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Intellectual capital and the profitability of pharmaceutical and biotechnological companies listed on the Warsaw Stock Exchange

Kapitał intelektualny a rentowność spółek farmaceutycznych i biotechnologicznych notowanych na Giełdzie Papierów Wartościowych w Warszawie

Abstract

The goal of this article is to determine the influence of intellectual capital (IC) with its components on the profitability of pharmaceutical and biotechnological companies listed on the Warsaw Stock Exchange. The time range of the study covers the years 2015–2021. Various research methods were used: descriptive analysis, desk research analysis, the A-VAIC method, descriptive statistics and panel model estimation. Time lag was applied to variables in panel models in order to verify whether IC affects the future profitability of enterprises. The findings confirmed the influence of IC on the profitability of assets and profitability of equity. Moreover, they revealed a varied influence of individual components of IC on the indicated measures describing the profitability. The study confirms that IC plays an important role in strengthening the profitability of pharmaceutical and biotechnological companies. As a result, it enables companies to achieve and maintain a sustainable competitive advantage, and thus shapes their market share. The results of this study should provide additional knowledge concerning the significance of IC in the context of its influence on the profitability of enterprises and interest a wide spectrum of people: scientists, management staff, representatives of supervisory institutions and market practitioners – investors and analysts.

Keywords
intellectual capital, pharmaceutical and biotechnological companies, profitability

Streszczenie

Celem artykułu jest określenie wpływu kapitału intelektualnego (KI) i jego komponentów na rentowność spółek farmaceutycznych i biotechnologicznych notowanych na Giełdzie Papierów Wartościowych w Warszawie. Zakres czasowy badania obejmuje lata 2015–2021. W badaniu wykorzystano różnorodne metody badawcze: analizę opisową, analizę *desk research*, metodę A-VAIC, statystykę opisową oraz estymację modelu panelowego. W modelach panelowych zastosowano opóźnienie czasowe (*time-lag*) zmiennych celem weryfikacji, czy KI wpływa na przyszłą rentowność przedsiębiorstw. Uzyskane wyniki potwierdziły wpływ KI na rentowność aktywów oraz rentowność kapitału własnego. Ponadto, ukazały zróżnicowany wpływ poszczególnych komponentów KI na wskazane miary opisujące rentowność. Badanie potwierdza, że KI odgrywa istotną rolę we wzmacnianiu rentowności spółek farmaceutycznych i biotechnologicznych. W rezultacie czynnik ten umożliwia spółkom osiąganie oraz utrzymanie trwałej przewagi konkurencyjnej, a przez to kształtuje ich udział w rynku. Wyniki niniejszego badania powinny dostarczyć dodatkowej wiedzy dotyczącej znaczenia KI w kontekście jego wpływu na rentowność przedsiębiorstw oraz zainteresować szerokie spektrum osób: naukowców, kadrę zarządzającą, przedstawicieli instytucji nadzorczych oraz praktyków rynkowych – inwestorów i analityków.

Słowa kluczowe
kapitał intelektualny, spółki farmaceutyczne i biotechnologiczne, rentowność

JEL: O34, L25, E22, G32, L65

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Introduction

In the age of the knowledge-based economy, intellectual capital (IC) is recognized as one of the most important capital in creating the value of enterprises, a factor contributing to a permanent competitive advantage and improvement of financial results (Bombiak, 2021, p. 22; Xu & Li, 2022, p. 313, 315). Intellectual capital is formed by intangible resources which stem from knowledge transformation, but also by knowledge itself.

The intangible resources constituting intellectual capital can be used simultaneously in various locations and in many ways. They represent both the input and the outcome of a company's activities. They cannot be acquired solely by money. Furthermore, they can provide various benefits at the same time (Itami & Roehl, 1987, p. 12–13).

This reveals the need to conduct research on the influence of IC on enterprises' financial results, including their profitability. Research of this kind requires measurement of IC, using an appropriate tool, since traditional measuring systems adopted for tangible capital occur insufficient (Michalczuk et al., 2021, p. 17). The return-on-assets methods are an interesting group, including among others VAIC™ – Value Added Intellectual Coefficient and its modifications. The advantage of the return-on-assets methods is the ease of calculations and reliability of results obtained, as they are mainly based on information derived from financial reporting (Sveiby, 2010, p. 3).

