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The effects of R&D performance on the profitability of highly innovative companies

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Abstract
Background: In modern business conditions, intangible assets have a dominant impact on the business performance of the company. R&D activities, the level of R&D investments and the efficiency of R&D investments affect company profitability. There are various performance indicators of R&D activities that have an impact on profitability.
Purpose: Bearing in mind that R&D is the precondition of growth and development of the company, as well as the efficiency of R&D investments, is the key determinant of economic corporate responsibility, the purpose of this paper is to investigate the effects of various performance indicators of R&D activities on companies' profitability. The aim of this paper is to investigate the effects of R&D investments, R&D intensity and return on R&D capital on the profitability of highly innovative companies.
Study design/methodology/approach: Correlation, regression and cluster analyses were performed to provide an empirical investigation of the impact of key R&D performance indicators on the return on assets (ROA) of highly innovative companies, which are on the list of the top R&D spenders in the world. The data for the analysis comprises 24 R&D-intensive companies for the period 2013-2021.
Findings/conclusions: The regression analysis results conducted on the determined clusters show that all three analyzed indicators of R&D activities have a positive and statistically significant impact on ROA in highly R&D-intensive companies. It is confirmed that the effects of various indicators of R&D activities are bigger in companies with higher RDII.
Limitations/future research: The sample encompasses the 24 companies listed among the top 50 R&D spenders worldwide, which is considered insufficient for extensive analysis. The other limitation is related to the short research period. As the R&D activities produce yields after several years, the possible direction for future research is to investigate the impact of accumulated R&D investment over several years on ROA.

Keywords
R&D investments; R&D intensity; return on R&D capital; profitability; efficiency; innovation; top R&D spenders

Introduction

In science and technology-based companies, R&D is a crucial input in creating new knowledge and products, generating future returns, as well as gaining and maintaining higher profitability in comparison to market rivals. To gain a competitive advantage in a rapidly changing, uncertain and competitive environment, a company needs to improve its business performance through efficient use of R&D investment with the aim of better R&D outputs and outcomes. Consequently, they will positively contribute to the enhancement of various financial and non-financial performances. Nowadays, every company strives to improve the efficiency of R&D investments in order to boost revenues, profits, labor productivity, profitability, technological innovation and competitiveness (Veselinović & Veselinović, 2019). Innovation activities or R&D activities affect business performance. According to Jin and Choi (2019), improvements in product innovation, as well as R&D investment and research resources, have a favorable impact on business performance (i.e., revenue and labor productivity).

Many companies choose to invest their revenue in R&D activity, as a valuable instrument of competitive struggle, in order to achieve expected returns in the future. In the technology era, those firms which allocate a higher level of investment in those activities are expected to earn more and generate higher levels of business performance than other companies which invest less (Chao, 2011). R&D-intensive companies will gain higher returns, and the positive relationship between R&D investment and returns is primarily due to risk compensation (Amoroso, Moncada-Paterno-Castello & Vezzani, 2017).

Considering all these facts, the aim of the paper is to empirically verify the importance of growing R&D investments, R&D intensity and efficiency of R&D investments for increased return on assets (ROA), as a vital indicator of the company's profitability. The structure of this paper is organized as follows. After the introduction, the next section provides a literature review of the main determinants of R&D activity and investments, as well as the existing literature on the relationship between R&D expenditures, R&D intensity indicator, the return on R&D investments and ROA. The following section focuses on the research methodology and is followed by the empirical data analysis. The last section provides the research results and discussions of empirical findings.

1. Literature review

1.1. R&D investments

During the last thirty years, the knowledge economy has achieved dominance based on the fact that the value of tangible assets has been decreased and replaced by the value of intangible assets (Petković, Krstić, & Rađenović, 2020; Paula & Silva Rocha, 2021). The business success or competitiveness of an enterprise increasingly depends on R&D as an element of structural intangible (intellectual) assets, which "includes employees, structural intellectual capital and employee relations with the enterprise stakeholders" (Jovanović, Petrović & Janjić, 2021). The survival and success of the company in the marketplace depend on the introduction of innovative changes in the company and the undertaking of R&D activities. In the conditions of rapid technological changes and highly competitive markets, R&D plays a critical role in establishing a competitive advantage, labor productivity, sales and profit growth. R&D activities are seen as a key stimulus to the innovative activities of companies and national economies. Innovation has been acknowledged as a very important factor influencing development (Cicea, Lefteris, Marinescu, Popa & Albu, 2021). Without effective R&D activities, innovation development in companies and national economies cannot be expected. Therefore, it is necessary to examine the performance of R&D activities at various levels (Janjić, Jovanović. & Simonović, 2021).

