The impact of intangible assets on the financial performance of Slovak ICT companies: a panel data regression analysis*

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Abstract

This paper investigates the impact of intangible assets on the financial performance of Slovak ICT companies in the context of the knowledge economy. The paper uses a panel data regression analysis to test the hypothesis that intangible assets have a significant positive effect on four indicators of financial performance: Return on Assets, Net Profit Margin, Assets Turnover, and Return on Equity. The paper analyzes a sample of 180 Slovak ICT companies for the period 2015–2019, using eight independent variables: Research and Development Intensity, Research and Development Intensity Squared, Software, Intellectual Property Rights, Acquired Intangible Assets, Leverage, Size, and Dummy variable for ICT sub-sectors. The paper applies various tests to select the appropriate estimation method and to check the adequacy of each model. The results partially confirm the hypothesis, as only Research and Development Intensity, Research and Development Intensity Squared, and Acquired Intangible Assets have a significant positive impact on some indicators of financial performance. The paper also finds that the influence of intangible assets varies depending on the type and measure of financial performance. The paper contributes to the literature on intangible assets and financial performance by providing empirical evidence from Slovak ICT companies. The paper also provides some implications for managers and policymakers to improve their intangible investment policy.

Keywords

intangible assets, financial performance, panel data regression, Slovak ICT companies, intangible investment policy

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1. Introduction

Over the past few decades, extensive discourse among researchers has centered on the evolving role of various types of capital in shaping the economic value and sustainability of enterprises, paving the way for their enduring success. Particularly noteworthy is the recognition of intellectual capital's pivotal role in this metamorphosis, influenced by shifts in production focus and management strategies. This shift is marked by a transition from the conventional emphasis on physical capital and labor to a spotlight on intellectual capital and the exchange of ideas, buoyed by intellectual property rights, particularly patents for their integration with technology [2, 3, 4, 5]. In this transformative landscape, the valuation and profitability of enterprises are increasingly tethered to their adeptness in harnessing their innovative potential and capitalizing on their intangible assets. Against the backdrop of overcoming the COVID-19 pandemic's repercussions [6, 7] and the global implementation of proactive sanctions strategies, which have led to reduced trade in conventional goods and services, the role of unique intellectual technologies in anchoring stable enterprise value gains prominence.

This new paradigm necessitates a growing reliance on national intellectual capital to fortify the economies of developed nations. Moreover, for numerous enterprises, financial performance hinges on the judicious crafting of policies that foster both the creation of novel intangible assets and the efficient utilization of existing ones. This involves their seamless integration into enterprise operations, fostering effective partnerships, governance, and control. In this context, enterprises frequently encounter network effects and an elevated exposure to market and technological risks. Consequently, a recalibration of business strategies becomes imperative, encompassing initiatives that leverage intangible assets to their strategic advantage. This is especially pertinent for high-tech entities, characterized by their substantial reliance on intangible assets to develop innovative technological products and services.

In light of these economic transformations, the quest for fresh theories and strategies is imperative to underpin informed decisions and management conduct in enterprises rich in intangible assets. A pertinent avenue of investigation is the impact of intangible assets on companies' financial performance, specifically focusing on the context of Slovak enterprises operating in the information and communications technology (ICT) sector. These companies, encompassing those engaged in information processing, storage, transfer, production of computing and telecommunication devices, and related services, epitomize high-tech enterprises. Their value creation processes are intrinsically linked to the efficient utilization of intangible assets. Investments in high-tech intangible assets within the ICT sector hold the promise of enhancing their financial metrics. However, as Huňady et al. [8] have indicated, Slovakia still exhibits a limited presence of business Research and Development (R&D) in the ICT sector. This suggests a cautious approach to intangible investments among Slovak ICT companies, possibly due to perceived risks and uncertainties surrounding their potential returns. Consequently, to mitigate such risks and uncertainties and to formulate an effective intangible investment policy, it becomes paramount to ascertain the intricate relationships between diverse intangible asset categories and various financial performance metrics.

Over the last decade, the Slovak Republic has witnessed vigorous development in its ICT sector. The number of individuals employed in the information and communication technology services sector surged from 28,905 in 2009 to 53,676 in 2019 [8], underscoring a near doubling of the workforce over the span of a decade. Reflecting this expansion, the ICT sector's contribution to the country's Gross Domestic Product (GDP) reached 4.2%, exerting significant influence on related industries as well. Endowed with numerous advantages, including high adaptability to enterprise activities, elevated value addition, well-established educational infrastructure, robust institutional networks, diversification in the telecommunications segment, strategic geographical positioning, extensive data and network coverage, and attractive investment incentives, the ICT sector garners substantial investor interest [9]. The Slovak government's active support for the sector, as evidenced by the provision of incentives such as tax reliefs, cash grants, job creation contributions, discounted real estate transactions, and a favorable R&D tax regime, further amplifies its allure [9]. Hence, examining the impact of intangible assets on the financial performance of Slovak ICT firms, within this conducive environment, assumes particular significance. Such an investigation can illuminate avenues for developing and fine-tuning intangible investment policies to enhance the financial performance of these companies.

Given the pivotal role of intangible assets in shaping the efficiency of high-tech enterprises, a research hypothesis has been formulated. This study hypothesizes a significant positive correlation between intangible assets and the financial performance of ICT companies. Recognizing that the strength of this influence may also vary based on company size, levels of borrowed capital, and sub-sector categorization within the ICT industry, the analysis of the impact of intangible assets on financial performance takes into account these factors. The resulting insights are expected to inform recommendations for Slovak ICT companies' intangible asset investment decisions.

2. Theoretical background

Problems of influence of intangible assets in their broad (economic) understanding on financial performance of high-tech companies are paid considerable attention of academicians. First of all, this is conditioned by the decisive role of intellectual capital for such enterprises in the context of the development of knowledge economy, which is based on ideas, R&D, innovations and technological progress. Scientists analyze of the impact of different intangible values on financial performance: intangible assets (the concept of IAS 38 [10]), intellectual capital (as a combination of human, organizational, and client capital), or separate components of two data. These studies cover different types of enterprises from different countries of the world, which represent different sectors of the economy. Since intellectual capital includes, to the most extent, all intangible assets that are the result of human intellectual activity, this article also analyzes the impact of intellectual capital and its components on the financial performance of ICT companies. In addition, a number of researchers are conducting studies of the impact of intangible assets both on individual components of financial performance, in particular, on profitability, and on broader categories, in particular, on total performance of the company or companies value.

Table 1 lists the number of articles and their quotations, which reveal the relationship between "Intangible assets" / "Intellectual capital" and "Financial performance" in science-based databases of Scopus, Web of Science and Google Scholar.

Table 1
Number of scientific articles by direction of researches and their quotations in academic literature for the period 2018–2022 as of July 01, 2022 (via Scopus, Web of Science and Google Scholar databases).