The goal of this article is to determine the influence of IC and its components on the profitability of pharmaceutical and biotechnological companies listed on the Warsaw Stock Exchange (WSE). The time range of the study covers the years 2015–2021. In this article, various research methods are employed: descriptive analysis, desk research analysis, the A-VAIC method, descriptive statistics and panel model estimation (multiple regression analysis). Time lag was applied to variables in panel models in order to verify whether IC also affects the future profitability of enterprises. A 1-year, 2-year and 3-year time lag was applied in the study.

The structure of the article is as follows. The first part includes literature review concerning the impact of IC on the profitability of enterprises. The second part describes the research methodology, the method of measuring IC and the characteristics of the research sample. The third part presents the research findings. This is followed by an analysis and a discussion of the research carried out. The article is concluded by a summary containing the research conclusions and presenting potential practical applications of findings, and suggestions regarding the directions of future research in the area.

Literature review

Changes in the socioeconomic environment observed over the last several decades result from the process of transition from an industrial economy, mainly based on the use of traditional production factors, to a knowledge-based economy (Komnenic et al., 2010, p. 25; Weqar et al., 2021, p. 180). As the significance of knowledge in the functioning of enterprises became apparent, a new concept of capital was elaborated. As a result, besides tangible, financial capital, other notions of capital began to appear, including IC. The concept was first developed at the turn of the 1980's and 1990's and soon became a subject of interest, not only for scientists but for businesses too, in the context of the IC measurement and practical application in the decision-making process (Edvinsson & Malone, 2001, p. 38–39).

A growth of interest in the concept of IC and the emphasis on its role in building the value and competitive advantage of enterprises has resulted in IC becoming the subject of scientific research. Initially, research was focused on: the definition, taxonomy, measurement and reporting of IC. Currently, studies concerning the influence of IC on financial results, including the profitability of enterprises, have become an important field (Gupta et al., 2020; Ovechkin et al., 2021).

Gupta et al. (2022) investigated the dependency between IC and the profitability of Indian pharmaceutical companies. The study demonstrated a significant, positive relationship between IC and profitability. However, it also showed varied influence of individual components of IC. A similar study on pharmaceutical companies listed on exchanges of the Indian pharmaceutical sector in Bombay was conducted by Smriti and Das (2017). Their analysis also indicated a positive impact of IC upon profitability. Moreover, empirical analysis demonstrated that structural capital and relational capital were components of IC that had a significant influence on the profitability of companies during the period studied.

A study carried out by Amin and Aslam (2017) on pharmaceutical companies listed on the London Stock Exchange confirmed that IC and its components have a positive and significant influence on the profitability of enterprises. Then, Kafili et al. (2022) proved that the IC of pharmaceutical companies listed on the Tehran Stock Exchange affects the return on assets (ROA). Anghel et al. (2018) analysed the

dependencies between IC and the profitability of selected biotechnological companies from different countries: the United States of America, Australia, Denmark, Switzerland, Ireland, Germany, France, and Sweden. The authors used two methods to measure IC: market value to book value (MV/BV) ratio and an original ratio of the efficiency of R&D expenditures (ECD). The findings of the study revealed a significant negative relationship between MV/BV on the one side, and ROA (return on assets) and ROE (return on equity) on the other, as well as a strongly positive and significant dependency between ECD, and ROA and ROE ratios.

The examples presented do not reflect the full spectrum of research concerning the influence of IC on enterprises' profitability. Instead, they only pertain to studies that concerned pharmaceutical and biotechnological companies. However, the results of research are not unambiguous and indicate varied influence of IC and its components on profitability. While most studies confirm positive influence, some other ones do not confirm such relationship (Chizari et al., 2016; Zhang et al., 2021). In effect, conclusions in the subject literature are diverse and often contradictory.

