INNOVATION IN EUROPE – DYNAMICS AND DETERMINANTS

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Abstract

The paper aims to examine the relationship between regional innovation and some main determinants, through a regression analysis, using the patent data as statistical indicators of the innovation activity. Analysis is carried at the 265 NUTS 2 regions of the European Union (28 countries) in the period 2008-2015, based on patent data provided by the European Patent Office and highlights the special role of the investment in the research activity in developing innovative capacity. Also, a greater share of the population with tertiary education can be a real support in the innovation process. Instead, the absolute increase of the demographic pool seems not to be a driver in this process, which is more important when we have considered the patent applications filed under the Patent Cooperation Treaty (PCT procedure) than the EPO patent applications was used.

Key words: innovation, NUTS 2 regions, patent indicators

JEL: O31, O52, I25

1. Patents as statistical indicators of invention activities

Nowadays, a premium is put on the Knowledge Economy, as evidenced not only by the dynamics of innovation activity in all countries, but also by the great interest in understanding the influence mechanisms of the innovative capacity of the economic actors (both at micro and macro level, individuals and firms/institutions) and its impact on society progress and human development. In assessing the performance of applied research and technological development, a leading indicator of analysis is the number of patents registered or those issued to / from patent offices around the world. According to the Frascati Manual (2002, p. 200): "a patent is an intellectual property right relating to inventions in the technical field." It is issued by a specialized office to a company, an individual or public body, whether the invention (product or process) is new (worldwide), involves an innovative and is susceptible of industrial application.

The benefits of patent as indicators of innovative activity are obvious: they provide information on a wide field of technologies, the number of patents being otherwise provided for several technological areas (ITC, nanotechnology, biotechnology, environment and health). This information not only allows the public to identify specific kinds of technologies, but they are detailed in the sense of the possibility of knowing the inventor / applicant, application date, other data regarding publication or citation (number and by whom). The data also concern the invention itself, meaning a full description and also the majority of inventions shall be subject to patenting by a legal office. In this way, you can know the intensity, quality, innovative activity structure for states and even for some smaller territorial areas and, most importantly, statistics on patents serve to follow the dynamics of the innovation process, cooperation in research and inventors mobility diffusion of technology between sectors and between countries, etc. All these data are available for longer periods and event in real time through national offices or regional (EPO, USPTO) or international (OECD, WIPO) organizations. However, the extremely high volume of data and the fact that there are other possibilities for keeping the secrecy of remaining unpatented inventions estabilish limitations of patents as indicators of innovation activity.

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2. National and regional innovation dynamics in the European Union

In this study, we will consider information on patent applications and issued patents available at the European Patent Office (EPO), explicitly in PATSTAT 2016 database that provides information on patents filed with national offices, the EPO, the USPTO and the Japanese Patent Office, as well as those filed under the international procedure - PCT. However, one source of information is the database REGPAT OECD (2016), from which we extract similar data at the level of regions covering a large number of countries. Thus, the indicators used reflect the commercial value of inventions covered by that particular office markets (US, EU), the main consuming markets in the world of technology.

2.1 Patent applications worldwide, European and national level

Between 2000 - 2015, at the European Patent Office were recorded on average 130 120 patent applications per year (according to the priority date), the EU Member States accounting for 55.627 of it. Thus, in relative terms, in 2014, requests were 39.6% in the EU, the US and Canada - 27.3%, Japan and South Korea - 19.5%, China (along with Taiwan and Hong Kong) and India accounting for 7.10%.

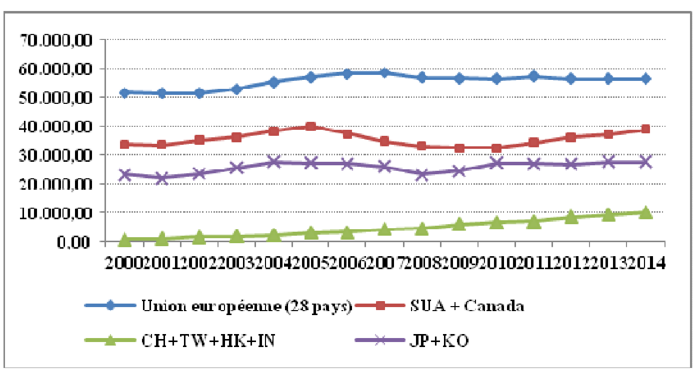
Table no. 1: **Patent applications filed with the EPO by priority year 2000 -2014 (numbers)**

