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THE INFLUENCE OF RESEARCH AND DEVELOPMENT AND PATENT ACTIVITY ON BUSINESS PERFORMANCE: THE CASE OF HIGH-TECHNOLOGY COMPANIES

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Abstract. *The purpose of the work is to determine the impact of R&D activities and patent activity on the business performance of high-tech companies with the largest number of patent applications according to the records of the World Intellectual Property Organization (WIPO).*
The research sample consists of 33 high-technology companies that were continuously on the WIPO's Top 50 PCT applicants list in the period from 2013 to 2020. Regression analyses have been performed to determine the impact of R&D activity and patent activity on the business performance of high-technology companies.
The research confirms the importance of R&D and patent activity for the business performance of high-technology companies. This study revealed that R&D investment, number of granted patents and published PCT applications have a positive influence on sales revenue, gross profit, operating profit, earnings before interest and taxes, earnings before interest, taxes, depreciation, and amortization, market capitalisation. The positive influence of patent activity indicators on return on equity is also present; however, the influence of R&D investment on return on equity is negative.
The research results have significant implications for R&D, intellectual property and corporate managers of high-tech companies in terms of significantly improving the efficiency of R&D investments and their impact on company's profitability. Also, there

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are significant implications related to improving the effectiveness of the innovation process and patent activity and their impact on other business performance.
The originality of this study is reflected in studying the influence of patent activity indicators on gross profit, earnings before interest and taxes, earnings before interest, taxes, depreciation, and amortization, and return on equity.

Key words: *R&D activity, patent activity, business performance, high-technology companies*

JEL Classification: O32, O34

INTRODUCTION

Nowadays, society and the economy are going through numerous and rapid changes that dictate the speed of their development. Adapting to those changes is a criterion for survival in the market. Earlier, with the industrial revolution, there were changes in productivity, which implied an increase in the productivity of the physical workforce. Today, the changes occurring in the market have a different character; they are based on the gaining of new competencies and their use through the differentiation of product development, production, services, and distribution. This means that today the focus is on knowledge resources i.e., the knowledge-based economy. In this sense, intellectual capital has an important role in achieving and maintaining competitiveness in the heated market competition.

It is important for various market participants to keep up with the competition or for those ambitious, potential market leaders, to be ahead of their competition. In order to achieve this, it is important that they possess knowledge that implies learning about something new, previously unknown to the competition, and with a perspective of success that always includes a certain level of risk. In conditions of intense competition and with ever shorter product life cycles, it is not easy for companies to maintain the continuity of their innovative activity. Also, apart from the continuity of innovative activity, it is necessary to achieve its optimal dynamics, because if innovations are implemented too quickly and multiple times, the company may have a problem of not being able to generate profit from its creative efforts and innovative solutions.

In order to obtain adequate knowledge, companies invest significantly in R&D. It is considered that R&D are the accelerator of the prosperity of modern society. R&D activities can improve companies' business performance (Rađenović et al., 2022). As a result of these activities, inventions that are the subject of patents are often created. Companies that own patents as a crucial element of their intellectual capital portfolio have specific strategies for using these elements of their portfolios, which imply the use of each individual patent in a certain way. Some of the patents they have can be beneficial for both company's performance and the country's macroeconomics performance where the company operates (Jovanović et al., 2022). Bearing in mind the importance of R&D activities, as well as patenting activity for the competitiveness of companies, and with a special emphasis on the importance of these activities when it comes to high-tech companies, the purpose of this study is to point out the importance that R&D activities and patenting have on business performance of high-tech companies. The goal of the work is to determine the impact of R&D and patent activities on the business success indicators of high-tech companies with the largest number of patent applications according to the records of the World Intellectual Property Organization (WIPO).

1. LITERATURE REVIEW

1.1. R&D activities and patenting as the driving force of high-tech companies' business performance

Given that high-tech companies operate in an environment that is determined by constant progress in technology and increasingly sophisticated consumer demands, high-tech companies must have the internal ability to generate new knowledge, as well as to know the way in which that knowledge can be used to create advantages on the market. R&D activities enable the companies to do so. "The annual research and development expenditures of a firm are considered to be investments which add to a firm's stock of knowledge" (Hall et al., 1986, p. 265). Investing in R&D makes it possible to use not only knowledge created within the company, but also knowledge obtained externally, from the environment. Depending on the ability of R&D activities to generate, obtain and use knowledge in an efficient and effective way, innovative output will be created. It is crucial to have a successful open innovation strategy that will increase the company's competitive advantage (Krstić & Jovanović, 2022). The ability to innovate one's own business is the fundamental competitive advantage of every modern company (Janjić & Rađenović, 2019).

Often, high-tech companies choose to protect their inventions with a patent as a form of intellectual property. They do this in order to prevent competition from using the invention and to maintain their monopolistic status in the market. In this way, they are enabled to make extra profit the whole time during the protection period of their invention that is provided by having a patent for that invention. Also, they can decide to license the patents they own and earn income in that way. It is also possible for them to use patents for strategic purposes. For example, they can keep them in their portfolio waiting for the right moment to use them for commercial purposes or to simply prevent competitors from exploiting the invention. Companies may define a broader scope of invention protection than necessary, in order to protect themselves from potential litigation for future innovations and to create barriers for rivals to commercialize their inventions (Blind et al., 2006; Blind et al., 2009). When it comes to high-tech companies, it is known that they allocate significant funds for R&D and that they have the reputation of being intensively innovative companies. Patents, as a form of intellectual property, have a large share in the intellectual capital portfolio of high-tech companies. That is why these companies should disclose intangible assets in an additional report, as well as patents as a particular position within intangible assets. In this way, they send a signal to the environment that their focus is on innovation activity, which has a positive effect on investors and increases the value of the company's goodwill.