Searching phrases	Results found			Sum of the times cited		
	Scopus	Web of Science	Google Scholar	Scopus	Web of Science	Google Scholar
"Intangible assets" and "Financial performance"	161	576	21	894	16100	38
"Intellectual capital" and "Financial performance"	329	970	494	2530	13904	2235

The results of analysis of scientific databases are obtained (table 1) testify to the existence of a considerable number of publications in this direction of researches, as well as their influence on scientific works of other authors, which is confirmed by a considerable number of references to data of other authors and their constant growth from year to year. The cluster analysis of the key words of the articles from the databases of the Scopus and Web of Science on the basis of the use of VOSviewer allowed to confirm this conclusion. There was also a large number of publications that examined the impact of structural elements of intangible assets or intellectual capital (research and development, intangible resources, customer capital, structural capital, human capital, social capital, relational capital) on financial performance (figure 1). In addition, publications have been identified that investigate the impact of intangible assets or intellectual capital on other types of indicators that characterize the performance of the enterprise – firm performance, business performance, corporate performance, firm value, effectiveness, efficiency, profitability, ROA, competitive advantage etc. (figure 2).

Little attention is paid directly to the issue of impact of intangible values on financial performance of ICT companies, although the presence of significant positive relationships between with two variables is confirmed in the vast majority of results. Gan and Saleh [11] studied the connection between intellectual capital components of corporate performance among high-tech companies listed on Bursa Malaysia, in particular, profitability, and productivity. Based on the use of regression analysis, it was found that companies with larger intellectual capital as a rule have better profitability (ROA) and more efficient productivity (ATO).

Li and Wang [12] investigated the impact of different intangible assets (R&D expenditure, employee benefit, sales training) on profitability indicators (ROA) of Hong Kong Listed IT companies using regression analysis. They found a positive relationship between intangible assets and ROA.

Dženopoljac et al. [13] examined the role of intellectual capital and its key components in provision for financial performance (ROA, ROE, ROIC, ATO) of Serbian ICT sector companies during 2009–2013. They used Value-added intellectual coefficient (VAIC) as a measure of the IC contribution to value creation. The results obtained by the authors revealed that only one component of VAIC – CEE (capital-employed efficiency) had a significant impact on financial performance indicators, except for the indicator ROIC. Khan [14] also used VAIC as firms intangibility measure when analyzed the impact of intellectual capital on the financial performance of the 51 Indian IT companies for the period 2006–2016. He found a significant positive association

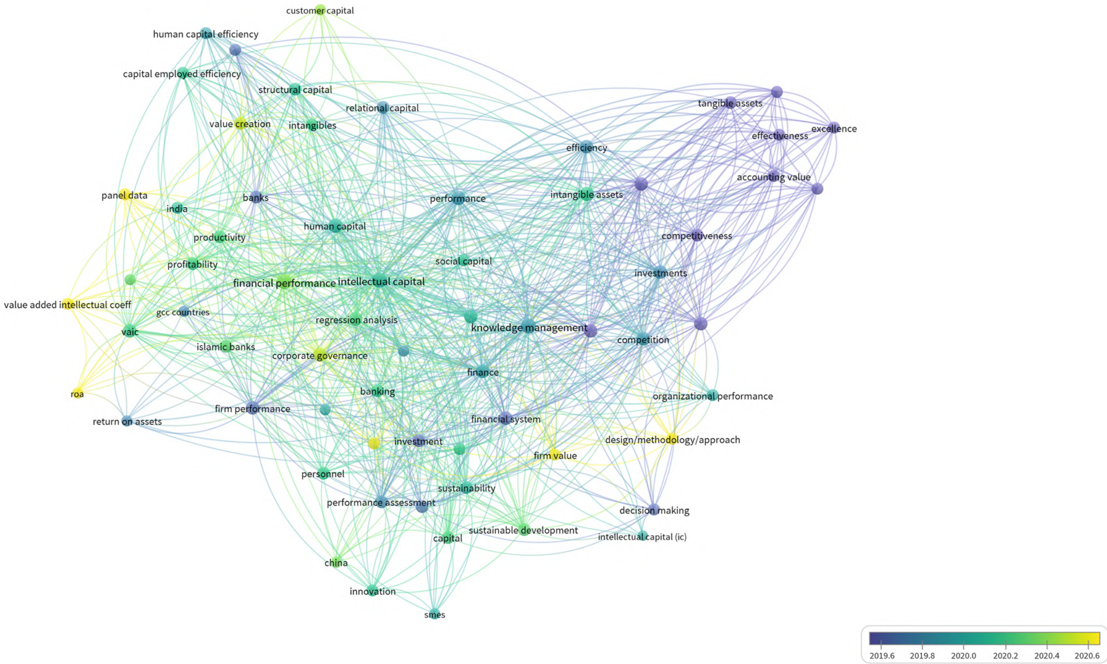

Figure 1: Bibliometric map of publications' keywords on the query "Intangible assets", "Intellectual capital" and "Financial performance" according to Scopus database in 2018–2022.

of VAIC with profitability, and an insignificant relationship with productivity, and significant positive association of CEE with profitability and productivity of Indian IT companies.

Zhang [15] analysed the relationship between degree of intangible assets and profitability for 17 Chinese listed telecommunication firms' for the period from 2014 to 2016. He found a positive and significant effect of Intangible assets ratio on ROA. Also, he emphasized the possibility of the inaccuracy of the obtained results due to the conservative nature of Chinese accounting standards rules in measuring intangible assets.

Huňady et al. [8] examined the role of innovations in performance of ICT sector companies from 24 countries during the years 2008–2016. Using regression analysis for macro-level data, they found positive effect of R&D expenditure on apparent labour productivity and value added in ICT sector.

Qureshi and Siddiqui [16] analyzed an effect of intangible assets on financial performance (ROA, ROE, ROIC, ATO and NPM) of the 80 global technology firms for the period from 2015 to 2018. They confirmed a significant negative effect of intangible assets on ROE, ROIC, ATO, and insignificant positive impact on companies' profitability. Moreover, the force of this influence considerably varies depending on the country's innovative development.

Lopes and Ferreira [17] also investigated the impact of intangibles on the performance indicators of major world technological firms (Turnover, ROA, ROE, ROS, EPS), have received evidence of existence of negative correlation between all intangible variables, control variables (Size, Leverage) with ROA. These conclusions are also confirmed by Sundaresan et al. [18], who investigated the impact of intangible assets on financial performance of 38 Taiwanese listed

