in the *business* economic sector.

As stated of before, a rather weak correlation between the costs of RDI (be they of labour of capital) may reflect a demand - driven labour market segment, where the employment intensity of the available human resources for the RDI sector is not a function of RDI system attractiveness (through payment or working conditions), but of the employers’ propensity and capability for research and innovation.

This conclusion is also supported by our previous analysis, where, in order to avoid reverse causality, we opted for “the level of expenditure (total, on labour and capital) per researcher” as predictive variable, in our models, instead of the GERD/capita. Those models rendered no significant coefficients, suggesting a lack of direct statistical causal relationship between the funding level and the attractiveness of research activities to the qualified human resources. Apart from possible model limitations, this may be explained by the fact that the research and career are an individual option propelled by vocation, by the innate continuous curiosity, and less a materialistic money-driven professional choice.

Therefore, in order to ensure a thriving RDI system, the policy makers would consider facilitating access to financial resources for the research units in the private and public sectors that are needed to secure technological, informational and human capital. But in order to fully capitalize on the potential labour force capable of high-performant research, they had better search not for raising its interest – which exists almost unconditionally – but for increasing and multiplying valuable research opportunities provided byproper infrastructure and management and for encouraging the development of working environments that stimulate creativity, cooperation, multidisciplinarity and research performance.

The national innovation performance level does increase, with a temporal lag, the share of university graduates employed as researchers, in all performing sectors. At the same time, the general level of economic development does not seem to bear on the employment intensity in research.

Employing the simple and multiple autoregressive equations on EU28 panel data allowed for robust and reliable statistic results. Nevertheless, drawing on such a heterogenous statistic panel of socio-economic contexts, we should be cautious when extending conclusions to one particular country, such as Romania. This important limitation will be addressed in our future research with clustering the EU countries after one of three main criteria – regarding the RDI system particularities, the input levels (such as the GERD) or the innovation performance level (SII). Each criterion seems important for the economic behaviour of both the demand and supply sides.

Another important drawback of our research lays in the reverse causality hypothesis. Between many of the predictive variables and the dependent variable, there may be a two-way causal relationship. We have already addressed this issue in two different ways: altering the predictive variable (the GERD/researcher, for example) or introducing the temporal lag in the independent variable. The results being inconclusive, we will still consider choosing another dependent variable for the "attractivity of the RDI for the human resources", that may be the share of doctoral students or doctoral degree holders (an indicator not available yet) in total university graduates.

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Table 1. Main results of the autoregressive models tested on the whole statistic sample

