The dependence of patents from R&D outlays and R&D employees in European Union countries

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Abstract: - The research described herein seeks to determine the regressive dependence of the number of patents on the outlays on research-and-development and the number of those employed in the R&D sector, and to calculate on this basis the marginal and average cost/resource-intensity and labour-intensity of patents in the European Union countries in the years 2016 and 2019. Studies have shown that the total of the flexibility of the number of patents versus R&D outlays and R&D employment was identical for both years (i.e., 0.97). Hence, a method to determine whether undulation exists with the same total flexibility has been demonstrated. A 5.4 per cent decrease in the intensity of flexibility in the number of patents was identified for 2019. The research has shown that the growth in the number of patents proves to be in line with the growth of mean labour-intensity of patents for the years concerned. This proves that the knowledge resource plays a specific part in creating the number of patents for the counties and years under examination.

Key-Words: - regression, R&D outlays, R&D employment, patents, European Union [EU] countries/Member States.

1 Introduction

As long as all the resources have market-determined alternative costs, allocation is effected at market prices. It is the nature of casual relationships that a change begins with a factor in deficiency, which leads to a change in the relative prices, assuming that the market is operable. Prices reflexively redirect the technological progress toward saving the factors which are relatively expensive. Then, in response to the signals from the market, outlays are allocated to scientific research which might alter the situation. The changes in the resources determine technological innovations to the extent enabled, in the short term, by the existing state of science.

Entrepreneurship is based on R&D's developmental function in a country's economy, which leads to the economy's innovativeness. Being original inventions that have never before appeared in the market, patents are an essential factor of economic development. An original product of intellectual effort of a creative individual or team is part of creative technical/technological development, owing to its being a world-scale novelty, with its creative input in the development of technique/technology of production or manufacture. Its role in the organisational change process is complementary. An increase in the number of patents and their efficient protection, as well as a possibly extensive popularisation of patents, is in the interest of the economy and the society.

Patents are the primary source of a country's science and innovative technology. This is due to their original resource which is rare in the market, is supply-related, and forms a potential outlay to be consumed by enterprises of the given economy. By way of capitalisation, the resource increases the productivity of the country's economy and its Gross National Product (GDP). An increase in the economy's innovativeness (number of patents) implies a higher innovative capacity and increased value of the country's economy. The increase in the economy's productivity leads, in turn, to social welfare.

Patents enable the protection of the elusive and changing knowledge. The study on the dependence of the number of patents on R&D outlays and the innovative knowledge of those employed in the R&D sector has produced curvilinear dependences, whereas the influence of the sector's employees proves negative [1], [2].

This article seeks to shed light on the reasons why the flexibility of the number of patents versus the knowledge resource of R&D employees is negative.

Based on the logic behind this relationship and its substantive evaluation, it forms the basis for increases in the numbers of patents in the countries concerned. The ascertainment by several authors of the fact that the relationship is curvilinear and the impact of the employed negative both limit the research potential of the problem in question; even if approximate, the rendering of this state of affairs will contribute to filling in the gap in the literature. An attempt is moreover made herein to explain the cost/resource-intensity and labour-intensity of patents, which only a few authors have pointed to as factors of essence. The objective is, after all, to assess whether patents provide us with innovations at a lower cost (outlay) than the alternative [3], [4].

The study seeks to determine the regressive dependence of the number of patents on the R&D outlays and R&D employed, and to determine the marginal and average cost/resource-intensity and labour-intensity of patents in the economies of the EU countries in the years 2016 and 2019.

The study is based on an underlying hypothesis that the number of patents versus the total flexibility in R&D outlays and R&D employed is identical as per the static and dynamic regression models.

The assumed research objective determines the following five sections: (i) related literature, (ii) a supply model of patents and dependences; (iii) empirical data and characteristics of the variables; (iv) econometric analysis and discussion; (v) conclusion.

2 Related literature

The innovation theory highlights, among other things, the importance of the competitiveness of a given economy. Increased value of innovation implies a higher degree of the economy's capitalisation. This also translates into a higher value of innovative enterprises listed on the stock exchange. Both theory and practice tell us that innovation is a factor capable of performing a defined train of internal stimulations [5].

