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THE ASSESSMENT OF PATENT ACTIVITY AND THE DISCRIMINANT ABILITY OF ITS DETERMINANTS

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Purpose: The purpose of this paper is to apply the discriminant analysis to assess the separation ability of determinants affecting the patent activity.
Design/methodology/approach: This paper applies the method of discriminant analysis to track the influence rate of the most often used factors affecting the patent analysis. The research was conducted for the European Union member states and Switzerland on the basis of the data from 2022 and the Eurostat basis.
Findings: The conducted research showed that the decision makers, wanting to increase the patent activity, have to, at first, pay attention to the level of economic growth, i.e. the factor mainly affecting the amount of expenses on R&D. However, it should be remembered that also human resources, including the research ones, play an important role in achieving high level of innovativeness. They are the main players while drawing up and implementing innovations. The influence of human resource is lower, indeed, it is very important. Contrary to Luxembourg, Finland, Sweden, Denmark or the Netherlands, the number of patents reported to EPO is very small in Poland (607 in 2022 or 671 in 2023). Indeed, it is a big growth because of about 10% but the number of patents per one million of professionally active people is not high - 11.5% EU, about 3.9% Scandinavian countries. In comparison to the countries with low GDP index, such as Greece or the Czech Republic, the patent activity of Poland is not high (86% of patents in Greece and 81% in the Czech Republic). Thus, the situation of our country is not advantageous, in comparison to the majority of the EU member states.
Research limitations/implications: It is necessary to include more determinants specifying the efficiency of innovativeness in the future research. The availability of data limited the years of analysis. One source of data was used to provide the reliability of analyses.
Practical implications: Focusing on the main factors affecting the patent activity may increase the companies competitiveness and it contributes to the competitiveness of the whole economy. The increase in the patent activity contributes to the achievement of a more competitive position in the market.
Originality/value: The performance of the analysis of the measurable effects of innovation policy in Poland in comparison to other countries will make it possible to indicate on which countries and determinants the attention should be paid to improve the innovation activity.
Keywords: patent activity, discriminant analysis, discriminant function.
Category of the paper: Research paper.

1. Introduction

The changes in individual countries caused that a big attention is paid on the introduction of new solutions in the activity of companies (Baruk, 2018). The implementation of such solutions provides better work management, decrease in the production costs and achievement of competitive advantage. The innovation potential of companies defined as the set of social and economic resources, constituting the basis of the company innovation activity, provides the possibility to create and implement innovations (Thompson, 2018; Guckenbiehl et al., 2021). Thus, the company success depends both on the finance the company possess as well as on the staff of R&D sector. So, these resources are the ones which the company possesses or should possess to increase its value and generate profits (Stefaniuk, 2019). Both elements (resources) refer not only to the management of knowledge resources but also to the process management which occurs in the company (Mauro, Borges-Andrade, 2020). Various sources of workers' knowledge and their permanent training, being a key element of organization development, play an important role in taking all decisions (Priyadarshini, Gao, O'Gorman, 2024). The lack or 'insufficiency' of these links cause that the risk connected with the performance of inappropriate growth scenarios grows in an organization. Thus, it is necessary to possess the information of cognitive and practical value to obtain competitive advantage. In this context, it is extremely important to possess the information about the validity and types of factors affecting the activity of companies.

Although some claim, that the competitiveness in the global market is the basic element driving the innovativeness of companies (Osieczko, Stec, 2019; Agarwal, 2018), financial expenses and human resources play, in this case, undoubtedly a crucial role. More and more attention is paid to the effectiveness of the taken actions and their results (inventions) in connection with the implementation of new solutions, which, in consequence, is strictly connected with the employees' professionalism.

Due to the fact that the expenses on research and development activity and intellectual capital of an organization decide on the appropriate company management and about its power, the question arises what external factors, from the entrepreneur's point of view, contribute to the discrimination of groups specifying the rate of patent activity.

Taking it into consideration, the research hypothesis was formed: The analysis of the selected external conditions affecting the company innovativeness will facilitate the monitoring of countries engagement in the improvement of implementing new solutions.

Taking the above into consideration, the purpose of this paper is to assess the separation activity of the selected factors affecting mainly the patent activity which is the criterion of company innovativeness measure in the European countries. The method of discriminant analysis was the research tool which allowed to perform this purpose.

Thus, the presented paper is an attempt to meet this purpose and is a proposal thanks to which it is possible to draw the entrepreneurs' attention to the importance of factors affecting the company innovativeness.

