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ANALYSIS OF HUMAN CAPITAL EFFICIENCY IN POLISH ENERGY COMPANIES

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Purpose: The Polish energy sector faces the need to change the production structure generates high demands, among others, on the sector's staff. Therefore the aim of the article is to analyse the efficiency of human capital in energy sector enterprises in Poland in the period 2010-2023.
Design/methodology/approach: The model chosen to estimate the efficiency and value of human capital is Pulic' VAIC™, which was compared with employee performance indicators. The study was conducted for six energy companies.
Findings: The research results indicate an increase in the efficiency and value of human capital, although they vary in individual companies. The basic factors determining the diversity of the results obtained are changes in the level of employment, different shares of coal in energy production and different shareholding structures. VAIC™ has proven to be stable method for estimating human capital efficiency in both the long and short term.
Research limitations/implications: The study was conducted with reference to energy entities operating in the Polish economic and energy specifics. In the perspective of further research, it is appropriate to expand the study entities to companies operating in other markets.
Practical implications: The VAIC™ approach and employee productivity indicators indicate a different hierarchy of companies in terms of human capital efficiency, therefore they should be used together, as complementary, and interpreted appropriately.
Originality/value: The contribution of the article to the existing literature is the repetition of research aimed at verifying the use-fulness of the VAIC™ model in estimating the efficiency of human capital and the confrontation of this indicator with employee performance indicators.
Keywords: value of human capital, human capital efficiency, energy companies, VAIC™, work efficiency.
Category of the paper: Research paper.

1. Introduction

Enterprises are increasingly looking for competitive advantage in intangible resources (Lerro et al., 2014), such as the value of intellectual capital (Iazzolino et al., 2019), including the potential of human resources (Buzavaite, Korsakiene, 2019; Nilsson, Ford, 2004). Intellectual capital does not have a unique definition, what is more, the authors see its structure differently (Milost, 2005), but human capital is always its integral component which is not divided into smaller elements.

The aim of the article is to assess the growth rate of efficiency and the value of human capital in energy companies in Poland over the last dozen or so years. The authors assume that the increase in the value of human capital is the basis for the increase in the competitiveness of enterprises and the ability to adapt to changing conditions. Human capital is very important in the energy sector in Poland due to the need for deep restructuring and the related challenges for staff.

The VAIC™ index proposed by Pulic (1998) was adopted as the basic method for estimating the efficiency and value of human capital. Due to the fact that the literature draws attention to the uncertainty regarding short-term estimates in the case of the VAIC™ indicator, this article compares it with changes in alternative work efficiency indicators (sales revenues to personnel costs and sales revenues per employee).

The research problems addressed in the article concern the growth rate of efficiency and the value of hu-man capital in Polish energy companies and the assessment of how well the indicators selected as a research tool reflects these changes in the long- and short-term perspective. In conditions of economic shocks and high inflation (which occurred in the last years of the analysis), changes in the value of human capital based on the level of personnel costs may indicate the strength of trade unions (the pace and amount of negotiated wage increases due to inflation) rather than actual changes in the value of human capital. Therefore, in order to limit the impact of inflation, a deflator was used in the case of the sales revenues per employee indicator.

In the world literature, research using the VAIC™ model focuses mainly on the banking and financial sectors (Ozkan et al., 2017). Our contribution to the literature is a supplement and additional verification of the useful-ness of the VAIC™ indicator in estimating the value of human capital in the energy sector. The undertaken re-search also allows to verify the statement that in the short term, especially in conditions of economic shocks, typical work efficiency indicators based on sales revenues reflect the efficiency of human capital better than VAIC™.

The article consists of a literature review, methodological part, research results, discussions and conclusions. The literature review is divided into three subchapters, presenting the concept and factors influencing human capital, VAIC™ as a method of measuring the value of human

capital as well as its efficiency and the challenges facing the Polish energy sector. In the last subchapter of literature review, four research hypotheses were also formulated. In the methodological part, apart from indicating the companies subject to analysis, the assumptions of data analysis were presented, aimed at verifying the hypotheses put forward.

2. Literature review and hypothesis development

2.1. Human capital in theoretical terms

It is most often assumed that the two basic elements of intellectual capital are human and structural capital (Edvinsson, Sullivan, 1996; Edvinsson, Malone 1997; Roos, 1997; Stewart, 1997). Some authors distinguish customer capital (Marr; Moustaghfir, 2005; Martínez-Torres, 2006; Pap et al., 2021) or customer capital and innovative capital (Chen et al., 2004) from structural capital. It should be noted that in all the above approaches, human capital appears as a separate element of intellectual capital and is not divided into smaller components.

Human capital, treated as resources related to the knowledge and skills of an individual, is considered a key element of economic development (Laroche et al., 1999; Lim et al., 2018; Angrist et al., 2021; Dańska-Borsiak, 2023; Zhang et al., 2023). The system that builds initial human capital is the formal education system, treated as a long-term investment in citizens – building their human capital before entering the labour market (Kraay, 2018; Lenkei, 2019; Wosiek, 2020). Appropriate education prepares for technological challenges (Becker, 1993), facilitates innovative activities (Nelson, Phelps, 1966; Mulliqi et al., 2018; Castelló-Climent, 2019; Diebolt, Hippe, 2019; Rossi, 2020), contributes to increasing technical progress, increasing work efficiency (Alataş, Çakir, 2016) and productivity of physical capital (Bodman, Le, 2013; Almendarez, 2013; Queirós, Teixeira, 2016; Wang et al., 2023).

From the perspective of the organization, Schultz (1961, p. 140) proposed the definition of human capital as "knowledge, skills and abilities of the people employed in an organization". Since human capital is the property of an employee who can invest his or her abilities, behaviour and energy in the companies of his or her choice, it is important to encourage him or her to join and stay in the organization in a way that generates benefits for both parties (Davenport, 1999; Mayo, 2001).

From an organizational perspective, human capital is more than the simple sum of the human capital of all employees. Due to cooperation, people co-create processes, practices, norms and standards, react and influence the organization's environment, building structural capital. Individual knowledge, skills and attitudes in-crease, social relationships and organizational systems are built, which creates values for both the organization and the individual (Storberg-Walker, 2004). The company invests in employee development,

taking into account the profitability of this investment (Lepak, Snell, 1999), preferring forms of development that do not generate direct costs (organized coaching, mentoring, learning-by-doing). Employees themselves can also improve their human capital through self-education (OECD, 1998; CIPD, 2017). Bornemann et al. (1999) indicated that companies that actively supported the development of their intellectual capital achieved better results.

The literature highlights differences in human capital in national, regional and sectoral terms. The current level of human capital in individual countries is historically determined. Its level is largely influenced by general economic institutions (Diebolt, Hippe, 2019; Pritchett, 2001; Acemoglu et al., 2014), including: a well-defined system of property rights, openness of the economy, and national security (Hanushek, Woessmann, 2008). The level of available human capital may explain differences in the development of individual regions and economic sectors (Diebolt, Hippe, 2019; Gennaioli et al., 2013). Migrations at the international, regional and sectoral levels, caused by differences in the level of salaries and working conditions offered there, cause a drain or inflow of innovative personnel to particular markets (Wielechowski et al., 2021; OECD, 1998). Gibbons et al. (2005) show that high-wage sectors employ highly skilled workers and obtain high returns on workers' skills.

