Productivity of Innovations in European Union Member States and Enterprises

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Abstract:

The regression dependence of sales value of new innovative products onto the total innovative expenditure in EU enterprises and member states has been analyzed considering a breakdown into groups of countries above or close to the EU innovation average (N=14) and a group of countries below the EU innovation average (N=14) in 2012 and 2016. Based on the Cobb-Douglas regression model, marginal and mean productivity values were determined within the range of total innovative expenditure in enterprises and countries above or close to the EU average innovation and below the EU average innovation in 2012 and 2016. The shaping of marginal and average productivity in the determined country and year groups allowed for an indication of the areas of rational management of the total innovative expenditure in these countries. The research confirmed the hypothesis that a group of countries above the EU innovation average, or those close to this average value, is located within the rational management zone, whereas countries below the EU innovation average are located within the initial zone of irrational management of the total innovative expenditure, regardless of the year in which the study was conducted.

Keywords: innovation; index innovation UE; new innovative products; innovative expenditures regression.

JEL Classification: F02; L11; O31.

Introduction

The concept of innovative entrepreneurial activity conditioned by the distance to reach the technological boundary was introduced into the Schumpeter's Theory by Howitt and Mayer-Foulkes (2005). This technological boundary determines the likelihood of innovation for enterprises that are approaching it. Both enterprises and their sectors that are closer to the technological boundary gain an increase in the productivity of total expenditures per one enterprise conducting innovative product and/or process activities. It is possible to point out the pressure resulting from the competition on the product market and the impact of globalization and trade liberalization which serves to strengthen the enterprise from the inside out while boosting the growth of powerful innovations. This pressure then develops into financial coercion (Alvarez and Crespi 2011).

This article presents innovation research which is one of the first on the national level and one that increments information on the innovative activity of an average innovative enterprise in individual EU member states, as divided into two sets of countries above or close to the EU innovation average and those states that are below the EU average for implementation of product and process innovations. Up to date, few studies have been conducted that encompass 28 countries of the associated economic region that is the EU. In addition, the EU Innovation Index used for the country classification, which is substantively based on the OECD Directive, ensures international comparability and reference to the rolling average level of innovation implementation over time in the EU. This criterion classifies EU member states into countries that use innovations above or close to the EU average or below the EU innovation average. We can trace here an analogy to the technological boundary contained in the Schumpeter's Theory. Therefore, the author proposes to incorporate the EU Innovation Index into the Schumpeter's Theory. This index is constantly calculated, which renders it current and precise. Thus, it constitutes a significant substantive enrichment of the Schumpeter's Theory of Innovation. The hitherto application of the technological boundary as the probability of innovation implementation is not very precise in view of the variability of technological solutions over time and the respective comparative difficulties they represent.

The issue of use of innovations in an enterprise is not only a question of great scientific significance but also of practical one. However, the state of theoretical knowledge in this field is still relatively meagre, while its connection with the Theory of Innovation remains rather unsatisfactory. The research conducted so far into the

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various aspects of the use of innovations is unsubstantial considering the importance and complexity of this issue; there is no comprehensive study covering the economic aspects of implementation, assessment and rational management of innovations in enterprises and national economies or associated regional economic ties.

The aim of the research is to identify enterprises and EU countries which are above or close to the EU innovation average and those below the EU innovation average. A further purpose of the study is to determine the marginal and average productivity of total innovative expenditure per one company conducting innovative product and process activities in EU member states in 2012 and 2016.

The premise of the study was the hypothesis that the productivity of total innovative expenditure lies in the initial zone of irrational management in the countries below the EU innovation average, whereas in countries which are above the EU innovation average or close are located in the zone of rational innovation management.

In order to achieve the established goal, the article has been divided into five sections. The first section presents the related reference literature. The second section describes the methodological procedures and dependencies. The third one describes data and variables. The fourth section presents the effects of an empirical study. Finally, the fifth section sums up the final considerations.

1. Literature Review

In the case of product innovations, the level of innovation in an enterprise and a country can be measured by the level of sales value of new innovative products. Similarly, to the case of process innovations, many countries choose such level of total innovative expenditure that contributes to the reduction of the cost of the innovation process (Mohnen and Hall 2013). A new innovative product usually requires new production technology. Its launch onto a newly created market also requires innovative marketing. New production technology alongside process innovation causes restructuring of the work flow in the enterprise (Siedschlag *et al.* 2010, Prokop *et al.* 2017). Expenses for innovative activities also include intense factors, such as purchase of equipment and software, process enhancement, feasibility and market research conducted prior to the launching of a new product onto the market. It is then that a part of innovation productivity reflects the price effects (Dobbelaere and Mairesse 2010, Brzozowski and Tchorek 2018).