Based on the knowledge resource production function theory, the external R&D capital causes an increase in scholarly articles, thereby increasing the internal R&D capital which, in turn, is fundamental to increased innovation, so that the development of the county's economy is balanced [6]. An increase in the Scopus-listed university scholarly articles in a year boosts the number of patents developed at the universities involved [7].

As the patent theory explains, patents contribute to maintaining incentives whilst also limiting the dispersion of the knowledge resource. Patents determine the investment in R&D and valorise the inventions. At the subsequent stage, patents inspire their implementation in the economy through the transfer of licences. Thus, the patents' prices grow more dynamically [8]. Studies have confirmed that external R&D partners have access to the patent's imminent knowledge resource and tacit IP knowledge. This situation implies that cooperation between enterprises leads to restricted competition between them [9].

In most countries, the national R&D activities enable to amass a global resource of knowledge and proactively manage it. The differences in the average national R&D outlay classify countries into developed and developing countries [10]. Studies have shown that the EU countries with high-quality R&D infrastructure have seen increases in creative output as part of their domestic R&D activity [11]. The growth theory explains that a fast pace of development increase, whilst preserving the necessary order, increases the efficiency of R&D resources and ensures the fast development of the economy concerned. R&D is a rare resource that is indispensable for creating patents; its lack inhibits the country's welfare [12]. The average R&D outlays in the EU are an important gauge of achieved innovation as compared to the respective economies within the EU.

With a high degree of novelty in an economy and a high R&D investment level, enterprises tend to implement patents in sectors where technological risks are high, and hence the need for a stringent protection standard, which can be satisfied by patents [13]. The application of patents changes in time through the development of industries in the countries concerned. This indicates the directions of technical/technological modifications [14]. In small enterprises in European countries, external funding is related to the rights to patents, whilst the novelty of patents is noted to a lesser degree [15].

In eastern Germany, the evaluation of enterprises based on technological change through R&D and innovation leads to additional employment and an increased supply of patents [16]. Patents determine the quality and functionality of a given project's technology/-ies, thus setting the techn(olog)ical standard and pointing to new inclinations toward increased innovation through R&D of capital [17].

The implementation of process innovations is productive in the short term, whereas supporting R&D activities develops innovative effects across longer periods, which might be an essential reason behind lagging in the long-term development of the economies of certain countries [18]. The development of innovations has become open-ended these days. The international division/distribution of labour as regards inventions and the increases in trade and profits imply specialisations of economies and form the basis of welfare of societies. This increases the total growth of innovation in the countries' economies [19]. Enterprises of a higher technological level are in need of increasingly higher-level technologies; hence, they are founded upon patents and the market [20]. The efficient use of rare resources by the country's R&D investment in the globalisation age is very important. Patents are about the production of integrated knowledge, and the growth rate of the latter is of importance [21]. Research has pointed to a concern related to misguided R&D, with respect to a better use of the source of innovation in the economy of a given country [22].

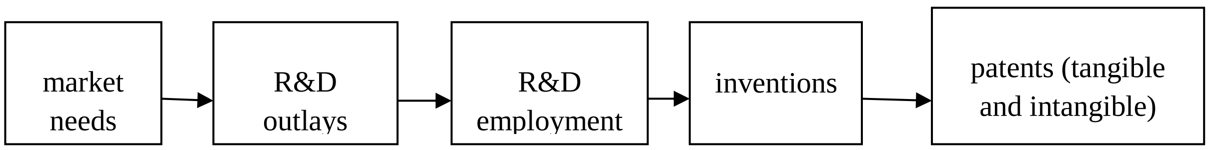
As it turns out, technological progress supported by R&D funds is more innovative than the external acquisition of technologies. Yet, R&D is complemented by purchases of technologies, thus increasing the innovation level and productivity of work. As research has shown, an increase in progress based on R&D and technology acquisitions prevents the attainment of top-level productivity [23]. Developing countries create highly-developed technologies with the use of R&D outlays and purchases of external technologies. With the growing development of a country's economy, the technological capacity of the more efficient acquired technologies increases. This combination increases the resource of knowledge in the country's economy [24]. Moreover, an increase in patents is positively correlated with external R&D, as the source of patent creation. In China, the growing implementation of innovative technologies is significantly supported by the decentralised economic policy [25].