Estimating the value of human capital is most often based on cost and/or income methods. From a cost perspective, the human capital of an individual employee is treated as expenditure on acquiring: resources of knowledge, experience and skills acquired at school, during on-the-job training and other forms of further education (Becker, 1993, Marr et al., 2004; Unger et al., 2011; Østergaard, Marinova, 2018). Estimates of the level of human capital based on the costs incurred by the state (providing a formal level of education), the family (expenditures on education, health care), the enterprises that employed the employee (expenditures on training and development at the workplace), and the employee himself are only an approximation value of human capital. They do not take into account the value of the employee's non-market activities (Jorgenson, Fraumeni, 1989), his or her personality traits and individual skills (Son, 2010; Lee, Lee, 2016).

An alternative to the cost approach are profitable methods of measuring human capital. They focus on the efficiency (productivity) of employees, which, according to economic theory, equals the equilibrium wage rate (Buesselmann, 2009). In the income approach, efficiency is identified with the received wage rate, which should optimally reflect the entire human capital of the individual (i.e. experience, training, education, health, etc.) (Škare, Lacmanović, 2015). In the literature, estimates of the value of a single employee's human capital based on individual remuneration have been criticized. First, it is difficult to defend the assumption that wage differentials accurately reflect differences in the efficiency of individual workers (Segu, Natoli, 2012). Secondly, the actual level of salaries is influenced by trade unions, which usually strive to convert the wage structure (Ahlroth et al., 1997). These reservations are less important in the case of estimating the human capital of the entire enterprise, which is based on the average performance of all employees.

The research undertaken in the article concerns the importance of human capital as one of the key resources for the development of an organization (Mahmood et al., 2014, Lim et al., 2018; Habib et al., 2019; Angrist et al., 2021), which is an issue important for both the theory of scientific management and management practice. The competitiveness of human resources can be assessed through the prism of human capital efficiency (Dakhli, De Clercq, 2004; Huggins et al., 2017). The level of achieved human capital efficiency indicates the degree of the employees allocation adequacy to tasks, determining the productivity of individual employee and employees teams (Feng, Graetz, 2020; Alekseeva et al., 2021; Schultheiss et al., 2023; Sheveleva et al., 2023). The basic methodological problem is the selection of appropriate measures of the value of human capital and its efficiency.

2.2. VAIC™ as a method for measuring the value of an enterprise's intellectual and human capital

Income methods include the Added Intellectual Value Coefficient (VAIC™), which was proposed by Pulic (1998) as a method for measuring the value of an enterprise's intellectual capital. He assumed that in a knowledge-based economy, employees are responsible for the market results achieved. They have intellectual potential, which consists of their ability to create value through the effective use of infrastructure (material capital) and relationships with the environment (market) (Pulic, 1998, 2008). Pulic proposed that VAIC™ should be treated as the sum of the equity capital coefficient (calculated as the ratio of value added to equity capital), the human capital coefficient (calculated as the ratio of value added to personnel expenses) and structural capital coefficient (calculated as the ratio of structural capital to value added). The sum of mentioned indicators creates an aggregated indicator that shows the company's overall efficiency in creating value and presents its intellectual capabilities (Pulic, 2008). VAIC™ indicates the efficiency of the used potential both in financial and intellectual terms, and can be used at the level of national economies, sectors, enterprises and their parts (Pulic, 2004). The main advantage of this indicator is the availability of data (added value, physical capital, intellectual potential – treated as personnel expenses) that come from the market (Pulic, 2000b). Since VAIC™ is positively related to a company's profitability and market value (Pulic, 2000a), managers can use it as a management tool (to improve the use of physical capital and intellectual potential (due to an increase in employee productivity) and identify internal inefficiencies (Pulic, 2000b).

Pulic emphasizes that human capital covers all employees. A good indicator of the intellectual potential used in an enterprise is the level of expenditures on personnel, treated as compensation for the time invested and knowledge input used. Labour inputs should not be treated as costs, but related to the creation of value by employees, whose involvement is reflected in the value added created (employees are a key resource for value creation) (Pulic, 2004, 2008). Pulic (2000a, 2004) proposes to calculate the efficiency of human capital as the quotient of the value added created in the company by its human capital, identified with total

salaries and benefits paid by company. Value added is an objective indicator of business success (Pulic, 2004), and the coefficient shows the actual productivity of the company's staff (the value that the company obtains from investing one monetary unit in its staff) (Pulic, 2008).

Supporters of the VAIC™ model assume that all employee-related costs are investments in employee knowledge. The company expects a return on these expenditures in the form of an increase in the added value generated (Iazzolino, Laise, 2013). An additional advantage of the indicator is that it is calculated based on publicly available financial statements, the credibility of which is checked during an audit (Tan et al., 2007; Nazari, Herremans, 2007; Young et al., 2009). VAIC™ focuses on assessing the efficiency of intellectual capital related to the use of its components (Iazzolino et al., 2014).

Critics of the Pulic' model point out that although it measures the efficiency of a company's employee and capital investments, human capital and structural capital, the obtained results cannot be identified with intellectual capital (Ståhle et al., 2011; Bakhsha et al., 2017). They also point out that it is not (as its author claims) a universal tool. Taking labour costs as a reference point, in conditions of strong differences in wage levels in individual countries, does not allow for international comparisons (Ståhle et al., 2011).

Andriessen (2004) pointed out that value added results from three sources: human, structural and financial capital. Determining the contribution of each of these three sources to added value requires examining the synergies between them. Additionally, identifying human capital with salary costs means that human capital in-creases with their increase (Bakhsha et al., 2017). Investing only in employee knowledge, as recommended by VAIC™, does not guarantee a return on investment, because efficiency also depends on other forms of capital (Marzo, 2022). Some of the expenses improving employee knowledge affect the value added in the long term, while the expenses are incurred by the company immediately (Andriessen, 2004), which is also agreed by Pulic (2004), VAIC™ is therefore not a good indicator of changes in human capital in the short term. Additionally, in Pulic' approach, an employee's individual knowledge (human capital) is contrasted with structural capital, treated as the difference between intellectual and human capital (Marzo, 2022).

Research on intellectual capital (including human capital) using the VAIC™ indicator gives mixed results. In the banking sector, most studies indicate a positive relationship between the efficiency of intellectual capital use and financial results. In the case of banks in the USA, it was even found that the efficiency of human capital has a greater impact on financial results than other components of intellectual capital (Meles et al., 2016). Empirical studies in Bangladesh have shown a positive and significant relationship between intellectual capital and bank performance (Nabi et al., 2020). In the case of the banking sector in Turkey, human capital efficiency has a positive impact on banks' performance, with the efficiency of capital employed having a greater impact on financial performance (Ozkan et al., 2017). An exception is the research on the banking sector in Italy (Puntillo, 2009), which did not show any relationship between the studied variables (except for the relationship between employee

efficiency and bank efficiency). Laing et al. (2010) found that the VAIC™ model is a robust tool for assessing the efficient use of intellectual resources in the hospitality sector in Australia.