2. Method

In the analyses of innovativeness the attention is often paid to the big influence of R&D expenses and human resources for knowledge and technique on creating and implementing new solutions including management. However, it is important not only to indicate the role of these resources but to determine how crucial they are when they influence the patent activity.

In order to discuss this issue of company innovativeness, the paper focuses on the most often considered diagnostic features, the more so that such a choice is confirmed by the domestic and foreign researchers in this field (Cohen, Soto, 2007; Weresa, 2003; Simao, Franco, 2018; Audretscha, Belitski, 2020; Sokołowski, 2018).

Thus, the following set was used as independent variables:

– Expenses on R&D activity (according to PPS per capita) for 1000 R&D staff – NBR;

– The total number of researchers on 1000 professionally active people in FTE – LB;

– GDP in EUR per 1000 residents of a given country (according to PPS per capita) – GDP.

In the clusters the countries were ordered to the group using the number of patents reported to EPO according to the reporting country per 1,000 professionally active people. If the mean did not exceed the mean for all countries, such unit was included in the group – low patent activity, in another situation to the cluster – high patent activity.

The discriminant analysis, showing the discrimination (separation) and classification (allocation), was used to solve the raised issue. The analysis was chosen which serves the optimal division of objects between groups, at the same time, indicating the determinant differentiating the clusters most strongly (Panek, 2009). The stepwise method was used here.

Then, the strength of the given discriminant variable influence on the group differentiation was specified and the strength of connections between discriminant variables was indicated. Then an attempt was made to find the case the closest to the centroid.

The "classification matrix" was used in the analysis to determine the correctness in qualifying the object to a given group as it gives the information about the number and percentage of objects classified in a cluster correctly. Moreover, the amount of the correctness percentage for belonging to the group allows to indicate the more efficient solution.

The research group included the EU member states and Switzerland as the country very highly classified in the world rankings of innovativeness and competitiveness. The data used in the paper come from the website EUROSTAT and refer to year 2020. Each variable was presented on the ratio scale. The research was performed in the program Statistica 13.3.

3. Results

Considering the patent activity, we examine not only the country economic situation but, at first, the number of patents. The number of inventions reported to EPO as well as the number of patents reported to EPO counted on a million of professionally active people has been growing in the majority of EU member states for the last two years. Although the number of patents grows in Lithuania, Latvia and Slovenia the most, Luxembourg, Sweden and Finland are top when it comes to the second parameter (Figure 1).

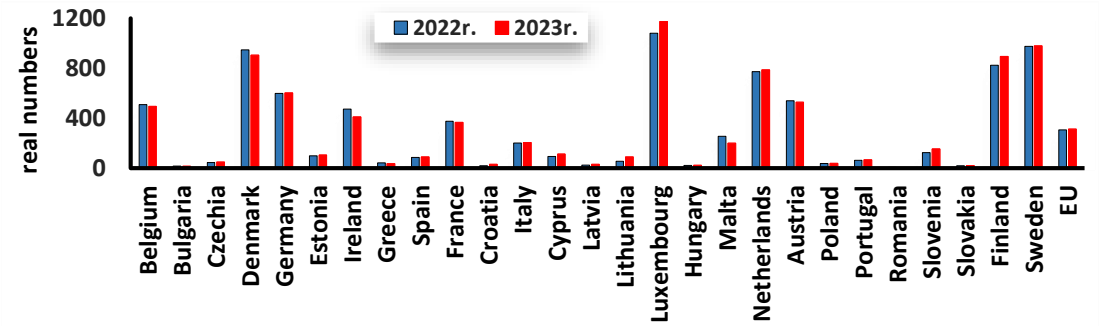

Figure 1. The number of patents reported to EPO for a million of professionally active people in EU.

Source: Own study based on EUROSTAT data.

The biggest changes in this scope can be observed in Croatia and Lithuania and the smallest in Germany and Sweden (Figure 2). The level of this dynamics is mainly caused by the rate of innovativeness and the size of GDP in particular countries.