Nowadays, the progress in econometric techniques induces an increase in empirical research (Cassiman and Golovko 2011). In the reference literature on the subject, the assessment of innovation implementation is usually executed by means of the labor productivity measure and the total factor of productivity (TFP) (Santana, Cavalcanti and Bezerra 2011). Labor productivity is criticized in terms of its instability in determining and increasing the total productivity gains, and in view of the difficulties in demonstrating productivity enhancement resulting from efficiency and adjusting production to employees (Britto 2009).

Labor productivity and its technical utilities constitute direct factors in the productivity of fixed assets. Examining them as interdependent relationships allows us to identify what part of the increase in labor productivity is caused by the increase in technical utilities (factors of an extensive nature), and which part is obtained by non-property-related means referred to as technical and organizational progress and innovation progress (factors of intense nature). Also, intense enterprises in Germany were among the first ones ever to use the knowledge resource for productivity assessment (Peters 2006).

The total factor of productivity (TFP) is the result of including the productivity of each factor resource into one productivity expression (Cassiman *et al.* 2010). The advantage of this solution is that it takes into account a substitution in the use of factors and synergy in the relationship between the factors in the situation of merging of two types of activity, whereas the disadvantage lies in the difficulty in measuring various factors of production and their partial productivity values. However, the total factor of productivity is often used in international economics for the needs of empirical research (Carvalho and Macedo de Avellar 2017).

An important role in the propensity and intensity of exports is played by the level of innovation implementation in EU enterprises and member states (Caldera 2010, Bustos 2011 and Tavassoli 2017). There is research-based evidence on the significant impact of innovative activities on the export rate (Ganotakis and Love 2011, Golovko and Valentini 2011, Becker and Egger 2013). Most of the research, however, focuses on the role of investment in R&D (Stanek *et al.* 2018). Nonetheless, these investments do not show a causal relationship with export support. Thus, the measure of the level of innovation implementation in a given country is the level of sales value of new innovative products in international trade. This means that R&D investments are included only in studies conducted on larger enterprises with separate R&D departments. This is an important consideration relative to the specification of empirical data in the study of innovation implementation. This is also the reason for the insignificant number of studies conducted into the role of innovation in the growth in the turnover of innovative production within the framework of economic cooperation between countries. Hence, R&D becomes an indirect

and unconvincing measure of innovation (Harris and Li 2008). In addition, the innovation indicator includes the entry of R&D innovations and the total new innovation production, and defines them using one Index of EU Innovation (Edquist and Zabala-Iturriagagoitia 2015). The open innovation mode allows you to acquire and share new product development projects (Torok and Toth 2013). However, the open innovation literature brings insufficient contributions at the international level (Chesbrough *et al.* 2014).

A well thought-out innovation policy consists in allowing the implementation of only high-productivity investments and the maximum technological and innovative progress by means of non-financial improvements. They do not constitute a qualitative element, as they are the result of certain mathematical transformations of the functioning factor structure.

The rivalry of innovation implementation is an important element of national policy, while the role of innovation as a result of modern knowledge being the motor of economy is crucial for EU member states (Kostoska and Mitrevski 2016). What is paramount in this respect, is research concerning global forecasts (Djogo and Stanisic 2016) and a theoretical interpretation of the factors of domestic competition (Cho and Moon 2013). These factors relating to the innovation, as well as the use and processing of information by means of Communication Technology, despite its direct and indirect impact, create a potential which affects the total productivity in proportion to the size of the sector in question (Gordon 2012).

Research on global prediction is of crucial importance in this respect (Djogo and Stanisic 2016). Recent studies show that developed economies provide important structural patterns for needed changes (Kostoska and Hristoski 2017).

Only an international comparison of productivity indicates a similarity of patterns in the global economy and its respective subeconomies. Competitiveness necessitates a choice of models of economic growth, based on consumption and stability of productivity (Vujović 2014). Innovation contributes to the growth of investment on volatile markets and to the increase in production factor efficiency. Therefore, the new quality structure expressing the measurement of productivity includes capital services with the help of information technology and software. The key economic indicator for assessing the use of innovation is productivity (Jorgenson 2011). On the other hand, strong relations with a bank increase the probability of export intensity and implementation of product innovations (Mancusi *et al*. 2018).

2. Econometric Model and Its Dependencies

Research shows that the implementation of innovation with the right relation of capital to work has a real impact on productivity (Brown and Guzman 2014).