Tan et al. (2007) for Singapore listed companies found that intellectual capital (IC) is positively related to firm performance, future firm performance, and growth rate, with the contribution of IC to firm performance varying by industry. Based on research in Malaysia, Gan and Saleh (2008) concluded that VAIC™ can explain profitability and productivity, but does not explain market valuation. Shiu (2006) analysed technology companies in Taiwan and found a positive correlation between VAIC™, profitability and market valuation and a negative correlation with productivity. Chan (2009), based on research conducted in Hong Kong, concluded that the final relationship between intellectual capital (IC) and the four analysed financial performance measures is only moderate. The study also showed that managers highly value physical capital as a factor in improving market valuation, productivity and profitability. Maditinos et al. (2011) found that the financial results of Greek companies indicate a higher valuation by investors of physical capital assets than intellectual capital. Research by Firer and Williams (2003) conducted in South Africa also indicates that investors focus on capital rather than intellectual assets. Additionally, these studies found no relationship between VAIC™ and profitability, productivity, and market value.

Taking into account theoretical considerations and the cited research results, the choice of VAIC™ as the human capital valuation method for the purposes of this article was dictated by three arguments. Firstly, applying the method only to human capital removes most of the objections raised against VAIC™ regarding the connections between the components of intellectual capital and the synergistic effects occurring between them. Secondly, referring the method to the energy sector in Poland removes reservations as to the possibility of using the indicator for comparisons in different countries and different sectors. Third, VAIC™ allows the use of reliable and audited data.

2.3. Challenges for the energy sector in Poland

Coal energy in the European Union countries has been under pressure for many years resulting from the cli-mate goals of the Green Deal, i.e. decarbonisation and achieving climate neutrality by 2050 (European Commission, 2020). The tool forcing the expected changes are additional costs imposed on the production of electricity from non-renewable sources due to carbon dioxide emissions (Pach-Gurgul, Ulbrych, 2019; Capros et al., 2014). The energy sector in Poland faces more serious challenges than in other EU countries (Szczepankiewicz and Mućko, 2016), because its energy mix is still dominated by coal – in 2023 in Poland, 39.9% of electricity came from hard coal and 21.1% from lignite (Swoczyna, 2024). The increase in the price of CO2 emission allowances in recent years has influenced the financial situation and strategic behaviour of Polish energy companies, forcing them to diversify their activities towards the use of low-emission energy sources (Nawrocki, Jonek-Kowalska, 2023).

The state's energy policy aims to reconcile maintaining the availability of power in the energy system with the gradual phase-out of coal-fired units and supporting investments in low- or zero-emission energy sources (Baran er al., 2022). Energy companies are also interested in this type of investments, seeing them as a condition for survival and an opportunity to improve financial results (van Beurden, Goessling, 2008; Zieliński, Adamska, 2022).

One of the conditions for the success of the transformation of the energy sector in Poland is having sufficiently effective human capital (Kuzior et al., 2022). Based on a literature review and assuming that energy companies have taken appropriate steps towards the development of human capital, the first hypothesis was put forward:

H1: The efficiency of human capital in Polish energy companies is gradually increasing.

When formulating the second hypothesis, the gradual economic growth in recent years and the fact that the energy sector in Poland is competitive in terms of salaries were taken into account (therefore, the energy sec-tor rather acquires highly efficient employees than loses them to other sectors). Since the analysed energy companies have a similar history and face similar challenges, but are at different stages of restructuring activities, the following hypothesis was formulated:

H2: The value of human capital per employee in energy enterprises in Poland is growing at a similar pace.

Assuming that the level of salaries is linked to work efficiency (rational actions of enterprises in terms of personnel expenditure) and in connection with the use of work efficiency as an alternative to the VAIC™ indica-tor, it was assumed hypothesis about their positive relationship:

H3: There is a positive correlation between human capital efficiency using the VAIC™ index and work efficiency.

Since VAIC™ is the proportion of the added value and the estimated value of human capital, it can also be treated as an assessment of the economic efficiency of this capital, assuming that efficiency is the proportion between the effects and inputs of economic activities (McConnell, 1984). Estimating the efficiency and value of human capital in recent years is exposed to deviations from long-term trends due to economic shocks. The first was the Covid-19 pandemic, the second was the outbreak of war in Ukraine, which resulted in, among others, a drastic increase in the prices of energy raw materials (which first affected the energy industry and its customers) and an increase in the inflation rate. Since the VAIC™ indicator is based on the level of salaries and their adjustments are postponed in time due to wage negotiation processes, the following hypothesis was put for-ward:

H4: In the short term, especially in the event of economic shocks, work efficiency is a better picture of changes in human capital efficiency than VAIC™.

3. Research methodology

Energy capital groups listed on the Warsaw Stock Exchange (ENEA, ENERGA, PGE, POLENERGIA, TAURON PE and ZE PAK) that dominate on the supply side of the energy market were selected for the study. In 2023, the three largest producers (PGE, ENEA and TAURON) had a total of over half of the installed capacity and were responsible for over 2/3 of electricity production in Poland (Urząd Regulacji Energetyki, 2024).

The verification of the first three hypotheses regarding the increase in the value of human capital was based on the VAIC™ coefficient and staff performance indicators and their growth rates, using data from financial statements published by companies:

$$Efficiency\ of\ Human\ Capital\ (VAIC) = \frac{Value\ Added}{Salaries\ and\ Benefits} \quad (1)$$

$$Value\ Added = Sales\ Revenues - Costs\ of Materials\ and\ Energy\ Consumption - Costs\ of\ External\ Services\ - Value\ of\ Sold\ Goods\ and\ Materials - Taxes\ and\ Fees \quad (2)$$

$$Work\ Efficiency\ Based\ on\ Number\ of\ Employees = \frac{Sales\ Revenues}{Average\ Number\ of\ Employees} \quad (3)$$

$$Work\ Efficiency\ Based\ on\ Personnel\ Costs = \frac{Sales\ Revenues}{Salaries\ and\ Benefits} \quad (4)$$

Since the construction of the indicators is based on financial data expressed in current prices, both in terms of the numerators and denominators, nominal data published by companies were used. In the case of value added calculations (2), due to the different approaches to including CO2-related costs in energy companies' operating costs (some entities report these costs under taxes and fees, others report them under the costs of materials and energy consumption, and still others do not disclose where they have allocated them), it was decided to include in external operating costs also the "taxes and fees" category.