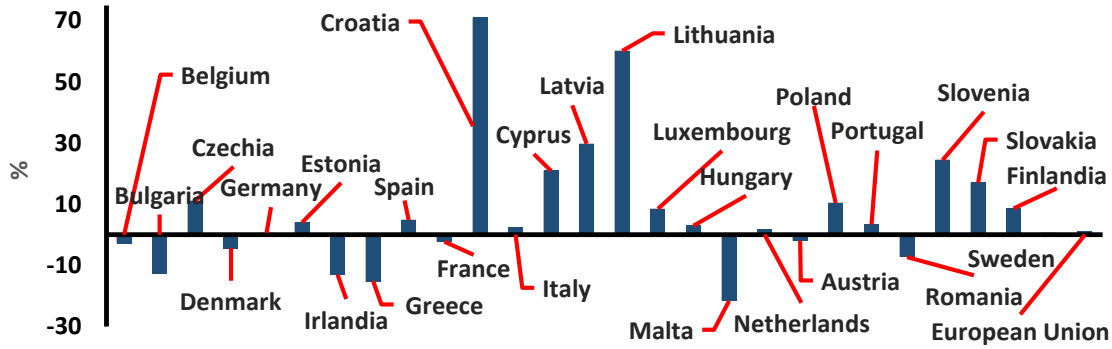

Figure2. Changes of the patents reported to EPO for a million of professionally active people in EU (2022-2023).

Source: Own study based on EUROSTAT data.

On the basis of the above charts, it is possible to make conclusions concerning the pace of innovativeness and number of patents in the country. Poland does not look good in comparison to the majority of countries but the increase in the number of patents by 5.45% was noticed in our country (2023 to 2022).

Thus, the variables with the highest discriminant strength, i.e. variables showing significant discrimination of groups, were introduced to the analyses to perform the given purpose (Table 1).

Table 1.
Summary of the analysis of the discriminant function

N = 28	Variables in the model: 3; Grouping: activity (2 groups) Wilks' Lambda: 0,15242 approx. F (3,24) = 44,488, p < 0,0000					
	Wilks lambda	**Wilks' partial**	**F deletion (1,23)**	**p**	**Tolerance**	**1-Tolerance**
NBR	0.240354	0.634135	13.84686	0.001063	0.960459	0.039541
LB	0.232298	0.656125	12.57837	0.001642	0.884460	0.115540
PKB	0.261936	0.581887	17.24513	0.000358	0.854129	0.145871

Source: Own work based on the STATISTICA program.

The discrimination of the patent activity is significant (LW = 0.15; F = 44.49 and p < 0.00) and good division into groups is confirmed by the Wilks' Lambda coefficient. On its basis the conclusion may be made that the considered variables have a significant discriminant power. The value of partial Wilks' lambda (CLW) informs that the GDP variable has the greatest contribution to the general discrimination (CLW = 0.58). Moreover, the value of F deletion statistics indicate that other variables have a significant contribution to the group discrimination (p < 0.002). Furthermore, the value of tolerance is a measure of variable redundancy. In the case of expenses on R&D, about 90% of information brought by this variable is not repeated by other variables included in the model.

Considering the number of groups (two) and independence variables (three), the result was:

$$\text{Number of discriminant functions} = \min(3,2) - 1 = 1 \quad (1)$$

The canonical analysis was performed to check its discriminant strength and the chi-square tests were performed to check the significance of functions (Table 2).

Table 2.
Significance of the discriminant function

Deleted elements	Chi-square tests for consecutive elements					
	Own value	**Canonical R**	**Wilks lambda**	**Chi-square**	**df**	**p**
0	5.560953	0.920643	0.152417	46.08783	3	0.000000

Source: Own work based on the STATISTICA program.

On the basis of the above table, it can be stated that this function is significant. On the basis of the obtained information it may be claimed that our results came from the population in which the groups appear in a natural way. Moreover, the model possesses a significant discriminant power ($\chi^2 = 46{,}09$; p = 0,00) - LW is not high and the significance level ≅ 0.

After the confirmation of the significance of the discriminant function, it can be presented in a following way:

$$FD = 7.76 - 0.05NBR - 0.22LB - 0.06PKB \quad (2)$$

However, the raw coefficients given in the function only indicate the values of discriminant functions and thus, do not include any information which may be used.

The standardized coefficients were used to check which variables determining the patent activity have the highest influence on the creation of discriminant functions. The function with them has the following form:

$$FD = -0.67NBR – 0.68LB – 0.76PKB \quad (3)$$

On the basis of the given information, it is possible to notice that GDP has the greatest influence on the creation of the function in the tested countries. Other two variables have a lower, but similar, influence, with the small indication of the advantage of LB variable. The received own value (5.56) and cumulated proportion (1.00) indicate the percentage of the explanation of the variance between groups by the discriminant function.

To specify the connection strength between canonical discriminant variables and analyzed primary variables, the correlation was calculated between primary variables and canonical elements. It may be concluded from the factor structure (Table 3) that the NBR variable – about 0,6 shows the highest dependence.