In the era of knowledge-based economies, R&D investments are essential for the success and survival of companies and national economies (Li, Nosheen, Haq & Gao, 2021; Dai, Fan, Wang & Xie, 2022). The most significant feature of R&D investment is its cumulative nature, which can lead to overall higher returns. Both the high level of uncertainty and risk and the specificity of the business model distinguish R&D investments from other types of investments, by their nature and other particular features. R&D activities are recognized as a major source of visible potential returns, reflected in growing sales revenue, profitability, market capitalization, business competitiveness, employment, and socio-economic welfare (Hall, Mairesse & Mohnen, 2010).

R&D investments are one of the most crucial elements in scientific and technological progress and present a significant source and basis of innovation (Wang, Lu, Huang & Lee, 2013). It is considered a dominant factor in the development and sustainability of the company (Dimitropoulos, 2020). R&D activities of companies are the main factor in enhancing their future financial performance and development. Some empirical studies have proved that the growth in R&D investments is positively correlated with future returns (profits) (Chan, Lakonishok & Sougiannis, 2002; Eberhart, Maxwell & Siddique, 2004; Tung & Binh, 2021). R&D investments do not generate immediate results and returns. Reasons leading to a gap between R&D investments and the return on those investments are related to the fact that some R&D outputs appear slowly and are short-lived, while others are long-lasting or used in future R&D.

1.2. Significance of R&D investments for profitability

Many researchers have used Return on Assets (ROA) and Return on Equity (ROE) indicators to determine the effects of R&D expenditures on profitability. Conducted studies at the beginning of the 21st century found a positive and consistent impact of R&D investment on business profitability (Roberts, 2001; Chen, Cheng & Hwang, 2005; Shah, Stark & Akbar, 2008; Ehie & Olibe, 2010; Pindado, De Queiroz & Torre, 2010; Ayaydin & Karaaslan, 2014; VanderPal, 2015; Freihat & Kanakriyah, 2017; Pan, Guo & Chu, 2021; Boiko, 2022). Serrasqueiro (2009) used dynamic panel estimators to research the sample of the 500 largest Portuguese companies for the period 1999-2003. The research's empirical results showed a positive and statistically significant association between growth and profitability in Portuguese companies. For example, Shin, Kraemer and Dedrick (2009) analyzed a data set of 200 firms in the electronic industry for the period 2000-2005, and the results revealed a positive and statistically significant relationship between R&D spending and gross profit, while the relationship between R&D expenditures, ROA and ROE was not statistically significant. Similarly, a sample of the world's top 20 pharmaceutical companies in 2010 showed that R&D expenditures had an important impact on sales and profitability, according to the regression analysis (Hajiheydari, Dastgir & Soltani, 2011) The study that included 187 firms in Portugal for the period 2002-2009, detected a significant and positive effect of R&D expenditures on profitability (Nunes & Serrasqueiro, 2015). If the period of observation in the analysis differs, the study (Kiraci, Celikay & Celikay, 2016), which was based on a sample of 46 publicly traded manufacturing firms listed on the Borsa Istanbul for the period 1998-2012, proved that R&D expenditure does not have a statistically significant impact on short-term profitability, while on the other hand exist a significant, positive and strong impact on long-term profitability.

The company's profitability may also be affected by the turnover of its assets (Pervan & Mlikota, 2013). Erdogan and Yamaltidona (2019) also revealed a positive association between R&D and profitability performance (ROA and ROE), in the sample of 62 production firms for the period 2008-2017, as well as Hazarika (2021) in the sample of 24 energy companies for the period 2007-2016. The regression analysis results showed a negative and linear impact of R&D intensity on ROA, while the effect of R&D intensity on ROE was statistically insignificant. Some recent research (Tung & Binh, 2021; Pham, Nguyen & Hoang, 2021) proved that R&D investments (spending) have a positive influence on revenues, profits, ROA, and ROE. Furthermore, the regression results imply that companies with high R&D outperform those with low R&D in terms of profit, revenue and ROA.