Increased R&D outlays in a given country amplify its exports through converged methods of production/manufacture, a boost in innovations, and the development of the country's economy. To create new economic sectors, rare resources and highly-efficient technologies, intensifying the economy's growth in the new direction, are indispensable [26]. Longer protection of patents keeps the enterprises' investments distant in time and space [27]. Studies have confirmed that the role of patents in the development of the market position of branded products has increased, with the use of valuable innovations in a given country's economy [28]. Research within a set of counties has indicated that tax benefits, in amount terms, are negatively correlated with domestic R&D outlays [29].

3 Econometric model and dependences

Patents are the measure of innovation supply; hence, increased R&D outlays imply increased innovation/patents. In order to foresee the number of patents, the ratio of R&D outlay intensity vs. R&D sector employment should be determined. The number of patents, being a variable depending upon R&D outlays and R&D employed, should be researched in the dimension of time (relation). Consequently, a selection of delays ought to be taken into account [30]. Through investing in R&D, patents are related to investment risk [31].

The dependence is researched based on a supply model of innovation:



The ratio of R&D outlays and R&D employed vs. patents is determinable with the use of the regression calculus compiled based on empirical data (1). The number of patents (P) is a function of R&D outlays and R&D employed (N) in the set of countries being the EU Member States:

$$P = f(R\&D)\,(N_{R\&D}) \qquad (1)$$

The maximum number of patents (P) is achieved, from the economic standpoint, when another increase in R&D outlays and another increase in R&D employed (N) no longer implies an increase in patents (ΔP). This ratio is described by the following equation [L = N; B+R = R&D]:

$$\frac{\Delta P}{\Delta(B+R)*\Delta(L_{B+R})} = 0 \qquad (2)$$

(2)

From the standpoint of a country's economy, it is important to assess whether the increase in the R&D

outlay, in Euro currency terms, and the increase in the number employed with R&D (ΔN) causes an additional supply of patents (ΔP), and sources of innovative technologies. The answer can be obtained based on marginal calculus (2). Knowing the function of patents (a model), the first derivative can be determined, which expresses the increase in patents (ΔP), with a given level of R&D outlays and R&D employment. If the increases in patents are valuated in Euro (P_{EURO}), similarly as the patent unit's cost/outlay (R&D), the optimum level of R&D outlays will be determinable; it equals the subsequent increase in R&D outlays, which will bring about an increase in patents equal to the value of the R&D outlay unit. Any further increase in the R&D outlays or employment is not legitimate since it will imply a loss (or risk). This relation can be expressed as follows (3) [L = N; B+R = R&D]:

$$\frac{\Delta P}{\Delta(B+R)*\Delta(L_{B+R})} * P_{EURO} = P_{B+R}$$ (patent units)(3)

(3)

In practice, the determination of the optimum number of patents in an economy calls for making use of the results of research into the increase of intensity of R&D outlays in the economy of each country concerned.

The technical/technological progress and IP imply pushing out the boundary of the optimum R&D outlays' level in the countries' economies. This takes place when patents based on deferral in time and space are replaced by a more intensive integration of the knowledge resource.

4 Data and variables

If pursued successively, research enables to detect new facts and associations between them, which favours the creation of solutions for inventions and/or discoveries. It benefits the operability of thought/logic, supports the description of phenomena and processes, helps solve problems (meet the objectives) and minimise the risk (of missing) [32]. The regional dimension of the EU is reasonable with respect to increasing R&D outlays and the regional transfer of the knowledge resource. An increase in R&D outlays precedes the increase in the number of patents—the source of the increase of innovative technologies in the EU Member States' economies. In line with the endogenic nature, a comprehensive increase in R&D outlays, R&D employment, and the number of patents can be considered as a conditional stochastic (ordered) process [33] (Table 1).

Table 1. Parameters of variables in R&D activities in EU countries, 2016 & 2019:

No.	Specification	Year	Unit of measurement	Symbol	Arithmetic average	Range [min.–max.]	Variability coefficient, %
1.	Number of patents in the EU countries: Belgium, Bulgaria, Czech Rep., Germany, Estonia, Ireland, Greece, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden	2016 2019	number number	Y1 Y2	2,157 2,301	11.0–24,932 19.0–26,805	248.9 248.1
2.	R&D outlays in the EU countries: Belgium, Bulgaria, Czech Rep., Germany, Estonia, Ireland, Greece, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden	2016	Euro currency	X1	11,465,928	134,536.0–139,492,794	252.4
3.	Number of R&D sector employees in the EU countries: Belgium, Bulgaria, Czech Rep., Germany, Estonia, Ireland, Greece, France, Croatia, Italy, Cyprus, Latvia,	2016 2018	number number	X2 X3	89,119 97,931	1,356.0–657894 1,443.0–707944	175.3 170.5

	Lithuania, Luxembourg, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden						

Source: Eurostat Statistics Database (inn_cis10_exp). European Innovation Scoreboard 2017, 2019 & 2020.

