# Empirical Evidence of Intangible Assets Improve the Financial Performance of Slovak ICT Companies

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Abstract: In the conditions of the knowledge economy, the financial performance of high-tech enterprises largely depends on the efficiency of the processes of creating and using intangible assets. To increase it, it is necessary to build an effective intangible investment policy, which should be based on an understanding of the role of certain types of intangible assets in increasing financial performance. The hypothesis of the study is the existence of a significant positive impact of intangible assets on the financial performance of ICT companies. A sample of 180 Slovak ICT companies for the period 2015–2019 has been investigated. The primary research method was the regression analysis of panel data, which was carried out using the GRETL software package. Four regression models were formed based on using such dependent variables as Return on Assets, Net Profit Margin, Assets Turnover, and Return on Equity. Each of the selected models included 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. For each of the models, an estimate panel data parameter was chosen based on the F-statistics test, Breusch-Pagan test, and Hausman test (Model 1-3 – Pooled OLS model, Model 4 – Fixed Effects Method). Adequacy of each of the models to the generated data was checked on the basis of the Normality test, Autocorrelation test (Wooldridge test for autocorrelation), and Heteroscedasticity test (White test, Wald test). The hypothesis of the study was partially confirmed, since only RDI, RDI2 and AIA have a significant positive impact on the financial performance of Slovak ICT companies. The strength and direction of influence of independent variables vary depending on the indicator characterizing financial performance. Only the independent variable AIA has a permanent inverse effect on all indicators of financial performance of Slovak ICT companies. It was established that the level of influence of control variables on indicators of financial performance is partial and multidirectional, and applies only to certain types of them.

## 1 INTRODUCTION

Over the last three decades, a significant number of scientists have been actively discussing the change in the role of different types of capital in the process of creating economic value of enterprises and ensuring their sustainable and long -term success. In particular, it is reminded on the determining role of intellectual capital in this process by shift in the "production mix" and management's focus, moving from the industrial focus (of capital and labour) to intellectual capital and trade in ideas, based on intellectual property rights, especially patents for its connection to technology (Daum, 2002; Abeysekera, 2008; Moberly, 2014; Ullberg et al., 2021). Under these conditions, the value of enterprises and their profitability become more dependent on their ability to effectively realize their existing innovative potential and to use their capitalized

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intangible assets. This issue is even more relevant in the period of overcoming the consequences of the COVID-19 pandemic and in the context of the introduction of a proactive sanctions policy of world leaders, which results in a reduction in trade in traditional goods and services, given the growth of the market of unique intellectual technologies, which ensure the formation of a stable value for enterprises.

In such new conditions, the economy of developed countries becomes increasingly dependent on the development of national intellectual capital. And for a large number of enterprises their financial performance depends on the effectiveness of implementation of the policy on creation of new and use of available intangible assets, ensuring their incorporation into the activity of the enterprise, the establishment of their effective partnership, stewardship and control. At the same time, the activity of enterprises under such conditions is characterized by frequent occurrence of network effects, high probability of occurrence of market and technological risks, which provides the necessity of rethinking their business strategies, which will include realization of strategic initiatives on intangible values. This is especially relevant for high-tech enterprises, whose activity is characterized by high level of usage of intangible assets and is aimed at creation of innovative technological products and services.

The presence of such economic changes in the global business environment makes it necessary to search for new theories and policies that would enable the scientific substantiation of decisions and behavior of management of companies with a high share of intangible assets used in the process of development and design of technological products and services to ensure their strong financial performance.

To determine impact of impossible assets on companies performance, the activity of Slovak companies from information and communications technology (ICT) sector was analyzed. Such enterprises, which relate to processes of processing, storage and transfer of information, production of computers and telecommuting devices, and also provision of related services, belong to high-tech enterprises, the process of creating value in which depends to a large extent on effective use of intangible assets. Investing in high-tech intangible assets of ICT sector enterprises should lead to the improvement of their financial indicators. However, as the studies Huňady et al. (Huňady et al., 2019), Slovakia still has only very small proportion of business R&D in ICT sector. This is evidence of the cautious policy of Slovak ICT companies to implement intangible investments as a result of the existence of significant risks and uncertainty as to the return of such investments. Therefore, in order to minimize such risks and eliminate uncertainty, in order to build an effective intangible investment policy at ICT enterprises need to identify features of relations between different types of intangible assets and different financial performance indicators.