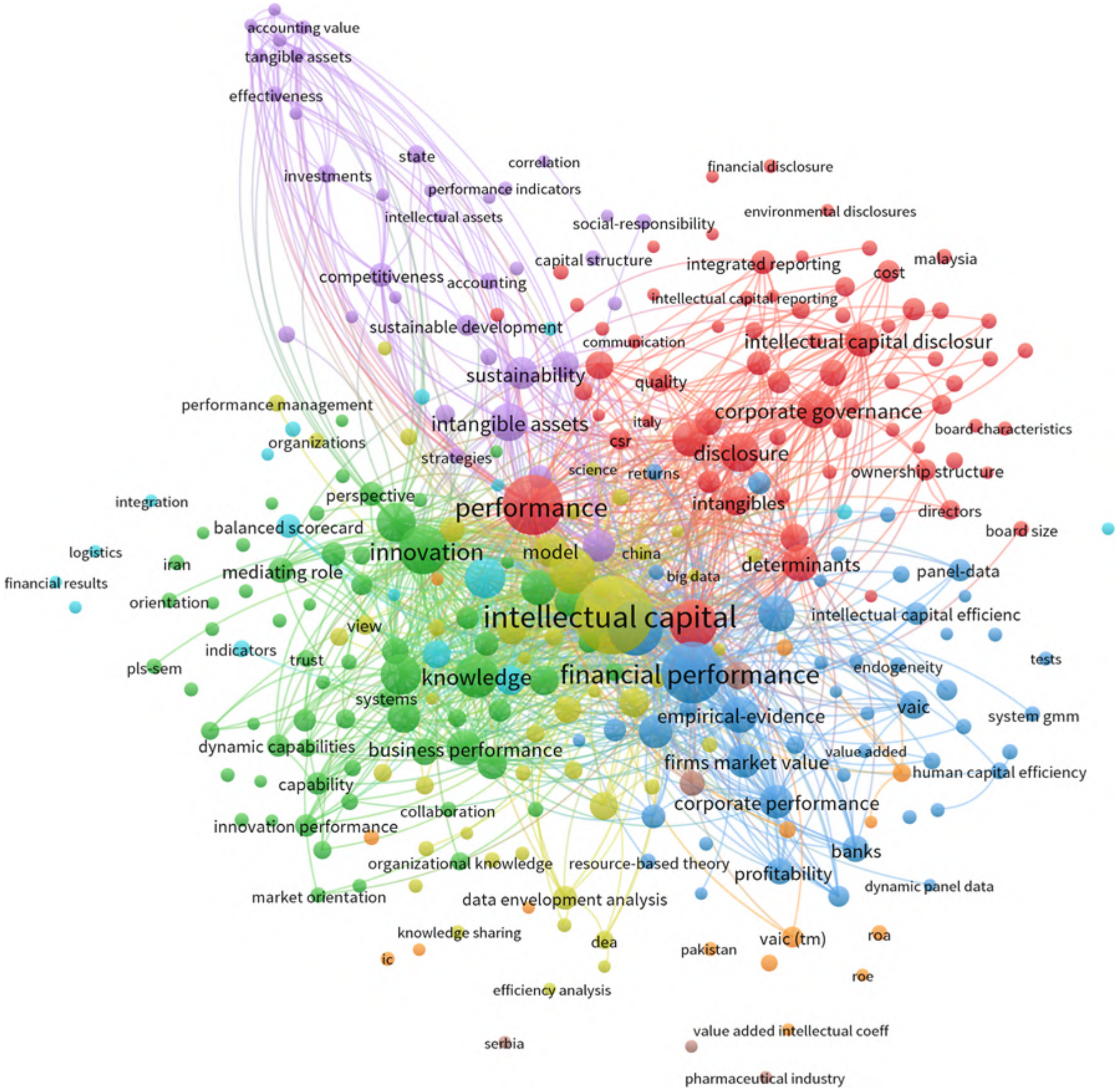

Figure 2: Bibliometric map of publications' keywords on the query "Intellectual capital" and "Financial performance" according to Web of Science database in 2018–2022.

technology firms for the period 2015–2019. The authors also revealed the existence of a lack of a significant relationship between intangible assets and ROA, but found significant influence of size on ROA. At the same time, they confirmed significant impact of intangibles on ROE. The results of the ROA received by Lopes and Ferreira [17], Sundaresan et al. [18] are in direct contradiction with most of the conclusions obtained by the authors who studied impact of intangibles on performance of ICT companies.

Radonić et al. [19] studied the role of intellectual capital components (human, relational, structural and innovation capital) in ensuring the achievement of financial performance indicators (ROA, ROE, Net Profit, etc.) of South-East Europe IT industry companies. In their study, as a theoretical background they used a resource-based view on intellectual capital, which involves analyzing the impact of its individual components on financial performance indicators. In particular, the authors established that innovation capital has the strongest impact and human capital has an indirect impact on the financial performance of IT companies. A similar resource-based approach was also used by Serpeninova et al. [20], who as a result of a study of the impact of intellectual capital on the profitability of Slovak software development companies (ROA, NPM, GPM, EBITM) found an absence of a significant relationship between them. The authors considered the main reason for this to be the imperfection of the current accounting standards, for instance, IAS 38, in terms of criteria for recognizing and evaluating the intellectual capital of enterprises.

The analysis of studies on the issues of the research made it possible to establish the existence of mutually contradictory evidence regarding the impact of intangible assets on the financial performance. In general, this does not allow the management of enterprises to effectively control intangible values aimed at creating internal value, and for investors – to receive clear signals for making effective investments. Considering the above, the following objectives were formulated: to measure the relationship between intangible assets and the financial performance of Slovak ICT companies; to investigate which components of intangible assets have the most significant or insignificant impact on the financial performance of Slovak ICT companies; to form recommendations for improving the investment policy of ICT companies, based on the level of significance of the elements of intangible assets from the point of view of increasing financial results.

3. Data and methodology

3.1. Sample selection

To determine whether intangible assets stimulate financial performance, was analyzed sample of 180 Slovak ICT companies for the period 2015–2019. In particular, the panel data information from financial statements of such enterprises, available in the open access, as well as the information from database "FinStat" was used to form panel data. Only those companies, for which the necessary information for the 5-year period was available, were included in the sample. The selected 180 companies provide a valid and complete set of data in order to carry out relevant statistical analysis.

Investigated enterprises proceeding from EU Economic Activity Classification and from the SK NACE 2 classification belongs to group 26 "Manufacture of computer, electronic and optical products", includes direct production of computers, computer peripheral equipment (input device, output device, input/output device), communication equipment (public switching equipment, transmission equipment, customer premises equipment), measuring, medical, navigation, radio, optical and other electronic equipment, as well as production of various types of accessories for such products (electrical boards, magnetic and optical media, etc.). In order to take into account the influence sub-sectors affiliation on financial performance of ICT companies two groups were allocated in their composition. The first group included enterprises dealing with the production of different types of electronics and components, and the second group involved enterprises producing communication equipment and components.

Based on the form of ownership, most of the companies investigated – 160, companies with limited liability, 16 – is a joint-stock company, 2 – production cooperative, 1 – limited partnership, 1 – general partnership. By type of ownership, the companies investigated are divided as follows: private domestic – 64%; foreign – 21%; international with a predominant private sector – 13%; cooperative – 1%; state – 1%.

3.2. Variables

In the research for characteristics of financial performance of ICT companies were used four dependent variables – Return on Assets, Net Profit Margin, Return on Equity, Assets Turnover, and used in their work by researchers for simiral empirical analysis of the relationship between intangibles values and company financial performance [11, 13, 16, 18, 19, 20]. For explanation of a relation between intangible assets and financial performance of ICT companies used intangible assets variables – Research and Development Intensity, Research and Development Intensity Squared, Software, Intellectual Property Rights, Acquired Intangible Assets. The election of such independent variable is justified by the financial statements of Slovak ICT companies in the disclosure of information about intangible assets. As it was revealed by Huňady et al. [8], the firm's ICT sector account for significant share of total business R&D expenditure in economy in most countries. Therefore, in the analysis impact of intangible assets on financial performance of ICT sector an important role should be assigned to R&D indicators. As a result, the study does not use the indicator of R&D costs but uses two calculation ratios that characterize the R&D of the companies. In addition, based on previous studies [21, 22, 20] in our study used three control variables – Leverage, Size and Dummy variable for ICT sub-sectors. Use of these variables will allow to control for a significant effects of company size, level of borrowing capital, and unseen role of ICT sub-sectors affiliation.