Numerous authors have examined the impact that patents have on business performance. Some of them indicated a positive impact of patents on a company's performance (Cho and Pucik, 2005), while others denied the existence of any impact (MacDonald, 2004) or even claimed that there is a negative impact (Artz et al., 2010). In this paper, the starting point is that there is a positive influence of R&D activities on patent activity, and then a positive impact of patent activity on the vital success indicators of high-tech businesses that have the largest number of patent applications according to the records of the WIPO.

1.2. Indicators of R&D activity and patenting

When considering R&D activity indicators, the most commonly used in empirical studies is *R&D investment (RD)*.

R&D investment (RD) is a key factor of progress, innovation and economic performance. It is a determinant of growth in productivity and competitiveness and a factor of sustainable and economic development. Investments in research and development cover all activities in creating innovative goods and services up to the point of market success. (Wesley & Wonglimpiyarat, 2020, p. 5). Investments in R&D that improve technological potential, are necessary in order to improve innovation ability and capacity. R&D expenditures are one of the most important determinants of innovation performance (Wang et al., 2013; Hunady et al., 2020). However, R&D investments include certain risks because they cannot be precisely predicted if they would result in success or failure in the near and further future.

The important fact that should be considered when examining the effect of R&D on corporate performance is that there is a certain time lag. That is because R&D activities need some time before they will be manifested in the innovative and financial indicators of a company (Lee & Lee, 2007; Rao et al., 2013; Yun & Kim, 2021).

There are many patent activity indicators that have been used in different studies and empirical research which reflect how the patent activities influence corporate performance. However, the majority of the studies used the number of patent applications and the number of granted patents as representative indicators for measuring patent activity.

The number of patent applications is a criterion1 of patent activity that is frequently used as a parameter of patent activity. It is logical to expect that the amount of patent applications has a beneficial effect on firm performance, despite quality considerations. Large patent portfolios are a sign of increased R&D activity and, consequently, higher levels of innovation. Large patent portfolios can also be strategically advantageous, such as obstructing rivals (Blind et al. 2006). A larger patent portfolio can also be utilized to keep out smaller possible rivals from operating in specific industries as well as increase the probability of licensing agreements or other types of trade with other companies. Additionally, the bigger patent output might be viewed as a good sign for the market.

The number of granted patents is another parameter of patenting activity that could indicate its success. The clarification of this measure is very simple because it may be considered that the procedure of granting the patent itself determines the value of patenting activity. Due to the fact that a granted patent has satisfied the requirements of novelty, advancement in technology, and commercial viability, it can be considered to be more valuable than a non-granted patent.

In order to explore the effect of patenting on business success indicators, many researchers have been aware of the time lag period that exists between the moment the patent was granted and the time when its usage starts to affect the business performance of the company. Therefore, they carried out their research by taking this fact into account (such as Cardinal (2010)).

1.3. The relation between R&D activity and business performance through patenting as a moderator

There are many studies in which the indirect effect of R&D activity on business success indicators has been investigated through its effect on patenting activity.

Yun & Kim (2021) explored the function that patents play in various R&D innovation activities, together with the implications of R&D innovation activities on the corporate management performance of innovative small and medium-sized enterprises (SME) in South Korea. These firms worked on innovative technology initiatives. The data for a five-year period (2015–2019) underwent panel regression and moderating impact analyses. The

findings demonstrated a significant positive impact of R&D on operating profit and revenue. This suggests that these activities contribute positively to management efforts. Therefore, from the standpoint of a corporate growth plan, firms should think about innovation activities realised by R&D investment. The outcomes of the research also revealed a favourable moderating influence of a firm's ability to hold patents on the effect R&D innovation activities have on business management performance.

Xu et al. (2022) examined the effect of corporate R&D input on patent performance and company operating income using regression analysis. The wastewater treatment companies were chosen for the research sample and the examined period is from 2013 to 2020. The findings indicate that the positive impact of R&D on operating income is moderated by patent activities (Xu et al., 2022).

Paula & Silva Rocha (2021) examined the impact of internal R&D and patent applications on business success on a sample of 751 enterprises from six Latin American countries. Their research results indicate that internal R&D has a beneficial impact on a company's performance which is measured by turnover growth, while patents have a negative impact. Patents are also impacted by internal R&D. Therefore, internal R&D has a negative indirect effect on performance.

Many studies show a positive role that patents have when considering the R&D activity influence on business performance; however, there are some studies that show the opposite, such as the study of Lanjouw and Schankerman (2004). Using a patent quality index, Lanjouw and Schankerman (2004) were able to demonstrate a negative relationship between the productivity of research in the firm and the patent quality index, but also a positive relationship between research productivity and the value of patented innovations at the market.

1.4. The relation between patenting and business performance

Some academicians have claimed and practically proven that patents have a positive influence on business performance (Cho & Pucik, 2005), whereas some argue there is no correlation between them (MacDonald, 2004). Others claim that a negative impact between patenting activity and business performance exists (Artz et al., 2010).