In the Slovak Republic over the past ten years, there has been active development of the ICT sector. In particular, the number of employees involved in the information and communication technology services sector in Slovakia increased from 28905 in 2009 to 53676 in the 2019 year (SARIO, 2021). This shows an increase in staff almost doubled in 10 years. ICT industry currently occupies an important place in the structure of the Slovak economy, representing 4,2% of GDP, and at the same time has a noticeable influence on other related industries. This industry is very attractive for investors due to the presence of significant potential for growth due to a number of advantages in comparison with other branches of economy in Slovakia: High level of adaptation of ICT to the activity of enterprises; high value added and wages (1,2 – 4,0 ths. eur.); well-developed ICT related educational system; well-developed ICT institutional network; diversification of telecommunication segment; strategic geographical location from the perspective of time zonation; high quality data and network coverage; attractive investment incentives for the ICT sector (SARIO, 2021). In addition, ICT sector is actively supported by Slovak government, as a result, investors are offered attractive investment incentives for the ICT sector (tax reliefs; cash grants; contributions for the newly created jobs; rent/sale of real estate for a discounted price) and special R&D tax regime (200% of the R&D expenses can be deducted from the tax base) (SARIO, 2021). Thus, impact research of intangible assets impact on financial performance of Slovak ICT companies in modern conditions, there is a particularly urgent need to define the directions of development and ways of adjustment of their intangible investment policy.

Based on the important role of intangible assets in ensuring the efficiency of high-tech companies research hypothesis was formulated. The hypothesis of the study is the existence of a significant positive impact of intangible assets on the financial performance of ICT companies. Because the force of such influence may also depend from company size, level of borrowed capital and belonging to sub-sector of ICT industry, these factors should also be taken into account in the analysis impact of intangible assets on the financial performance, and the results obtained should be used in formulating recommendations to management of Slovak ICT companies for investments in intangible assets.

## 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 (Deloitte Touche Tohmatsu Limited, 2022)), 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.

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 (Gan and Saleh, 2008) the connection between intellectual capital components was studied corporate performance of high-techn 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 (Li and Wang, 2014) 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. (Dženopoljac et al., 2016) 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 (Khan, 2018) 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 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 (Zhang, 2017) 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. (Huňady et al., 2019) examined the role of innovations in performance of ICT sector com-

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).

| | Results found | | | Sum of the times cited | | |
|---|---|---|---|---|---|---|
| Searching phrases | 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 |