Moreover, most studies in this scope are focused on investigating the influence of IC on the profitability of enterprises without any time lag being taken into account, whereas, due to its nature, IC may only affect future financial results. This is a firm argument in favour of the need to conduct further research that applies time lag for the purpose of investigating the influence of IC on enterprises' future financial results. This is indicated, among others, by Dženopoljac et al. (2022, p. 55), stating that the failure to immediately prove the influence of IC on enterprises' profitability is proof of the need to study its delayed effect and predictive power on generated results. Such an approach is further substantiated by the fact that IC is very often understood by researchers as a set of elements like: employees' competencies, customer loyalty, which are not visible in current reporting as they do not cause a gain in profit within a short period of time. The effects may be revealed only after many years (Sopińska, 2008, p. 103).

Dženopoljac et al. (2022) conducted a study in which they evaluated whether IC may affect the future profitability of companies listed on the Kuwait Stock Exchange. The authors applied a 1–year, 2-year and 3-year time lag. The results demonstrated that IC has significant predictive power with respect to a company's ROA and ROE, with greater predictive power for a 2-year time lag. With a 3-year time lag taken into account, the model's fit decreases significantly. Dženopoljac et al. (2019), also applying time lag, analysed the relationship between IC and the profitability of global petroleum and gas companies. The study provided evidence for existence of a dependency between IC and the future ROE. Chen et al. (2005), applying a 1-year, 2-year and 3-year time lag to independent variables, investigated the relationship between IC and the current and future profitability of Taiwanese exchange-listed companies. Their study demonstrated that IC has a positive relationship with the future profitability of companies. Naidenova and Parshakov (2013) investigated the relationships between IC and the profitability of American enterprises from various sectors. The study showed that, in the pharmaceutical industry, human and structural capital impacts profitability only over a period longer than four years.

Research methodology

The goal of this article is to determine the influence of IC and its components on the profitability of pharmaceutical and biotechnological companies listed on the WSE. For the purposes of achieving this, the following research questions were formulated:

1. Does intellectual capital, with its components, have a positive influence on the return on assets of pharmaceutical and biotechnological companies listed on the Warsaw Stock Exchange?
2. Does intellectual capital, with its components, have a positive influence on the return on equity of pharmaceutical and biotechnological companies listed on the Warsaw Stock Exchange?

Due to the nature of the data (time-series-cross-section data), panel models were used to achieve the goal. Panel data are data observed in at least two dimensions. They combined cross-sectional data with time series, i.e. data are observed on multiple objects for multiple time periods (Kufel, 2007, p. 164). GRETL software was used to perform statistical analyses.

In this article various research methods are employed: descriptive analysis, desk research analysis, the A-VAIC method, which is a modification of the classical VAIC™ model, descriptive statistics and panel model estimation (multiple regression analysis). Time lag was applied with respect to variables in panel models for the purpose of checking whether components of IC (measured using the Adjusted Value Added Intellectual Coefficient – A-VAIC) also affect the profitability of the analysed companies over a long period.

The research sample included pharmaceutical and biotechnological companies listed on the WSE.

The choice of companies of this type as the research subject was dictated by the fact that the activity of pharmaceutical and biotechnological companies is largely based on the use of IC (Amin & Aslam, 2017; Smriti & Das, 2017; Anghel et al., 2018). Entities with such a profile of activity use specialized knowledge, know-how, modern technologies and build relational capital with customers, hence they often serve as a field of research on IC. The Polish pharmaceutical and biotechnological sector is currently acknowledged to be one of the most innovative fields of the economy, which is another reason why enterprises of this type were chosen. The advantages of the Polish pharmaceutical and biotechnological industry are, among other things, generic prescription drugs and OTC drugs. Poland is becoming a new European centre for the production of complex generic and biosimilar drugs and is strengthening its role as one of the leading manufacturers of generic products. The Polish pharmaceutical market is the sixth largest market in the European Union, and its primary advantage is a highly qualified staff (The Polish Investment and Trade Agency, 2022, p. 20). Moreover, the pharmaceutical industry is a leader when it comes to product innovations, surpassing the production of computers, electronics and optical products in this regard (The Polish Investment and Trade Agency, 2021).