It is also useful to look at these relations in crisis conditions. Dimitropoulos (2020) used a sample of Greek firms for the period 2003–2016, to investigate the impact of R&D investments on profitability. Based on regression results, he stated that before the crisis R&D expenses had a negative impact on profitability, but during the crisis (2011-2016) the level of R&D investments improved profitability. Interestingly, there is evidence to the contrary. Namely, some studies (Kounnou & Kyrkilis, 2020) proved that the influence of R&D on profitability has no statistical significance.

1.3. Significance of R&D intensity for profitability

In the last 20 years, the impact of R&D intensity on firm performance has attracted the attention of many researchers, policymakers, and practitioners. R&D intensity (measured by Research intensity or R&D intensity) is crucial for assessing technical efficiency and innovative activity (Chao & Kavadias, 2013; Leung & Sharma, 2021). Based on the literature, R&D intensity is recognized as an

important indicator for determining the firm's strategic use of R&D (Lin, Lee & Hung, 2006).

When it comes to the relationship between R&D intensity and business performance, Zhaohui and Xiaokangs (2011) conducted research in China on a sample of medical and biochemical manufacturers and proved a weak, but significant correlation between R&D intensity and business performance in the same year, as well as a strong and considerable association between R&D intensity and business performance in the following year. Similarly, Dave, Wadhwa, Aggarwal and Seetharman (2013) detected a powerful connection between R&D intensity and gross profit. Other studies (Chao & Kavadias, 2013) proved that a balance between R&D intensity and the portfolio strategy of new product development facilitated company profitability. In accordance with that, Jaisinghani (2016) analyzed the business performances of 55 Indian pharmaceutical companies for the period 2005-2014. The dynamic panel data and generalized method of moments showed that R&D intensity and business performance are positively correlated.

Most previous studies have reported a positive link between R&D intensity and firm performance, but some findings indicate negative relations or no relations at all (Chandler and Hanks 1994). Kim and Kim (2018) proved that the negative impact of environmental costs on a company's profitability as measured by its Return on Assets (ROA) is reduced (decreased), as the firm's R&D intensity increases. According to Chen, Guo, Chen and Wei, (2019), R&D intensity does not always correlate with a company's performance. In their research, ROA is negatively correlated with R&D intensity during the first period when R&D investment is made, while R&D has a negative impact on ROA. There are also opposite findings. Bloemendaal (2020) discovered a negative correlation between R&D intensity and profitability indicators (ROE and ROA), as well as a negative impact of R&D on financial performance. Other authors (Rasvelj & Aristovnik, 2020; Leung & Sharma, 2021) also revealed the same. Ravšelj and Aristovnik (2020) found that R&D intensity is negatively correlated with ROA, ROE and ROS (return on sales). Leung and Sharma (2021) researched a sample of 385 private companies listed on the Shanghai and Shenzhen stock markets. According to their findings, R&D intensity has a negative influence on profitability (short-term financial performance), but a positive impact on business value (long-term financial performance).

1.4. Significance of return on R&D capital for profitability

The efficiency of used R&D capital (which may be treated as investments in R&D) could be calculated by a valuable indicator - Return on R&D capital (RORDC). Companies can expect future returns on R&D investments (capital) if they can transform the results of their innovative projects into true sales growth (Cohen, Diether & Mally, 2013). Foster, Linden, Whiteley and Kantrow (1985) explained this indicator as a measure of the contribution of R&D investments (capital) to profits. In other words, these authors defined the return on R&D capital as the quotient of profits and the value of R&D investments (capital). According to Foster et al. (1985), RORDC depends on two indicators: R&D productivity and R&D yield.

Chesbrough and Liang (2008) state that the firms in the globally-oriented segment have larger returns on R&D investment (i.e., the RORDC indicator) in comparison with the firms in the domestically-oriented segment. From theoretical and empirical aspects, the return on R&D investments (or R&D capital) has been the subject of extensive literature (Lev & Sougiannis 1996; Kothari, Laguerre & Leone, 2002; Anagnostopoulou & Levis 2008).