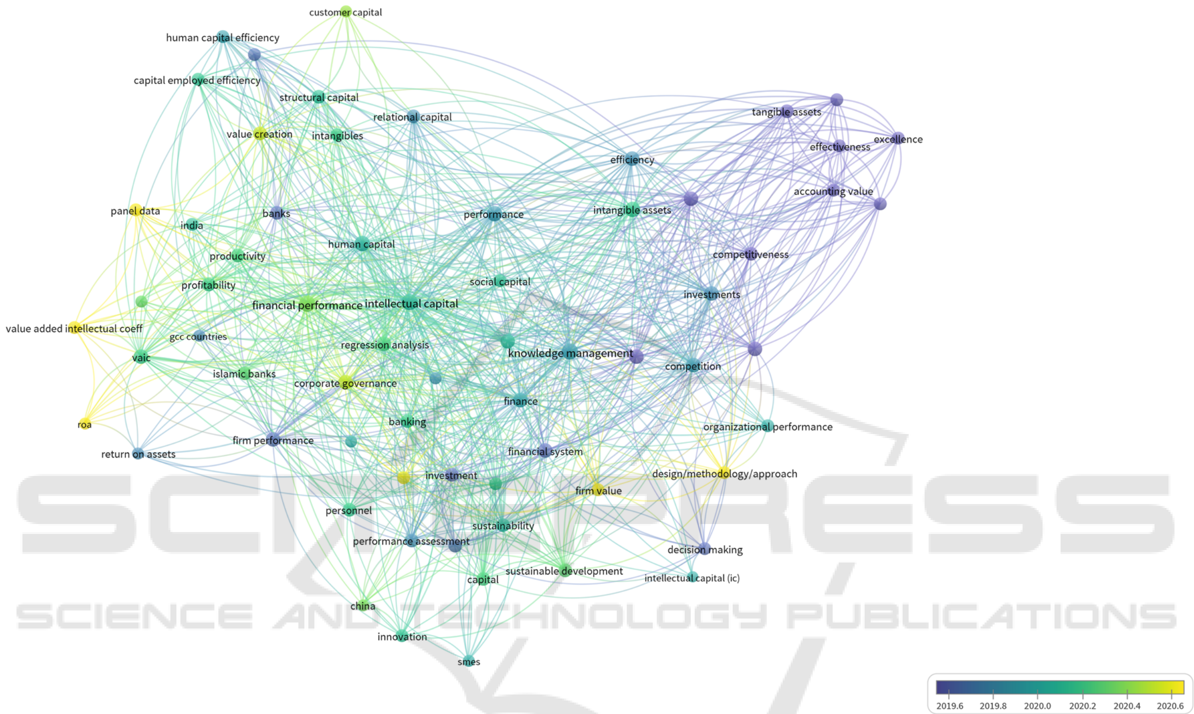


Figure 1: Bibliometric map of publications’ keywords on the query “Intangible assets”, “Intellectual capital” and “Financial performance” according to Scopus database in 2018–2022.



panies 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 (Qureshi and Siddiqui, 2020) 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 (Lopes and Ferreira, 2021) 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 in labor Sundaresan et al. (Sundaresan et al., 2021), which investigated the impact of intangible assets on financial performance of 38 Taiwanese listed 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. Received Lopes and Ferreira (Lopes and Ferreira, 2021), Sundaresan et al. (Sundaresan et al., 2021) the results of the ROA are in direct contradiction with most of the conclusions obtained by the authors who studied impact of