The study covered companies headquartered on the territory of Poland and with financial statements denominated in the Polish currency. Entities headquartered outside Poland (so-called "foreign issuers"), not subject to Polish law, were excluded from the sample. The research sample encompassed 12 companies listed on the WSE. Secondary data were obtained from annual consolidated financial statements, or unit statements where a company only publishes such statements. The time range of the study covered the years 2015–2021. The timing of the study's start was mainly due to the fact that the consequences of the global financial crisis (during 2007–2009) were revealed in the preceding years, and many new companies, having debuted on the WSE only several years before, were listed in the pharmaceutical and biotechnological sectors. The closing of the time range, instead, was dictated by the availability of data.

One of the return-on-assets methods was used to measure IC and its components, namely the VAIC™ method, developed by Pulic (2004). The application of VAIC™ was justified by its widespread use in research on IC (Xu & Li, 2022; Xu et al., 2023). The goal of this method is to investigate the efficiency of creating value added from both tangible and intangible assets. The computation algorithm is based on available data published in annual statements (subject to external auditing), which confirms the reliability and objectivity of findings obtained (Fijałkowska, 2013, p. 72).

Based on an analysis of trends in research on IC in the foreign literature, a modification of the classical VAIC™ method was used in the study. This is the A-VAIC method developed by Nadeem et al. (2019). These authors introduced two changes to Pulic's method. Firstly, they adjusted the calculation of value added (VA) by adding research and development (R&D) expenses incurred, which are treated as investments, not as costs. In addition, due to the problems with calculating structural capital efficiency (SCE) in the classical VAIC™, they are replaced by R&D costs in the A-VAIC method. The result is the innovation capital efficiency coefficient (INVCE), which is the ratio of VA to R&D expenditures. Despite this improvement, the A-VAIC model still has the same limitations as the original model (Smuda-Kocoń, 2019), i.e.: significant simplification in determining the value of human capital (treatment of all expenditures for employee purposes as a component of assets) and not accounting for all components of IC – omission of relational capital. Moreover, this method cannot be applied if an enterprise does not conduct research and development activity. Despite the indicated limitations, the application of the A-VAIC method is justified from the perspective of the present study. This is of particular importance in the context of the companies under analysis. Innovative pharmaceutical and biotechnological enterprises incur substantial expenses for R&D work every year. The high value of R&D expenditures reflects the essence of activity of this type of enterprises, which is to utilize the latest scientific and technological achievements to develop medicinal products that are as effective as possible (IINFARMA & Deliotte, 2022, p. 24). The formula for calculating components of the A-VAIC coefficient is presented in Table 1.

Two types of models were applied to investigate the influence of IC and its components on the profitability of the pharmaceutical and biotechnological companies studied. Standard panel model estimation was used to investigate the influence of IC on ROA. Dynamic panel model estimation (dynamic panel regression analysis) was applied to investigate the influence of IC on ROE. Referring to the A-VAIC model, econometric regression equations were determined for the dependent variables. Finally, 1-year, 2-year and 3-year time lags were applied in estimation.

Three types of variables were used in the study: dependent variables (ROA, ROE), independent variables (HCE, INVCE, CEE) and two control

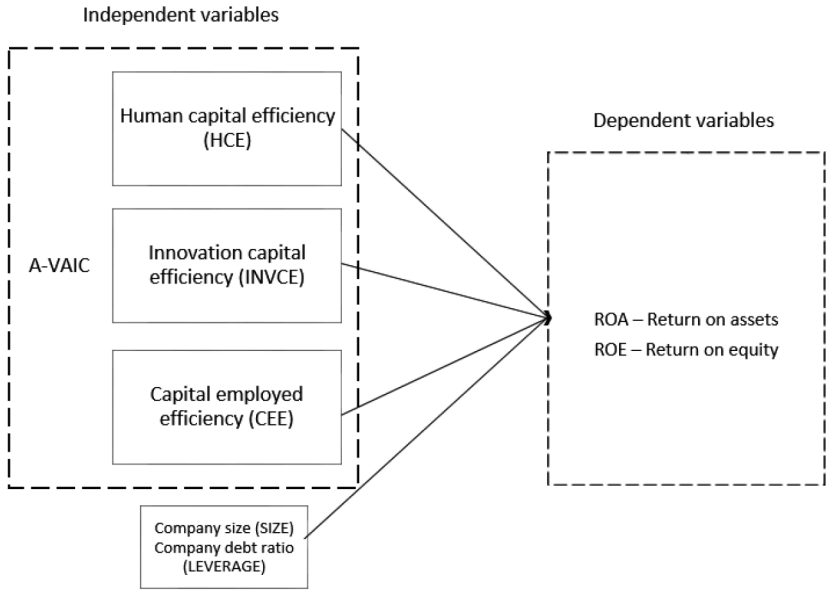
Table 1. Procedure for calculating the Adjusted Value Added Intellectual Coefficient A-VAIC