Types, calculation procedures, and abbreviations used in the Variables study are shown in table 2.

The dynamics of four indicators, that characterize financial performance of Slovak ICT companies (ROA, NPM, ROE, ATO) for the period 2015–2019 showed in figure 3.

Figure 3 displays the change in time of financial performance indicators for the 2015–2019 period. It allows to identify a number of common trends: Simultaneous growth in all indicators for 2017–2018 years; decrease in ATO, ROA and NPM indicators for 2015–2016 years, their growth in 2016–2018 years, as well as their simultaneous decrease in 2018–2019; during 2018–2019 years only growth of ROE indicator occurs. In general, common behavior was found for ATO, ROA and NPM, as well as almost completely different behavior of ROE compared to these indicators.

4. Research models

To understand the relationship between intangible assets and financial performance indicators, this study examined four following models:

Model 1: $\mathrm{ROA}_{it} = \alpha + \beta_1 \cdot \mathrm{RDI}_{it} + \beta_2 \cdot \mathrm{RDI2}_{it} + \beta_3 \cdot \mathrm{SOFT}_{it} + \beta_4 \cdot \mathrm{IPR}_{it} + \beta_5 \cdot \mathrm{AIA}_{it} + \beta_6 \cdot \mathrm{LEV}_{it} + \beta_7 \cdot \mathrm{l\_SIZE}_{it} + \beta_8 \cdot \mathrm{DVICTSS}_{it} + \epsilon_{it}$

Table 2
Variable definitions and abbreviations.

Variable	Calculation (Source)	Abbreviation
Dependent Variables		
Return on Assets	Net turnover / Total Assets	ROA
Net Profit Margin	Net profit / Total Sales	NPM
Assets Turnover	Total Sales / Total Assets	ATO
Return on Equity	Net profit / Total Equity	ROE
Independent Variables		
Intangible Assets Variables		
Research and Development Intensity	Capitalized R&D Costs / Total Sales	RDI
Research and Development Intensity Squared	Squared function of RDI	RDI2
Software	Software (Intangible Asset)	SOFT
Intellectual Property Rights	Valuable Intellectual Property Rights	IPR
Acquired Intangible Assets	Acquired long-term intangible assets are charged until the time of their use	AIA
Control Variables		
Leverage	Total liabilities / Total Assets	LEV
Size	Logarithm of Total Assets	l_SIZE
Dummy variable for ICT sub-sectors	1 for electronic producers, 0 for communication producers	DVICTSS

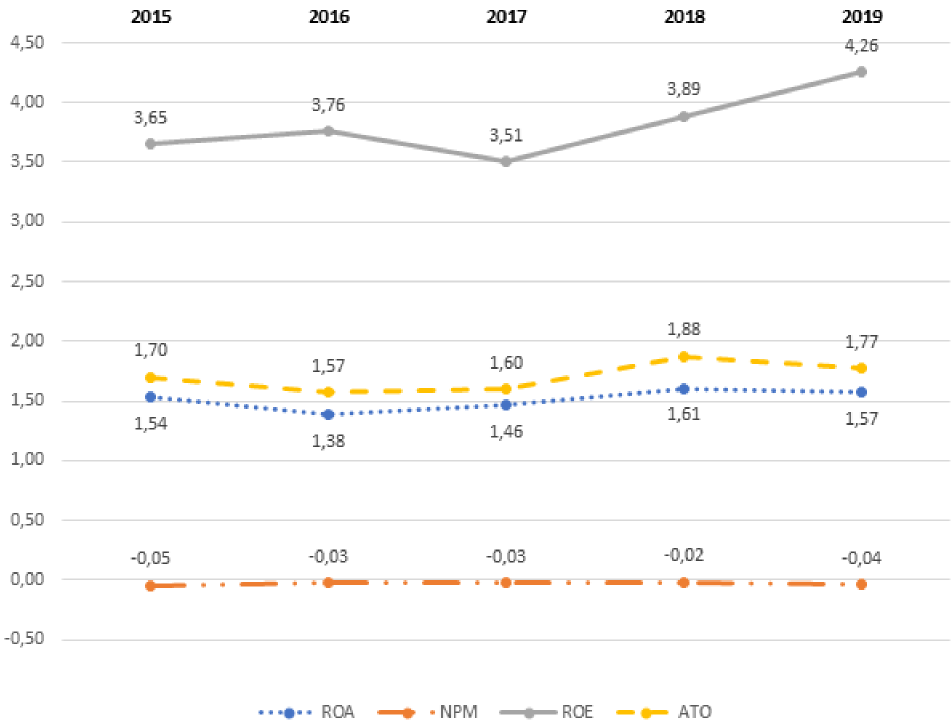

Figure 3: Dynamics of financial performance indicators of Slovak ICT companies for the 2015-2019 period.

Model 2: $NPM_{it} = \alpha + \beta_1 \cdot RDI_{it} + \beta_2 \cdot RDI2_{it} + \beta_3 \cdot SOFT_{it} + \beta_4 \cdot IPR_{it} + \beta_5 \cdot AIA_{it} + \beta_6 \cdot LEV_{it} + \beta_7 \cdot l\_SIZE_{it} + \beta_8 \cdot DVICTSS_{it} + \epsilon_{it}$

Model 3: $ATO_{it} = \alpha + \beta_1 \cdot RDI_{it} + \beta_2 \cdot RDI2_{it} + \beta_3 \cdot SOFT_{it} + \beta_4 \cdot IPR_{it} + \beta_5 \cdot AIA_{it} + \beta_6 \cdot LEV_{it} + \beta_7 \cdot l\_SIZE_{it} + \beta_8 \cdot DVICTSS_{it} + \epsilon_{it}$

Model 4: $ROE_{it} = \alpha + \beta_1 \cdot RDI_{it} + \beta_2 \cdot RDI2_{it} + \beta_3 \cdot SOFT_{it} + \beta_4 \cdot IPR_{it} + \beta_5 \cdot AIA_{it} + \beta_6 \cdot LEV_{it} + \beta_7 \cdot l\_SIZE_{it} + \beta_8 \cdot DVICTSS_{it} + \epsilon_{it}$

where: ROA, NPM, ATO, ROE – dependent variables, where i is entity and t is time;

α – Identifier;

μ – Variance introduced by the unit-specific effect for unit i;

β – Regression coefficient;

RDI, RDI2, SOFT, IPR, AIA – independent intangible variables, LEV, l_SIZE, DVICTSS – independent control variables;

ϵ_{it} – error term.

Figure 4 shows the conceptual framework of the study.