Table 3.
Coefficients of factor structure for canonical variables

Matrix of factor structure Correlation variables – canonical elements	**variable**	NBR	LB	PKB
	correlation coefficient	-0.569088	-0.468233	-0.396545

Source: Own work based on the STATISTICA program

The allocation of objects to groups, i.e. the main significance for the correctness of the test results, was checked in the further stage of the analysis. The square Mahalanobis distance was indicated to give the smallest distances of an individual object (country) to the centroid. On the basis of the obtained results, it was stated that all of presented 28 countries were classified correctly. Belgium, Austria and the Netherlands in the cluster (big activity) and Slovakia, Lithuania and Spain in the second group were the closest to the adapted point the coordinates of which correspond to the group mean of each discriminant variable.

To confirm the correctness of belonging to the clusters, the matrix of classification of the considered countries to the groups specifying the patent activity (Table 4).

Table 4.
Values in the classification matrix of objects

	Rows: Observed classification Columns: assumed classification		
	% correctness	**Gr. 1 p = 0,39286**	**Gr. 2 p = 0,60714**
Low patent activity	100,00	11	0
High patent activity	100,00	0	17
Total	100,00	11	17

Source: Own work based on the STATISTICA program.

Analyzing the values included in table 4, it may be noticed that the classification of companies to all groups is correct and the probability is not significant. Due to the fact that the applied grouping has a 100% correctness it may be stated that the random classification of countries is as beneficial as using the classification function.

4. Discussion

The innovativeness activity is considered as a basic power driving modern companies. The new solutions implemented by it (the technological, managerial, organizational ones) show the "significance" of the company existence and create the path of its development. This development mainly depends on the R&D expenses and possessed human resources. Knowledge and information and in reality ability to obtain and use them decide about the market success of a given company (Zastempowski, 2010; Stefaniuk, 2019; Biedka, 2021; Corvello et al., 2023). Thus, using these elements it is possible to react on the needs of potential customers, take an advantageous competitive position or make changes in management and it may affect the company performance in a positive way (Aslam et al., 2023; Clò, Florio, Rentocchini, 2020). So it is possible to talk about the driving force of innovations referring to the creation of new value by creative connection of production processes and market, development of technologies, change of management (Kim et al., 2018). In this context the company innovativeness at the domestic level, understood as the ability and motivation of companies to search and implement scientific research, new ideas/inventions permanently is strictly connected with the innovativeness of the economy. As it is known, it depends on the innovativeness of region which depends on the company innovativeness activity. Thus, it is possible to state that the level of the economy innovativeness in a given country is connected with the company tendency to implement new solutions and efficiency of their management. The strong connection of these two innovativeness is a cause to implement various projects either at the domestic or Union level with the consideration of the specification of a given country (Fedirko, O., Fedirko, N., 2021).

This issue is connected with leading the innovativeness policy at the macro level which is a significant factor affecting the company innovativeness (patent) activity (Łącka, 2010). This activity is mainly affected by the finance designed in GDP on research and development activity. It may be a big problem in countries with low GDP but a range of programs offered by the European Union may be a support here (Kim, Yoo, 2019; Szatlach, 2018). It perceives the development level of economies in particular countries by the prism of the influence of new solutions on the company management or activity. However, it should be noticed that measuring the innovativeness meets a lot of problems (among others the companies do not obtain information e.g. about the diffusion of innovations, about the level of modernity of introduced products and services towards the existing ones or competitiveness). Thus, identifying by the EU the innovativeness activity with the patent activity may constitute a solution in this matter. The number of patents and in reality its change allows to specify the engagement of countries towards the development of innovativeness. Although the countries may pay attention to the implementation of modern solutions, the measurable result which is the number of reported and received patents, does not have to reflect the level of its engagement

(Nowak, 2012). It may be the matter of the quality of the reported patent applications or the inefficiency of the system or the inappropriate (mistaken) management.