Hsieh et al. (2003) compared the rates of return on R&D investment and fixed asset investment in the pharmaceutical and chemical industries. Also, they found that an investment in R&D earns an operating profit return much higher than the industry cost of capital. Cincera & Veugelers (2014) explained the differences in the Return on R&D rates for European and US young leading R&D firms. However, in the scientific literature, the absence of studies which analyze the connection and impact of return on R&D capital and profitability indicators (ROA and ROE) is evident.

2. Methodology

Considering all the previously mentioned facts and the literature review, the analysis in the study was performed in two phases. Firstly, the panel data analysis was conducted to estimate the impact of various performance indicators of R&D activities (R&D investments, R&D intensity and return on R&D capital) on the company profitability (ROA) of R&D intensive companies. Secondly, cluster analysis was used to explore the homogeneity of the 24 innovative companies in the research sample. The list of variables is shown in Table 1. The independent variables used in this study are

R&D expenditures (RDI), R&D Intensity Indicator (RDII), and Return on R&D or Return on R&D Capital (RORDC).

Table 1 List of used variables

Variable	*Variable Type*
R&D expenditures in million $ *(RDI)*	Predictor
R&D Intensity Indicator *(RDII)*	Predictor
Return on R&D Capital *(RORDC)*	Predictor
Return on Assets *(ROA)*	Dependent

Source: the authors' calculation based on SPSS software

RDII differs across various industries and achieves the highest value in high-technology companies. For period *t*, it is calculated according to the following formula (Savrul & Incekara 2015):

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

RORDC shows how much of the company's gross profit in the current year comes from the R&D expenditures from the previous period. It is calculated according to the following formula (Christensen & Van Bever 2014):

$$RORDC_t = Gross\ profit_t : R\&D\ expenditure_{t-1} \quad (2)$$

ROA is calculated according to the following formula:

$$ROA_t = EBIT_t : As_t \quad (3)$$

where: EBIT – Earnings before Interest and Tax, As – Assets. The use of EBIT, as a category of profit, allows us to eliminate the impact of different tax systems that exist in different countries, as well as the impact of financial decisions made by managers in different companies.

The initial sample was divided into two separate clusters, and regression analysis was carried out on each of these clusters. The clusters were formed based on the R&D intensity (RDII) and efficiency of R&D investments (Return on R&D capital - RORDC).

In order to analyze the effects of R&D investments on profitability and to test the defined hypothesis, the sample of EU and non-EU companies presented in the EU Industrial R&D Investment Scoreboard was employed. The EU Industrial R&D Investment Scoreboard provides the R&D investment database for benchmarking the performances of individual R&D intensive companies against the best global competitors in their sectors.

The data used in this study were taken from the financial statements of 24 R&D intensive companies covering the period 2013-2020. The sample contains 24 companies that are listed on the top 50 R&D spenders list in each year during the analyzed period. Other companies that dropped out of this list in some years during the analyzed period were excluded from the sample. Among the group of top 24 R&D investors, there are 9 companies based in the EU and 15 non-EU companies.

Table 2 Sample of companies that are listed in the top 50 R&D spenders list by industries and countries

Company	Country	Industry
Airbus	Netherlands	Aerospace & Defense
Amgen	US	Health Industries
AstraZeneca	UK	Health Industries
Bayer	Germany	Health Industries
BMW	Germany	Automobiles & other transport
Bristol	US	Health industries
Daimler	Germany	Automobiles & other transport
Ericsson	Sweden	ICT producers
Ford Motor	US	Automobiles & other transport
General Motors	US	Automobiles & other transport
GlaxoSmith Kline	UK	Health Industries
Huawei	China	ICT producers
Johnson & Johnson	US	Health Industries
Merck Us	US	Health Industries
Novartis	Switzerland	Health Industries
Panasonic	Japan	Others
Pfizer	US	Health Industries
Qualcomm	US	ICT producers
Robert Bosch	Germany	Automobiles & other transport
Roche	Switzerland	Health Industries
Sanofi	France	Health Industries
Siemens	Germany	ICT producers
Sony	Japan	Others
Volkswagen	Germany	Automobiles & other transport

Source: Authors' calculation according to annual financial reports of analyzed companies that are publicly available (official company websites)

Table 3 Sample of companies that are listed on the top 50 R&D spenders list

Company	*Average RDI*	*Average RDII*	*Average RORDC*
Airbus	3,681.9	0.05	2.45
Amgen	3,932.3	0.18	4.58
AstraZeneca	5,662.6	0.23	3.50