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
World	116620	114,913	118,436	123,945	131,589	136,198	135,189	132,633
UE-28	51754	51,440	51,524	52,972	55,458	57,168	58,351	58,494
USA + Canada	33768	33477	35114	36190	38274	40027	37593	34819
CH+TW+HK+IN	802	1082	1559	1906	2183	3072	3370	4218
JP+KO	23372	22082	23424	25518	27736	27341	27119	26072
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**% în 2014**
World	126,824	128,550	132,057	134,928	137,170	140,043	142,705	100,00
UE-28	56,938	56,687	56,602	57,285	56,600	56,571	56,561	39,64
USA + Canada	33049	32445	32582	34474	36156	37393	38997	27,33
CH+TW+HK+IN	4553	6068	6642	7124	8432	9262	10135	7,10
JP+KO	23393	24658	27208	27015	26879	27619	27756	19,45

Source: Eurostat, 2016

Increases in these latter countries were the most outstanding, given that in 2000 they cumulate only 0.68% of applications filed with the EPO worldwide. According to Eurostat (2016), the total patent applications filed with the EPO sectors increased in 2014 by 22.37% worldwide compared to 2000 (from a total of 116 620 to a total of 132 633).

Figure no. 1: **International comparisons on EPO patent applications based on priority year 2000 – 2014 (numbers)**



Source: Eurostat, 2016

The European Union had the lowest growth rate over the entire period (only 9.29%), while in India and China, together with Hong Kong and Taiwan the increase was of 126.68%. Regarding Member States of the European Union, there are great differences among them on the innovation output (result).

For comparison, we chose the indicator number of patent applications per 1 million inhabitants between old and new Member States, the average in the latter (EU-13) is over 14.2 times lower than in EU-15. Moreover, the gap was recessed from the beginning, when it was only 13.5 times (as shown in Table 2).

Table no. 2: **Average patent applications number per 1 million inhabitants in the EU, 2000-2014,**

	2000	2001	2002	2003	2004	2005	2006	2007
UE-28	106.31	105.40	105.37	107.95	112.59	115.58	117.54	117.39
Zona € (19)	131.84	132.20	131.92	134.97	141.36	144.82	146.78	145.73
UE-15	136.75	134.60	130.31	137.65	148.27	148.73	153.58	149.51
UE-13	5.09	6.20	6.33	5.41	8.46	10.40	8.22	10.03
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	
UE-28	113.81	112.9	112.49	113.55	111.95	111.66	111.59	
Zona € (19)	141.08	140.25	138.85	139.53	136.68	135.53	134.77	
UE-15	148.58	143.49	144.87	147.57	148.54	150.20	152.18	
UE-13	11.03	11.55	9.84	10.13	9.62	10.89	10.70	

Source: Eurostat, 2016

The situation at national level reflects most important differences. Thus, in Germany, patent applications filed with the EPO in 2014 exceeded 20.670, while in Romania and Bulgaria there were only 102, respectively 47 license claims over the same period.

Figure no. 2a: **The intensity of patents: EPO applications per 1 million inhabitants, 2000 - 2014**

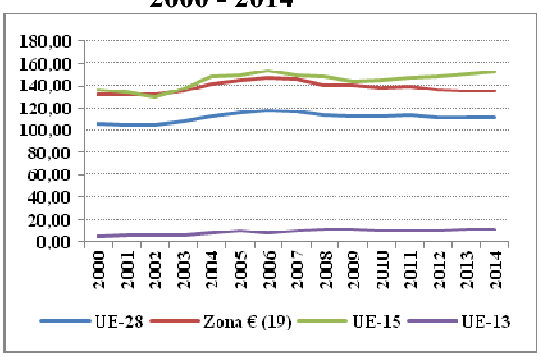
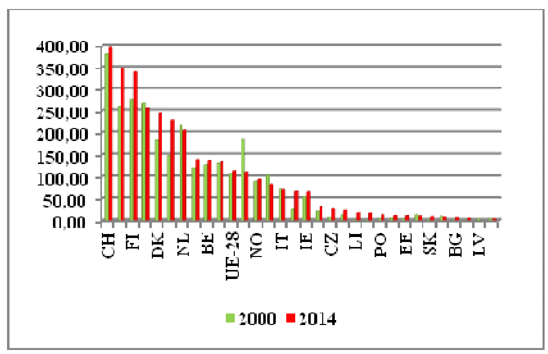