Due to the intensification of inflation processes in recent years and changes in price regulations imposed by the state regulator, a deflator based on the proportion of changes in nominal and real GDP in the analysed period was used to verify the 4-th hypothesis. This made it possible to obtain data in real prices, which is especially important in the case of the work efficiency based on the number of employees indicator:

$$Real\ Sales\ Revenues = \frac{Nominal\ Sales\ Revenues}{(1+deflator)} \quad (5)$$

$$Real\ Work\ Efficiency\ Based\ on\ Number\ of\ Emloyees = \frac{Real\ Sales\ Revenues}{Average\ Number\ of\ Employees} \quad (6)$$

As the study considers three different indicators to assess the efficiency of human capital, based on the same sources of financial data, but using different data, a correlation analysis was also assumed between human capital estimated using the VAIC™ index and work efficiency indicators. Such calculations will allow to determine whether the results obtained with the indicators used were similar.

4. Research results

Figure 1 shows changes in the efficiency of human capital estimated according to VAIC™ in comparison with work efficiency in two approaches (based on number of employees and based on personnel costs). In the case of POLENERGIA, the fastest increase in sales revenues compared to the beginning of the analysed period forced the use of a separate scale (it is the smallest company, which only in 2022 and 2023 exceeded the employment level of 300 people). With a relatively stable increase in efficiency according to VAIC™, what is noteworthy is the dramatic increase in revenue-based efficiency indicators in the last two years (except for POLENERGIA). While this could be expected in the case of the work efficiency based on number of employees indicator (the index's numerator increased due to the increase in energy prices), the slightly lower increase in the work efficiency based on personnel costs indicator indicates a much weaker increase in employee expenditure (than the increase in energy prices).

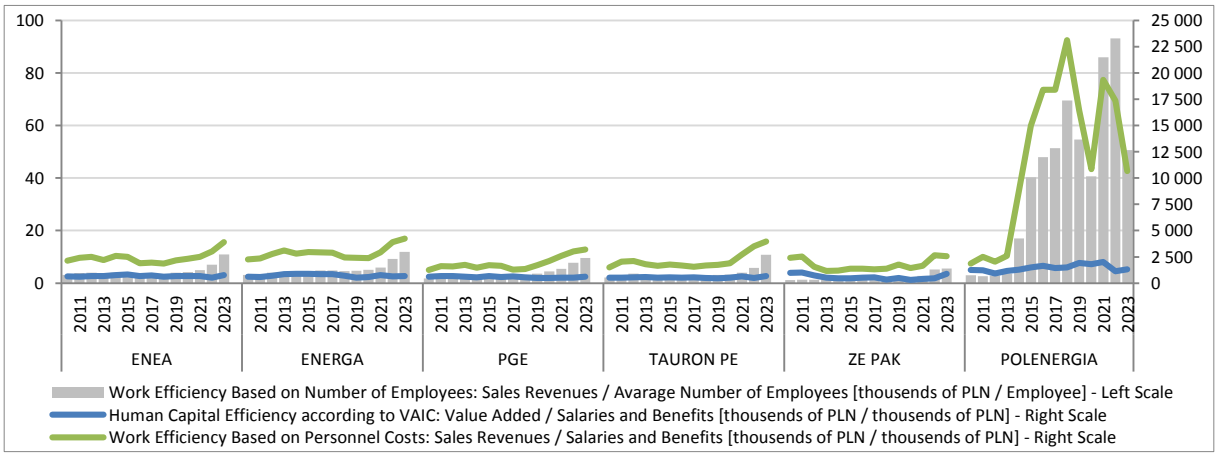

Figure 1. Human capital efficiency and work efficiency in the analysed Polish energy companies in 2010-2023.

Source: Own work.

The percentage changes in the analysed approaches to human capital efficiency are presented in Table 1.

Table 1.
Changes in the efficiency of human capital and work efficiency in the analysed Polish energy companies in 2010-2023

	Human Capital Efficiency According to VAIC™			Work Efficiency Based on Number of Employees			Work Efficiency Based on Personnel Costs		
	Growth Rate 2010-2023	Annual Growth (Average)	Standard Deviation	Growth Rate 2010-2023	Annual Growth (Average)	Standard Deviation	Growth Rate 2010-2023	Annual Growth (Average)	Standard Deviation
ENEA	19%	4%	18%	258%	12%	21%	84%	6%	14%
ENERGA	9%	2%	16%	283%	12%	17%	89%	6%	13%
PGE	1%	1%	11%	428%	15%	19%	155%	9%	17%
TAURON PE	33%	3%	16%	400%	16%	28%	167%	9%	18%
ZE PAK	-9%	5%	37%	404%	15%	26%	6%	3%	25%
POLENERGIA	5%	3%	21%	1620%	48%	111%	473%	28%	74%

Source: Own calculations.

In four of the analysed companies, the work efficiency based on number of employees indicator was growing the fastest, the work efficiency based on personnel costs indicator was second, while the VAIC™ ratio was growing the slowest. In the case of ZE PAK, the VAIC™ indicator grew faster than work efficiency based on personnel costs. This could be the result of the largest changes in the employment level in that company (Table 2), causing changes in the staff structure. A specific case is POLENERGIA, which has achieved improvements in work efficiency several times higher than in other companies according to work efficiency based on number of employees and work efficiency based on personnel costs indicators.

These differences in the picture of human capital efficiency in terms of various indicators may be related to the fact that the level of the VAIC™ indicator in the Polish energy sector is determined by depreciation write-offs and CO_2 fees. The four leading companies in this respect have large assets related to coal energy, which require high depreciation charges. The lower result of ZE PAK results from the redemption of some assets during the analysed period, and the negative result for the entire analysed period of the POLENERGIA company results from the dominance of renewable energy sources as a source of generated energy (lack of coal assets and related depreciation write-offs and CO_2 fees).

Referring to the first hypothesis put forward in the article, changes in the considered measures of human capital efficiency and work efficiency in the analysed Polish energy companies in the years 2010-2023 were positive. In the case of work efficiency indicators based on sales revenues, the final improvement was mainly determined by recent years.

Figure 2 shows changes in the value of human capital per employee estimated according to VAIC™, taking into account changes in employment and the level of personnel costs. The inclusion in relation to a single employee is justified by the different initial employment levels in the analysed companies, as well as the personnel movements that occurred in them during the analysed period.

