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THE INFLUENCE OF R&D ON PATENT ACTIVITY OF HIGH-TECHNOLOGY COMPANIES

Abstract

In order to maintain a competitive advantage, occupy a leadership position on the market and take on the role of a creator of the "rules of the game", high-tech companies rely on their innovation activity, and invest significantly in research and development (R&D) activity, the output of which are inventions that are the potential subject of patent protection. The company's patent activity is an indicator of its innovation activity and an instrument that the company can use to achieve various business goals. The goal of this research is to determine the impact that research and development activities have on patent activity of high-tech companies that are on WIPO's Top 50 PCT applicants list from 2013 to 2020. Using a panel regression analysis, it was established that investments in research and development have a positive impact on the company's patent activity expressed by the number of granted patents and the number of published PCT applications. Also, it was determined that the return on investment in research and development has a positive impact on the number of granted patents, but a negative impact on the number of published PCT applications. Finally, no statistically significant impact of research and development intensity on patent activity indicators was found.

Keywords: *research and development, patents, innovation activity, high-technology companies*

JEL classification: *O32, O34*

УТИЦАЈ ИСТРАЖИВАЊА И РАЗВОЈА НА ПАТЕНТНУ АКТИВНОСТ ВИСОКОТЕХНОЛОШКИХ КОМПАНИЈА

Апстракт

У циљу одржавања конкурентске предности, заузимања лидерске позиције на тржишту и преузимања улоге креатора „правила игре", високотехнолошка

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предузећа се ослањају на своју иновациону активност, значајно улажу у активност истраживања и развоја, чији су аутпут проналасци који су потенцијални предмет патентне заштите. Патентна активност предузећа индикатор је његове иновационе активности и инструмент који предузеће може користити за постизање различитих пословних циљева. Циљ истраживања је да утврди утицај који активности истраживања и развоја имају на патентну активност високотехнолошких предузећа која се налазе на листи „50 највећих подносилаца међународних патентних пријава“ Светске организације за интелектуалну својину у периоду од 2013. до 2020. године. Применом панел регресионе анализе установљено је да улагања у истраживање и развој имају позитиван утицај на патентну активност предузећа изражену бројем признатих патената и бројем објављених међународних патентних пријава. Такође, утврђено је да принос на улагања у истраживање и развој има позитиван утицај на број признатих патената, али негативан утицај на број објављених међународних патентних пријава. На крају, није установљен статистички значајан утицај интензивности истраживања и развоја на индикаторе патентне активности.

Кључне речи: *истраживање и развој, патенти, иновациона активност, високотехнолошка предузећа*

Introduction

The modern business environment of high-tech companies is characterized by the intense dynamics of changes that direct the pace of market competition. Businesses are forced to adapt to the speed of change in order to survive in the market and improve intellectual performance (Krstić, 2009). Innovative activity is the main instrument for achieving business success. High investments in research and development activities are a precondition for the creation of innovative solutions that provide high-tech companies with achieving and maintaining a competitive advantage on the market and sustainable development (Jovanović, Krstić & Berezjev, 2022).

The outputs of research and development (R&D) can often be inventions that satisfy the criteria of patentability (Vasić, Kecman, & Mladenović, 2016). In this case, companies can decide to submit a patent application for their invention to a national office of intellectual property of the country in which they want to obtain patent protection. Patents can have a strategic importance for companies, that is reflected in the possibility of excluding competition from the market, generating revenue from licensing, attracting external capital, etc. (Krstić, Janjić, Jovanović & Milanović, 2021). High-tech companies, which have high expenditures in research and development, often come up with inventions that can be imitated by the competition, which causes the original inventor to lose part of the market share, as well as part of the profit (Rađenović, Krstić, Janjić & Vujatović, 2023). By owning a patent over a certain invention, the company prevents the competition from exploiting its invention and retains all the benefits of placing the innovative product on the market (Jovanović, Krstić & Radjenović, 2023).

Bearing in mind the importance that patent activity has for companies, especially for high-tech companies whose basis of business success is its innovation activity, it is necessary

to create a patent portfolio as an output of research and development activities, which will maximize the value of the company's innovation efforts The purpose of the research is to explore the impact that research and development activities have on the patent activity of high-tech companies that are on WIPO's Top 50 PCT applicants list from 2013 to 2020.