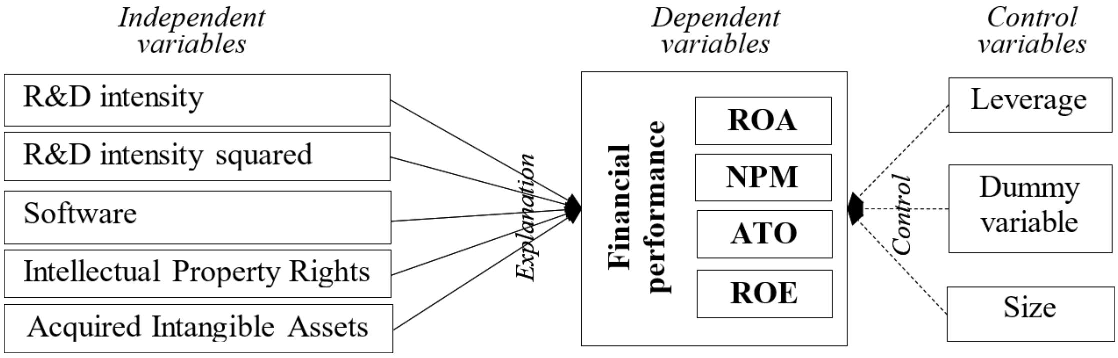

Figure 4: Conceptual framework of the study.

5. Results

5.1. Descriptive statistics and correlations

The descriptive statistics (observation, mean, median, standard deviation, minimum, maximum) of a full sample are presented in table 3.

From table 3 it can be observed that the full sample is measured with 180 units. The largest deviations in variables are related to SOFT ($5{,}95 \cdot 10^4$), IPR ($2{,}89 \cdot 10^4$), AIA ($1{,}61 \cdot 10^5$) and ROE (4,30). Large differences between the minimum and the maximum values of ROA, ATO, and ROE show that the financial performance levels of ICT companies are quite distinct. For some variables (ATO, LEV, IPR, AIA, l_SIZE) the mean value is greater than the standard deviation value, as a result, the data in these variables have a small distribution. ROA, NPM, and ROE have a higher standard deviation than their mean. This indicates a relatively large set of ratios that will characterize the normal distribution curve and will not be outliers. The closeness of the mean (13,5) and median (13,3) values for l_SIZE indicates a high level of symmetry in the

Table 3
Descriptive statistics of variables (based on observations 1:1 – 180:5).

Variables	Observation	Mean	Median	St. Dev.	Minimum	Maximum
ROA	180	1,51	1,27	1,52	2,75e-005	24,9
NPM	180	-0,0325	0,00798	0,501	-6,80	2,97
ATO	180	1,70	1,39	1,61	6,88e-005	24,6
ROE	180	3,81	2,33	4,30	0,000120	38,2
LEV	180	0,438	0,429	0,265	0,000	0,988
RDI	180	0,129	0,000	0,652	-0,0346	9,91
RDI2	180	0,442	0,000	4,96	0,000	98,2
SOFT	180	$2{,}00 \cdot 10^4$	0,000	$5{,}95 \cdot 10^4$	0,000	$5{,}18 \cdot 10^5$
IPR	180	$8{,}27 \cdot 10^3$	0,000	$2{,}89 \cdot 10^4$	$-2{,}57 \cdot 10^4$	$2{,}67 \cdot 10^5$
AIA	180	$2{,}00 \cdot 10^4$	0,000	$1{,}61 \cdot 10^5$	0,000	$3{,}20 \cdot 10^6$
l_SIZE	180	13,5	13,3	2,00	8,35	18,9

distribution of range values, that is, the size of the studied enterprises. The mean value of the LEV ratio is 0,438, and this means that approximately 44% of the total assets of ICT companies are financed through borrowed resources.

In general, correlation matrix of variables used in Models 1-4 (figure 5), testifies to absence multicollinearity problem, since in most cases, the correlation coefficient is less than 0,5 (−0,5). The only exception is the high correlation coefficient between variables RDI and RDI2 (0,9), which is understandable given that RDI2 is a squared function of RDI. However, as Özkan [23] notes, the practice of applying such mutually-correcting indicators is normal in the regression analysis performed to check the effect of interrelated variables on financial performance indicators. In particular, simultaneous use in regression models of variables RDI and RDI2 allows to detect presence U-inverted relation between R&D and financial performance of a company.

5.2. Selection of estimate panel data parameter

The choice of estimate panel data parameter for each of the selected models plays an important role in the regression analysis of panel data. This parameter should be adequately correlated with the data used in the corresponding model. Proceeding from F-statistics test for Model 1 F(179; 712) = 1,17767 with p-value 0,0766456, which is more than 0,05 and confirms null hypothesis in relation to pooled OLS model. The need for such a choice estimate parameter for Model 1 also confirmed the application Breusch-Pagan test, according to which chi-square (1) > 2,04561 p-value = 0,152645, which is larger than 0.05 and confirms zero hypotheses. The use of F-statistics test and Breusch-Pagan test also confirmed the need for use pooled OLS model as a quality estimate parameter for Model 2. For Model 3 after application F-statistics test it was received F(179; 712) = 1,23387 with p-value 0,0331413, that is less than 0,05 and testifies to the adequacy of application Fixed effects method (FEM). However, this conclusion is refuted as a result Breusch-Pagan test, according to chi-square (1) > 3,58479 p-value = 0,0583107, which is larger than 0,05 and confirms zero hypothesis of adequacy pooled OLS model. Considering the results Hausman test (p-value = prob(chi-square (8) > 4,34179) = 0,825045), according to which more appropriate is the application of Random effects method (REM) than FEM, for

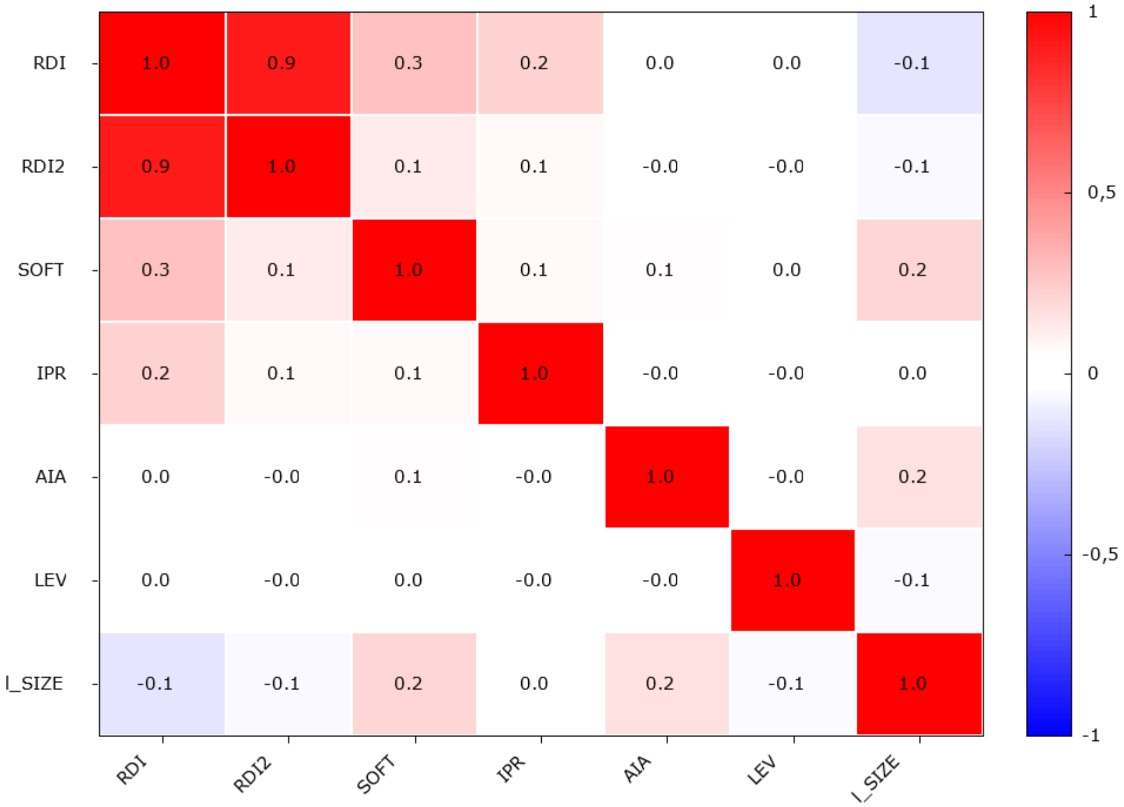

Figure 5: Correlation matrix of variables used in Models 1-4 (calculated via GRETL software package).