The internal variability of the number of patents in time (Table 1) is identical, though their arithmetic average is higher by almost 7 per cent between 2016 and 2019. The internal variability of R&D outlays is similar. This indicates that a coexistence relation occurs between the number of patents and R&D outlays, which means that two time series are variable in the same direction (positive coexistence).

The internal variability of the number of R&D employed is 5 per cent lower, whereas their number in the set and the arithmetic average are, similarly, higher by 10 per cent in 2018, compared to 2016. Usually, this time series goes in the same direction (positive coexistence). A moving total process appears here in parallel with the moving average with the same proportionality, whereas certain conditions of concurrence overlap with the regression coefficients, in the static and dynamic models.

5 Econometric analysis and discussion

The regressive dependence is formed of sets of empirical data regarding the number of patents relative to R&D outlays and the number of R&D employed. The sets encompass the number, or total value in Euro, for the economies of: Belgium, Bulgaria, Czech Republic, Germany, Estonia, Ireland, Greece, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden; N=24.

Curvilinear power regressions (models) of the Cobb-Douglas type are broken down in Table 2.

Table 2. Power regressions of the number of patents (Y1 & Y2) related to R&D outlays (X1) and R&D employed (X2 & X3) in the EU countries, 2016 and 2019:

Year	a*	Regression coefficient (parameter)			Standard error				t test				R^2 corrected
		X1	X2	X3	a	X1	X2	X3	a	X1	X2	X3	
2016	0.0000045	1.80	-0.83		1.71	0.30	0.34		7.2	5.9	-2.5		0.84
2019	0.0000085	1.71		-0.74	1.51	0.27		0.30	7.7	6.4		-2.5	0.87

Source: as in Table 1. Calculations by the author.
* Equation constant, delogarithmised (absolute term); parameter significance for both equations: range 0.00–0.02.

The figures in Table 2 show the regressive dependence of the number of patents (Y1 & Y2) on the R&D outlays (X1) and the number of R&D employees (X2 & X3) for the EU countries in the years 2016 and 2019. The Y1 regression is static, while Y2 is dynamic.

The multiple partial correlation coefficient R (being a positive square root of R^2) between the dependent variable and two independent variables correlated owing to the influence of one or other variables equals 92.5% and 93% for the static and dynamic model, respectively. The correlation does not determine a cause-and-effect relationship [34]. Collinearity may cause that the parameters' signs will be different than expected [35]. The literature offers a number of practical rules to determine when collinearity appears. Mutual correlation of variables poses no problem when it does not exceed the general level of multiple partial correlation (R) [36]. This condition is met in the static and dynamic models assumed for study. For both models, the standard errors of all the regression coefficients (parameters) are lower than 50% of their respective absolute values. The absolute values of the t test demonstrate few-fold increases compared to the values of the regression coefficients. The probabilities, referred to as significance levels of all the regression coefficients are, for both models, in the range of 0.00–0.02. Econometric analysis of the variability of the number of patents, compared to R&D outlays and R&D employed, is feasible based upon positive statistical evaluation of the regression coefficients.

Taking the variables into account (Table 2) and the regression of the supply of the number of patents for a set of countries, the regression's parameters, determinable is the absolute term, the R&D outlay parameter and the R&D employment parameter, whereas the parameters for X1, X2, and X3 are, in parallel, partial flexibilities with respect to the supply of the number of patents (Y1 & Y2). Knowing these flexibilities, one can determine in advance how the supply of the number of patents will change resulting from a change in the independent (explanatory) variable.

The determined regression of the number of patents is an aggregated regression of supply in the set of countries. The R&D outlays level is an important element in patent supply regression. Responses of the economies of the countries concerned are determined by the characteristics and structure of selected segments of these economies. The intensity of R&D outlays is close to the conditions of each of these economies. The responses are triggered in proportion to the R&D's position in the total costs/outlays. Aggregated R&D outlays are related to the rates of change in the productivity and population's income of the economies concerned. The independent variables in the models are identifiable as endogenic. The basic feedbacks take place between the R&D outlays resource and the knowledge resource of R&D employees in the set of economies.