Figure no. 2b: **Patent applications per 1 million inhabitants, 2000 and 2014**



Source: own preparation based on Eurostat data, 2016

Except Malta and Cyprus, Romania and Bulgaria ranks last in the EU, even if they had a relative increase in importance, but the initial level of 7 applications in Bulgaria and 6 requests in Romania (in 2000) would require a much higher growth rate, in order to reach the European average of 112 patents per 1 million inhabitants. From this point of view Romania was found in last place in the European Union with an average of 5.11 patents filed per 1 million inhabitants and Bulgaria on the last but one place, with 6.5 such applications in 2014.

2.2 European patent applications in NUTS 2 regions

At NUTS level 2 regions, the spatial distribution of the number of patents filed with EPO in 2012 highlights the coexistence of areas where these differences are extreme. Thus, we could outline several regional poles in central Europe, comprising most regions of Germany and Austria, the south of England and the Scandinavian Peninsula, as well as a number of regions in central-western and southern France and in northern Italy. Cartographic distribution of patent applications filed under the international (PCT) is very similar, still observing a certain concentration of the regions with the highest values of the indicator.

Figure no. 3a: **The regional distribution of EPO patents, 2012 (numbers)**

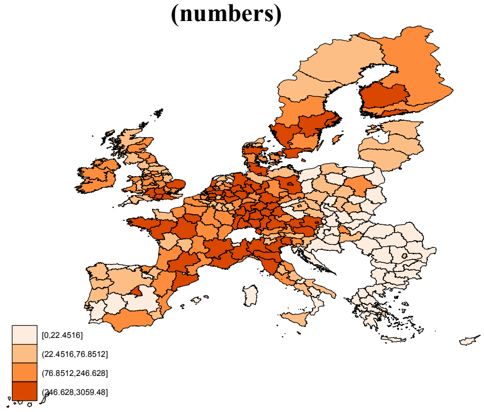
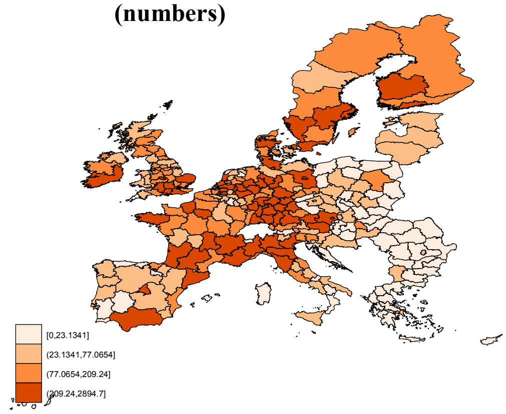


Figure no. 3b: **The regional distribution of PCT patents 2013 (numbers)**



Source: own preparation in STATA 14.0, based on Eurostat and OECD data, 2016

The regions with the lowest number of patents filed with EPO and PCT include large areas of eastern and south-eastern, mainly from Bulgaria, Romania and Greece.

2.3 Patent applications in high-technology and ITC

Patents are granted for inventions in all fields of technology. But we observe developments in some maintaining an average of over 310,000 in the first decade, while in 2013 their number drop to about half at EPO.