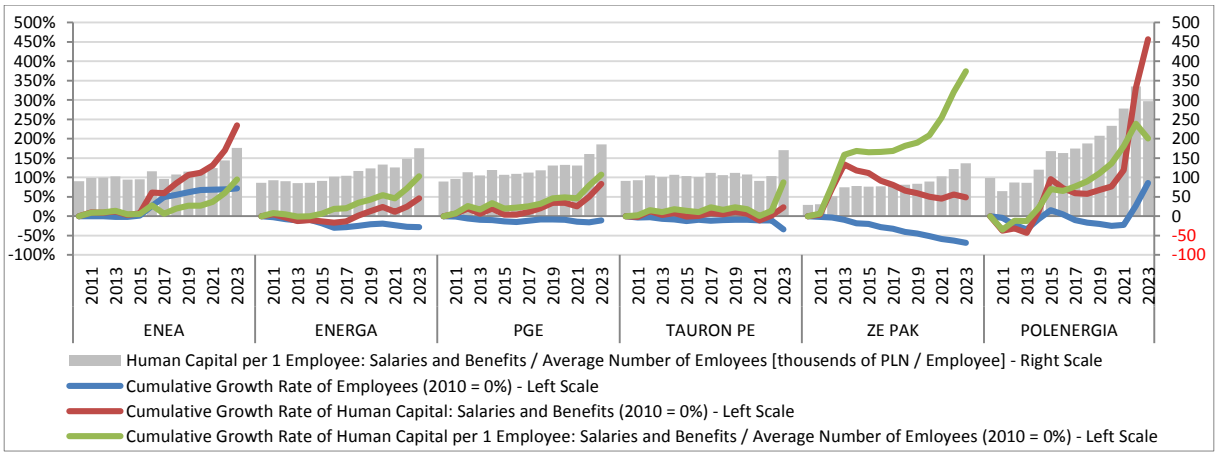

Figure 2. Human capital and its growth rate in the analysed Polish energy companies in 2010-2023. Source: Own work.

All analysed companies recorded an increase in the value of human capital per employee. Significant differences in the list may result from several reasons, the most important of which is the change in employment levels. In the analysed period, companies that are extreme in this approach recorded an increase in employment by 86% (POLENERGIA) and a decrease in employment by 69% (ZE PAK). With such a large staff turnover, the VAIC™ indicator based on salaries and benefits is determined to a greater extent by the structure of employees dismissed and hired, rather than changes in the value of human capital of employees employed in the company on a continuous basis. From this perspective, ZE PAK, while reducing employment by 69%, recorded an increase in the value of human capital per employee by 49%, which may indicate that the group of the most highly qualified employees remained in the company, while the group with lower than average qualifications (and lower salaries) was among those dismissed. On the other side of the ranking was TAURON PE, which, while reducing employment by 34%, recorded an increase in the value of human capital per employee by only 23%, which would indicate no improvement in the internal employment structure (loss of employees with at least medium qualifications).

One of the main reasons for changes in employment levels in individual companies is the structure of energy sources. At the beginning of the analysed period, ZE PAK based energy production on three power plants using brown coal (less calorific and more emissive than hard coal), one of which was shut down during the analysed period. POLENERGIA, where employment is growing, is by far the smallest company, produces energy based on renewable energy sources and partly gas, and does not use coal. Three of the four largest energy companies, producing electricity mainly from coal, show similar declines in employment levels. This indicates a gradual restructuring process. The exception in this group is ENEA, which recorded a significant increase in employment in the analysed period.

Table 2.
Changes in the value of human capital and the average number of employees in the analysed Polish energy companies in 2010-2023

	Human Capital: Salaries and Benefits			Average Number of Employees			Salaries and Benefits per Employee		
	Growth Rate 2010-2023	Annual Growth (Average)	Standard Deviation	Growth Rate 2010-2023	Annual Growth (Average)	Standard Deviation	Growth Rate 2010-2023	Annual Growth (Average)	Standard Deviation
ENEA	235%	11%	15%	72%	4%	8%	95%	6%	11%
ENERGA	46%	3%	10%	-28%	-2%	6%	103%	6%	8%
PGE	84%	5%	11%	-11%	-1%	3%	107%	6%	10%
TAURON PE	23%	2%	11%	-34%	-3%	8%	87%	6%	19%
ZE PAK	49%	5%	22%	-69%	-8%	5%	374%	14%	20%
POLENERGIA	457%	21%	43%	86%	8%	27%	200%	11%	21%

Source: Own calculations.

Referring to the second hypothesis put forward in the article, the analysed energy companies in the years 2010-2023 were characterized by different growth rates in the level of human capital. Although in the case of all surveyed entities there was an improvement over the period under study, in the case of the Tauron PE Group it was negligible, with additionally low variability. At the same time, it can be noted that in the case of most companies, the first half of the period under consideration (2010-2016) was characterized by a clearly lower dynamics of changes than the second half (2016-2023).

The article uses three different indicators to assess the efficiency of human capital, based on the same sources of financial data, but using different data. Table 3 presents the results of correlation and determination between human capital estimated using the VAIC™ index and work efficiency indicators based on sales revenues. Calculations were made to determine whether the results obtained with the indicators used were similar.

Table 3.
Results of the Pearson linear correlation analysis between human capital estimated using the VAIC™ index and work efficiency indicators in the analysed Polish energy companies in 2010-2023

	Work Efficiency Based on Number of Employees vs Human Capital Efficiency (VAIC™)		Work Efficiency Based on Personnel Costs vs Human Capital Efficiency (VAIC™)	
	Pearson's linear correlation coefficient	R^2	Pearson's linear correlation coefficient	R^2
ENEA	0.052	0.003	0.167	0.028
ENERGA	-0.157	0.025	0.217	0.047
PGE	-0.311	0.097	-0.327	0.107
TAURON PE	0.571*	0.326	0.512	0.262
ZE PAK	-0.017	0.000	0.651*	0.424
POLENERGIA	0.529	0.280	0.614*	0.377

* $p < 0.05$

Source: Own work.

The calculations show that in the analysed energy entities there is no clear correlation between the efficiency of human capital according to VAIC™ and work efficiency indicators. Therefore, it can be concluded that the indicators used in the article reflect changes in the analysed value (human capital efficiency) in a different way and an attempt can be made to determine which of them does it better.

The fourth hypothesis put forward in the article assumed that in the short term, especially in the event of economic shocks, work efficiency indicators are a better picture of changes in the efficiency of human capital than VAIC™. This formulation of the hypothesis resulted from literature studies. Table 4 contains a summary of average changes in the analysed indicators for all analysed companies in three-year periods.

Table 4.
Average changes in indicators of human capital efficiency and work efficiency in the distinguished periods calculated on the basis of annual growth rates in the analysed Polish energy companies in 2011-2023

		2011-2014	2014-2017	2017-2020	2020-2023	2011-2023
Human Capital Efficiency (VAIC™)	**ENEA**	7%	-1%	-2%	8%	3%
	ENERGA	14%	-1%	-11%	7%	2%
	PGE	-5%	5%	-7%	8%	0%
	TAURON PE	0%	1%	-1%	13%	3%
	ZE PAK	-22%	6%	-9%	45%	5%
	POLENERGIA	4%	5%	9%	-5%	3%
	Average	**0%**	**2%**	**-3%**	**13%**	**3%**
Work Efficiency Based on Number of Employees	**ENEA**	1%	-9%	13%	38%	11%
	ENERGA	3%	8%	2%	34%	12%
	PGE	4%	-5%	25%	29%	13%
	TAURON PE	-1%	-1%	5%	52%	14%
	ZE PAK	6%	3%	9%	43%	16%
	POLENERGIA	137%	55%	-4%	25%	53%
	Average	**25%**	**9%**	**8%**	**37%**	**20%**
Work Efficiency Based on Personnel Costs	**ENEA**	3%	-9%	6%	19%	5%
	ENERGA	6%	1%	-6%	22%	6%
	PGE	-3%	-3%	18%	15%	7%
	TAURON PE	-6%	-2%	7%	29%	7%
	ZE PAK	-20%	3%	5%	24%	3%
	POLENERGIA	83%	31%	-12%	10%	28%
	Average	**11%**	**4%**	**3%**	**20%**	**9%**
Real Work Efficiency Based on Number of Employees	**ENEA**	0%	-10%	9%	23%	6%
	ENERGA	2%	7%	-1%	17%	6%
	PGE	3%	-7%	23%	15%	8%
	TAURON PE	-2%	-1%	2%	31%	7%
	ZE PAK	5%	2%	6%	17%	8%
	POLENERGIA	135%	53%	-6%	16%	49%
	Average	**24%**	**7%**	**6%**	**20%**	**14%**

Source: Own work.