In his research of the patenting practices of American manufacturing companies, Mansfield (1986) discovered that while patents were crucial to innovation performance in a few industries, such as chemicals and pharmaceuticals, they were comparatively insignificant in other industries, including electrical goods, primary metals, instruments etc. Hagedoorn and Cloodt (2003) discovered a correlation between business success and an indicator compound of R&D inputs, number of patents, patent citations, and new product announcements. Oh (2003) sampled and experimentally assessed 89 firms from an initial sample of the top 150 businesses with the highest number of registered patents from 1998 to 2002. The number of patent applications had an impact on corporate growth, and it was determined that the number of applications per employee had an effect on productivity, proving that the quantitative aspect of patents was an important factor in financial performance. Despite not directly examining any performance metrics, Mann and Sager (2007) discovered that patenting in small firms in the software industry is positively connected with their survival.

Scherer (1965) analysed the impact of patent registrations on revenue, sales growth, and profit rates of 365 businesses from the Fortune 500 list as the subject of his research. He established that there is a positive relationship between the number of patent registrations and

the rate of sales growth and that the rise in sales has a beneficial effect on profits. Comanor & Scherer (1969), in their study of 57 businesses from pharmaceutical industry in the U.S., found that sales were affected by both the number of patent applications and registrations, with the number of patent applications having a bigger effect. The study by Ernst (1995) examined how corporate success is related to "patent activity" and "quality level of patent technology" of corporations. The corporate performance index and the patent index were used to confirm the link between the two variables and showed there is a strong correlation between them.

According to research by Ernst (2001), patents are useful tools for securing technological innovations and have a favourable effect on firm sales. According to Nerkar and Roberts (2004), sales income is positively correlated with a company's stock of patents. Also, Lee & Yoon (2006) proved that the number of granted patents had a substantial impact on sales and net profit margins in a study of 100 firms by implementing regression analysis. Additionally, Czarnitzki and Kraft (2010) discovered that a company's patent stock had a significant and consistent impact on profitability in their examination of a sample of companies from manufacturing in Germany. In their research, Yang et al. (2021) examined the influence of characteristics of patents on the performance of corporate management of SMEs. The sample they analysed consisted of 278 SMEs. The results of their research indicate that the independent variables (number of patents and the average score of patents) are relevant for differentiating between corporates that experienced an average sales growth rate that was greater than twice as high as that of SMEs in general and those that experienced growth less than twice as high (Yang et al., 2021).

Griliches (1981) discovered a strong correlation between firm market value of large American companies and what he refers to as its "intangible" capital, which was measured by prior R&D spending and the number of patents. Pakes (1985) demonstrated in his study the positive effect of successful patent applications on the market value of the company. The valuation of large Australian companies was examined by Bosworth and Rogers (2001). According to their research, there is a positive and strong correlation between R&D and patent activity on the one hand, and market value on the other as determined by Tobin's q. Using patents and citations from 1963 to 1999, Hall et al. (2005) discovered a positive relationship between business market value and the ratios of R&D to assets stocks, patents to R&D, and citations to patents. In their study of information and communication companies, Hall and MacGarvie (2010) discovered that companies with software patents had somewhat higher market values than those without software patents.

We can notice that many studies show a positive influence of patent activity on business performance, such as sales, earnings, market value, and profitability. However, there are some studies in which their results, partly or completely, show a negative influence of patent activity on business performance or no impact on it.

In the study of Griliches et al. (1991), the impact of patenting policies on changes in market value was examined. They discovered that patent factors have essentially no impact on market value. Neuhäusler et al. (2011) examined the influence of different patent indicators on a company’s market value in a sample of 479 firms, in a period from 1990 to 2007. The outcomes demonstrate an insignificant correlation between the number of patent applications and firm market value, suggesting that the patent portfolio's plain size is only a partial indicator of the technology base. The influence of the share of granted patents on firm market value could not be confirmed nor disproved because none of the models in their analysis had statistically significant results.

Artz et al. (2010) examined the link between the company's commitment to investments in R&D and the resulting innovative results (the number of patents granted and the number of new product announcements). Then, they examined the relationship between patents and product announcements. Finally, they examined the impact of innovative results on return on assets (ROA) and sales growth. They tested their hypotheses on a sample of 272 companies from 35 industries. The results of their research indicate that investments in R&D have a positive influence on the number of granted patents and that the number of granted patents has a positive effect on product announcements, and product announcements have a positive impact on ROA and sales growth. However, a negative impact of granted patents on ROA and sales growth was established. These outcomes might be a result of the rise of strategic patenting, in which more businesses are employing patents as tactical tools.

Andries & Faems (2013) examined the effects of patenting on licensing, innovation, and financial success in a sample of 358 manufacturing companies. Their study shows that patenting helps SMEs commercialize product ideas. Furthermore, improved innovation performance leads to larger profit margins. The ability of companies to license knowledge to outside parties is also increased by patenting operations, and this beneficial effect is noticeably stronger for large companies. However, neither SMEs nor major corporations benefit financially in the short term from these external licensing operations. The study also shows that neither SMEs nor large businesses have significant cost disadvantages as a result of their patenting operations.

Lee et al. (2015) research the varied impacts of patents on sales, earnings, and market value in 28 international IT businesses, including patents generated from a) internal R&D, b) collaboration between university and industry, and c) transactions. They discovered that internal R&D-generated patents improve sales, profits, and market value. Purchased patents do not improve sales, but they do have minor, short-term beneficial effects on market value and profit. Patents developed by university-industry partnerships increase sales after more than two years, but they decrease market value. Internal R&D is continuously crucial for long-term business expansion, suggesting that the best way to foster inbound open innovation is by acquiring concepts, technology, and talent for internal R&D. Short-term growth is boosted by purchased patents, whereas medium and long-term growth depends on university-industry partnerships.