Bayer	4,850.1	0.10	6.15
BMW	5,240.6	0.05	4.10
Bristol	4,060.5	0.21	4.17
Daimler	8,318.6	0.05	4.61
Ericsson	4,503.1	0.16	1.95
Ford Motors	7,183.3	0.05	3.67
General Motors	7,050.0	0.05	2.43
GlaxoSmith Kline	5,437.6	0.14	4.53
Huawei	10,180.1	0.14	3.46
Johnson & Johnson	9,369.1	0.13	5.78
Merck Us	8,623.1	0.21	3.23
Novartis	9,001.6	0.18	3.68
Panasonic	4,289.4	0.06	4.56
Pfizer	7,753.6	0.15	5.36
Qualcomm	5,365.8	0.23	4.34
Robert Bosch	6,894.9	0.09	3.85
Roche	10,858.2	0.21	3.49
Sanofi	5,977.7	0.15	4.57
Siemens	8,122.0	0.09	4.02
Sony	4,310.8	0.06	5.46
Volkswagen	15,285.1	0.06	3.14

Source: the authors' calculation according to annual financial reports of analyzed companies that are publicly available (official company websites)

The following hypotheses are tested in this study:

H1: A positive correlation exists between R&D investments, R&D intensity indicator, the return on R&D capital and return on assets;

H2: R&D investments, R&D intensity indicator, and return on R&D capital positively influence the profitability;

H3: There is heterogeneity between companies based on R&D intensity indicator and return on R&D capital;

H4: The impact of R&D investments, R&D intensity indicator and return on R&D capital on profitability is bigger in companies with higher R&D intensity indicator.

Correlation, regression, and cluster analyses are employed to test the validity of the defined hypotheses.

3. Research results and discussion

3.1. Descriptive statistics analysis

The descriptive statistics are presented in Table 4. The average R&D expenditures (RDI) in the analyzed companies are 7.4 billion $. The minimum value of 2.08 billion $ was recorded in Bristol in 2015, while the maximum value of 22.38 billion $ was recorded in Huawei in 2021. The average RDII in the analyzed companies is 0.1308, while the minimum value of 0.0381 was recorded in Daimler in 2019, and the maximum value of 0.3227 was recorded in Merck US in 2020. The average value of RORDC in the analyzed companies is 3.9812, while the minimum value of 1.5432 was recorded in Airbus in 2016, and a maximum value of 8.1069 is recorded in Sony in 2019. The average value of ROA in the analyzed companies is 0.0746, while the minimum value of 0.0017 was recorded in Sony in 2014, and the maximum value of 0.2634 in Roche in 2013.

Table 4 Descriptive Statistics

Variable	*Min*	*Max*	*Mean*	*Std. Dev.*
RDI	2.077	22.3843	7.4135	3.5831
RDII	0.0381	0.3227	0.1308	0.0704
RORDC	1.5432	8.1069	3.9812	1.2296
ROA	0.0017	0.2634	0.0746	0.0516

Source: the authors' calculation based on SPSS software

3.2. Correlation and regression analysis

In order to perform the correlation and regression analyses all variables are transformed into log values. The correlation analysis was performed in order to test the validity of the first hypothesis (H1), and the results are presented in Table 5.

Table 5 Correlations

	RDI	*RDII*	*RORDC*	*ROA*
RDI	1			
RDII	0.1861*	1		
RORDC	-0.0939	0.0346	1	
ROA	0.1851*	0.5358*	0.2490*	1

Note: * Correlation is significant at the 0.01 level (2-tailed)
Source: the authors' calculation based on SPSS software

According to the results, there is a positive correlation between ROA and all three R&D performance indicators (RDI, RDII, RORDC). Results show that the positive correlation between R&D investments and ROA is weak and statistically significant (0.1851), whereas the correlation between RORDC and ROA is moderate and statistically significant (0.2490). These results are in line with the results of Daldavi and Mansuri (2018), who found a linear correlation between R&D investments and profitability indicators. The strongest positive correlation is between the RDII and ROA (0.5358). These results partially correspond to the results of Morbey (1988) and Shaikh, O'Brien and Peters (2018), who also revealed a correlation between R&D intensity

indicator (RDII) and profitability indicators, but in a weak form. These results confirm the first hypothesis (H1) and are interesting from the managerial perspective, as they indicate that there is a linear association between R&D investments, R&D intensity, the efficiency of R&D investments and company profitability measured by ROA.