Model	Dependent var.	Predictive var.	Var. coefficient	Standard error	t-test	Probability	Durbin-Watson[1)]	Adj. R-squared[2)]	F test
1	ShRUGTot	ShRUGTot(-1) GERDINH C	0.713 0.00079 0.3062	0.0360 0.0002 0.088	19.8 3.25 3.49	0.0000 0.0013 0.0005	1.89	0.943	162.17 p=0.0000
2	ShRUGTot	SHRUGTOT(-1) GERDBESINH GERDGOVINH C	0.68 0.0009 -0.001 0.514	0.48 0.0003 0.0010 0.105	17.93 3.39 -1.20 4.91	0.0000 0.0008 0.2316 0.0000	1.88	0.944	161.91 p=0.0000
3	ShRUGTot	SHRUGTOT(-1) LCGOVINH LCBESINH C	0.66 -0.0041 0.0031 0.447	0.0431 0.0028 0.0007 0.115	15.4 -1.44 4.18 3.89	0.0000 0.1511 0.0000 0.0001	1.65	0.959	200.19 p=0.0000
4	ShRUGTot	SHRUGTOT(-1) CEGOVINH CEBESINH C	0.752 -0.007 0.003 0.493	0.035 0.0053 0.001 0.078	21.67 2.67 -1.33 6.30	0.0000 0.1833 0.0079 0.0000	1.72	0.957	194.3 p=0.0000
5	ShRUGTot	SHRUGTOT(-1) LCTOTINH C	0.641 0.003 0.191	0.0430 0.0006 0.0911	14.89 5.24 2.10	0.0000 0.0000 0.0369	1.58	0.962	217.97 p=0.0000
6[3)]	ShRUGTot	SHRUGTOT(-1) CETOTINH C	0.9600 0.0013 0.027	0.0126 0.0004 0.026	75.42 2.88 0.96	0.0000 0.0026 0.3149	1.76	0.953	351.45 p=0.0000
7[4)]	ShRUGTot	SHRUGTOT(-1) LCTOTINH CETOTINH C	0.941 0.0012 0.0002 0.0381	0.0145 0.0006 0.0001 0.0273	64.93 1.98 1.97 1.40	0.0000 0.0502 0.0487 0.1633	1.74	0.956	416.15 p=0.0000
8[4)]	ShRUGTot	SHRUGTOT(-1) LCTOTINH (-1) C	0.95 0.00028 0.0535	0.0146 8.55E-05 0.0295	64.82 3.27 2.06	0.0000 0.0012 0.0401	1.86	0.956	448.14 p=0.0000
9[4)]	ShRUGTot	SHRUGTOT(-1) LCBESINH(-1) C	0.95 0.00035 0.066	0.0142 0.0001 0.0257	66.34 3.21 2.57	0.0000 0.0015 0.0104	1.86	0.954	486.00 p=0.0000
10	ShRUGTot	SHRUGTOT(-1) CEGOVINH CEBESINH C	0.752 -0.007 0.003 0.493	0.035 0.0053 0.001 0.078	21.67 -1.33 2.67 6.30	0.0000 0.1833 0.0079 0.0000	1.72	0.956	194.30 p=0.0000
11[3)]	ShRUGTot	SHRUGTOT(-1) GDPEU28 C	0.096 1.23E-06 0.055	0.013 1.05E-06 0.031	74.55 1.17 1.78	0.0000 0.2436 0.076	2.10	0.936	3091.61 p=0.0000
12[3)]	ShRUGTot	SHRUGTOT(-1) SII C	0.93 0.36 -0.05	0.029 0.22 0.11	32.04 1.66 -0.44	0.0000 0.1002 0.6587	1.85	0.912	577.46 p=0.0000
13[3)]	ShRUGTot	SHRUGTOT(-1) SII (-1) C	0.96 0.363 -0.112	0.020 0.151 0.074	47.06 2.40 -1.51	0.000 0.0181 0.1345	2.08	0.961	1341.89 p=0.0000
14	TPRD	TPRD(-1) GDPEU28 C	0.985 8.72E-07 0,0167	115,38 2,095 2,2200	115.38 2.09 2.20	0.0000 0.0368 0,0284	1.91	0.986	1490
15	TPRD	TPRD(-1) SII C	0.67 1.1 -0.16	0.075 0.37 0.16	8.85 2.96 -0.99	0.0000 0.0038 0.3242	2.18	0.983	424.79 p=0.0000

1) In the autoregressive model, the autocorrelation in the residuals is avoided, thus the Durbin-Watson test would render values close to 2.

2) While isolating the observed independent variable, the autoregressive model also integrates all the other simultaneous undetermined factors in the one-year lag dependent variable included among the predictors. Thus, the autoregressive model would explain most of the variation in the dependent variable, and R^2 will render high values.

3) Models tested for spatio-temporal random effects (acc. to Hausman test)

4) Models tested for cross-sectional random effects (acc. to Hausman test). All other models were tested for spatial and temporal fixed effects (acc. to the redundant fixed effects test)

Table 2. Main results of the autoregressive models tested on each of the various research performing sectors