The flexibility of the number of patents proves to have been the highest in relation to R&D outlays in the countries under study in the year 2016 (1.80; cf. Table 2). The flexibility of the number of patents is negative versus the employed in R&D (-0.83) sector. Based on the estimated parameters of the model (Y1), it is ascertainable that, with the other factors remaining unaltered, a 10% increase in R&D outlays causes an increase in the number of patents by 18%, on average, whereas a 10% increase in R&D employed implies the number of patents decreased by 8.3%, on average—for the countries in question, as of 2016. In turn, an increase in the total flexibility of R&D outlays, and the number of R&D employed (0.97) by 10% causes a 9.7% growth in the number of patents. This regression dependence is constant, where for each amount of R&D outlays and R&D employed, the same number of patents is ascribed: Y1=X1 * X2.

In the dynamic model (Y2; cf. Table 2), the number employed with R&D is higher by 9.88% (2018; Table 1); the arithmetic average in the R&D employed set is also higher by 9.88%. This has contributed to a decrease in the absolute value of parameters: 1.71 (X1) and (-0.74) (X3). Based on the model Y2's estimated parameters, one finds that with the other factors remaining unchanged: a 10% increase in R&D outlays implies an average growth in the number of patents by 17.1%, whilst a 10% increase in R&D employed contributes to a 7.4% decrease in the number of patents. The total flexibility of the supply of the number of patents, in relation to R&D outlays and the number of R&D sector employees, equals 0.97. The aggregate 10% increase in R&D outlays and R&D employed translated into a growth in the number of patents in the countries concerned by 9.7%, on average, for the year 2019. Again, the regression relation is constant. When comparing the total flexibility rates, which for both models is 0.97, it seems that no undulation, as explained by Schumpeter's theory, appears in the supply models of patent development.

Assuming that, in a given model, the total flexibility (of parameters) is in the range of 0 < X1 + X2 or (X3) < 1, where the parameter for X1 is the measure of the intensity of the flexibility's impact on the number of patents in respect of R&D activity, whereas X2 (X3) is the measure of the intensity of negative flexibility: then, $P_{n+1\ (patents)}$ = parameter X1 / the total of parameters X1+X2 or (X3), where n approaches infinity. What this means is that, with multiple completion of the process, the probability approaches a certain limit which equals the ratio between the measure of the positive intensity of flexibility and the aggregate measurements (parameters) of positive and negative flexibility intensities. Thus, the patents: P_{n+1} = 1.80 / 1.80 + (-0.83) = 1.86 (model Y1) and 1.71 / 1.71 + (-0.74) = 1.76 (model Y2). This explains that in 2019, compared with 2016, with increased employment of R&D by almost 10%, the flexibility of creation of a number of patents through R&D outlays and R&D employed is decreased, on average, by 5.4 per cent for the countries under analysis. This indicates that the dynamic supply model under study determines the appearance of undulation in the relative increase in the supply of the number of patents (technologies).

As a variable, the set of R&D employees is characterised by a high degree of aggregation, inhomogeneity, internal contradiction, and complexity of the employment structure. Diversity in the set of the employed is quite deep in individual countries; this is true for the educational background, labour fee, age groups, and the disproportionate influence of technical armament on the productivity of labour; even for male workers employed relative to the norms, a negative parameter occurs. In employment models, the model (R^2) is not satisfactorily good, whilst the employment demonstrates a curvilinear dependence.

There appears a relation between two sets if the distribution of numerical characteristics of one of the sets depends upon the values of numerical characteristics of the other. Positive feedback is convergent and divergent, and has an identical sign; negative feedback weakens the interdependent influence of descriptive variables and has an opposite sign. Negative feedback implies automatic adjustment of covariance of the variables, as it favours the reinstatement of balance between the variables, if upset by interference. The feedback seeks to preserve a norm which can be either of the constant (invariable) quantity, programmed variable, follow-up variable, anticipative variable, and/or optimum variable. Material-and-energy feedback and personal feedback are the basis of a number of naturally operating servomechanisms (as instruments determining technical and balance-sheet proportions). A servomechanism is a control mechanism designed for automated control; it is a rigid feedback. A cumulative change theory is also of importance to the explanation of the progress process; it explains the dependences of positive feedbacks where one altered descriptive variable reinforces the impulses stimulating this alteration on a feedback basis.