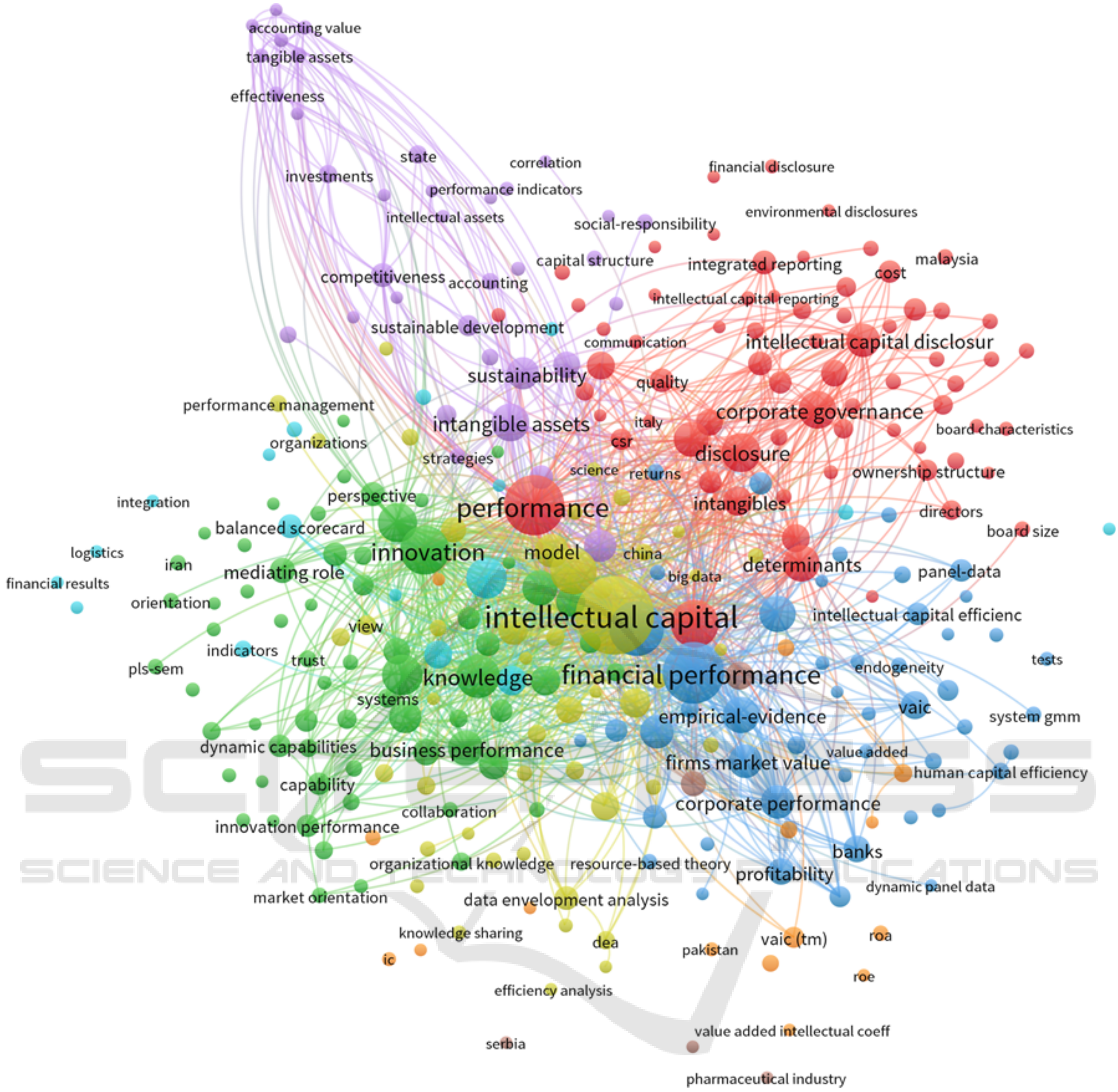


Figure 2: Bibliometric map of publications' keywords on the query "Intellectual capital" and "Financial performance" according to Web of Science database in 2018–2022.

intangibles on performance of ICT companies.

Radonić et al. (Radonić et al., 2021) 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. (Serpeninova et al., 2022), 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

*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%.

*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 (Gan and Saleh, 2008; Dženopoljac et al., 2016; Qureshi and Siddiqui, 2020; Sundaresan et al., 2021; Radonić et al., 2021; Serpeninova et al., 2022). 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 Huňady et al. (Huňady et al., 2019), 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 (Ievdokymov et al., 2020; Zavalii et al., 2022; Serpeninova et al., 2022) 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 1 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,