Model no.	Dependent Variable	Predictive Variables	Variable Coefficient	Standard Error	t-stat	Probability	Adj. R-squared	F test	Durbin-Watson
1	SHRUGBES	SHRUGBES(-1) GERDBESINH C	0.743 0.0008 0.039	0.036 0.0002 0.0357	20.81 4.28 1.09	0.0000 0.0000 0.2768	0.955	210.13 p=0.0000	1.86
2	SHRUGGOV	SHRUGGOV(-1) GERDGOVINH C	0.934 0.0002 0.0023	0.0116 6.75E-05 0.0044	80.66 3.47 0.515	0.0000 0.0006 0.6063	0.946	461.19 p=0.0000	2.11
3	SHRUGHES	SHRUGHES(-1) GERDHESINH C	0.76 0.001 0.1144	0.033 0.00033 0.0305	23.07 2.90 3.75	0.0000 0.0040 0.0002	0.939	151.76 p=0.0000	1.95
4	SHRUGBES	SHRUGBES(-1) LCBESINH CEBESINH C	0.66 0.002 0.0012 0.061	0.039 0.0004 0.006 0.043	16.95 4.46 2.00 1.43	0.0000 0.0000 0.0454 0.1558	0.975	341.09 p=0.0000	1.79
5	SHRUGGOV	SHRUGGOV(-1) CEGOVINH LCGOVINH C	0.65 -0.003 0.003 0.0512	0.040 0.0013 0.0007 0016	16.06 -2.05 4.49 3.21	0.0000 0.0416 0.0000 0.0015	0.953	171.67 p=0.0000	1.65
6	SHRUGHES	SHRUGHES(-1) LCHESINH CEHESINH C	0.65 0.005 -0.004 0.115	0.039 0.0008 0.0014 0.038	16.41 5.79 -2.79 3.06	0.0000 0.0000 0.0056 0.0024	0.942	141.02 p=0.0000	1.79
7[1)]	SHRUGBES	SHRUGBES (-1) GDPEU28 C	0.097 -6.05E-07 0.043	0.013 8.73E-07 0.018	73.34 -0.69 2.35	0.0000 0.4886 0.0190	0.950	4019.9 p=0.0000	2.04
8[1)]	SHRUGGOV	SHRUGGOV(-1) GDPEU28 C	0.952 3.56E-07 -0.0016	0.011 2.00E-07 0.0067	88.51 1.78 -0.23	0.0000 0.0757 0.8181	0.946	3634.19 p=0.0000	2.12
9[2)]	SHRUGHES	SHRUGHES(-1) GDPEU28 C	0.956 8.0E-07 0.0165	0.0122 4.39E-07 0.0163	78.59 1.84 1.01	0.0000 0.0664 0.3130	0.9333	2932.53 p=0.0000	2.06
10[3)]	SHRUGBES	SHRUGBES(-1) SII(-1) C	0.903 0.383 -0.115	0.0321 0.182 0.086	9.47 2.02 -0.65	0.0282 0.0211 0.0133	0.968	197.03 p=0.0000	1.97
11[2)]	SHRUGGOV	SHRUGGOV(-1) SII(-1) C	0.96 0.04 -0.02	0.012 0.022 0.013	76.21 1.84 -1.15	0.0000 0.0683 0.2506	0.978	2427.58 p=0.0000	2.17
12[2)]	SHRUGHES	SHRUGHES(-1) SII(-1) C	0.94 0.15 -0.03	0.025 0.065 0.038	36.78 2.29 -0.67	0.0000 0.0242 0.5017	0.925	682.57 p=0.0000	2.09

1) Models tested for spatial and temporal random effects (acc. to Hausman test)

2) Models tested for spatial random effects (acc. to Hausman test)

3) Model tested for temporal random effects (acc. to Hausman test)

All other models tested for transversal and longitudinal fixed effects (acc. to redundant fixed effects test)

Table 3. Short description of the variables employed

Variable	Definition
SHRUGTOT	SHare of Researchers in University Graduates - total
SHRUGBES	SHare of Researchers in University Graduates – employed in the Business Economic Sector
SHRUGGOV	SHare of Researchers in University Graduates – employed in the Government Sector
SHRUGHES	SHare of Researchers in University Graduates – employed in the Higher Education Sector
GERDINH	GERD per Inhabitant
GERDBESINH	BERD per inhabitant
GERDGOVINH	Public Expenditure for RD per inhabitant
LCTOTINH	Labour costs per inhabitant - total
LCBESINH	Labour costs per inhabitant – in the Business Economic Sector
LCGOVINH	Labour costs per inhabitant – in the Government Sector of performance
LCHESINH	Labour costs per inhabitant – in the Higher Education Sector of performance
CETOTINH	Capital Expenditure per inhabitant – total
CEBESINH	Capital Expenditure per inhabitant - in the Business Economic Sector
CEGOVINH	Capital Expenditure per inhabitant - in the Government Sector of performance
CEHESINH	Capital Expenditure per inhabitant in the Higher Education Sector of performance
SII	Summary Innovation Index
GDPEU28	Gross Domestic Product (PPS calculated for EU28)
TPRD	Total Personnel in R&D, as the share in total employed workforce