Garavito Hernandez & Rueda Galvis (2021) investigated the innovation and contribution of the registration of patents to the sales growth on a sample of 1,746 companies in Colombia in the manufacturing sector. Their findings confirm that patent registration has a detrimental impact on business efficiency. However, the research results show a positive correlation between incremental product improvements and the achievement of sales success.

2. METHODOLOGY OF RESEARCH

The goal of this study is to explore the impact of R&D and patent activity indicators on the business performance of companies in the high-tech sector. The research is based on the data of the following indicators: R&D activity indicator - R&D investment (RD); Patent activity indicators - Number of granted patents (NGP), Published PCT applications (PPCTA); Business performance - Sales revenue (SR), Gross profit (GP), Operating profit (OP), Earnings before interest and taxes (EBIT), Earnings before interest, taxes, depreciation and amortization (EBITDA), Market capitalisation (MC), Return on equity (ROE).

Therefore, Figure 1 shows the research model.

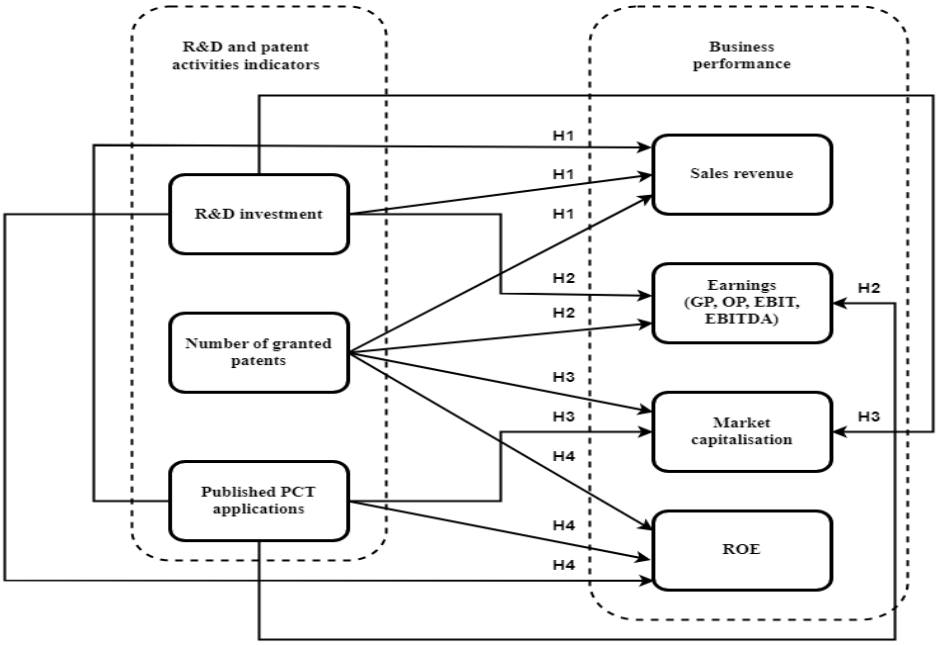

Fig. 1 Research conceptual framework
Source: Authors' presentation

The variables used in the research are explained and their computation process is presented.

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

The number of granted patents (NGP) represents the number of patents granted by USPTO (*USPTO* is the abbreviation of *United States Patent and Trademark Office*), 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 PCT. The PCT helps patent applicants in the process of patent protection, aids patent offices with their positive decisions for granting patents, and is a source of technical information relating to those inventions which is available to public. The PCT allows applicants to get protection for an invention in 157 contracting states simultaneously by filing a single international patent application.

SR, GP and OP are already calculated and presented in the companies' income statements. The following formula shows how the EBIT is computed (Krstić, 2022):

$$EBIT = Net\ profit + Income\ tax + Other\ taxes \pm Net\ financial\ profit\ (loss) \quad (1)$$

EBITDA allows comparisons of businesses operating in various nations and industries, with various internal finance policies, as well as accounting procedures for depreciation of tangible and amortization of intangible assets, EBITDA is an analytically better indicator. The following formula shows how the EBITDA is computed (Krstić, 2022):

$$EBITDA = EBIT + Depreciation + Amortization \quad (2)$$

MC is computed using the following formula:

$$MC = Number\ of\ shares * Share\ price \quad (3)$$

ROE is a traditional measure of company's profitability and it is calculated in the following way:

$$ROE = GP : E \quad (4)$$

In the previous formula, GP stands for Gross profit and E stands for equity which is calculated in the following way (Krstić, 2022):

$$E = Total\ assets - Total\ liabilities - Non\text{-}controlling\ interests \quad (5)$$

The following hypotheses were defined bearing in mind the various research presented in the literature review:

Hypothesis H1:
The R&D investment, Number of granted patents and Published PCT applications have a positive impact on the Sales revenue in the following year.

Hypothesis H2:
The R&D investment, Number of granted patents and Published PCT applications have a positive impact on the Gross profit, Operating profit, EBIT and EBITDA in the following year.

Hypothesis H3:
The R&D investment, Number of granted patents and Published PCT applications have a positive impact on the Market capitalization in the following year.

Hypothesis H4:
The R&D investment, Number of granted patents and Published PCT applications have a positive impact on the ROE in the following year.