The conducted study reveals a strong and positive correlation between RDII and ROA. Furthermore, the correlation between R&D investments and ROA is low and statistically significant, whereas the correlation between RORDC and ROA is moderate and statistically significant. These results confirm our first hypothesis (H1).

After the diagnostic checking was performed to determine the appropriate panel data model (Table 6), the random effect model (REM) was chosen for fitting the data, and the results are presented in Table 7. Namely, the results of the F-test point towards the FEM model, while the results of the Breusch-Pagan LM test point towards the REM model. The final decision was made based on the results of the Hausman test, according to which the REM model is appropriate at a 5% significance level (p=0.0691).

Table 6 Diagnostic tests

Model	F-test	reusch-Pagan LM	Hausman
	H_0: Pooled, H_1: FEM	*H_0: Pooled, H_1: REM*	*H_0: REM, H_1: FEM*
Model	4.12 (0.0000)	40.56 (0.0000)	7.09 (0.0691)

Note: p values are given in ( )

Source: the authors' calculation based on SPSS software

The model analyses the impact of RDI, RDII and RORDC on ROA in 24 companies covering the period 2013-2021. After performing the REM model, the Pasaran CD (cross-sectional dependence) test was used to test whether the residuals are correlated across companies. The results of the Pasaran CD test revealed the presence of the cross-sectional dependence (3.095, p=0.0020), and hence the REM model with Driscoll and Kraay standard errors was used and is presented in Table 6.

The obtained results show that R&D investments (RDI) are not statistically significant, whereas R&D intensity indicator (RDII) and return on R&D capital (RORDC) have a positive and statistically significant impact on the company's profitability. The estimated model explains a 33.97% change in ROA and this model is statistically significant as confirmed by the Wald statistics. Individual specific errors can explain 25.71% of the entire composite error variance.

The conducted study confirms that R&D investments, R&D intensity and efficiency of R&D investments (RORDC) have a positive impact on the company's profitability (ROA). The efficiency of R&D investments has the strongest influence on company profitability. These results confirm our second hypothesis (H2).

The positive, but statistically insignificant impact of R&D investments on profitability, is in line with the study conducted by Kiraci, Celikay and Celikay, (2016) and Kounnou and Kyrkilis (2020). Namely, the results of the previously mentioned research proved that R&D expenditure did not have a statistically significant impact on profitability, as in this study.

The increase in the RDII by 1% leads to an increase in ROA by 0.6361%, and this is very important for managers. These results are in line with the results obtained by Ayaydin and Karaaslan (2014), who found a positive effect of R&D intensity (RDII) on ROA.

In addition, it is not only important the share of R&D investments in sales revenue, but also the economic efficiency of those investments. The regression results confirm that the increase in the RORDC by 1% leads to an increase in ROA by 0.8263%, thus confirming that the management of companies in the research sample has made good business, investment, and financial decisions aiming to increase the efficiency of R&D investments, and this is especially important for creating positive contributions of those decisions in the increase of ROA. Hence, managers should increase RORDC through their business decisions, and then they can expect to increase ROA as the indicator of company profitability. The obtained results confirm the second hypothesis (H2), as all indicators positively influence ROA, whereas the RDII and RORDC are statistically significant, and R&D investments are not.

Table 7 Regression results

	Const	*RDI*	*RDII*	*RORDC*	R^2	*ρ*
ROA	2.6877 [-9.25] (0.000)	0.0613 [1.09] (0.306)	0.6361 [6.70] (0.000)	0.8263 [4.26] (0.003)	0.3397	0.2571
					Wald statistics	51.82 (0.0000)

Note: t values are given in [ ], p values are given in ( )

Source: the authors' calculation based on SPSS software

3.3. Cluster analysis

Cluster analysis is performed to investigate whether there are differences among companies regarding R&D investment intensity (RDII) and R&D investment efficiency (RORDC). The squared Euclidean distance measure was used to calculate the distance between the data points, while Ward's method was used to calculate the similarity of the data. The results of the cluster analysis displayed two clusters (C1 and C2) in the dendrogram in Fig. 1.