Relations between fixed assets (and technology – innovation) and the value of sales of new innovative products are reflected in the asset productivity ratio (pertaining to technology and innovation), which is related to the remaining economic and econometric categories. The source of productivity growth is capital and labor, which explain less than 50% of this growth (Hall 2011).

The relation of asset productivity (or innovation) ($\frac{P}{M}$) occurring between the technical labour utilities ($\frac{M}{L}$) and work efficiency ($\frac{P}{L}$) can be presented as follows:

$$\frac{P}{M} = \frac{P}{L} / \frac{M}{L} \quad (1)$$

It follows that:

$$\frac{P}{L} = \frac{M}{L} * \frac{P}{M} \quad (2)$$

The substantive principle of rational management suggests that the reverse of the relation between the productivity of fixed assets (pertaining to technology and innovation) as the capital intensity of the sold innovative production, which can be recorded as follows:

$$\frac{M}{P} = \frac{M}{L} / \frac{P}{L} \quad (3)$$

It is (3) a relationship between the capital intensity of innovative production ($\frac{M}{P}$) and the technical labour utilities ($\frac{M}{L}$) and labour productivity ($\frac{P}{L}$). A directly proportional dependence of capital intensity of the new innovative production sold in relation to the technical labor utilities and a change of the relation to $\frac{M}{L}$ / $\frac{P}{L}$ is in inversely proportional dependence to work productivity, with a simultaneous expansion of interpretation possibilities.

Physical capital has a positive effect on preserving the export of new innovative production sold (Andersson and Lööf 2009).

In turn in (4), the level of labor productivity is directly proportional to technical utilities and inversely proportional to the capital intensity of new innovative production sold, or to the inverse value of asset productivity:

$$\frac{P}{L} = \frac{M}{L} / \frac{M}{P} \quad (4)$$

Just like in the case of average relationships, you can present their marginal relations as follows (5):

$$\frac{\Delta P}{\Delta M} = \frac{\Delta P}{\Delta L} / \frac{\Delta M}{\Delta L} \quad (5)$$

Between the magnitude of the marginal and average productivity of a given factor there is a dependence of proportionality by the product-based establishment of the elasticity coefficient (power) of this factor relative to the dependent variable (mathematically, marginal productivity is the first derivative). Relations between productivity growth and the level of innovation are highly non-linear (curvilinear) (Huergo and Jaumandreu 2004). Based on the Cobb-Douglas regression, this allows for a calculation of marginal productivity and average productivity of the total innovation expenditure in an average EU enterprise and country (or in sets of countries with different levels of innovation). The use of the Cobb-Douglas model indicates that the majority of innovation assessments are of a cross-sectional character after a period of three years. It follows that the measures of innovation (level) are of a *post factum* character, and hence modern measures strengthen the cross-sectional assessment and the long-term nature of the course of these effects.

3. Data and Variables

The latest microeconomic research on innovation allowed for the recognition of the actual value of new innovative production sold as a direct measure of innovation (Jienwatcharamongkhol and Tavassoli 2015). It has the causal effect of product differentiation and market development. Expenditure on R&D is just the first step towards innovation, and one which does not guarantee its success. There are rational justifications for the implementation of both concepts (Hall 2011).

The classification of EU enterprises and countries was made on the basis of the Innovation Index, which encompasses the sum of R&D and the sales value of new innovative production, and constitutes one EU Innovation Index (Edquist and Zabala-Iturriagagoitia 2015). It combines a measure of a microeconomic and macroeconomic nature.

The value of sales of new innovative products was adopted as a dependent variable and it was calculated per one enterprise conducting innovative product and process activities in EU countries above or close to the EU innovation average (Y1 and Y3). The following set of countries was distinguished: Austria, Belgium, Cyprus, Denmark, Estonia, Finland, France, the Netherlands, Ireland, Luxembourg, Germany, Slovenia, Sweden and the United Kingdom (N=14) in 2012 and 2016. The measure of the sales value of new innovative products defines the degree of achievement of the company's objective and the extent to which the enterprise is satisfying social needs (increase in value for the client).

The second set is the value of sales of new innovative products as calculated per one company conducting innovative product and process activities in EU countries which lie below the EU innovation average (Y2 and Y4). The following set of countries was selected: Bulgaria, Croatia, the Czech Republic, Spain, Lithuania, Latvia, Malta, Poland, Portugal, Romania, Slovakia, Hungary and Italy (N=14)) in 2012 and 2016.