1. Literature review

There are many studies in which the link between R&D and patenting activity is indicated. The results of some studies show the positive influence of R&D on patenting. Pakes and Griliches (1984), Bound et al. (1984) and Hall et al. (1986) found a strong and positive link between R&D expense and the number of patents. Their samples included a wide range of organizations and industries. Cardinal and Hatfield (2000) examined the organizations in the pharmaceutical industry. They found that companies that placed a stronger focus on R&D investment were more productive in terms of creating inventions which were measured by the number of patents. Ahuja and Katila (2001) have also come to the deduction about a strong correlation between R&D investment and patents in their study that was focused on the chemical industry. The same conclusion was indicated by the results of the study of the companies in the computer industry by Hagedoorn and Duysters (2002).

Kim & Marschke (2004) broke down the increase in patents at the industry level into parts that correspond to a) more money being allocated for R&D, b) an increase in the overall patent yield of each R&D dollar, and c) changes in the patent yield in certain industries. Computer hardware and pharmaceuticals, two high-tech industries, were responsible for 22% of the growth in patents. Although these two sectors witnessed the largest R&D growth among those they studied, the pharmaceutical sector's patent expansion was constrained by a fall in its yield. They demonstrate that higher R&D expenditures are responsible for 70% of the rise in patents.

In their study, Bilbao-Osorio & Rodríguez-Pose (2004) examined the influence of R&D spending of the public, corporate, and HE sectors on innovation (measured as the number of patent applications per million people). Also, they analysed the impact of innovation and the growth of innovation on economic growth. The findings show that R&D spending overall, and higher education R&D spending in the EU's peripheral regions in particular, is positively correlated with innovation. However, the existence and strength of this link depend on socioeconomic factors unique to each region, which have an impact on each region's ability to convert R&D investment into innovation and, ultimately, innovation into economic growth.

Peeters and van Pottelsberghe de la Potterie (2006) showed that companies that invest more in basic and applied research encounter higher levels of patenting. Their study was based on the examination of 150 manufacturing and service companies. Paula & Silva Rocha (2021) have found that internal R&D has a positive influence on patent applications on a sample of 751 enterprises from six Latin American countries.

Although there are many studies which show a positive effect of R&D activity on patent activity, there are some studies which show the opposite.

According to the research by Graves and Langowitz (1993), growing R&D investment has a negative impact on the ability of organizations in the pharmaceutical industry to produce inventions. In their research, Lanjouw and Schankerman (2004) show a negative relationship

between research productivity at the firm level and the patent quality index. Danguy et al. (2010) demonstrate in their study a direct correlation between R&D expenditures and patent counts at the industry level. It is asserted that the notion of "propensity-to-patent" ought to be divided into two categories: "appropriability propensity" and "strategic propensity". The research is based on a special panel dataset of 19 countries, 18 industries, and 18 years. Research productivity, appropriability propensity, and strategic propensity have an impact on the link between R&D and patents.

2. Methodology of research

The aim of the study is to explore the impact of R&D activity on the patent activity of high-tech companies based on the various performances which are presented in Figure 1 within the conceptual framework of this study.

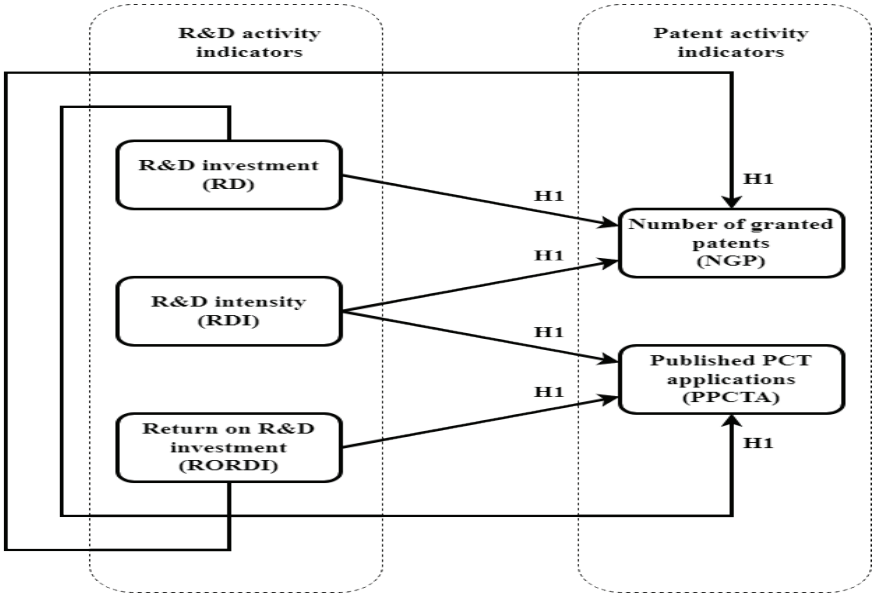

Figure 1: The conceptual framework
Source: Authors' presentation

The explanation of the variables used in the research and the method of their calculation is given in the following text.