The financial statements of the 33 high-technology companies that are on the WIPO's Top 50 PCT applicants list in the period from 2013 to 2020 were the database for this research. The other 17 companies were not included in the sample because they were not continuously on the WIPO's Top 50 PCT applicants list during the research period. The selected companies for this research, according to the mentioned criterion are: 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. By studying annual reports of the named companies, WIPO's PCT yearly review, USPTO's website and other publicly available databases, secondary data was obtained to calculate research variables and conduct analysis. 264 observations are covered by the analysis.

In the first two models, RD is an independent variable, while NGP and PPCTA are dependent variables. In the next two models, RDI is an independent variable, while NGP and PPCTA are dependent variables. In the next two models, RORDI is an independent variable, while NGP and PPCTA are dependent variables. In the seventh-thirteenth model, the influence of NGP on SR, GP, OP, EBIT, EBITDA, MC and ROE is assessed. The last seven models explore the influence of PPCTA on SR, GP, OP, EBIT, EBITDA, MC and ROE.

The Stata program (version 12.0) was used to test the suggested framework.

First, natural logarithm values were used to transmit all raw data.

Second, in 20 study models, panel regression analysis was performed to assess the impact of the independent variable on the dependent variable.

Finally, the fixed-effect model (FEM) and random effect model (REM) were tested following the identification of a balanced dataset and confirmation that the assumptions are true. The Hausman test was then run on each model to determine whether to use FEM or REM. The significance level for the Hausman test was set at 0.05. All results statistically significant less than 0.05 suggest the use of FEM, in other cases, when statistical significance is above 0.05, REM should be used (Gujarati, 2004).

3. RESULTS OF EMPIRICAL RESEARCH

The following part of the work presents the research models, which are examined using panel regression analysis of the data. First, Table 1 presents the effects of Research and development investment (RD) influence on business performance.

Table 1 Panel regression results – R&D investment as a predictor

Independent variable	Research models						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	ln SR FEM	ln GP FEM	ln OP FEM	ln EBIT FEM	ln EBITDA FEM	ln MC FEM	ln ROE FEM
Constant	7.848	7.206	6.851	6.985	5.371	9.236	4.277
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ln L1RD	.444	.384	.282	.266	.498	.333	-.125
	(0.000)	(0.000)	(0.047)	(0.063)	(0.000)	(0.000)	(0.000)
F / χ^2	**210.87**	**103.87**	**3.99**	**3.51**	**52.89**	**22.97**	**13.39**
	(0.000)	**(0.000)**	**(0.047)**	**(0.063)**	**(0.000)**	**(0.000)**	**(0.015)**
R^2	.997	.995	.942	0.941	0.985	0.987	0.895

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

The explanation of the panel regression results where R&D investment is a predictor are given in Table 2.

Table 2 The explanation of the panel regression results – R&D investment as a predictor

Models	Explanation of the results
Model 1 measures the influence that RD has on SR in the following year. The positive influence is hypothesized.	The model explains 94.7% variation in data, and it is statistically significant (F = 210.87, p = 0.000). If RD increases by 1%, SR will increase by 0.444% in the following year and its effect is statistically significant at the 0.01 significance level.
Model 2 measures the influence that RD has on GP in the following year. The positive influence is hypothesized.	The model explains 99.5% variation in data and is statistically significant (F = 103.87, p = 0.000). If RD increases by 1%, GP will increase by 0.384% in the following year and its effect is statistically significant at the 0.01 significance level.
Model 3 measures the influence that RD has on OP in the following year. The positive influence is hypothesized.	The model explains 94.2% variation in data and is statistically significant (F = 3.99, p = 0.047). If RD increases by 1%, OP will increase by 0.282% in the following year and its effect is statistically significant at the 0.05 significance level.
Model 4 measures the influence that RD has on EBIT in the following year. The positive influence is hypothesized.	The model explains 94.1% variation in data and is statistically significant (F = 3.51, p = 0.063). If RD increases by 1%, EBIT will increase by 0.266% in the following year and its effect is statistically significant at the 0.1 significance level.
Model 5 measures the influence that RD has on EBITDA in the following year. The positive influence is hypothesized.	The model explains 98.5% variation in data and is statistically significant (F = 52.89, p = 0.000). If RD increases by 1%, EBITDA will increase by 0.498% in the following year and its effect is statistically significant at the 0.01 significance level.
Model 6 measures the influence that RD has on MC in the following year. The positive influence is hypothesized.	The model explains 98.7% variation in data and is statistically significant (F = 22.97, p = 0.000). If RD increases by 1%, MC will increase by 0.333% in the following year and its effect is statistically significant at the 0.01 significance level.
Model 7 measures the influence that RD has on ROE in the following year. The positive influence is hypothesized.	The model explains 89.5% variation in data and is statistically significant (F = 13.39, p = 0.015). If RD increases by 1%, ROE will decrease by 0.125% in the following year and its effect is statistically significant at the 0.05 significance level.

Source: Authors' calculations

Based on the explanation of the results in Table 2, we can conclude that models 1-7 are statistically significant. The positive impact of R&D investment on the indicators SR, GP, OP, EBIT, EBITDA, and MC – was confirmed. However, when it comes to the impact of R&D investment on return on equity, a negative impact was found. The high value of the variance of the dependent variable in all models, which is explained by the influence of R&D investment, means that R&D investment is a significant factor of the value of business performance of high-tech companies.

Table 3 illustrates how the Number of granted patents (NGP) influences previously mentioned business performances.

The explanations of the panel regression results where the Number of granted patents is a predictor are given in Table 4.