The basis for the separation of the above sets of innovative enterprises and countries is the EU Index of Innovation (an arithmetic mean). This index determines the direction of changes in innovations undertaken by those countries and, at the same time, it constitutes the boundary between the various sets of innovations – not unlike the technological boundary in the Schumpeter's Theory. Since it serves to identify the actual state of innovation, the EU Innovation Index is an objective measure of international spatio-temporal comparisons and it constitutes a substantive contribution to the Schumpeter's Innovation Theory. The sets of values of sales of new innovative products in various enterprises and countries according to the sources shown in Table 1 was assigned the total innovative expenditure per one company conducting innovative product and process activities in EU member states (X1 and X3) above or close to the EU innovation average (N = 14) in 2012 and 2016 and those below the EU innovation average (X2 and X4) (N = 14) in 2012 and 2016, see Table 1.

The year 2012 determines the state and the innovation level before the 2013-2015 wave, while the year 2016 presents the state and level in the aftermath of this wave. That makes for four years following one year of reviews (Mairesse and Mohnen 2010). Research confirms that during the first year, the process innovation increases productivity (1.5%), while in the subsequent three and more years it starts decreasing over further three

and more years (Huergo and Jaumandreu 2004). However, it is not possible to separate wave periods, whereby the ending year is also the beginning of the next wave (Bengtsson and Tavassoli 2018). This results in a narrowing range of sets and in an increase in set homogeneity, which changes the influence of variables in the estimation process (collinearity). With respect to the data obtained in 2012 in countries above or close to the EU innovation average, the value of sales of new innovative products was growing by 71.5% in 5 countries, while in nine countries, it was reduced by 134%. However, in two countries below the EU innovation average, the value of sales of new innovative products was growing by 15.3%, while in 12 countries it was reduced by 207.4% in 2016.

On the other hand, total innovative expenditure per one company conducting innovative product and process activities in 5 countries above or close to the EU innovation average was growing by 71.7%, and in 9 countries its value decreased by 123%. The total innovative expenditure per one company conducting innovative product and process activities in 3 EU countries below the EU innovation average increased by 15.7%, while in 11 countries it diminished by 252%. In countries above the EU innovation average or those close to it, the increase in sales value of new innovative products is similar to the increase in total innovative expenditure, while the decrease is also similar. In contrast, in 2016, in countries below the EU innovation average, the value of sales of new innovative products increased in the same way as the total innovative expenditure, and it was falling accordingly to the deepening of the decrease in total innovative expenditure (by 44.6%). It can be assumed that in countries below the EU innovation average and those with a deeper decline in total innovative expenditure, the relationship of sales revenues to innovative expenditure is beneficial (favorable economic calculation) and thus the productivity of total innovative expenditure is higher.

The data presented as sets of variables are transformative in nature, and the dependent variable (Y1, Y2, Y3 and Y4) and the independent variable (X1, X2, X3 and X4) are of a comprehensive nature (aggregated) (Wixe 2015).

The R&D value is often a measure of the current year (Hall 2011), hence following the three-year period (wave), it is better to implement total innovative expenditure in the Cobb-Douglas model in order to verify the past period of application of innovation in the enterprise and the country in question. The value of sales of new innovative products constitutes the level of verification by the market (in terms of quantity and price).

Two groups of EU countries were examined using the Cobb-Douglas model before and after the expiry of the three-year period, whereby, the categories of marginal and average productivity of the total innovative expenditure in 2012 and 2016 were also taken into consideration.

The randomness of the distribution of the random component was examined using a graphical analysis and a batch number test, with a significance level of 0.05. Graphical analysis and a series number test verify the hypothesis about the accuracy of model selection (Table 2). The normality of the random component was examined using the Shapiro-Wilk test. The calculated values related to critical values at the significance level of 0.05 do not dismiss the hypothesis that the distribution of random components is normal. The autocorrelation was assessed by means of the Durbin-Watson test and no autocorrelation of the random component was determined at the significance level of 0.05. The hypothesis of homoscedasticity of random components was verified using the Godfeld-Quandt test (Aczel 2002, 587). At the significance level of 0.05, the recorded critical values of Snedecor's distribution are higher than those calculated, and, consequently, there is no reason to reject the hypothesis of homoscedasticity of the random components.

4. Econometric Effects and Discussion

The basis of the research are the sets of empirical data pertaining to the value of sales of new innovative products per one company conducting innovative product and process activities in a given country above or close to the EU innovation average in the following countries: Austria, Belgium, Cyprus, Denmark, Estonia, Finland, France, The Netherlands, Iceland, Luxembourg, Germany, Slovenia, Sweden and the United Kingdom and in member states below the EU innovation average: Bulgaria, Croatia, Czech Republic, Spain, Lithuania, Latvia, Malta, Poland, Portugal, Romania, Slovakia, Hungary and Italy in 2012 and 2016.