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 |

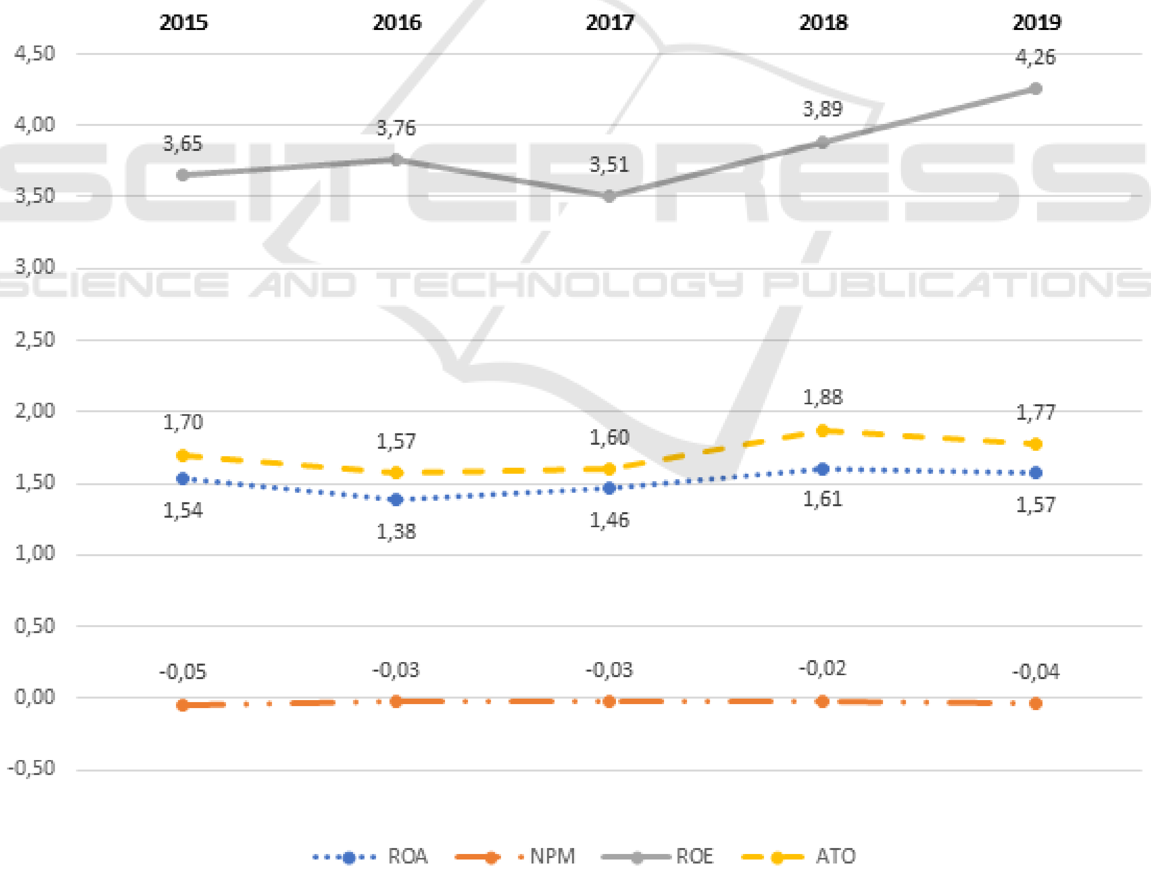


Figure 3: Dynamics of financial performance indicators of Slovak ICT companies for the 2015-2019 period.

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

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

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

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

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

$\alpha$ – Identifier;

$\mu$ – Variance introduced by the unit-specific effect for unit *i*;

$\beta$ – Regression coefficient;

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

$\varepsilon_{it}$ – error term.

Figure 4 shows the 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 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 (Özkan, 2022) 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 Model 3 more appropriate also

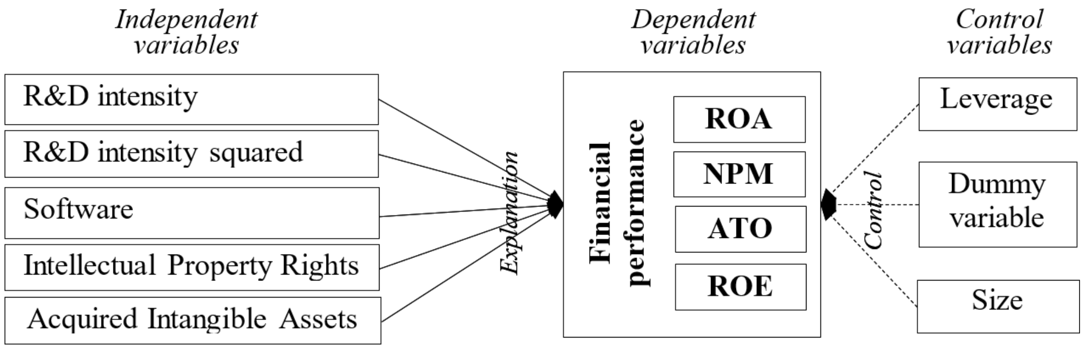


Figure 4: Conceptual framework of the study.

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 | 2,00e+004 | 0,000 | 5,95e+004 | 0,000 | 5,18e+005 |
| IPR | 180 | 8,27e+003 | 0,000 | 2,89e+004 | -2,57e+004 | 2,67e+005 |
| AIA | 180 | 2,00e+004 | 0,000 | 1,61e+005 | 0,000 | 3,20e+006 |
| l_SIZE | 180 | 13,5 | 13,3 | 2,00 | 8,35 | 18,9 |

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 (Özkan, 2022; Serpeninova et al., 2022).

## 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 regres-


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



sions have significant influence, force and direction of such influence.

Model 1 can be interpreted through the following equation:

$\hat{y} = 1,83324 - 1,16410 \cdot 10^{-6}x_1 + 0,110937x_2 + 1,65440 \cdot 10^{-6}x_3 + 1,34184 \cdot 10^{-6}x_4 - 4,98766 \cdot 10^{-7}x_5 - 0,137738x_6 - 0,0379800x_7 + 0,168307x_8$
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 (Lehenchuk et al., 2022). Similar U-inverted behavior is common to most of the costs of non-material nature, in particular, social and environmental costs (Sokil et al., 2020). 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.

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 | $1{,}65440 \cdot 10^{-6}$ | $5{,}38521 \cdot 10^{-7}$ | 3,072 | 0,0021 | *** |
| IPR | $1{,}34184 \cdot 10^{-6}$ | $9{,}24827 \cdot 10^{-7}$ | 1,451 | 0,1468 | |
| AIA | $-4{,}98766 \cdot 10^{-7}$ | $1{,}38889 \cdot 10^{-6}$ | −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) | $1{,}86 \cdot 10^{-22}$ |

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 |

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

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 | $2{,}76920\cdot10^{-6}$ | $6{,}38619\cdot10^{-7}$ | 4,336 | <0,0001 | *** |
| IPR | $4{,}61116\cdot10^{-6}$ | $1{,}59970\cdot10^{-6}$ | 2,883 | 0,0039 | *** |
| AIA | $-4{,}38715\cdot10^{-7}$ | $1{,}36505\cdot10^{-7}$ | –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.