Table 3 Panel regression results – NGP as a predictor

Independent variable	Research models						
	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
	ln SR REM	ln GP REM	ln OP FEM	ln EBIT FEM	ln EBITDA REM	ln MC REM	ln ROE REM
Constant	9.599 (0.000)	8.662 (0.000)	7.855 (0.000)	7.838 (0.000)	7.588 (0.000)	10.940 (0.000)	3.073 (0.000)
ln L1NGP	.327 (0.000)	.290 (0.000)	.226 (0.088)	.228 (0.088)	.326 (0.000)	.182 (0.007)	.150 (0.015)
F / χ^2	**104.04 (0.000)**	**58.15 (0.000)**	**2.93 (0.088)**	**2.94 (0.088)**	**22.79 (0.000)**	**7.31 (0.007)**	**5.97 (0.015)**
R^2	.346	.226	.944	0.942	0.094	0.028	0.018

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

Table 4 The explanation of the panel regression results – NGP as a predictor

Models	Explanation of the results
Model 8 measures the influence that NGP has on SR in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 104.04$, $p = 0.000$). If NGP increases by 1%, SR will increase by 0.327% in the following year and its effect is statistically significant.
Model 9 measures the influence that NGP has on GP in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 58.15$, $p = 0.000$). If NGP increases by 1%, GP will increase by 0.29% in the following year and its effect is statistically significant.
Model 10 measures the influence that NGP has on OP in the following year. The positive influence is hypothesized.	The model explains 94.4% variation in data and is statistically significant ($F = 2.93$, $p = 0.088$). If NGP increases by 1%, OP will increase by 0.226% in the following year and its effect is statistically significant at the 0.1 significance level.
Model 11 measures the influence that NGP has on EBIT in the following year. The positive influence is hypothesized.	The model explains 94.2% variation in data and is statistically significant ($F = 2.94$, $p = 0.088$). If NGP increases by 1%, EBIT will increase by 0.228% in the following year and its effect statistically significant at the 0.1 significance level.
Model 12 measures the influence that NGP has on EBITDA in the following year. The positive influence is hypothesized.	Model fit is significant at the level of $p < 0.01$ ($\chi^2 = 22.79$, $p = 0.000$). If NGP increases by 1%, EBITDA will increase by 0.326% in the following year and its effect is statistically significant.
Model 13 measures the influence that NGP has on MC in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 7.31$, $p = 0.007$). If NGP increases by 1%, MC will increase by 0.182% in the following year and its effect is statistically significant.
Model 14 measures the influence that NGP has on ROE in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 5.97$, $p = 0.015$). If NGP increases by 1%, ROE will increase by 0.15% in the following year and its effect is statistically significant.

Source: Authors' calculations

Data in Table 4 indicate that the models 9-14 are statistically significant. The positive impact of the Number of granted patents on all indicators of business performance in the following year - SR, GP, OP, EBIT, EBITDA, MC, and Return on equity – was confirmed.

Table 5 presents the results of Published PCT applications (PPCTA) influence.

Table 6 gives the explanations of the panel regression results where Published PCT applications is a predictor.

Table 5 Panel regression results – PPCTA as a predictor

Independent variable	Research models						
	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20	Model 21
	ln SR REM	ln GP REM	ln OP REM	ln EBIT REM	ln EBITDA REM	ln MC REM	ln ROE REM
Constant	10.811 (0.000)	9.666 (0.000)	6.244 (0.000)	6.289 (0.000)	8.174 (0.000)	10.822 (0.000)	3.155 (0.000)
ln L1PPCTA	.146 (0.005)	.140 (0.012)	.439 (0.009)	.432 (0.011)	.236 (0.012)	.197 (0.023)	.123 (0.087)
F / χ^2	**7.79 (0.005)**	**6.27 (0.012)**	**6.77 (0.009)**	**6.47 (0.011)**	**6.38 (0.012)**	**5.18 (0.023)**	**2.93 (0.087)**
R^2	.035	.012	.028	.027	.028	.023	.002

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

Table 6 The explanation of the panel regression results – PPCTA as a predictor

Models	Explanation of the results
Model 15 measures the influence that PPCTA has on SR in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 7.79$, $p = 0.005$). If PPCTA increases by 1%, SR will increase by 0.146% in the following year and its effect is statistically significant.
Model 16 measures the influence that PPCTA has on GP in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 6.27$, $p = 0.012$). If PPCTA increases by 1%, GP will increase by 0.14% in the following year and its effect is statistically significant.
Model 17 measures the influence that PPCTA has on OP in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 6.77$, $p = 0.009$). If PPCTA increases by 1%, OP will increase by 0.439% in the following year and its effect is statistically significant.
Model 18 measures the influence that PPCTA has on EBIT in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 6.47$, $p = 0.011$). If PPCTA increases by 1%, EBIT will increase by 0.432% in the following year and its effect is statistically significant.
Model 19 measures the influence that PPCTA has on EBITDA in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 6.38$, $p = 0.012$). If PPCTA increases by 1%, EBITDA will increase by 0.236% in the following year and its effect is statistically significant.
Model 20 measures the influence that PPCTA has on MC in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 5.18$, $p = 0.023$). If PPCTA increases by 1%, MC will increase by 0.197% in the following year and its effect is statistically significant.
Model 21 measures the influence that PPCTA has on ROE in the following year. The positive influence is hypothesized.	The model is statistically significant ($\chi^2 = 2.93$, $p = 0.087$). If PPCTA increases by 1%, ROE will increase by 0.123% in the following year and its effect statistically significant at the 0.1 significance level.