The subsequent sets of empirical data represent the total innovative expenditure per one enterprise conducting innovative product and process activities in a given country above or close to the EU innovation average and below the EU innovation average in the above-mentioned EU member states in 2012 and 2016.

Table 1. Parameters of variables in EU enterprises and countries conducting innovative activities (2012, 2016)

Item	Specification	Year	Unit of Measurement	Symbol	Arithmetic Mean	Range min. - max	Coefficient of variation %
1.	The value of sales of new products per one enterprise conducting product and process activities in EU countries (above or close to the EU innovation average): Austria, Belgium, Cyprus, Denmark, Estonia, Finland, France, the Netherlands, Ireland, Luxembourg, Germany, Slovenia, Sweden and Great Britain (14).	2012 2016	1 thousand Euro 1 thousand Euro	Y1 Y3	3060 3010	770-6,970 840-7,030	64,1 70,2
2.	The value of sales of new products per one enterprise conducting product and process activities in EU countries (below the EU innovation average): Bulgaria, Croatia, Czech Republic, Greece, Spain, Lithuania, Latvia, Malta, Poland, Portugal, Romania, Slovakia, Hungary, Italy (14).	2012 2016	1 thousand Euro 1 thousand Euro	Y2 Y4	2245.7 2130.7	570-9,170 500-10,450	105,9 127,8
3.	Total expenditure per one enterprise conducting innovative product and process activities in EU countries (above and close to the EU innovation average): the same countries as in item 1.	2012 2016	1 thousand Euro 1 thousand Euro	X1 X3	1253.9 1205.6	230-2,434 151.2-2,193	55,4 53,6
4.	Total expenditure per one enterprise conducting innovative product and process activities in EU countries (below the EU innovation average): the same countries as in item 2.	2012 2016	1 thousand Euro 1 thousand Euro	X2 X4	601.3 497.0	206-1,137 180.7-1,171.5	51,1 59,0

Source: Eurostat Statistics Database (inn_cis8_exp); European Innovation Scoreboard (2017); Author's calculations

The parameters of the variables of enterprises and EU countries have been included in Table 1. The data presented in Table 1 show that the range of sales values of new innovative products in countries above or close to the EU innovation average and those below this average varies significantly, especially between different EU member states. The comparison of internal variability between variables in groups of countries shows that the value of sales of new innovative products is generally similar in terms of years, and significantly diversified when it comes to the innovation levels (6% and 22%). This means that the lower the level of innovation in a given set of countries, the more dispersed around the average in the set are the values of the characteristics of the sales of new innovative products. This indicates that the value of sales of new innovative products on the markets of countries located below the EU innovation average is shaped by the number of new innovative products and their respective prices. This means that in the markets of these countries these products get a higher price and a higher value of product sales, which in turn indicates their smaller supply and an increase in their exportation.

On the other hand, the range of total innovative expenditure is conditioned by the level of the relative EU innovation average, and not by the year in which the research was conducted. In countries below the EU innovation average, the range of total innovative expenditure is narrowed to less than a half relative to the countries above or close to the EU innovation average, where it is expanded by more than a half. The internal variability of the total innovation expenditure is analogous, regardless of the level of innovation and the year in which the study was performed. This means that the value of the innovation expenditure trait is similarly distributed around the average

in all EU member states. This fact points to the coinciding role of this value in the shaping of the value of sales of new innovative products in all EU countries.

Table 2 shows the curvilinear regressive relation of the examined sets (groups) of countries in a tabular form. The data presented in Table 2 show the regressive dependence of the value of sales of new innovative products (Y1, Y2, Y3 and Y4) on the total innovative expenditure (X1, X2, X3 and X4) in EU countries in 2012 and 2016.

The strength of the relationship expressed by the multiple-partial correlation coefficient (R) between the value of sales of new innovative products and the total innovation expenditure in countries above or close to the EU innovation average amounts to 50% and 55%, and in countries below the EU average it amounts to 62% and 72%. The correlation does not indicate a causal relationship (Griffith, Huergo, Mairesse and Peters 2006). Hence, regression dependence has been studied. Standard errors of all regression coefficients (parameters) are lower than 50% of their absolute values. However, all absolute values of the t-test are several times higher than the values of regression coefficients. And the level of significance of all regression coefficients ranges from 0.00 to 0.05. Statistical assessments of regression coefficients indicate the possibility of their use in the econometric analysis of the volatility of value of sales of new innovative products with respect to the total innovation expenditure recorded in enterprises and EU member states.