Figure no. 4a: **Distribution of high tech patents, EPO priority year, 2012 (numbers)**

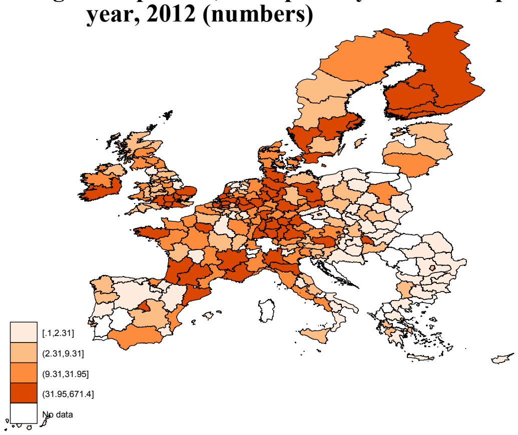
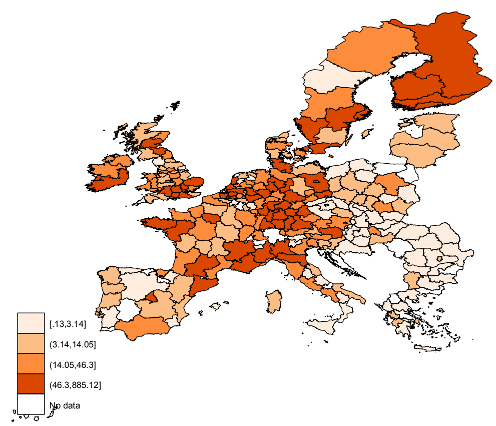


Figure no. 4b: **Distribution of ITC patents, EPO priority year, 2013 (numbers)**



Source: own preparation in STATA 14.0, based on Eurostat data

This dynamic was registered in the EU, where differences between countries are extreme. Thus, as for 2013 the EU-15 holds 96.82% and the new Member States (2013) only 3.18%.

Innovation - broadly defined as the creation of new products, processes, marketing and organizational innovations - is difficult to measure because of its inherent complexity and the limited data available. Research and development activities, respectively patent development evolved in correlation with GDP. R & D investments that support innovation are long-term investments; however, the economic crisis, difficulties in accessing funds necessary to support innovation activity, reducing demand for innovation, risk aversion prolonged state of partial recovery in the dynamics of patent applications. Moreover, the spatial distribution of R & D expenditure shows a similarity with the directly observable patent applications.

Figure no 5a: **Regional distribution of R&D expenditures, % of GDP (2013)**

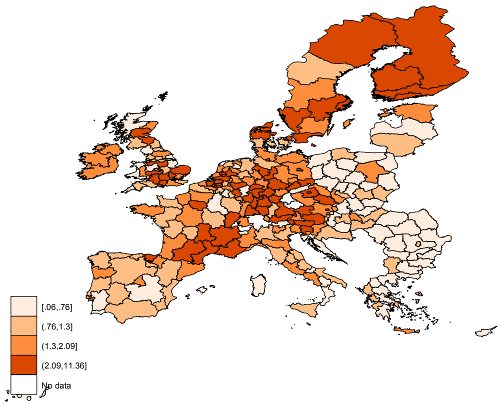
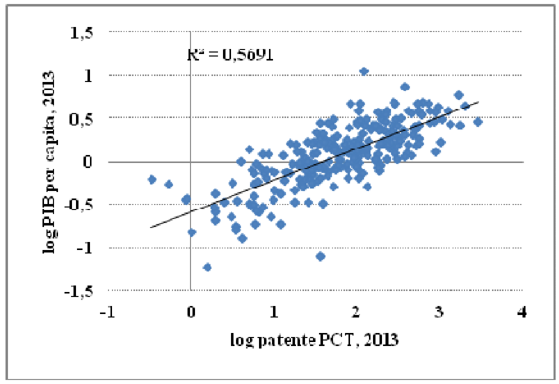


Figure no 5b: **The correlation between R&D expenditures and GDP per capita (2013)**



Source: own preparation in STATA 14.0, based on Eurostat and OECD data, 2016

The correlation between expenditure on research - development and the number of patent applications is relevant in this regard, indicating a potential significant of these expenses in increasing regional innovative capacity.

3. Evaluation of the production function of the European regional innovative capacity

The period analyzed in this study is quite broad, ie 2000 - 2015 (or 2012 for indicators available up to that year), the data are considered on an annual basis, since in a few cases observations are zero ((in some studies is the explanatory variable is the average over a number of years, uUSAlly three, in order to eliminate the zero values of the indicator). In this way, the total number of observations of models is high, taking into account the analysis was conducted on NUTS 2 units that include the whole EU area (out of the 276 regions a few islands were excluded).