Source: Authors' calculations

It can be noted, according to the explanation of the results in Table 6, that the models 15-21 are statistically significant. The positive impact of the published PCT applications on all indicators of business performance in the following year - SR, GP, OP, EBIT, EBITDA, MC, Return on equity – was confirmed.

Having in mind all the presented results it is noticeable that the research hypotheses H1, H2 and H3 have been confirmed. However, the research hypothesis H1 has been partly confirmed.

4. DISCUSSION

The research results indicate that the first hypothesis has been confirmed, i.e. the positive impact of R&D investment, number of granted patents and published PCT applications on the sales revenue in the following year has been determined. The positive impact of investment in R&D on sales revenue was also determined in the research of Yun & Kim (2021). Furthermore, the positive impact of the number of patents on sales revenue was identified within the study of Scherer (1965), while the research of Comanor & Scherer (1969) and Ernst (1995) discovered the positive impact of the number of patent applications and the number of patents on sales revenue. Similar conclusions are present in the research of Ernst (1995), Ernst (2001), Nerkar and Roberts (2004), Lee & Yoon (2006) and Yang et al., 2021. Lee et al. (2015) point out that internal R&D-generated patents and patents developed by partnerships between university and industry increase sales; however, purchased patents do not improve sales. On the other hand, Artz et al. (2010) and Garavito Hernandez & Rueda Galvis (2021) found a negative impact of the number of recognized patents on sales revenue. Such a situation is possible due to the preservation and use of the patent for strategic purposes. Given the established positive impact of R&D activities and patent activity on the sales revenue of high-tech companies, they should view their investments in R&D and their patent portfolio as a strategic means of increasing market share.

The second hypothesis that the R&D investment, number of granted patents and published PCT applications have a positive impact on the GP, OP, EBIT, EBITDA in the following year has been confirmed. Yun & Kim (2021) have come to the same conclusion regarding the effect of R&D investment on operating profit. Xu et al. (2022) reached a similar conclusion when the influence of patent activity, as a moderator of the influence of R&D activities, on operating profit is in question. Lee et al. (2015) found that internal R&D-generated and purchased patents have beneficial effects on profit. On the other hand, Andries & Faems (2013) indicate that companies do not realize positive financial effects in the short term from their patent activity. Considering the established positive impact of indicators of research and development activities and patent activity on profit, high-tech companies should see these activities as a generator of corporate growth.

The third hypothesis was also confirmed, that is, the research and development investment, number of granted patents and published PCT applications have a positive impact on the MC in the following year. The results of the Griliches (1981) research are in agreement with the stated conclusion. Within the study, a positive influence of R&D expenditures and the number of patents on the market value was determined. The positive impact of successful patent applications on the market value of companies was proven in the research of Pakes (1985). A significant positive correlation of R&D activities and patent activities, on the one hand, and the market value of companies, on the other, was also

determined in the research of Bosworth and Rogers (2001), Hall et al. (2005) and Hall and MacGarvie (2010). However, Griliches et al. (1991) and Neuhäusler et al. (2011) found in their studies that there is no impact of patent activity on market value. Lee et al. (2015) discovered that patents which are results of internal R&D activity and purchased patents increase market value, while patents developed by university-industry partnerships decrease it. The positive impact of R&D activities and patent activity on the market value of high-tech companies, which was established in this research, indicates the importance of innovativeness of companies and that the market recognizes, values and rewards it.

The fourth hypothesis that the research and development investment, number of granted patents and published PCT applications have a positive impact on the return on equity in the following year has been partially confirmed. The positive impact has been proven regarding the influence of the number of granted patents and published PCT applications on the return on equity in the following year. However, the influence of the R&D investment on the return on equity in the following year is negative. In the research of Czarnitzki and Kraft (2010) and Andries & Faems (2013), the positive impact of patent activity on profitability was confirmed. On the other hand, Artz et al. (2010) found a negative impact of the number of recognized patents on profitability. For high-tech companies that have significant investments in R&D, it is important to keep in mind the longer period of time needed to achieve a return on investment that ensures a satisfactory level of profitability.

Bearing in mind the research results of this study, as well as the research results of the studies presented within the literature review, it can be noted that the originality of this study is reflected in studying the influence of patent activity indicators on GP, EBIT, EBITDA and return on equity.

6. CONCLUSION

The research investigates the effect of R&D activities and patent activities on the business performance of high-tech companies. The indicator of research and development activities that was used in the empirical part of the work is Research and development investment. Indicators of patent activity, that were also used in the empirical part of the work, are the number of granted patents and published PCT applications. Business performance indicators on which the impact of patent activity indicators was examined are: sales revenue, gross profit, operating profit, earnings before interest and taxes, earnings before interest, taxes, depreciation and amortization, market capitalization and return on equity.

The first hypothesis that the research and development investment, number of granted patents and published PCT applications have a positive impact on the sales revenue in the following year, has been confirmed. This is in accordance with the conclusions of research such as Comanor and Scherer (1969), Lee and Yoon (2006), Yang et al. (2021), Yun & Kim (2021), etc.

The second hypothesis that the research and development investment, number of granted patents and published PCT applications have a positive impact on the gross profit, operating profit, earnings before interest and taxes, earnings before interest, taxes, depreciation and amortization in the following year has been confirmed. Yun & Kim (2021) have come to the same conclusion regarding the impact of research and development investment on operating profit. Xu et al. (2022) reached a similar conclusion when the

influence of patent activity, as a moderator of the influence of R&D activities, on operating profit is in question.