Table 2. Power regressions of the value of sales of new innovative products per one enterprise (Y1, Y2, Y3 and Y4)

Year	a*	Regression Coefficient (Parameter)				Standard Error				T-Test				R^2
		X1	X2	X3	X4	X1	X2	X3	X4	X1	X2	X3	X4	
2012	108.85	0.45				0.22				1.89				0.50
2012	3.00		0.99				0.36				2.75			0.62
2016	59.74			0.53				0.23				2.30		0.55
2016	5.01				1.15				0.34				3.44	0.71

Note: * Delogarithmised equation constant (free expression); ** in countries above or close to the EU innovation average and in those below this average (as presented in Table 1) from the total innovative expenditure per one enterprise (X1, X2, X3 and X4) conducting innovative product and process activities in EU countries (as presented in Table 1) in 2012 and 2016. The range of the level of significance of the parameters: 0.00 - 0.05.

Source: Eurostat Statistics Database (inn_cis8_exp); European Innovation Scoreboard (2017). Author's calculations.

Regression coefficients (parameters) at X1, X2, X3 and X4 indicate flexibility (elasticity coefficients) (Solow 1956) of the value of sales of new innovative products with respect to the total innovation expenditure above or close to the EU innovation average and below the EU innovation average in enterprises and EU countries (Table 2).

The elasticity of the value of sales of new innovative products was at its highest in relation to the total innovative expenditure in enterprises and countries below the EU innovation average in 2016 (1.15). This fact points to the type of a regressive relationship of more than proportional nature, which is, therefore, to be interpreted as curvilinear. In contrast, in the same group of countries in 2012, the elasticity of the value of sales of new innovative products with respect to the total innovative expenditure amounted to 0.99. We are dealing with a constant regressive relationship, which assigns the same value of the dependent variable Y2 = X2 to each independent variable.

The elasticity of the value of sales of new innovative products with respect to the total innovation expenditure in countries above or close to the EU innovation average is less 2.17 times (0.53) lesser than in countries below the EU innovation average in the same year, that is in 2016. In contrast, in countries above the EU innovation average or those which are close to it, the elasticity of sales of new innovative products with respect to the total innovation expenditure was at its lowest in 2012 and amounted to 0.45. The nature of dependencies in countries above or below the EU innovation average was less than proportional and curvilinear in 2012 and in 2016.

The 10%, increase in total innovation expenditure in countries below the EU innovation average with the other expenditures remaining unchanged, is associated with an increase in the value of sales of new innovative products, and in 2012 it amounted to 9.9% and to 11.5% in 2016. In the wake of the wave, the increase in total innovative expenditure by 10% between 2012 and 2016 resulted in an increase in the value of sales of new innovative products by 1.6%. In contrast, in countries above the EU innovation average or those close to it, the 10% increase in the total innovation expenditure (with the other expenditure remaining unchanged) caused a surge in sales of new innovative products by 4.5% in 2012, and by 5.3% in 2016. In countries which are above the EU innovation average or close to it in the wave period, with a 10% increase in the total innovative expenditure, the increase in the value of sales of new innovative products amounted to 0.8%. At the same time, the increase in the

value of sales of new innovative products was twice as high in countries below the EU innovation average. This is explained by the theory of international integration, from which it follows that the actual integration benefits occur when the economies of various countries are competitive. Such a condition engenders trade, which consists in shifting production from economies with higher costs to lower-cost economies. The range of total innovative expenditure is smaller, and the value of sales of new innovative products is higher in the economies of countries below the EU innovation average (Table 1). The low level of innovative expenditure leads to a faster shrinkage of enterprises than in the case of those that respond to the Chinese competition (Bloom, Draca and Van Reenen 2016).

As a result of the liberalisation of the internal EU turnover, more costly production in countries is replaced by cheaper imports from other member states, while cheaper production from these countries gets exported to other EU member states (production effect). The effect of trade creation is beneficial because it leads to lower production costs and savings in production factors in EU countries. The consumers of EU countries also gain in this situation (price decrease), while the released factors are shifted to another production where their productivity will be higher. The total EU national income is thus also growing, as does the competition of the integrated economic group. Trade integration also induces long-term effects such as growth in production and trade efficiency, allocation efficiency, economies of scale, dynamic efficiency over time, as well as economic growth in EU member states. The increase in the innovation level in rich countries in the sectors where China wields relative benefits, reduces the standard trade profits (Levchenko and Zhang 2010).

The econometric analysis of the macroeconomic classic function of the Cobb-Douglas form has a significant interpretive meaning for the parameters which express the average elasticity of the value of sales of new innovative products versus the total innovation expenditure in the studied groups of EU countries (Table 1). They also allow for determining the marginal and average productivity of these outlays. The indicated changes in marginal and average productivity in the examined EU member states and in the surveyed years allow for a determination of the areas of rational management of the total innovative expenditure in the studied groups of countries.