3.1. Determinants of patent applications growth - models description and research hypotheses

The dependent reference variable is the number of patent applications identified in each region, applied through the PCT procedure, by inventor's country of origin and the priority date. In a traditional model of knowledge production function (KPF), introduced Griches (1979), we have included the human capital endowment, measured by number of university graduates; and the number of resident population as a control variable, in order to capture the relative size of the regions.

The specification of the main log linearized model is as follows:

$$\log patents = \beta_0 + \beta_1 \log R\&D\ expenditures + \beta_2 \log human\ capital + \beta_3 \log population + \beta_4 \log employment\ rate + \varepsilon$$

As you can see, the reference dependent variable is the number of patent applications identified in each region, but assessments were made considering both those applied to EPO and the PCT procedure and as whole number too, as well as high tech or information and communications technology patents.

The research hypotheses to be tested econometric are formulated as follows:

I.1: Production of patents is in direct positive correlation with financial allocations for research - development.

I.2: For an intense activity of innovation /patenting is essential a high level of working age population with a university degree (I.2.1) or even secondary school(I.2.2).

I.3**:** Physical capital stock is an important contribution to knowledge creation.

I.4**:** The regional dimension is a key demographic development of regional innovative capacity.

I.5**:** There is a supportive role for steady development of innovation activity is the integration on the labor market, which could provide the input for the innovative process successful conduct.

3.2. Innovation's influence in Europe. Results and conclusions

Table 3 presents the results of estimates of specifications from a basic model, using the method with fixed effects (FE) in the simple way (1, 4, 6, 8) and using the robust option (models 3, 5, 7 and 9).

Table no. 3

The estimation results of the production function of knowledge at regional level, where the dependent variable is measured by patent applications filed under the PCT, 2000 - 2013

	m1 b/se	m2 b/se	m3 b/se	m4 b/se	m5 b/se	m6 b/se	m7 b/se	m8 b/se
log_chel_cd	0.260***	0.194***	0.149***	0.181***	0.196***	0.171***	0.162***	0.176***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
log_edu_tert	1.098***	1.042***	0.888***	0.909***	1.090***	1.052***	1.083***	1.132***
	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
log_edu_sec		1.133***	0.856***			0.720***	0.763***	
		(0.12)	(0.14)			(0.14)	(0.14)	
log_pop	-0.002	-0.546*	-1.187***				-1.603***	
	(0.27)	(0.27)	(0.36)				(0.35)	
log_fbkf			0.245***	0.300***				
			(0.04)	(0.04)				
log_ocup				-0.999***	-0.617**	-0.424*		
				(0.21)	(0.21)	(0.21)		
log_fbkf_%_pib					0.120	0.155*	0.084	0.082
					(0.07)	(0.07)	(0.07)	(0.06)
log_dens_pop								-1.730***
								(0.36)
Constanta	0.199	1.779	5.479*	2.151***	1.799**	0.051	8.764***	3.873***
	(1.68)	(1.65)	(2.25)	(0.56)	(0.56)	(0.66)	(2.21)	(0.79)
R-squared	0.241	0.271	0.247	0.229	0.209	0.220	0.233	0.213
F	238.207	209.144	130.524	146.596	130.357	110.753	121.274	133.956
N observations	2503.000	2503.000	2230.000	2217.000	2217.000	2217.000	2230.000	2231.000

* p<0.05, ** p<0.01, *** p<0.001

Source: own preparation in STATA 14.0

We note that choosing the model with fixed effects followed Hausman test result indicating this method as the correct compared to estimating using random effects (RE), $p \leq 0.05$ reflecting the inconsistency ofthe latter method. In each specification, the explanatory factors include action on research and development (ie expenditure assigned for this purpose), human capital (education level of the population), demographic pool and regional employment size.

The results obtained lead to the following remarks:

1) In all effect estimates for input on research spending - development, their role is clear, statistically significant, robust and important as the magnitude of the economic impact (I.1 hypothesis is confirmed). Thus, a 1% increase in these expenditures lead to an increased number of patent applications with values ranging from 0.149%(Model 2) to 0.260% (Model 1). The constant effect of this determinant, regardless of the others considered factors, reflects its particular importance.