Marginal quantity is a measure of the positive or negative alteration of certain quantities/amounts in reciprocal regressive dependence when the explanatory variable changes by a unit (by an infinitely small value). It is calculated along with regression analysis, where it is expressed by the regression derivative (cf. Tables 3, 4, 5 6, & 7).

Table 3. Marginal and average cost/resource-intensity of patents in the EU countries in 2016:

Number of patents (Y1)	R&D outlays (X1), in EUR	Cost/resource-intensity:	
		EUR average/patents	EUR marginal/patents
2,177.34	12,803,469	5,880.32	10,584.57
7,510.40	25,472,401	3,391.62	6,104.91
15,532.80	38,141,334	2,455.54	4,419.96
26,028.54	50,810,266	1,952.10	3,513.78
38,857.40	63,479,199	1,633.65	2,940.56
53,916.76	76,148,131	1,412.33	2,542.19
71,126.38	88,817,064	1,248.72	2,247.70
90,420.76	101,485,996	1,122.37	2,020.27
111,744.86	114,154,929	1,021.57	1,838.82
135,051.34	126,823,861	939.08	1,690.34

Source: Author's calculation, based on Table 1 & 2 data.

Table 4. Marginal and average labour-intensity of patents in the EU countries in 2016:

R&D outlays (X1)	Number of R&D employees (X2)	Labour- intensity:	
		average R&D employed/number of patents	marginal R&D employed/number of patents
2,443.90	61,041	24.98	-20.73
1,387.57	120,726	87.01	-72.21
994.15	180,411	181.47	-150.62
784.20	240,096	306.16	-254.12
652.23	299,781	459.62	-381.49
560.99	359,466	640.77	-531.84
493.83	419,151	848.77	-704.48
442.17	478,836	1,082.91	-898.82
401.10	538,521	1,342.62	-1,114.37
367.59	598,206	1,627.38	-1,350.72

Source: Author's calculation, based on Table 1 & 2 data.

Based on the data specified in Table 3, the marginal cost (resource)-intensity of patents exceeds the average whilst the decrease in the marginal cost-intensity of patents is larger and causes a lower drop in the mean cost-intensity of patents. Though successively decreasing, the marginal cost (resource)-intensity of patents, similarly to the average one, their equalisation within the range of

R&D outlays, as the number of patents in the countries concerned grows, proves impossible. The equalisation of the marginal and average cost/resource-intensity of patents is one of the criteria for the optimum allocation of R&D outlays in the patent development process. The use of the economic category of marginal cost-intensity of patents assumes that the decisions made in the patent development process in the countries under study in 2016 were methodologically reasonable. This situation lies in the initial zone of irrational ascending/descending increment in the development of patents. With a negative marginal labour-intensity of patents (Table 4), the average one being positive and growing, then, with an increase in the R&D employed, the number of patents successively decreases. This takes place in the zone of an absolutely irrational patent development process (negative increments) in the countries under study.

Table 5. Marginal and average cost/resource-intensity of patents in the EU countries in 2019:

Number of patents (Y2)	R&D outlays (X1), in EUR	Cost/resource-intensity:	
		EUR average/patents	EUR marginal/patents
2,452.83	12,803,469	5,219.87	8,925.97
7,952.75	25,472,401	3,202.97	5,477.07
15,860.79	38,141,334	2,404.76	4,112.13
25,900.91	50,810,266	1,961.72	3,354.54
37,899.87	63,479,199	1,674.92	2,864.11
51,733.91	76,148,131	1,471.92	2,516.98
67,308.03	88,817,064	1,319.56	2,256.45
84,545.88	101,485,996	1,200.37	2,052.63
103,384.13	114,154,929	1,104.18	1,888.15
123,768.93	126,823,861	1,024.68	1,752.21

Source: Author's calculation, based on Table 1 & 2 data.