If we assume that the value and efficiency of human capital changes successively, a better picture of these changes is an indicator whose deviations from the trend are smaller. The data shows that human capital efficiency according to the VAIC™ model is characterized by lower variability than work efficiency indicators based on sales revenues, both in the long

and short periods. This also applies to changes in work efficiency based on number of employees in real terms (after taking into account price changes in the period 2011-2023 – last rows of Table 4). On the one hand, this indicates a better (more stable) estimation of changes in the efficiency of human capital by VAIC™ both in the long and short term, also in conditions of economic shocks. This is definitely true from an accounting perspective. On the other hand, limiting ourselves only to the VAIC™ indicator would be an oversimplification.

5. Discussion

The inspiration for taking up the topic of the article was the need to verify how the VAIC indicator and work efficiency indicators based on sales revenues reflect changes in the level and efficiency of human capital in the Polish energy sector.

None of the hypotheses presented in the article have been fully and positively verified. The first two hypotheses regarding a similar rate of growth in efficiency and the value of human capital in the entire sector and a better approximation of these changes in the short term by work efficiency indicators have not been fully confirmed by the available data. Differences in changes in efficiency and growth of human capital in individual companies are determined by several factors. Firstly, in the case of the Polish energy sector, the VAIC™ indicator is largely influenced by the structure of fixed assets in the analysed companies (a large share in the added value of depreciation in companies with coal assets). Secondly, the analysed companies are at different stages of life. Five of them are in the maturity phase, they are large organizations based on the production of energy from coal, while the sixth company is in the growth phase and is based on the production of energy from renewable energy sources. Thirdly, the results obtained for the last year indicate that in conditions of high inflation, changes in the valuation of human capital are determined to a large extent by the bargaining power of trade unions, limited by the current financial situation of enterprises. Salary costs increase depending on the negotiated level of salary increases; as data shows, this process is delayed in Polish enterprises. Fourth, comparisons of the value of human capital are made difficult by significant changes in employment levels. The shareholding structure may also be a factor influencing the scale of employment changes. In four of the companies under consideration (apart from ZE PAK and POLENERGIA), the controlling interest is held by the state, which may slow down changes for energy security and social reasons, under pressure from trade unions that are strong in the sector (ZE PAK, however, carried out a very deep reduction in employment in the analysed period). "Private" companies (without a state controlling stake) achieved significantly faster improvement in indicators based on sales revenues generated by employees. Such results may indicate better personnel management by "private" companies, but it should be emphasized that they were also characterized

by the highest increase in salaries and benefits per employee (the improvement in indicators did not occur at the "expense" of employees). Fifthly, the reliability of data obtained both on the basis of VAIC™ and work efficiency is limited by the state regulation of energy prices (limiting their increase, especially for households) (Prohorovs, 2022; Goldthau, Youngs, 2023).

The third hypothesis regarding the correlation between the estimates of changes in human capital performance according to the three applied approaches was not confirmed, even though both VAIC™ and work efficiency indicators use similar financial values from the same source.

If the reliability of human capital efficiency indicators is assumed to be their stability, the hypothesis that VAIC™ in the short term reflects changes in human capital efficiency worse than work efficiency indicators due to the shift in time of the effects of the company's personnel expenditures was not confirmed (Pulic, 2004; Andriessen, 2004). VAIC™ turned out to be more stable both in the long term and in all three-year periods. Being more stable in accounting terms, it could be accepted as a better picture of changes in human capital efficiency. However, this conclusion is too far-reaching. If we compare both groups of indicators, it turns out that the increase in the work efficiency based on number of employees indicator is the highest in companies that have the lowest VAIC™ indicators.

The contribution of the article to the existing literature is the repetition of research aimed at verifying the usefulness of the VAIC™ model in estimating the efficiency of human capital and the confrontation of this indicator with work efficiency indicators.

The obtained results allow us to determine directions for further research. First of all, it is important to answer the question whether similar relationships between VAIC™ and work efficiency indicators occur in other sectors of the Polish economy or whether they result only from the specificity of the energy sector (Diebolt, Hippe, 2019; Gennaioli et al., 2013). Since the indicators used in the article reflect changes in the analysed value (human capital efficiency) in different ways, one can attempt to determine which of them does it better. The answer to this question can be based, on one hand, on the valuation of the market value of enterprises and, on the other hand, on the analysis of internal labour resources in individual enterprises (their structure according to the level of education and work experience).

In the Polish energy sector, it is planned to separate coal assets (transferring them to a separate company under state supervision), which is to enable energy companies to reach for external sources of financing (most banks refuse to finance investments of enterprises using coal). Introducing this intention would allow for a more reliable comparison of the efficiency of human capital in Polish energy enterprises. It is advisable to repeat the study after a few years, after the end of inflationary processes, salaries adjustments that should be expected under pressure from trade unions (Ahlroth et al., 1997) and the separation of coal assets.

The article points to the specificity of the Polish coal-based electricity production sector, which will be abandoned in the Polish energy sector in a much longer time horizon than in other EU countries (about twenty years). The specificity resulting from the national context is the main limitation for generalizations of the results obtained during the study.

6. Summary

Comparing changes in the efficiency of human capital in the Polish energy industry is difficult due to a number of factors, the most important of which are high changes in the level and structure of employment (some companies increase employment, some reduce it) related to restructuring processes. This prevents reliable comparisons of human capital efficiency across entire companies and makes it difficult to estimate human capital per employee. Restructuring processes will intensify when (if) the state decides to separate coal assets from the structure of energy companies.

Referring to the results of the conducted research, attention is drawn to the ambiguous conclusions resulting from VAIC™ and work efficiency indicators. Their comparison shows that the largest companies under state control achieve mostly the highest improvement in the efficiency of human capital measured by the VAIC™ method. At the same time, they were outpaced in the case of the work efficiency based on number of employees indicator by "private" companies, one of which decided to undergo deep restructuring (and abandon the extraction of lignite and energy production from it within a few years), while the other one is growing based on investments in renewable energy sources. The basic conclusion resulting from this confrontation is the recommendation to use the VAIC™ indicator and work efficiency indicators together when assessing the efficiency of human capital.