Model 3 more appropriate also consider the application of pooled OLS model. For Model 4 after application of F-statistics test F(179; 712) = 1,32394 of p-value 0,00693691, which is less than 0,05 and shows the adequacy of application of FEM. This is the test followed by the p-value = P(chi-square (1) > 6,04321) = 0,0139599.

5.3. Assumption test results

To verify the adequacy of the Panel data for Models 1-4 that is collected about ICT companies, it should be diagnosed using Normality test, Autocorrelation test and Heteroscedasticity test. Normality test for all Models 1-4 allowed to detect abnormal distribution of the error. For example, for Model 1 for chi-square (2) = 4119,75 p-value = 0, which is less than 0,05, and does not confirm zero hypotheses about the normal distribution of balances. Review null hypothesis about no first-order autocorrelation based on usage Wooldridge test for autocorrelation allowed to confirm it for all four models. In particular, for all Models 1-4 p-value it is more than 0,05 (0,73367; 0,923389; 0,193049; 0,227822), confirming null hypothesis. White test was used to check the heteroscedasticity of a models 1–3. Since the obtained p-value for each of the three models (0,284134; 0,999935; 0,421088) is more than the critical value, the zero hypothesis about the absence of heteroscedasticity is forgiven. For Model 4 with estimate parameter FEM was applied non-parametric Walk test, which also was established the presence of heteroscedasticity. In particular, chi-square(180) = 78593,1 p-value = 0 was received. Since p-value is less than 0,05, there is an inhomogeneous observation and a different variance of a Model 4 random error, which confirms the existence of heteroscodesticity.

To solve the problem of inadequacy of all Models 1–4 used by this data due to the problem of improper distribution of the error and heteroscedasticity, the use of robust estimators is proposed. They help minimize or eliminate impact of outliers in a Models 1-4, improving the results of panel data regression analysis. Practice of use robust standard errors in regression analysis was also used in research of scientists who study the impact of intangible assets and their components on the performance of enterprises [23, 20].

5.4. Panel data regression results

Model 1 (ROA). Tables 4–5 show the results of regression analysis performed using pooled OLS model. They show how the independent variable will affect the dependent variable, which of the regressions have significant influence, force and direction of such influence.

Table 4
Model 1 (ROA). Pooled OLS model (Robust standard errors), using the observations 1–900.

Variable	Coefficient	Standard error	z	P-value	Significance by t-statistics
const	1,83324	0,632512	2,898	0,0038	***
RDI	−1,16410	0,157720	−7,381	<0,0001	***
RDI2	0,110937	0,0175566	6,319	<0,0001	***
SOFT	$1{,}65440\cdot10^{-6}$	$5{,}38521\cdot10^{-7}$	3,072	0,0021	***
IPR	$1{,}34184\cdot10^{-6}$	$9{,}24827\cdot10^{-7}$	1,451	0,1468	
AIA	$-4{,}98766\cdot10^{-7}$	$1{,}38889\cdot10^{-6}$	−3,591	0,0003	***
LEV	−0,137738	0,214780	−0,6413	0,5213	
l_SIZE	−0,0379800	0,0454674	−0,8353	0,4035	
DVICTSS	0,168307	0,105500	1,595	0,1106	

Note: *** Significant at the 1% level.

Table 5
Model 1 (ROA). Pooled OLS model (Robust standard errors), using the observations 1–900.

Indicator	Value	Indicator	Value
Mean dependent var.	1,511304	S.D. dependent var.	1,524745
Sum squared resid.	1991,445	S.E. of regression	1,495014
R-squared	0,047173	Adjusted R-squared	0,038618
F(8, 179)	21,20706	P-value (F)	$1{,}86\cdot10^{-22}$

Model 1 can be interpreted through the following equation:

$\hat{y} = 1,83324 - 1,16410 \cdot 10^{-6} x_1 + 0,110937 x_2 + 1,65440 \cdot 10^{-6} x_3 + 1,34184 \cdot 10^{-6} x_4 - 4,98766 \cdot 10^{-7} x_5 - 0,137738 x_6 - 0,0379800 x_7 + 0,168307 x_8$ where: $\hat{y}$ – ROA; x_1 – RDI; x_5 – AIA; x_2 – RDI2; x_6 – LEV; x_3 – SOFT; x_7 – l_SIZE; x_4 – IPR; x_8 – DVICTSS.

Based on the results of the regression analysis, const, RDI, RDI2, SOFT and AIA are statistically significant (there are stars in the last column of table 4), having the highest level of significance at the 1% level. Accordingly, these indicators have the highest impact on ROA. In addition to RDI and AIA, other significant indicators have a direct impact on ROA and RDI and AIA are rotating. The presence of a different direction of influence in RDI and RDI2 indicates the presence of U-inverted relationship between R&D and ROA [24]. Similar U-inverted behavior is common to most of the costs of non-material nature, in particular, social and environmental costs [25]. The results also show that there is no significant influence of control variables (Lev, l_SIZE, DVICTSS) on ROA.

The overall content of the regression coefficient of Model 1 is that with an increase of 1 directly influencing the ROA, the last increase in the ratio will be increased. For example, if SOFT is increased by 1, the ROA will increase by 1,65440 $\cdot 10^{06}$. And for indicators that have a positive impact on ROA, their increase by 1 for ICT enterprises will result in corresponding decrease of ROA (depending on the coefficient of regression).

Table 5 indicates that the coefficient of determination (R-squared) of Model 1 is 0,047173. This means only that 4,7% of the variation of ROA can be explained by the variation of the independent variables (const, RDI, RDI2, SOFT, IPR, AIA, LEV, l_SIZE, DVICTSS).

Model 2 (NPM). Model 2 can be interpreted through the following equation:

$\hat{y} = -0,274718 + 0,0626252x_1 - 0,00669466x_2 - 5,13111 \cdot 10^{-8}x_3 + 2,00654 \cdot 10^{-7}x_4 - 5,88982 \cdot 10^{-8}x_5 - 0,0630010x_6 + 0,0269143x_7 - 0,0517929x_8$

where: $\hat{y}$ – NPM; $x_1 - x_8$ – the same as in Model 1.