The third hypothesis that the research and development investment, number of granted patents and published PCT applications have a positive impact on the market capitalization in the following year has been confirmed. Research such as Hall et al., (2005), Hall and MacGarvie (2010), Lanjouw and Schankerman (2004) etc. reach the same conclusion.

The fourth hypothesis that the research and development investment, number of granted patents and published PCT applications have a positive impact on the return on equity in the following year has been partly confirmed. The positive impact has been proven regarding the influence of the number of granted patents and published PCT applications on the return on equity in the following year. However, the influence of the research and development investment on the return on equity in the following year is negative. In the research of Czarnitzki and Kraft (2010) and Andries & Faems (2013), the positive impact of patent activity on profitability was also confirmed.

The originality of this study is reflected in studying the influence of patent activity indicators on gross profit, earnings before interest and taxes, earnings before interest, taxes, depreciation and amortization and return on equity.

However, there are some limitations that we encountered through our research. The companies in the analysed sample were chosen by using the criterion that they were on the WIPO's Top 50 patent applicants list in the period from 2013 to 2020. 33 out of 50 companies were on the list throughout the examined period and the data for the other 17 companies was unavailable since they were not on that list every year through the examined period. Also, the patent activity indicator - Number of granted patents included only patents that were granted by the USPTO, which is one of the 5 biggest national patent offices and it has and shares the statistics on the number of granted patents by organisations. That is not the case with other intellectual property offices. Usually, the data presented by other national intellectual property offices, which refers to patent statistics, includes the number of granted patents by countries, or only the statistics about patent applications (such as the European Patent Office).

The research results contribute to the management of high-tech companies in making future decisions in the field of R&D and intellectual property, as well as to the management of business performance. Namely, the positive impact of R&D investment on all observed business performance, except for return on equity, indicates that it is necessary to make decisions about investments rationally and thoroughly, bearing in mind the longer period of time required to realize the return on investments in R&D that implies a positive impact on the profitability of the company. Managers of intellectual property should strive to maximize the positive impact that patents have on business performance when making decisions related to the use of the patent portfolio. Finally, managers managing business performance should have built-in coordination and communication with the previously mentioned management in order to align the decisions and timing of their realization in the field of R&D and intellectual property with the financial aspect of a business.

This research indicates and confirms the importance that R&D activity, as well as patenting activity, have on the business performance of high-tech companies. In this research, the direct influence of independent on dependent variables, namely the indicators of R&D activities and patent activities on the indicators of business performance has been examined. It is recommended for future research that control variables, which will be related to the size of

the company or the sector in which it operates, should be included in the analysis. It is also desirable to continue and expand the research, by examining the impact of research and development and patenting activity on business performance in the next 2 to 5 years. This research examines their impact on business performance in the following year. Regarding that R&D and patenting activities require a certain time in order to maximize their benefits for the company, it is necessary to take a longer period into account when examining the impact of these activities on business performance. That is in order to obtain a precise conclusion about the effectiveness and efficiency of investing in these activities, which are the core of recognition and differentiation of high-tech companies on the market and the factor of their competitiveness and business success.

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UTICAJ AKTIVNOSTI ISTRAŽIVANJA I RAZVOJA I PATENTNE AKTIVNOSTI NA POSLOVNE PERFORMANSE: SLUČAJ VISOKO-TEHNOLOŠKIH KOMPANIJA

Cilj rada je da se utvrdi uticaj aktivnosti istraživanja i razvoja i patentne aktivnoti na poslovne performanse visokotehnoloških kompanija sa najvećim brojem patentnih prijava prema evidenciji Svetske organizacije za intelektualnu svojinu.

Itsraživački uzorak čine 33 visokotehnološke kompanije koje se kontinuirano nalaze na ovoj listi Top 50 PCT aplikanata Svetske organizacije za intelektualnu svojinu u periodu od 2013. do 2020. godine. Regresiona analiza je primenjena kako bi se utvrdio uticaj aktivnosti istraživanja i razvoja i aktivnosti patenta na poslovne performanse visokotehnoloških kompanija.

Istraživanje potvrđuje značaj istraživačko-razvojne i patentne aktivnosti za poslovanje visokotehnoloških kompanija. Ova studija je otkrila da ulaganja u istraživanje i razvoj, broj odobrenih patenata i broj objavljenih PCT prijava imaju pozitivan uticaj na prihod od prodaje, bruto dobit, poslovnu dobit, zaradu pre kamata i poreza, zaradu pre kamata, poreza, deprecijacije i amortizacije, tržišnu kapitalizaciju. Pozitivan uticaj indikatora patentne aktivnosti na prinos na kapital je takođe prisutan, međutim, uticaj ulaganja u istraživanje i razvoj na prinos na kapital je negativan.

Evaluacija predstavljenih rezultata može poslužiti kao osnova za dalje zaključke, doprineti postojećoj literaturi i strategiji istraživačko-razvojne i patentne aktivnosti visokotehnoloških kompanija.

Originalnost ove studije ogleda se u proučavanju uticaja indikatora patentne aktivnost - broj odobrenih patenata i broj objavljenih PCT prijava - na bruto dobit, zaradu pre kamata i poreza, zaradu pre kamata, poreza, amortizaciju i prinos na sopstveni kapital.

Ključne reči: *istraživanje i razvoj, patentna aktivnost, poslovne performanse, visokotehnološke kompanije*