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References

1. Acemoglu, D., Gallego, F.A., Robinson, J.A. (2014). Institutions, human capital and development. *Annual Review of Economics, 6(1),* pp. 875-912.
2. Ahlroth, S., Björklund, A., Forslund, A. (1997). The Output Of The Swedish Education Sector. Review of Income and Wealth. *International Association for Research in Income and Wealth,* 43(1), pp. 89-104. https://doi.org/10.1111/j.1475-4991.1997.tb00202.x

3. Alataş, S., Çakir, M. (2016). The Effect of Human Capital on Economic Growth: A Panel Data Analysis. *Journal of Administrative Sciences, 14(27),* pp. 539-555.
4. Alekseeva, L., Azar, J., Giné, M., Samila, S., Taska, B. (2021). The demand for AI skills in the labor market. *Labour Economics, Vol. 71, No. 6,* 102002. https://doi.org/10.1016 /j.labeco.2021.102002
5. Almendarez, L. (2013). Human Capital Theory: Implications for Educational Development in Belize and the Caribbean. *Caribbean Quarterly, 59(3/4), Special Issue: Building Sustainability in Belize: Through Education, Culture and Technology*, pp. 21-33.
6. Andriessen, D. (2004). *Making Sense of Intellectual Capital: Designing a Method for the Valuation of Intangibles*. Amsterdam, Nederland: Elsevier Butter-worth-Heinemann.
7. Angrist, N., Djankov, S., Goldberg, P.K., Patrinos, H.A. (2021). Measuring human capital using global learning. *Nature, 592(7854),* pp. 403-408. doi: http://dx.doi.org/10.1038/ s41586-021-03323-7
8. Bakhsha, A., Afrazeh, A., Esfahani Pour, A. (2017). A Criticism on Value Added Intellectual Coefficient (VAIC) Model. *International Journal of Computer Science and Network Security, 17(6),* pp. 59-71.
9. Baran, J., Szpor, A., Witajewski-Baltvilks, J. (2020). Low-carbon transition in a coal-producing country: A labour market perspective. *Energy Policy, 147*, 111878. doi: https://doi.org/10.1016/j.enpol.2020.111878
10. Becker, G.S. (1993). *Human capital: a theoretical and empirical analysis with special reference to education*. Chicago, USA: University of Chicago Press.
11. Bodman, P., Le, T. (2013). Assessing the roles that absorptive capacity and economic distance play in the foreign direct investment productivity growth nexus. *Applied Economics, 45(8),* pp. 1027-1039. doi: https://doi.org/10.1080/00036846.2011.613789
12. Bornemann, M., Knapp, A., Schneider, U., Sixl, K.I. (1999). Holistic measurement of intellectual capital. International Symposium: Measuring and Reporting Intellectual Capital: Experiences. *Issues and Prospects Conference*, Amsterdam, Nederland, 9-10 June. Retrieved from: www.oecd.org/dataoecd/16/20/ 1947871.pdf, 2.05.2023.
13. Buesselmann, S. (2009). *Human Capital and Economic Growth, Analyzing the Impact of Skilled Labour on Economic Prosperity*. Saarbruecken, Germany: VDM Verlag.
14. Buzavaite, M., Korsakiene, R. (2019). Human Capital and the Internationalisation of SMEs: A Systemic Literature Review. *Entrepreneurial Business and Economics Review, 7(3),* pp. 125-142. doi: https://doi.org/10.15678/EBER.2019.070307
15. Capros, Q., Paroussos, L., Fragkos, Q., Tsani, S., Boitier, B., Wagner, F., Busch, S., Resch, G., Blesl, M., Bollen, J. (2014). Description of models and scenarios used to assess European decarbonisation pathways. *Energy Strategy Reviews, 2*, pp. 220-230. doi: https://doi.org/10.1016/j.esr.2013.12.008

16. Castelló-Climent, A. (2019). The Age Structure of Human Capital and Economic Growth. *Oxford Bulletin of Economics and Statistics, 81(2),* pp. 394-411. doi: https://dx.doi.org 10.1111/obes.12274
17. Chan, K.H. (2009). Impact of intellectual capital on organisational performance: An empirical study of companies in the Hang Seng Index (Part 2). *Learning Organization, 16(1),* pp. 22-39. doi: https://doi.org/10.1108/09696470910927650
18. Chen, J., Zhu, Z., Xie, H.Y. (2004). Measuring intellectual capital: a new model and empirical study. *Journal of Intellectual Capital, 5(1),* pp. 195-212. doi: https://doi.org/ 10.1108/14691930410513003
19. CIPD (2017). *Human capital theory: assessing the evidence for the value and importance of people to organisational success – Technical report, May 2017*. Ulster University, UK. Retrieved from: https://www.cipd.org/globalassets/media/knowledge/knowledge-hub/ reports/human-capital-theory-assessing-the-evidence_tcm18-22292.pdf, 21.05.2023.
20. Dakhli, M., De Clercq, D., (2004). Human capital, social capital, and innovation: a multi-country study. *Entrepreneurship & Regional Development*. *Vol. 16, No. 2*, pp. 107-128. doi:10.1080/08985620410001677835
21. Dańska-Borsiak, B. (2023). Human capital convergence in European NUTS 2 regions. *Equilibrium – Quarterly Journal of Economics and Economic Policy, 18(2),* pp. 367-392. doi: https://doi.org/10.24136/eq. 2023.011
22. Davenport, T.O. (1999). *Human Capital: What It Is and Why People Invest It*. San Francisco, USA: Jossey-Bass Publishers.
23. Diebolt, C., Hippe, R. (2019). The long-run impact of human capital on innovation and economic development in the regions of Europe. *Applied Economics, 51(5),* pp. 542-563. doi: https://doi.org/10.1080/00036846.2018.1495820
24. Edvinsson, L., Malone, M. (1997). *Intellectual Capital: Realizing Your Company's True Value by Finding Its Hidden Roots*. New York, USA: Harper Collins Publishers.
25. Edvinsson, L., Sullivan, P. (1996). Developing a model of managing intellectual capital. *European Management Journal, 14(4),* pp. 356-364. doi: https://doi.org/10.1016/0263-2373(96)00022-9
26. European Commission (2020). Sustainable Europe Investment Plan: European Green Deal Investment Plan. *The European Economic And Social Committee And The Committee Of The Regions*. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/ ?uri=CELEX%3A52020DC0021, 15.05.2022.
27. Feng, A., Graetz, G., (2020). Training Requirements, Automation, and Job Polarisation. *The Economic Journal, Royal Economic Society, 130(631),* pp. 2249-2271. https://doi.org/10.1093/ej/ueaa044
28. Firer, S., Williams, S.M. (2003). Intellectual capital and traditional measures of corporate performance. *Journal of Intellectual Capital, 4(3),* pp. 348-60. doi: https://doi.org/10.1108/ 14691930310487806