Table 3 presents the marginal and extreme productivity of the total innovative expenditure in EU countries above the EU innovation average or close to it in 2012.

Table 3. Marginal and average productivity of the total innovative expenditure in EU countries above or close to the EU innovation average in 2012

Value of sales of new innovative products (Y1) expressed in thousand EUROS.	Total innovative expenditure (X1) expressed in thousand EUROS.	Productivity:	
		mean EURO/EURO	marginal EURO/EURO
1,701.27	450.00	3.78	1.70
2,034.99	670.00	3.04	1.37
2,312.35	890.00	2.60	1.17
2,554.02	1,110.00	2.30	1.04
2,770.52	1,330.00	2.08	0.94
2,968.09	1,550.00	1.91	0.86
3,150.77	1,770.00	1.78	0.80
3,321.33	1,990.00	1.67	0.75
3,481.81	2,210.00	1.58	0.71
3,633.72	2,430.00	1.50	0.67

Source: Author's calculations based on the data from Table 1 and Table 2

The data in Table 3 show that the marginal productivity of the total innovative expenditure decreases (up to zero), while also causing a decrease in the productivity of the average expenditure, albeit at a slower pace. The nature of these changes means that the global productivity of these outlays (which has not been included) increases, while the rate of this growth is tending towards zero. The nature of the changes in marginal productivity and in the average of the total of innovation expenditure indicates that the total innovative expenditure in the rational management zone was used in the group of countries above the EU innovation average or those close to this mean in 2012.

In turn, the data in Table 4 show that the marginal productivity of total innovative expenditure in the group of countries below the EU innovation average decreases until it gets equal with the mean productivity of these outlays, which continues to grow, whereas the global productivity of these expenditures (which was not included therein) is grows at a slower pace. The nature of these changes unfolds in the initial irrational management zone, and thus in the zone of the start of a wave of innovation in this group of EU countries in 2012.

Table 4. Marginal and average productivity of total innovative expenditure in EU countries below the EU innovation average in 2012

Value of sales of new innovative products (Y2) expressed in thousand EUROS.	Total innovative expenditure (X2) expressed in thousand EUROS.	Productivity:	
		mean EURO/EURO	marginal EURO/EURO
847.30	299.00	2.83	2.81
1,107.83	392.00	2.83	2.80
1,367.75	485.00	2.82	2.79
1,627.16	578.00	2.82	2.79
1,886.15	671.00	2.81	2.78
2,144.78	764.00	2.81	2.78
2,403.10	857.00	2.80	2.78
2,661.14	950.00	2.80	2.77
2,918.92	1,043.00	2.80	2.77
3,176.48	1,136.00	2.80	2.77

Source: Author's calculations based on the data from Table 1 and Table 2

Table 5. Marginal and average productivity of total innovative expenditure in EU countries above the EU innovation average or close to it in 2016

Value of sales of new innovative products (Y3) expressed in thousand EUROS	Total innovative expenditure (X3) expressed in thousand EUROS	Productivity:	
		mean EURO/EURO	marginal EURO/EURO
1,342.41	355.00	3.78	2.23
1,707.63	559.00	3.05	1.80
2,013.74	763.00	2.64	1.56
2,283.19	967.00	2.36	1.39
2,526.97	1,171.00	2.16	1.27
2,751.48	1,375.00	2.00	1.18
2,960.79	1,579.00	1.88	1.11
3,157.73	1,783.00	1.77	1.04
3,344.34	1,987.00	1.68	0.99
3,522.13	2,191.00	1.61	0.95

Source: Author's calculations based on the data from Table 1 and Table 2

It follows from the data shown in Table 5 that in the group of countries above the EU innovation average or in those close to it, the marginal productivity of the total innovative expenditure is decreasing (up to zero), while it also affects the decrease of the average productivity of these expenditures at a slower rate. The not included, global productivity is then growing, albeit tending towards zero. The nature of these changes indicates the zone of rational management of the total innovative expenditure in 2016.

The data included in Table 6 present the dependencies of the productivity category of the total innovative expenditure recorded in the EU group of countries below the EU innovation average in 2016. With the increase of the total innovative outlays, their marginal productivity increases and exceeds the average productivity of such expenditure, which is then growing more slowly. The global productivity of these outlays (not included) is increasing faster and faster. However, this is characteristic of the initial zone of irrational management, which is the entrance zone for the commencement of the innovation wave.