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) | $1{,}15\cdot10^{-17}$ |

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 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:

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

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 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.

## 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 (Li and Wang, 2014), Dženopoljac et al. (Dženopoljac et al., 2016), Zhang (Zhang, 2017). The presence was also established of negative and significant impact of AIA on all financial performance indicators, this confirms the results of the research (Qureshi and Siddiqui, 2020; Lopes

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 | $5{,}89712\cdot10^{-6}$ | $2{,}18175\cdot10^{-6}$ | 2,703 | 0,0069 | *** |
| IPR | $8{,}97938\cdot10^{-7}$ | $3{,}30604\cdot10^{-6}$ | 0,2716 | 0,7859 | |
| AIA | $-1{,}27997\cdot10^{-6}$ | $3{,}62115\cdot10^{-7}$ | –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: 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 |

and Ferreira, 2021). 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 (Qureshi and Siddiqui, 2020). 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 (Zhang, 2017) also points out, Radonić et al. (Radonić et al., 2021). Therefore, the findings of this study confirm the proposal of Serpeninova et al. (Serpeninova et al., 2022) 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 (Gan and Saleh, 2008) 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 (Del Monte and Papagni, 2003) 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

The present research was performed in order to study the effects of intangible assets on the financial performance of high-tech companies. For this purpose, the activity of 180 Slovak ICT companies over the period 2015–2019 was analyzed. Such research is especially relevant in the conditions of the ICT sector's important role in the development of the Slovak economy. As a result, Slovak Government creates the necessary favorable institutional conditions for further development of ICT companies and implements special programs to stimulate investment in this sector.

Panel data regression analysis was used as the basic method of research. Return on assets, Net Profit Margin, Assets Turnover and Return on Equity were selected as dependent variables that characterize financial performance. For each of these indicators a model was formed, which included eight independent variables. It is intangible assets variables (Research and Development Intensity, Research and Development Intensity Squared, Software, Intellectual Property Rights, Acquired Intangible Assets), and three – control variables (Leverage, Size, Dummy variable for ICT sub-sectors) for the 2015–2019 period. For each of the models the estimate panel data parameter was chosen based on F-statistics test, Breusch-Pagan test and Hausman test (Model 1–3 – pooled OLS model, Model 4 – FEM). The adequacy of each of the models of the formed data was tested on the basis of the Normality test, Autocorrelation test (Wooldridge test for autocorrelation) and Heteroscedasticity test (White test, Walk test) with the application of the GRETL software package. Based on the incomplete adequacy of the models to the generated data the expediency of robust standard errors use was substantiated.

The hypothesis of the study was partially confirmed as a result of the conducted research. The results of panel regression analysis have shown that not all types of intangible assets have a significant positive impact on the financial performance of Slovakia ICT companies. Only RDI, RDI2 and AIA have significant influence of different forces on all four types of dependent indicators, which characterize the financial performance of the company. This is evidence of the expediency of management making investments in these types of intangible assets of the Slovak ICT companies. The presence of different directions of influence of RDI and RDI2 on indicators of the financial performance testifies to existence of U-inverted relationship between R&D and such indicators of two types. By the first type (Models 1, 3, 4) RDI is out of the zone of return of investments in R&D, and RDI2 is within it. And by the second type (Model 2) RDI enters the profit zone, and RDI2 is already outside it. Based on these results, management of ICT companies may decide to make additional investments in R&D or to reduce them in order to provide better financial performance of the company. In all models studied, the independent variable AIA has a high level of significance, but turns to the performance of financial performance of Slovak ICT companies. This shows that long-term intangible assets have not yet been put into operation, and therefore need to be more quickly brought into business processes of Slovak ICT companies. In addition, there should be an effective system of planning processes for acquisition of intangible assets in accordance with the company's needs as an element of its intangible investment policy.

Research results also show that when using leverage, Size and Dummy variable for ICT sub-sectors as a control variables only l_SIZE has a significant impact on NPM (1% level) and ATO (5% level), DVICTSS on NPM (10% level) and LEV on ROE (1% level). That is, the level of influence of control variables on the indicators of financial performance is partial and varied, and applies only to certain types of them, in particular, not at all affecting ROA.

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