Item no.	Variable	Calculation formula*
1.	Value added (VA)	VA = OP + EC + D + A + R&D expenses
2.	Human capital efficiency (HCE)	HCE = VA / HC, where: HC = EC
3.	Innovation (structural) capital efficiency (INVCE)	INVCE = VA / R&D expenses
4.	Capital employed efficiency (CEE)	CEE = VA / CE
5.	Intellectual capital efficiency (ICE)	ICE = HCE + INVCE
6.	Adjusted Value Added Intellectual Coefficient (A-VAIC)	A-VAIC = HCE + INVCE + CEE

* OP – operational profit; EC – employment costs; D – depreciation; A – amortization; CE – capital employed, corresponding to the book value of net assets; R&D expenses – expenses for research and development works.

Source: original work based on: Nadeem et al. (2019), p. 395–407.

Figure 1. Scheme of the proposed research model



Source: original work.

variables (size of the enterprise measured by the natural logarithm of the sum of assets; leverage – debt ratio measured by the ratio of total debt to the book value of total assets) (Soewarno & Tjahjadi, 2020, p. 1093). In addition, the research model tested in the present study is presented in Figure 1.

Research results

Descriptive statistics of dependent (explained), independent (explanatory) and control variables covered by the study are presented in Table 2.

The most varied ratio is ROE, and the least varied are size and debt ratio (or leverage). Analysing the independent variables determining intellectual capital efficiency, it is observed that pharmaceutical and biotechnological companies listed on the WSE generate the greatest return on every Zloty invested in INVCE – PLN 12.490 on average. The return on HCE is PLN 4.722 on average, and the return on CEE – PLN 0.337. Moreover, the HCE and INVCE coefficients are characterized by high variability, which indicates that enterprises of this type differ substantially between one another in terms of human and innovation capital efficiency.

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Table 2. Descriptive statistics of variables

Variables	*N*	Minimum	Maximum	Mean	Standard deviation	Coefficient of variation [%]
Dependent variables						
ROA	84	–1.033	1.498	–0.083	0.305	367.470
ROE	84	–6.200	11.460	–0.013	1.601	12315.385
Independent variables						
HCE	84	–4.899	102.100	4.722	15.420	326.557
INVCE	84	–22.420	323.800	12.490	41.700	333.867
CEE	84	–2.697	2.246	0.337	0.646	191.691
Control variables						
Size	84	9.030	14.290	11.700	1.230	10.513
Leverage	84	0.036	1.516	0.432	0.262	60.648

Source: original work.

In the case of the model with ROA as the dependent variable, dynamic panel regression analysis was the first step. The results of research demonstrated that the previous ROA value has no significant influence on the current ROA level. This is why dynamic models were abandoned for this variable, and the standard panel model estimation method was applied instead.

For this purpose, it was necessary to take into consideration two types of effects – fixed effects (FE) and random effects (RE). Hausman's test was carried out in order to select better-estimated parameters. The results of the test indicated that the parameters of the FE model have better properties than the parameters of the RE model. The choice of the fixed effects model is also supported by the nature of the analysed objects. If the studied objects belong to the same sector and it is important to estimate group effects for those specific objects, then the FE model is more appropriate in most cases. The distribution of the y variable is then considered conditionally, for determined values of α_i (Dańska-Borsiak, 2011, p. 49–50).