Based on table 6, the most significant effect on NPM is changed to l_SIZE. Accordingly, with the growth of the enterprise volume by 1 increases the value of the NPM indicator by 0,0269143. Significant at the 5% level in NPM explanation have regressors const, RDI, RDI2 and AIA. Also significant at the 10% level is the DVICTSS regression, which has an indirect effect. Indirect effects on NPM are also affected by the RDI2 and AIA indicators. This means that, as investments in such types of intangible assets increase, the corresponding (depending on the regression coefficient) reduction of the dependent variable will occur. By comparing the coefficient of Model 2 with RDI and RDI2, it is possible to note the existence of the upper limit of investments in R&D of Slovak ICT companies, after which their negative impact on NPM will already be observed.

Table 7 indicates that the R-squared of Model 2 is 0,01, a very low value and does not allow to speak about the significant role of intangible assets in NPM provision. This means that 1,33% of the variation of the NPM can be explained by the variation of regressors.

Model 3 (ATO). Model 3 can be interpreted through the following equation:

$\hat{y} = 2,80330 - 1,42622x_1 - 0,134772x_2 + 2,76920 \cdot 10^{-6}x_3 + 4,61116 \cdot 10^{-6}x_4 - 4,38715 \cdot 10^{-7}x_5 - 0,139781x_6 - 0,0951285x_7 + 0,150857x_8$

where: $\hat{y}$ – ATO; $x_1 - x_8$ – the same as in Model 1.

For dependent variable ATO except for LEV and DVICTSS, all other regressions are significant. In particular, l_SIZE significant at the 5% level, and all other regressions (const, RDI, RDI2, SOFT, IPR and AIA) significant at the 1% level. Direct effects on ATO from the regression data are RDI2, SOFT and IPR, while others are affected. In particular, as in Model 1 for ROA, making a small amount of investments in R&D of Slovak ICT companies has a negative impact on ATO. Only their implementation from a certain volume, in particular, in the volume of RDI2, ensures

Table 6

Model 2 (NPM). Pooled OLS model (Robust standard errors), using the observations 1–900.

Variable	Coefficient	Standard error	z	P-value	Significance by t-statistics
const	−0,274718	0,116547	−2,357	0,0184	**
RDI	0,0626252	0,0295138	2,122	0,0338	**
RDI2	−0,00669466	0,00314309	−2,130	0,0332	**
SOFT	$-5{,}13111 \cdot 10^{-8}$	$1{,}17552 \cdot 10^{-7}$	−0,4365	0,6625	
IPR	$2{,}00654 \cdot 10^{-7}$	$1{,}99115 \cdot 10^{-7}$	1,008	0,3136	
AIA	$-5{,}88982 \cdot 10^{-8}$	$2{,}90523 \cdot 10^{-8}$	−2,027	0,0426	**
LEV	−0,0630010	0,0813673	−0,7743	0,4388	
l_SIZE	0,0269143	0,00838749	3,209	0,0013	***
DVICTSS	−0,0517929	0,0272405	−1,901	0,0573	*

Note:
* Significant at the 10% level;
** Significant at the 5% level;
*** Significant at the 1% level.

Table 7

Model 2 (NPM). Pooled OLS model (Robust standard errors), using the observations 1–900.

Indicator	Value	Indicator	Value
Mean dependent var.	-0,032511	S.D. dependent var.	0,501315
Sum squared resid.	222,9308	S.E. of regression	0,500203
R-squared	0,013291	Adjusted R-squared	0,004432
F(8, 179)	2,238141	P-value (F)	0,026686

Table 8

Model 3 (ATO). Pooled OLS model (Robust standard errors), using the observations 1–900.

Variable	Coefficient	Standard error	z	P-value	Significance by t-statistics
const	2,80330	0,637648	4,396	<0,0001	***
RDI	−1,42622	0,174982	−8,151	<0,0001	***
RDI2	0,134772	0,0192228	7,011	<0,0001	***
SOFT	$2{,}76920 \cdot 10^{-6}$	$6{,}38619 \cdot 10^{-7}$	4,336	<0,0001	***
IPR	$4{,}61116 \cdot 10^{-6}$	$1{,}59970 \cdot 10^{-6}$	2,883	0,0039	***
AIA	$-4{,}38715 \cdot 10^{-7}$	$1{,}36505 \cdot 10^{-7}$	−3,214	0,0013	***
LEV	−0,139781	0,233510	−0,5986	0,5494	
l_SIZE	−0,0951285	0,0438796	−2,168	0,0302	**
DVICTSS	0,150857	0,124085	1,216	0,2241	

Note:
** Significant at the 5% level;
*** Significant at the 1% level.

the growth of ATO. Based on an equal to 1,3 RDI2 growth by 1 increases the NPM value by 0,0269143. Table 9 indicates that the R-squared of Model 3 is 0,056. This means that 5,61% of the variation of the ATO can be explained by the variation of regressors.

Model 4 (ROE). Model 4 can be interpreted through the following equation:

Table 9
Model 3 (ATO). Pooled OLS model (Robust standard errors), using the observations 1–900.

Indicator	Value	Indicator	Value
Mean dependent var.	1,703817	S.D. dependent var.	1,614880
Sum squared resid.	2212,759	S.E. of regression	1,575898
R-squared	0,056170	Adjusted R-squared	0,047696
F(8, 179)	15,95424	P-value (F)	$1{,}15 \cdot 10^{-17}$

$\hat{y} = -1,06067 - 2,79903x_1 + 0,272431x_2 + 5,89712 \cdot 10^{-6}x_3 + 8,97938 \cdot 10^{-7}x_4 - 1,27997 \cdot 10^{-6}x_5 + 8,94081x_6 + 0,0265371x_7 + 0,392670x_8$

where: $\hat{y}$ – ROE; $x_1 - x_8$ – the same as in Model 1.

Model 4 has five statistically significant regressors – RDI, RDI2, SOFT, AIA and LEV (table 10). All of them have the highest level of significance – 1%, therefore they have the greatest influence on the dependent variable (ROE). The equation of Model 4 shows that most of the independent variables (RDI2, SOFT, IPR, LEV, l_SIZE and DVICTSS) have a direct influence, and only two variables (const, RDI and AIA) have a rotational influence on the ROE. As in Models 1 and 3, Model 4 has a U-inverted relationship between R&D and ROA, characterized by the need to increase investment in R&D of Slovakia ICT companies to ensure their positive impact on ROE.

Table 10
Model 4 (ROE). FEM (Robust standard errors), using the observations 1–900.

Variable	Coefficient	Standard error	z	P-value	Significance by t-statistics
const	−1,06067	1,27812	−0,8299	0,4066	
RDI	−2,79903	0,466001	−6,006	<0,0001	***
RDI2	0,272431	0,0565526	4,817	<0,0001	***
SOFT	$5{,}89712 \cdot 10^{-6}$	$2{,}18175 \cdot 10^{-6}$	2,703	0,0069	***
IPR	$8{,}97938 \cdot 10^{-7}$	$3{,}30604 \cdot 10^{-6}$	0,2716	0,7859	
AIA	$-1{,}27997 \cdot 10^{-6}$	$3{,}62115 \cdot 10^{-7}$	−3,535	0,0004	***
LEV	8,94081	0,614350	14,55	<0,0001	***
l_SIZE	0,0265371	0,0848603	0,3127	0,7545	
DVICTSS	0,392670	0,344744	1,139	0,2547	

Note: *** Significant at the 1% level.