Table 6. Marginal and average productivity of total innovative expenditure in EU countries below the EU innovation average in 2016

Value of sales of new innovative products (Y4) expressed in thousand EUROS	Total innovative expenditure (X4) expressed in thousand EUROS	Productivity:	
		mean EURO/EURO	marginal EURO/EURO
3,278.96	279.00	11.75	13.52
4,649.51	378.00	12.30	14.15
6,075.58	477.00	12.74	14.65
7,547.05	576.00	13.10	15.07
9,057.13	675.00	13.42	15.43
10,600.92	774.00	13.70	15.75
12,174.69	873.00	13.95	16.04

Value of sales of new innovative products (Y4) expressed in thousand EUROS	Total innovative expenditure (X4) expressed in thousand EUROS	Productivity:	
		mean EURO/EURO	marginal EURO/EURO
13,775.51	972.00	14.17	16.30
15,401.01	1,071.00	14.38	16.54
17,049.24	1,170.00	14.57	16.76

Source: Author's calculations based on the data from Table 1 and Table 2

The established levels of marginal productivity and the average total innovation expenditure in EU countries above or close to the EU innovation average indicate that the use of total innovative expenditure in both 2012 and 2016 remained well within the rational management zone. In contrast, in countries below the EU innovation average, although marginal productivity equaled the average productivity of total innovative expenditure in 2012, while in 2016, the marginal productivity of these expenditures grew faster than the average productivity of total innovative expenditure, both values were growing five times faster in 2016 compared to 2012, however, in these years, they remained in the entrance zone of irrational management.

Table 7. An average growth rate of the value of sales of new innovative products (Y1, Y2, Y3 and Y4)*

Specification	Table 3	Table 4	Table 5	Table 6
Value of sales of new innovative products (Y1)	8.80			
Value of sales of new innovative products (Y2)		15.82		
Value of sales of new innovative products (Y3)			11.31	
Value of sales of new innovative products (Y4)				20.10
Total innovative expenditure (X1)	20.61			
Total innovative expenditure (X2)		15.92		
Total innovative expenditure (X3)			22.41	
Total innovative expenditure (X4)				17.27
Productivity: - marginal - average	 -9.79 -9.79	 -0.15 -0.15	 -9.07 -9.07	 2.42 2.42

Note: within the range of total innovative expenditure (X1, X2, X3 and X4) and an average growth rate of marginal and average productivity of the total innovative expenditure in EU countries in 2012 and 2016%.

Source: Author's calculations based on the data presented in Table 3, Table 4, Table 5 and Table 6 using a dynamics based on variables and the geometric mean.

The growth rate within the range of total innovation expenditure in groups of countries above or close to the EU innovation average and those below the EU innovation average in 2012 and 2016 has been shown in Table 7.

Conclusion

The conducted research confirms the hypothesis that the productivity of total innovative expenditure remains in the entry zone of irrational management in the group of countries below the EU innovation average, and in countries above the EU innovation average or those close to, it is located in the rational management zone.

The intensity of total innovative expenditure in enterprises and EU countries, although it differentiates the marginal and average productivity of the total innovative expenditure and their rationality of management, yet in countries below the EU innovation average the implementation of total innovative expenditure increases their marginal and average productivity, even in the case of irrational management of these outlays. In contrast, in EU enterprises and countries above the EU innovation average or those close to it, the wave of innovation gets blurry over time, while marginal productivity and average innovation expenditure, although they are lower while being relatively stable and remaining in the rational management zone in the economies of these EU countries. In contrast, in countries below the EU innovation average, shaping the marginal and average productivity of total innovation expenditure situates these member states in the initial irrational management zone and characterizes the continuous commencement of the wave, making it difficult to identify it.

The real benefits of integration in the EU are obtained in countries above or close to the EU innovation average (Table 1). This is due to the increase in competitiveness, especially in the group of countries with an increase in the effect of the trade creation, which occurs by means of shifting (turnover) of production from these economies, from those with cheaper production to those with more expensive production, albeit within the grouping. It is a production effect. The effect of trade creation is beneficial since it leads to lower production costs and savings in production factors.

Consumers also gain from this effect as prices fall. The released factors of production are allocated on the scale of the integrated area, which is consistent with the principle of cost minimization. Productivity and the competition's cost advantage are on the increase. Lowering the price level intensifies consumption and leads to a lower new price balance. It is then that the level of innovation and the number of new innovative products are growing.

The EU Innovation Index used to classify the sets of countries with a structured innovation implementation allowed for a spatio-temporal determination of the regressive dependence of the value of sales of new innovative products on the total innovation expenditure in enterprises and countries. In turn, this dependence made it feasible to assess the efficiency of innovation management in EU member states.

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