All of the models created were tested for heteroscedasticity (variation of variance of a random component), normality of distribution of random component residuals, autocorrelation, cross-sectional dependency and co-linearity (VIF). In the case where autocorrelation and heteroscedasticity (variation of variance of residuals) of random errors occurred, correction by Arellano's method (1987, p. 431–434) was carried out to improve the estimator's efficiency. The backward stepwise method was applied in the study, which is based on the simultaneous introduction of explanatory variables into analysis, followed by elimination of non-significant variables, until a model containing only statistically significant variables is obtained. The proposed research models explaining the nature of dependencies between variables are presented in Tables 3–5.

Models no. I and II are characterized by low explanatory power: for model I – 46.65% and 8.55%, and for model II – 50.02% and 14.38%, respectively (LSDV R^2 and Within R^2). This means that the INVCE and CEE coefficients affect the future value of ROA, however they are not the principal components determining the level of this ratio. In comparison to other factors having a stronger influence on the value of ROA, INVCE and CEE, they explain the ROA level obtained in the future only to a small extent. Model no. I indicates that growth of the INVCE coefficient by one unit in the current period causes growth of ROA in the long time period by 0.002 units ROA on average ($p < 0.01$), ceteris paribus. Meanwhile, model no. II indicates that growth of the INVCE coefficient by one unit in the current period causes growth of ROA in the long time period by 0.005 units ROA on average ($p < 0.01$), ceteris paribus.

Model no. III is characterized by a higher explanatory power than models no. I and II. It amounts to, respectively, 75.11% and 58.54% (LSDV R^2 and Within R^2). Model no. III indicates that growth of the HCE coefficient by one unit in the current period causes growth of ROA in the long time period by 0.051 units ROA on average ($p < 0.01$), ceteris paribus. Growth of the INVCE coefficient by one unit in the current period causes growth of ROA in the long time period by 0.006 units ROA on average ($p < 0.01$), ceteris paribus. In turn, growth of the CEE coefficient by one unit in the current period causes growth of ROA in the current period by 0.249 units ROA on average, ceteris paribus. This means that financial and physical resources continue to have the greatest

Table 3. Model I – results of panel model estimation (fixed effects model); dependent variable ROA; 1-year time lag

Variables	Coefficient *B*	Standard error	*Z* (distribution)	Significance
Const.	–0.0979	0.0129	–7.5700	<0.0001
INVCE	0.0017	0.0003	5.3710	<0.0001
INVCE_1	0.0007	0.0001	6.2740	<0.0001
CEE_1	–0.0697	0.0289	–2.4080	0.0161
LSDV R^2 = 0.4665				
Within R^2 = 0.0855				

Source: original work.

Table 4. Model II results of panel model estimation (fixed effects model); dependent variable ROA; 2-year time lag

Variables	Coefficient *B*	Standard error	*Z* (distribution)	Significance
Const.	–0.1656	0.0053	–31.3800	<0.0001
INVCE	0.0024	0.0003	7.2990	<0.0001
INVCE_1	0.0009	0.0001	7.1610	<0.0001
INVCE_2	0.0016	0.0001	11.0900	<0.0001
LSDV R^2 = 0.5002				
Within R^2 = 0.1438				

Source: original work.

Table 5. Model III results of panel model estimation (fixed effects model); dependent variable ROA; 3-year time lag

Variables	Coefficient *B*	Standard error	*Z* (distribution)	Significance
Const.	4.2043	4.4707	0.9404	0.3470
HCE	–0.0049	0.0020	–2.4000	0.0164
HCE_1	0.0558	0.0167	3.3500	0.0008
INVCE	0.0027	0.0009	3.0550	0.0023
INVCE_1	0.0028	0.0006	4.3950	<0.0001
CEE	0.2485	0.0907	2.7390	0.0062
SIZE	–1.1139	0.6594	–1.6890	0.0912
SIZE_1	2.2674	0.9018	2.5140	0.0119
SIZE_2	–2.3499	0.6710	–3.5020	0.0005
SIZE_3	0.7754	0.2267	3.4200	0.0006
LEV	–2.0573	0.6411	–3.2090	0.0013
LEV_1	2.6037	0.7830	3.3250	0.0009
LEV_2	–1.7113	0.5960	–2.8710	0.0041
LEV_3	2.4921	0.5864	4.2500	<0.0001
LSDV R^2 = 0.7511				
Within R^2 = 0.5854				

Source: original work.

impact on the current profitability of enterprises of this type.