2) A consistent pool of labor with tertiary education is essential for obtaining good results in innovation, hence the we find a large economic significance of the effect. Introducing the complementary variable of population with secondary education also seems to support the regional innovative capacity growth, even if the economic importance of its impact is not as high as for the the population with university degree. This confirms what was otherwise expected, respectively the importance of higher education that should characterize an increasingly larger share of the population (I.2 hypothesis).

3) The size of the regional demographic pool in absolute value, however, is at odds with innovation capacity, a larger number of the population is not a supporting factor of economic development and of innovation. In conjunction with the outcomes of education, this emphasizing the need for action to increase quality workforce and not only the number of population (actually the opposite effect on patenting is obvious when we introduced a variable on secondary education in the models, that in the end enhances the negative role of the quantitative dimension of this regional indicator). Thus, I.4. hypothesis is not verified

4) The absolute size of the employed workforce is not in a direct, positive corelation with the dependent variable, its effect is negative in combination with various other drivers or using different techniques. This result could be explained by the decreasing number of workers in the years under analysis, mainly as an effect of the economic crisis. As a conclusion, we can say that the results confirm the predictions of theoretical and empirical literature, even in these simple models of evaluation. However, if the absolute number of employees does not appear to be relevant, it is particularly important to increase the integration of labor elasticity, patent applications relation with the employment rate being direct, statistically significant and robust (hypothesis I.5).

In the following models (Table 4) we took into account that the production of knowledge is characterized by a delay between spending on R&D and production of new innovations legally protected by filing patent applications (Jaffe, 1986 și 1989).

Table nr. 4: **Effects of the influencing lag variables introduction**

	m1 b/se	m2 b/se	m3 b/se	m4 b/se	m5 b/se	m6 b/se	m7 b/se
	PCT applications				***EPO applications***		
L.log_chel_cd	0.260***	0.240***	0.239***	0.183***	0.133**	0.093*	0.131**
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)
log_edu_tert	1.108***						
	(0.06)						
log_pop	-0.098						
	(0.31)						
L.log_edu_tert		1.116***	1.102***	1.042***	1.490***	1.302***	1.358***
		(0.06)	(0.06)	(0.06)	(0.07)	(0.08)	(0.08)
L.log_pop		-0.131	-0.457	-1.163***	-1.749***	-2.206***	-1.133**
		(0.30)	(0.34)	(0.34)	(0.37)	(0.38)	(0.39)
L.log_ocup			0.439*	0.559**			
			(0.21)	(0.21)			
L.log_edu_sec				1.050***			
				(0.13)			
log_ocup_salariati						1.533***	
						(0.21)	
log_rata_ocupare							1.315***
							(0.27)
Constanta	0.766	0.982	1.783	4.174*	10.551***	9.421***	4.542
	(1.88)	(1.86)	(1.91)	(1.91)	(2.27)	(2.27)	(2.58)
R-squared	0.219	0.223	0.224	0.249	0.225	0.242	0.235
F	187.898	192.149	140.219	128.936	173.965	139.193	135.993
N observations	2268.000	2259.000	2201.000	2201.000	2051.000	2002.000	2021.000

* p<0.05, ** p<0.01, *** p<0.001

Source: own preparation in STATA 14.0

To estimate the function of generating knowledge we have adopted model widely used in literature, having as drivers of innovation activity the expenditures in R&D, the education level, the size of the labor market with a one year lag from the previous period.

The first four models in shown in Table 4 include as dependent variable applications through the PCT procedure and the last three the application filed with the EPO. The results obtained confirm those earlier and the ones widely accepted in the literature, underlining once again the key role of this indicator in a sustained innovation activity conclusions.

Thus, the introduction of lag variables like the investment in more research activity – developmentand the share of population with higher education are factors of particular relevance for innovative dynamic in analyzed areas. In all models, both in the first four where the dependent variable is measured by patent applications filed under international procedure, and those submitted to the EPO (last three columns) elasticities of innovation activity in relation to the two indicators have a plus sign and are statistically significant, with a critical magnitude of the economic impact. We also note that an increase in employment is in those circumstances has a real positive influence on innovativeness of the European regions. As such, the combined effect of education, investment in research and degree of integration into the labor market is confirmed as a factorial complex with direct implications on innovative performance of EU regions.

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