The R&D investment (RD) is equivalent to expenditures in R&D.

The R&D intensity (RDI) indicator is defined as expenditures in R&D in the current year (*t*) divided by the company's sales in the current year (*t*) (Savrul & Incekara, 2015):

$$R\&D\ intensity_t = R\&D\ expenditures_t : Sales\ revenue_t \quad (1)$$

Return on R&D investment (RORDI) shows how much of the gross profit in the current year (*t*) realized from the R&D investment in the previous year (*t-1*) (Christensen and Van Bever, 2014):

$$Return\ on\ R\&D\ investment_t = Gross\ profit_t : R\&D\ expenditures_{t-1} \quad (2)$$

The number of granted patents (NGP) represents the number of patents granted by the United States Patent and Trademark Office (USPTO), as one of the 5 biggest national intellectual property offices in the world. Published PCT applications (PPCTA) show the number of published patent applications on the international level according to Patent Cooperation Treaty (PCT).

Considering the presented research results of various authors, the following hypothesis H1was defined:

The R&D investment (RD), R&D intensity (RDI) and Return on R&D investment (RORDI) have a positive impact on the Number of granted patents (NGP) and Published PCT applications (PPCTA) in the next year.

The sample contains of 33 companies that operate in the high-tech sector and that are on WIPO's Top 50 PCT applicants list in the period from 2013 to 2020. These are the following companies: Samsung, Siemens, Huawei, LG Electronics, Ericsson, Sony Corporation, Microsoft, 3M, Apple, Intel, Bosch, Applied Materials, Qualcomm, Fujifilm, Murata Manufacturing, BASF SF, Hewlett-Packard Development Company, Panasonic Corporation, Mitsubishi Electric, NEC Corporation, Sharp Corporation, Hitachi, ZTE, Philips, Kyocera, Nokia, Google, LG Chemicals, Densco, Tencent, Halliburton Energy, BOE Technology, and Shenzhen China Star Optoelectronics Technology. Data for calculating the research variables for the mentioned companies were collected from their annual reports, WIPO's PCT annual review, USPTO's website and other publicly available databases. The analysis covers 264 observations.

In the first two models, R&D investment (RD) is the independent variable. In the next two models, the R&D intensity (RDI) is the independent variable. In the last two models, Return on R&D investment (RORDI) is the independent variable. In all six models, Number of granted patents (NGP) and Published PCT applications (PPCTA) are dependent variables.

The hypothesis of the research was tested using the program Stata (version 12.0) by applying the panel regression analysis. After the identification of a balanced dataset and that the assumptions are met, the fixed-effect model (FEM) and random effect model (REM) were tested. In order to select FEM or REM, the Hausman test was performed for each test. The significance cut-off point of Hausman test was 0.05. According to that, the selection of FEM was indicated by all values statistically significantly less than 0.05. On the contrary, REM was the wright choice.

3. Results of empirical research

The following part of the work presents the research models, which are investigated by employing panel regression analysis of the data. Firstly, the results of R&D investment (RD) influence on patent activity indicators are presented in Table 1.

Table 1: Results of panel regression – R&D investment as a predictor

Independent variable	Research models	
	Model 1	Model 2
	ln NGP	ln PPCTA
	FEM	REM
Constant	2.410 (0.000)	6.074 (0.000)
ln L1RD	.493 (0.000)	.099 (0.000)
F / $\chi 2$	61.04 (0.000)	12.68 (0.000)
R^2	0.859	0.006

Note: p-value in the parentheses, ln – natural logarithm, L1 – one year lagged value.
Source: Authors' calculations

Based on the methodological assumptions of the panel regression analysis that were previously established, models 1 and 2 are statistically significant.

Model 1 measures the influence that RD has on NGP in the next year. It is hypothesized the positive influence. Model fit is significant at the level of $p < 0.01$ ($F = 61.04$, $p = 0.000$). R^2 indicates that the independent variable explains 85.9% of the variance of the dependent variable. If R&D investments increase by 1%, the Number of granted patents will increase by 0.49% in the next year and its effect is statistically significant.

Model 2 measures the influence that RD has on PPCTA in the next year. It is hypothesized the positive influence. Model fit is significant at the level of $p < 0.01$ ($\chi 2 = 12.68$, $p = 0.000$). If R&D investments increase by 1%, PPCTA will increase by 0.099% in the next year and its effect is statistically significant.

Table 2 presents the results of R&D intensity (RDI) influence on patent activity indicators.