In the case of the ROE dependent variable, the time-lagged dependent variable was statistically significant, which is why it was justified to apply dynamic panel model estimation (dynamic panel regression analysis) using the Arellano-Bond estimator (Arellano & Bond, 1991). Only two panel models using the 2-year and 3-year time lag, respectively, are presented. The model with a 1-year time lag was not presented in the case where none of the variables being a component of the VAIC™ model (HCE, INVCE, CEE) were statistically significant. This means that, over the short period, no capital coefficient has a significant influence on ROE. The proposed research models explaining the nature of dependencies between variables are presented in Tables 6 and 7.

Analysing the developed models, it can be observed that, in the case of model no. IV, growth of the INVCE coefficient by one unit in the current period causes growth of ROE in the long time period by 0.010 units ROE on average ($p < 0.01$), ceteris paribus. Model no. V indicates that growth of the HCE coefficient by one unit in the current period causes growth of ROE in the long time period by 0.148 units ROE on average ($p < 0.05$), ceteris paribus. Meanwhile, growth of the INVCE coefficient by one unit in the current period causes growth of ROE in the long time period by 0.021 units ROE on average ($p < 0.01$), ceteris paribus.

Table 6. Model IV – results of dynamic panel model estimation; dependent variable ROE; 2-year time lag

Variables	Coefficient	Standard error	Z (distribution)	Significance
ROE(–1)	–0.2505	0.0302	–8.2950	<0.0001
INVCE_1	0.0049	0.0009	5.6610	<0.0001
INVCE_2	0.0080	0.0020	4.0950	<0.0001
SIZE	–1.1837	0.6437	–1.8390	0.0659
LEV_1	8.2050	1.4269	5.7500	<0.0001
LEV_2	–8.5005	1.4753	–5.7620	<0.0001
Sum of residual squares	224.8715		Standard residual error	1.5305

Source: original work.

Table 7. Model V – results of dynamic panel model estimation; dependent variable ROE; 3-year time lag

Variables	Coefficient	Standard error	Z (distribution)	Significance
RROE(–1)	–0.4157	0.0384	–10.8400	<0.0001
HCE_1	0.1883	0.0893	2.1070	0.0351
HCE_3	0.0218	0.0080	2.7270	0.0064
INVCE_2	–0.0099	0.0027	–3.7400	0.0002
INVCE_3	–0.0201	0.0028	–7.3040	<0.0001
CEE	0.5956	0.1337	4.4560	<0.0001
CEE_1	0.8705	0.1806	4.8210	<0.0001
CEE_2	1.4500	0.4934	2.9390	0.0033
CEE_3	4.7405	0.8137	5.8260	<0.0001
SIZE_1	5.1074	1.6506	3.0940	0.0020
SIZE_2	–8.2956	1.1396	–7.2800	<0.0001
SIZE_3	5.3191	0.9401	5.6580	<0.0001
LEV_1	7.9185	0.8632	9.1740	<0.0001
LEV_2	–15.8905	2.5150	–6.3180	<0.0001
Sum of residual squares	41.5795		Standard residual error	0.7599

Source: original work.

It can also be observed that the influence of human capital on ROE is visible only after the passage of three years. Analysis also showed that, in model V (similarly as in model no. III), capital employed has a significant positive influence on ROE. Growth of CEE by one unit causes the greatest increase in ROE among all components of the A-VAIC model. When CEE grows by one unit in the current period, this will cause growth of ROE in the long time period by 5.408 units ROE on average ($p < 0.01$), ceteris paribus. This means that financial and physical resources still largely determine the profitability of enterprises of this type, including the ROE ratio.