Table 11 indicates that the LSDV R-squared of Model 4 is 0,51. This is quite a high value compared to the 1–3 models, but not enough to speak about the significant role of intangible assets in providing of financial performance of ICT companies. This means that 51,61% of the variation of the ROE can be explained by the variation of the regressors.

Table 11
Model 4 (ROE). FEM (Robust standard errors), using the observations 1–900.

Indicator	Value	Indicator	Value
Mean dependent var.	3,812005	S.D. dependent var.	4,304137
Sum squared resid.	8058,382	S.E. of regression	3,364216
LSDV R-squared	0,516144	Within R-squared	0,348421

6. Discussion

The results obtained in the article partially confirm the conclusions of the analyzed works on the role of intangible assets in the promotion of financial performance of high-tech companies. As for some regressions, they are in conflict with such conclusions. The existence of a positive and significant relationship between intangible assets and some financial performance measures was confirmed, which is also set in the works of Li and Wang [12], Dženopoljac et al. [13], Zhang [15]. The presence was also established of negative and significant impact of AIA on all financial performance indicators, this confirms the results of the research [16, 17]. At the same time, the direction and influence of different types of regressions used in the study are not the same in all formed models, but depends on a particular kind of financial performance indicator. One of the reasons for this is that the relationship between intangible assets on financial performance may depend on macroeconomic factors, in particular, on the level of science capacity in the industry and on the level of innovation in the country, which is noted by Qureshi and Siddiqui [16]. Another reason for such results may be incomplete information about intangible assets disclosed in the financial statements of Slovak ICT companies. In turn, this is a consequence of the conservatism of the current methodology of recognizing and evaluating intangible assets, which Zhang [15] also points out, Radonić et al. [19]. Therefore, the findings of this study confirm the proposal of Serpeninova et al. [20] regarding the necessity of expanding the criteria for recognizing and the structure of financial reporting for high-tech companies regarding intangible assets.

The results of the survey refutes the conclusions of Gan and Saleh [11] on the positive impact of the company's size on the improvement of financial performance (ROA), but such an impact was found with respect to NPM. The above confirms the hypothesis of Del Monte and Papagni [26] that to increase the returns from intangible investments should be provided with their proper quality level, not quantitative imitations. Therefore, an intangible investment policy of ICT companies should be based not only on quantitative parameters, that is, not on the basis of total investment in the company, but on the individual role of certain types of intangible assets in improving of financial performance.

The study has some limitations, which should be taken into account by other scientists when evaluating the results of a study. Firstly, given the sufficient breadth of the term "financial performance", a list of dependent variables used in the study can be specified. Second, the list of independent variables used in a study can be expanded by uncapitalized intangible assets that also affect the financial performance of Slovakia ICT companies. However, it is necessary to separate from the composition of different types of expenses of ICT companies those expenses connected with creation of intangible assets (client, ecological, social, etc.), as such data are not in financial statements of companies. Third, to determine the role of intangible assets in improvement of financial performance, research can be carried out not only on the examples of companies of ICT industry, but also on the example of other branches of economy. This will allow to carry out an interindustry comparison and establish in which areas of management of enterprises should pay the most attention to development of an intangible investment policy.

7. Conclusion

This research was undertaken with the objective of comprehending the ramifications of intangible assets on the financial performance of high-tech enterprises. The focus of this study was the analysis of 180 Slovak ICT companies over the period spanning 2015 to 2019. This inquiry gains particular pertinence against the backdrop of the pivotal role that the ICT sector plays in propelling the development of the Slovak economy. The Slovak Government has proactively established conducive institutional conditions to facilitate the growth of ICT companies and has initiated specialized programs to incentivize investments in this sector.

Panel data regression analysis served as the foundational methodology for this investigation. The financial performance was characterized through four dependent variables: Return on Assets, Net Profit Margin, Assets Turnover, and Return on Equity. For each of these indicators, a distinct model was constructed, incorporating eight independent variables. The intangible asset variables encompassed Research and Development Intensity, Research and Development Intensity Squared, Software, Intellectual Property Rights, and Acquired Intangible Assets. Additionally, three control variables were integrated: Leverage, Size, and a Dummy variable denoting ICT sub-sectors, within the temporal scope of 2015 to 2019. The selection of the optimal panel data parameter for each model was grounded in statistical tests, such as the F-statistics test, Breusch-Pagan test, and Hausman test (Models 1 to 3 – pooled OLS model, Model 4 – Fixed Effects Method). To assess the models' compatibility with the generated data, the Normality test, Autocorrelation test (Wooldridge test for autocorrelation), and Heteroscedasticity test (White test, Walk test) were employed, substantiating the application of robust standard errors due to partial model adequacy.

The study's hypothesis was affirmed to a certain extent through the outcomes of the panel regression analysis. The results unveiled that not all categories of intangible assets wield a significant positive influence on the financial performance of Slovak ICT companies. Specifically, Research and Development Intensity (RDI), Research and Development Intensity Squared (RDI2), and Acquired Intangible Assets (AIA) exhibited substantial impact across various degrees on the four distinct financial performance indicators. This emphasizes the rationale for management to channel investments into these specific categories of intangible assets for Slovak ICT companies. Furthermore, the contrasting directions of influence of RDI and RDI2 on financial performance indicators underscore the existence of a U-inverted relationship between R&D investment and the financial performance metrics. Depending on the model, RDI either operates beyond the threshold of returns on R&D investments or within it, while RDI2 exhibits the inverse relationship. These findings offer managerial insights into optimizing R&D investments based on the desired financial performance outcomes. Remarkably, across all models, Acquired Intangible Assets (AIA) demonstrated substantial significance but negatively affected the financial performance of Slovak ICT enterprises. This indicates the need for more expeditious integration of these long-term intangible assets into the operational fabric of the companies.

Furthermore, the research underscores the need for a comprehensive system to plan the assimilation of intangible assets, tailoring them to the company's exigencies as a core component of its intangible investment strategy. The analysis of control variables, including Leverage, Size, and Dummy variable for ICT sub-sectors, demonstrated selective impact on financial performance indicators. Notably, only the variable l_SIZE exhibited a significant influence on Net Profit Margin (NPM) and Assets Turnover (ATO), with implications for managerial considerations in optimizing these metrics. The variable DVICTSS exhibited limited significance on NPM, while LEV affected Return on Equity (ROE). These findings underscore the nuanced and selective nature of control variables' influence on various financial performance indicators, with no discernible effect on Return on Assets (ROA).

In the broader context, this study serves to illuminate the intricate relationships between intangible assets and financial performance in the ICT sector. The insights garnered herein have the potential to inform prudent decision-making within the domain of intangible asset investments and their subsequent impact on financial performance for Slovak ICT companies. Furthermore, this research offers valuable insights for policy and strategic adjustments aimed at fostering the incorporation of long-term intangible assets into business operations, thus enhancing financial performance. As the ICT sector continues to evolve and shape the Slovak economy, these findings can serve as a compass guiding effective strategies for leveraging intangible assets in this dynamic landscape.

As the global business environment continually evolves, future research endeavors could delve deeper into the interplay between various intangible asset categories and financial performance across different industries and geographical contexts. Such investigations would not only enrich the existing body of knowledge but also provide actionable insights for enterprises seeking to optimize their financial performance through targeted intangible asset investments.

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