Table 2: Results of panel regression – R&D intensity (RDI) as a predictor

Independent variable	Research models	
	Model 3	Model 4
	ln NGP	ln PPCTA
	REM	REM
Constant	6.763 (0.000)	7.025 (0.000)
ln L1RDI	-.064 (0.237)	.024 (0.603)
F / $\chi 2$	1.40 (0.237)	.27 (0.603)
R^2	0.002	0.012

Note: p-value in the parentheses, ln – natural logarithm, L1 – one year lagged value.
Source: Authors' calculations

The panel analysis of the RDI effect on patent activity indicators revealed a negative sign of influence in model 3 and a positive sign of influence in model 4, but in both cases, it is not statistically significant.

Table 3 presents the results of Return on R&D investment (RORDI) influence on patent activity indicators.

Table 3: Results of panel regression – Return on R&D investment (RORDI) as a predictor

Independent variable	Research models	
	Model 5	Model 6
	ln NGP	ln PPCTA
	REM	FEM
Constant	6.732 (0.000)	7.257 (0.000)
ln L1RORDI	.130 (0.022)	-.269 (0.001)
F / $\chi 2$	5.25 (0.022)	11.90 (0.000)
R^2	0.016	0.832

Note: p-value in the parentheses, ln – natural logarithm, L1 – one year lagged value
Source: Authors' calculations

Based on the assumptions of the panel regression analysis, models 5 and 6 are statistically significant.

Model 5 measures the influence that RORDI has on NGP in the next year. It is hypothesized the positive influence. Model fit is significant at the level of $p < 0.05$ ($\chi 2 = 5.25$, $p = 0.022$). If RORDI increases by 1%, the NGP will increase by 0.13% in the next year and its effect is statistically significant.

Model 6 measures the influence that RORDI has on PPCTA in the next year. It is hypothesized the positive influence. Model fit is significant at the level of $p < 0.01$ ($F = 11.90$, $p = 0.000$). R^2 indicates that the independent variable explains 83.2% of the variance of the dependent variable. If RORDI increases by 1%, the PPCTA will decrease by 0.269% in the next year and its effect is statistically significant.

Therefore, the research hypothesis H1 is partly confirmed according to the presented results.

Conclusion

This paper examines the impact of R&D activities on patenting activity of high-tech companies. The indicators of R&D activities, which were used in the empirical part of the work, are R&D investments (RD), R&D intensity (RDI) and Return on R&D investment (RORDI). Indicators of patent activity, on which the influence of the R&D indicators was examined are Number of granted patents (NGP) and Published PCT applications (PPCTA).

The research hypothesis that the R&D investment (RD), R&D intensity (RDI) and Return on R&D investment (RORDI) have a positive impact on the Number of granted patents (NGP) and Published PCT applications (PPCTA) in the next year is partially confirmed. It is confirmed that an increase in R&D investment has a positive impact on the Number of granted patents (NGP) and Published PCT applications (PPCTA) in the next year. This result is consistent with the research such as Ahuja and Katila (2001), Hagedoorn and Duysters (2002), Kim and Marschke (2004). When it comes to Return on R&D investment (RORDI) the results show that an increase in Return on R&D investment (RORDI) leads into an increase in Number of granted patents (NGP) in the next year, but a decrease in Published PCT applications (PPCTA) in the next year. The panel analysis of the R&D intensity effect on patent indicators revealed results that were statistically insignificant.

The novelty of this research reflects in studying the impact of Return on R&D investment (RORDI) on patent activity indicators - Number of granted patents (NGP) and Published PCT applications (PPCTA).

Certain limitations were present when conducting the research. Namely, the research period from 2009 to 2020 conditioned the sample size. The sample on which the research was conducted consists of companies which were continuously on WIPO's Top 50 patent applicants list in the observed period - 33 companies. Also, the patent activity indicator Number of granted patents (NGP) refers to the number of patents granted only by the United States Patent and Trademark Office (USPTO), as one of the 5 largest intellectual property offices in the world. Other national or regional intellectual property offices do not provide insight into the number of granted patents at the company level.

The results of the research have significant implications for the R&D management and the management of intellectual property of high-tech companies. Bearing in mind that greater investments in R&D contribute to a greater number of patent applications and a greater number of granted patents, it is necessary that they be at a high level in order for the company to create an optimal patent portfolio. The intellectual property management of the company should maximize the value of the outcomes of R&D activities, by submitting patent applications for inventions that meet the conditions of patentability in order to create a patent portfolio of the company that can serve as a means of creating a competitive advantage and which is a signal of intense innovative activity of the company.

The conducted research observes the impact of R&D activities from the previous year on the patent activity of the current year. Given that the process of patenting is long, it is recommended in future research to study this impact over a longer period of 3 to 5 years.

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