However, abstracting from this, it is possible to notice that the patent activity of the European states may be differentiated, which may be the result of the amount of expenses on R&D i.e. the level of the economic growth of the countries indirectly. Considering the aspect of differences in the GDP levels per capita, it is possible to notice the division into "old" and "new" EU member states, which does not contribute to the comparison of patent activity expressed as the number of reported patents calculated per professionally active people. Despite this fact, such reporting seems to be justified as the creativity is more interesting in this case than the absorption itself. Nevertheless, it should be noticed that the situation in which the countries that accessed the Union recently have a high pace of the innovativeness efficiency growth is the most common in the EU. It is mainly connected with the effect of cointegration, the development of intellectual capital or fostering innovations (Nasir, Zhang, 2024). Although the patent activity, in the general approach, increases, it is more visible in the case of the number of reported than accepted patents. As Szajt claims, the mean relation of the reported ones to the accepted ones is at the level of 50% in the EU (Szajt, 2010). This relation increased by 2.53 percentage point in 2022. Considering the situation of Poland in relation to the EU member states, we can notice that our position is not beneficial. The number of patents reported to EPO per a million of professionally active people in Poland amounted to about 35 (2022) and about 39 (2023), whereas it was on average 307 and 311 respectively in the EU member states. Luxembourg, Scandinavian countries and the Netherlands among the EU member states and Switzerland (as an associated state) are the leaders and Romania, Bulgaria and Slovakia take the lowest positions. The situation of our country was a bit better in 2023 when it comes to the number of patents reported to EPO – 671 and granted patents -258 (increase by 10.5% and 35.2% respectively, in comparison to 2022). According to the Patent Office of the Republic of Poland, Poland is at the seventh place concerning the rate of the increase in reporting among the EPO members (Polish Patent Office, 2024), the patents reported most often referred to medical technologies, pharmaceuticals and land engineering.

However, it should not be forgotten that there are numerous barriers in drawing up, introducing and using new solutions. The barriers of the innovativeness activity development comprise at first high costs of preparation and implementation of the innovations and the lack of appropriate staff (Różański, 2020; Holl, Peters, Rammer, 2023). These barriers are particularly visible during any crises as it is difficult to meet the global competitiveness in the economic and technological aspects in this time (Jemala, 2021). The help of the state may be regarded necessary in a difficult situation. It is supported by the fact that the companies need more support of innovativeness by the government e.g. by creating various types of incentives to invest in research and innovations (Maradana et al., 2017; Bircan, Gençler, 2015; Balsalobre-Lorente et al., 2021). The entrepreneurs should be sure that their companies are supported in the absorption of knowledge and management of innovations which will be beneficial not only

for them but also for the economy. Thus, not only the amount of R&D expenses is significant here but also the number of researchers as their creativity and openness for the creativity of the others decide about the innovative potential (Szajt, 2016; Castaneda, Cuellar, 2020). Although the values of these both variables decide on the patent activity, the indisputable fact is that mainly % of GDP designated on R&D causes that the state sectors with the highest research and development potential are the most effective.

5. Conclusions

The patent activity constitutes an important criterion of the innovativeness assessment in every country especially when they try to decrease the technological gap and to increase their economic benefits. Thus, it is important to notice on which elements the attention should be paid in the performed innovativeness activity, especially with not high (low) share of expenses on research and development in % of GDP.

The analyses in the article indicate the adverse situation concerning the reported patents in Poland in comparison to the Scandinavian countries. It is confirmed by the European Innovation Scoreboard, according to which our country takes one of the last places in the ranking which shows the rather low position in the area of innovativeness. In this case the verification of innovativeness policy and the sources of innovation financing is necessary. However, it is not assumed that this process will finish soon, especially that its results will depend on the level of economic growth and changes in the approach to human management. Although some changes occur, they are not sufficient.

Moreover, the conclusion can be made on the basis of the presented indicators that the patent activity is really differentiated in the countries – starting from Switzerland, Sweden and Denmark and ending with the so called new EU member states. The situation is not satisfactory in the countries of Middle and Eastern Europe and its solution seems to be strict cooperation with the Scandinavian companies, proper human resource management and designating more money on innovations. It may affect the company innovativeness in a positive way and thanks to that its competitiveness.

The proper specification which variables affect the patent activity the strongest help to manage the companies and the results of discriminant model, which makes it possible to verify the patent activity of a given company is an easy and fast way, facilitate it. The performed research confirms that using the discriminant analysis to assess the intensiveness of patent activity by examining factors affecting the company innovativeness may constitute a significant completion of tools used by persons monitoring the situation of an organization. The results of the described method may serve as a system of warnings against inappropriate actions.

The performed analyses show that at first, the development level of a given country and then the number of persons affecting the creation of innovations the most, i.e. researchers, and the percentage of GDP designated on R&D should be considered while assessing the effect of economic subjects' activity (patent activity). Paying attention to such a set of variables may cause that at first the factors mainly affecting the innovativeness will be considered at examining companies. The improvement of the management of finances and human resources in a company may be a consequence of such actions.

Summing up, the analysis presented in the paper, being an attempt to assess the separation abilities of the main indicators of patent activity assessment, may be used to perform research on the creation of a tool supporting the actions of persons taking strategic and operational decisions in companies in the future.

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