Table 6. Marginal and average labour-intensity of patents in the EU countries in 2019:

Number of patents (Y2)	Number of R&D employees (X3)	Labour- intensity:	
		average R&D employed/number of patents	marginal R&D employed/number of patents
2,729.97	65,670	24.06	-17.80
1,647.95	129,897	78.82	-58.33
1,224.14	194,124	158.58	-117.35
990.77	258,351	260.76	-192.96
840.66	322,578	383.72	-283.95
734.96	386,805	526.29	-389.46
655.99	451,032	687.56	-508.80
594.44	515,259	866.79	-641.43
544.95	579,486	1,063.37	-786.90
504.17	643,713	1,276.78	-944.82

Source: Author's calculation, based on Table 1 & 2 data.

Similarly as in 2016, the marginal cost-intensity of patents in 2019 (Table 5) was higher than the average, but their decreases were in a closer relation than those of 2016. A critical point in the R&D outlays curve is, always, the number of patents as from which R&D outlays began to grow, compared to the number of patents created; the absolute number is lower in the negative marginal labour-intensity of patents for the countries under study in 2019 (Table 6), though the number of employed in the R&D sector grew by approx. 10% compared to the 2016 figure. The drop in the number of patents, given their lower mean labour intensity, was higher than in 2016. The explanation is that the influence of the increased number of R&D employed was stronger than in 2016.

Table 7. Increase in the variables and their cost/resource-intensity and labour-intensity in the studies countries, 2016 and 2019 (%):

Variable	From Table 3:	From Table 4:	From Table 5:	From Table 6:
Number of patents (Y1)	58.19	-18.98		
Number of patents (Y2)			54.60	-17.11
R&D outlays (X1), EUR	29.02		29.02	
Cost-intensity: – average – marginal	 -18.44 -18.44		 -16.55 -16.55	
Number of R&D employed (X2)		28.87		
Number of R&D employed (X3)				28.87
Labour-intensity: – average – marginal		 59.06		 55.47

Source: Author's calculation, based on Table 3, 4, 5 & 6 data, geometric average applied.

The rate of growth of the number of patents developed with the help of R&D outlays and the average number of R&D employees equalled 58.19% in 2016, whereas in 2019 it decelerated to 54.6% (Table 7). With the average R&D outlays, the number of patents supported by R&D employees disclosed a negative growth rate: -18.98% as of 2016 and -17.11% as of 2019. R&D outlays disclose the same rate of growth for the countries and years under study. The marginal and average cost-intensity of patents show a negative growth rate for both years concerned. The number of R&D employed, in spite of its approx. 10% growth in 2018, shows the same growth rate, convergent with the growth rate of R&D outlays for both years under study. In turn, the average labour-intensity of patents (the marginal one being negative) has a growth rate convergent with the rate of growth of the number of patents for both years concerned, its growth rate compared to 2016 slowed down by 2019 by 3.6 per cent. The growth rate of the number of patents convergent with the growth rate of the average labour-intensity of patents points to a particular role of the resource of knowledge in the development process of the number of patents for the countries and years under analysis.

6 Conclusions

The research has confirmed the hypothesis whereby the number of patents, versus the total flexibility of R&D outlays and R&D employed is identical for the countries and years under concern. As the studies have shown, this is not however to state that there is no undulation occurring between the supply-based static versus the dynamic model of patents. On the contrary, it has been pointed out that between 2016 and 2019, the flexibility decreased, on average, by 5.4 per cent. A possible method for calculating this state has been proposed.

Based on the research, the growth rate of R&D outlays and R&D employed is identical for the countries and years under study. The growth rate of patents, though diversified for the years concerned (undulation), is for every year convergent with the rate of growth of the average labour-intensity of patents in the countries under analysis. This dependence has not been infringed even by the number of R&D employees that saw an approx. 10% growth in 2018. This is evidence that the knowledge resource plays a specific part in the patent creation process in the countries and years under analysis. It can also be concluded that the same situation occurs, with an identical growth rate in R&D outlays and R&D employed, when the work seniority and enhanced skills increase up to a certain quantity/value and then remain at the same level. This may be confirmed by the regressive dependence of human capital, which is a function of knowledge and skills. Therefore, the increase in the number employed with R&D before 2019 (in 2018) could decrease the undulation down to the difference in the deceleration of the increase of patents between the years concerned, being 3.6 per cent as of 2019.

In the future, research will be continued on the application of econometric methods for a deeper explanation of the problem of the patent development process in the EU countries.

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