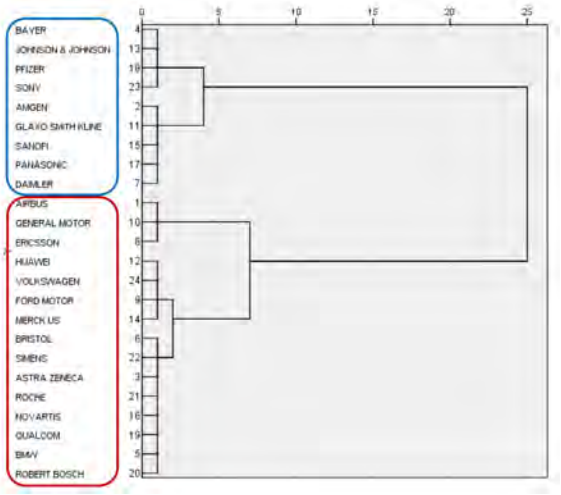

Figure 1 Dendrogram
Source: the authors' calculation based on SPSS software

These results confirm hypothesis H3 that there is heterogeneity between companies based on the R&D intensity indicator and return on R&D capital.

The characteristics and basic descriptive statistics of clusters are presented in Table 8. Cluster 1 shows better R&D investment intensity (*RDII*), whereas the efficiency of R&D investment (*RORDC*) is smaller compared to cluster 2. This means that those companies investing more in R&D do not necessarily have the higher value of *RORDC*, i.e., higher R&D investment intensity does not lead to an increase in the efficiency of R&D investments. This efficiency depends on successfully marketed created value, but also on the revenue to R&D expenditures ratio and the revenue to cost ratio.

Table 8 Results of hierarchical clustering

Cluster (C)	*RDII*	*RORDC*
C1 (n=15)	0.1380±0.07756	3.3590±0.62682
C2 (n=9)	0.1189±0.05101	5.0183±0.62327
Total (n=24)	0.1308±0.06824	3.9812±1.02355

Source: the authors' calculation based on SPSS software

To investigate the differences among analyzed firms regarding RDII, a regression analysis was performed on the determined clusters, and the results are presented in Table 9. The Pasaran CD test was conducted on both models, and the results showed no presence of cross-sectional dependence for Cluster 1 (-0.677, p= 0.4984), while the results of the Pasaran CD test revealed the presence of cross-sectional dependence for Cluster 2 (2.982, p=0.0029), and hence the REM model with Driscoll and Kraay standard errors was used.

For the first cluster - *C1* - R&D investments (*RDI*), R&D intensity (*RDII*) and efficiency of R&D investments (*RORDC*) have positive and statistically significant impact on the company's profitability (*ROA*). RORDC has the strongest impact and this impact is statistically significant at a 1% level of significance, whereas the impact of R&D investments and R&D intensity is not statistically significant. If *RORDC* increases by 1%, *ROA* will increase by 1.46%, ceteris paribus. The estimated model explains 57.94% of the change in *ROA* and this model is statistically significant as confirmed by the F statistics.

Table 9 Regression results for clusters

ROA	Const	RDI	RDII	RORDC
Cluster 1	-5.2177 [-2.13] (0.037)	0.4148 [0.71] (0.482)	0.2917 [0.39] (0.700)	1.4641 [3.19] (0.002)
	R2	*Adjusted R2*	*F statistics*	
	0.5794	0.5123	3.68 (0.0161)	
ROA	Const	RDI	RDII	RORDC
Cluster 2	-2.6089 [-7.21] (0.000)	0.0029 [0.03] (0.975)	0.6097 [4.37] (0.002)	0.8631 [5.68] (0.000)
	R2	*ρ*	*Wald statistics*	
	0.3860	0.2453	44.68 (0.0000)	

Note: for cluster 1, t values are given in [ ], p values are given in ( ) for cluster 2, z values are given in [ ], p values are given in ( )
Source: the authors' calculation based on SPSS software

For the second cluster - C2, R&D intensity and RORDC have a positive and statistically significant impact on company profitability – ROA, while RDI has a positive, but statistically insignificant impact. If RDII increases by 1%, ROA will increase by 0.6097%, ceteris paribus. If RORDC increases by 1%, ROA will increase by

0.8631%, ceteris paribus. The estimated model explains a 38.6% change in ROA and this model is statistically significant as confirmed by the Wald statistics ($p<0.01$).