Discussion

The results of research confirmed positive influence of IC on ROA and ROE, using the time lag. However, they also revealed varied influence of individual components (Sardo & Serrasqueiro, 2017; Nguyen, 2023). INVCE and HCE have a significant, positive influence on future ROA value, as confirmed by the studies of other scientists (Chen et al., 2005; Xu et al., 2019). Positive influence of INVCE is visible after applying just a 1-year time lag. Meanwhile, a significant, positive influence of HCE on ROA is only revealed in the model where a 3-year time lag is applied. This is confirmed by the study conducted by Naidenova and Parshakov (2013, p. 644). It is also observed that, in the case of models with the ROA dependent variable, as the time lag is extended, the influence of IC components on the future ROA ratio increases. Bhattu-Babajee and Seetanah (2022) reached similar conclusions – according to these authors, IC components have a positive influence on the future profitability of enterprises. They confirmed that this influence is stronger in the long term in comparison with the short term.

In turn, HCE and INVCE have a significant, positive influence on future ROE values. Similarly as in the case of ROA, the influence of HCE on ROE is only revealed in the model where a 3-year time lag was applied. The exception, inconsistent with the subject literature, is the negative influence of INVCE on the future ROE value in the model using a 3-year time lag, in which growth of INVCE will cause a decrease in ROE value in the long term. In the opinion of the authors of this article, this result may indicate that one-time R&D expenditures incurred by enterprises several years ago will not increase profitability in the future, and to the contrary, they show a negative influence on ROE. This is why enterprises should systematically sustain R&D expenditures and invest in innovation (structural) capital, so that these actions will have a long-term, positive influence on ROE.

In summary, analysis showed that, in most models, innovation (structural) capital has a significant, positive influence on profitability (Razafindrambinina & Anggreni, 2011, p. 70). In the case of pharmaceutical and biotechnological companies, a well-developed intangible infrastructure supporting operations is of decisive significance to such enterprises, and this infrastructure is represented by, among other things: processes, IT systems, patents, brands, licenses, intellectual property rights, trademarks, infrastructure and strategy. The results obtained confirm studies by other scientists analysing the influence of IC on the profitability of pharmaceutical and biotechnological enterprises as well as on the profitability of other types of enterprises.

However, this study has some limitations. They arise from the fact that focus in this research was placed on a short-term time horizon and a small research sample, thus not encompassing the entire Polish pharmaceutical and biotechnological sector. The sample was limited only to companies listed on the WSE, while many companies with a substantial share of these markets are not listed on the stock exchange. Moreover, focus was placed only on selected ratios describing the profitability of the analysed entities. The limitations are also due to the weaknesses of the A-VAIC method used to measure IC. For this reason, caution is required when generalizing these findings.

Conclusions

The study presented in this article made it possible to evaluate the influence of IC on the profitability of pharmaceutical and biotechnological companies listed on the WSE. The innovation of this study was based on the use of the A-VAIC method – a modification of the classical VAIC™ model – for measurement of IC, as well as on the application of a time lag for the purpose of verifying whether IC has a positive influence on the future profitability of enterprises.

This study filled a gap in research in the field of dependencies occurring between IC and the profitability of enterprises. This aspect is still insufficiently represented in the research of Polish scientists. In turn, from a practical perspective, the goal of the research was to: confirm the need for monitoring of the sources generating IC, conduct research on its measurement and successive allocation of financial resources to its development. In the authors' opinion, these

activities will contribute to maximization of the economic results of individual enterprises, and in a global context, will spur development of the entire economy.

In summary, the results of this study may interest a broad spectrum of people: scientists, management staff, representatives of supervisory institutions and market practitioners: investors and analysts.

This study is a starting point for further research, which is recommended to:

- cover a broader group of entities (e.g. all companies belonging to the Polish biotech sector or companies from these sectors in different countries in Europe and around the world),
- take into account a greater number of metrics describing the financial results of enterprises (e.g. ATO, NPM, GPM, EBIT and EBITDA), as well as market results of enterprises listed on the WSE (e.g. EPS and P/E ratio),
- use other modified methods for measuring IC based on the VAICTM method, such as Modified Value Added Intellectual Coefficient – MVAIC.

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