The conducted cluster analysis revealed two clusters – one of the highly R&D intensive companies with lower efficiency of R&D investments and another of less R&D intensive companies with higher efficiency of R&D investments. The regression analysis results within the first cluster demonstrate that only the efficiency of R&D investments has a positive and statistically significant impact on company profitability (ROA). Findings for the second cluster confirm that R&D intensity and efficiency of R&D investments have a positive and statistically significant influence on company profitability (ROA), while the impact of R&D investments, although positive, is statistically insignificant. It is in line with the result of Wu et al. (2020). Hence, these results confirm our hypothesis (H4) that the effects of various indicators of R&D activities are bigger in companies with higher RDII.

Conclusion

The paper contributes to the existing literature and provides new empirical evidence on this topic by highlighting the importance of R&D investments in improving return on assets. The originality of the work is reflected in the comprehensive analysis of the impact of 3 key indicators of R&D activity on the profitability of top R&D spenders in the world. The analysis especially contributes to the existing literature, bearing in mind that there is no comprehensive analysis of various research and development indicators on the company's profitability. In particular, there is a lack of evidence in the academic literature about the connection and impact of return on R&D capital and profitability indicators. This specific indicator of R&D performance (RORDC) has not yet been analyzed in terms of contributing to the profitability of the company. Further, the study contributes to the current literature as the existing studies do not consider the importance of the efficiency of R&D investments from the aspect of profitability. Finally, the originality is also reflected in the chosen sample – these are the companies that are the biggest R&D spenders. The originality of the work from the aspect of practice is reflected in the fact that it highlights the importance of not only the amount of allocation for R&D but also the efficiency of these activities in the company. It is indicated that experts in R&D functions must monitor various indicators of R&D activities.

Certain practical implications and benefits for modern managers can also be highlighted. Namely, such evidence points to the importance of the research and development department in companies if the company wants to operate profitably in the long term. The research indicates the direct influence of allocations for investments in the company's intangible assets on profitability indicators. Additionally, this paper contributes to the raising awareness of the importance of investing in R&D, as well as the impact of the intensity and efficiency of R&D investments on profitability. It is useful for top managers of companies, especially those responsible for R&D in companies, because it indicates the importance of research and development activities to boost profitability. The research is beneficial and gives recommendations for corporate managers as well as policymakers and implementers of R&D strategies. Namely, it can provide practical implications, giving guidelines for decision-making to potential R&D investors. It is pointed out to them that apart from the level of investment in R&D, they must take into account the efficiency of those investments. Decision makers are thus suggested to specifically provide R&D investment support to the most efficient companies in this area and to formulate policies to encourage their R&D efficiency, in order to ultimately improve their profitability (from which public policymakers benefit directly). Employees, especially qualified and talented ones, are motivated to work in companies that invest more in R&D and are more efficient in this area, which indicates the security of their job and because it supports the success of the company (through superior profitability). The positive correlation between R&D investments and the profitability of the company as well as the positive impact of the efficiency of investment in R&D on the profitability of the company emphasizes the importance of investment in R&D activity and indicates the justification of the hypotheses.

There are certain limitations in any scientific-research study that serve the purpose of critical re-examination, rather than dismissing the study findings. The first limitation is related to the research sample. Namely, the sample encompasses 24 companies listed among the top 50 R&D spenders worldwide according to EU Industrial R&D Investment Scoreboard and which were on this list in all analyzed years (which is why the

sample was reduced from 50 to 24 companies) which is considered insufficient for extensive analysis. The other limitation is related to the short research period (2013-2020), which makes it difficult to apply complex econometric methodologies. Hence, the extension of the research period is one direction for future studies. This could provide more empirical background for this issue. Finally, the limitation of this study stems from the fact that it investigates the impact of R&D indicators on short-term company profitability. As the R&D activities produce yields after several years, the possible direction for future research is to investigate the impact of accumulated R&D investment over several years on ROA. These limitations point to future research directions, especially in the context of comparing the analyzed industries with other industries as well as the effects of COVID-19 in this segment.

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