29. Gan, K., Saleh, Z. (2008). Intellectual capital and corporate performance of technology-intensive companies: Malaysia evidence. *Asian Journal of Business and Accounting, 1(1),* pp. 113-130.
30. Gennaioli, N., La Porta, R., Lopez-de-Silanes, F., Shleifer, A. (2013). Human capital and regional development. *The Quarterly Journal of Economics*, *128(1),* pp. 105-164. doi: https://doi.org/10.1093/qje/qjs050
31. Gibbons R., Katz, L.F., Lemieux, T., Parent, D. (2005). Comparative Advantage, Learning, and Sectoral Wage Determination. *Journal of Labour Economics*, *23(4),* pp. 681-724. doi: https://doi.org/10.1086/491606
32. Goldthau, A.C., Youngs, R., (2023). The EU Energy Crisis and a New Geopolitics of Climate Transition. *Journal of Common Market Studies*, *61*, pp. 111-124, doi: https://doi.org/10.1111/jcms.13539
33. Habib, M., Abbas, J., Noman, R., (2019). Are human capital, intellectual property rights, and research and development expenditures really important for total factor productivity? An empirical analysis. *International Journal of Social Economics*, *46(6),* pp. 756-774. doi: https://doi.org/10.1108/IJSE-09-2018-0472
34. Hanushek, E.A., Woessmann. L. (2008). The Role of Cognitive Skills in Economic Development. *Journal of Economic Literature, 46(3),* pp. 607-668. doi: https://doi.org/ 10.1257/jel.46.3.607
35. Huggins, R., Prokop, D., Thompson, P., (2017). Entrepreneurship and the determinants of firm survival within regions: human capital, growth motivation and locational conditions. *Entrepreneurship & Regional Development*, *29(3-4),* pp. 357-389, doi:10.1080 /08985626.2016.1271830
36. Iazzolino, G., Laise, D. (2013). Value added intellectual coefficient (VAIC): A methodological and critical review. *Journal of Intellectual Capital*, *14(4),* pp. 547-563. doi: https://doi.org/10.1108/JIC-12-2012-0107
37. Iazzolino, G., Laise, D., Migliano, G. (2014). Measuring value creation: VAIC and EVA. *Measuring Business Excellence, 18(1),* pp. 501-514. doi: https://doi.org/10.1108/MBE-10-2013-0052
38. Iazzolino, G., Migliano, G., Dattilo, M.I. (2019). The impact of Intellectual Capital on Firms' Characteristics: an empirical analysis on European listed manufacturing companies. *International Journal of Industrial Engineering and Management*, *10(3),* pp. 219-237. doi: http://doi.org/10.24867/IJIEM-2019-3-242
39. Jorgenson, D.W., Fraumeni, B.M. (1989). The accumulation of human and non-human capital, 1948-1984. In: R.E. Lipsey, H.S. Tice (Eds.), *The Measurement of Savings, Investment and Wealth* (pp. 227-282). Chicago: University of Chicago Press.
40. Kraay, A. (2018). Methodology for a World Bank Human Capital Index. *Policy Research Working Paper*, *8593*. Washington: World Bank. Retrieved from https://openknowledge. worldbank.org/handle/10986/30466, 4.05.2023.

41. Kuzior, A., Arefieva, O., Kovalchuk, A., Brożek, P., Tytykalo, V. (2022). Strategic Guidelines for the Intellectualization of Human Capital in the Context of Innovative Transformation. *Sustainability, 14(19),* 11937. doi: https://doi.org/10.3390/su141911937
42. Laing, G., Dunn, J., Hughes-Lucas, S. (2010). Applying the VAIC model to Australian hotels. *Journal of Intellectual Capital, 11(3),* pp. 269-283. doi: https://doi.org/10.1108/14691931011064545
43. Laroche, M., Mérette, M., Ruggeri, G.C. (1999). On the Concept and Dimension of Human Capital in a Knowledge-Based. *Canadian Public Policy, 25(1),* pp. 87-100.
44. Lee, J-W., Lee, H. (2016). Human capital in the long run. *Journal of Development Economics, 122,* pp. 147-169. doi: http://dx.doi.org/10.1016/j.jdeveco.2016.05.006
45. Lenkei, B. (2019). *Essays on Human Capital*. London: Middlesex University.
46. Lepak, D.P., Snell, S.A. (1999). The Human Resource Architecture: Toward a Theory of Human Capital Allocation and Development. *The Academy of Management Review, 24(1),* pp. 31-48. doi: https://doi.org/10.2307/259035
47. Lerro, A., Linzalone, R., Schiuma, G. (2014). Managing intellectual capital dimensions for organizational value creation. *Journal of Intellectual Capital, 15(3),* pp. 350-361. doi: https://doi.org/10.1108/jic-05-2014-0063
48. Lim, S.S., Updike, R.L., Kaldjian, A.S., Barber, R.M., Cowling, K., York, H., Friedman, J., Xu, R., Whisnant, J.L., Taylor, H.J., Leever, A.T., Roman, Y., Bryant, M.F., Dieleman, J., Gakidou, E., Murray, C.J.L. (2018). *Measuring hu-man capital: a systematic analysis of 195 countries and territories.* Seattle: Institute for Health Metrics and Evaluation, University of Washington. doi: http://dx.doi.org/10.1016/S0140-6736(18)31941-X
49. Maditinos, D., Chatzoudes, D., Tsairidis, C., Theriou, T. (2011). The impact of intellectual capital on firms' market value and financial performance. *Journal of Intellectual Capital, 12(1),* pp. 132-151. doi: https://doi.org/10.1108/14691931111097944
50. Marr, B., Moustaghfir, K. (2005). Defining Intellectual Capital: A Three-dimensional Approach. *Management Decision, 43(9),* pp. 1114-1128. doi: https://doi.org/10.1108/00251740510626227
51. Marr, B., Schiuma, G., Neely, A. (2004). Intellectual capital – defining key performance indicators for organizational knowledge assets. *Business Process Management Journal, 10(5),* pp. 551-569. doi: https://doi.org/10.1108/14637150410559225
52. Martínez-Torres, M.R. (2006). A Procedure to Design a Structural and Measurement Model of Intellectual Capital: An Exploratory Study. *Information & Management, 43(5),* pp. 617-626. doi: https://doi.org/10.1016/j.im.2006.03.002
53. Marzo, G. (2022). A theoretical analysis of the value added intellectual coefficient (VAIC). *Journal of Management and Governance, 26(2),* pp. 551-577. doi: https://doi.org/10.1007/s10997-021-09565-x
54. Mayo, A. (2001). *The Human Value of the Enterprise Valuing People as Assets-Monitoring, Measuring, Managing*. London: Nicholas Brealey Publishing.

55. McConnell, C.R. (1984). *Economics*. New York/St. Louis: McGraw-Hill.
56. Meles, A., Porzio, C., Sampagnaro, G., Verdoliva, V. (2016). The impact of intellectual capital efficiency on commercial bank performance: Evidence from the US. *Journal of Multinational Financial Management*, *36(1),* pp. 64-74. doi: https://doi.org/10.1016/j.mulfin.2016.04.003
57. Milost, F. (2005). Dynamic monetary model of intellectual capital evaluation. *Proceedings of the 6th Internation-al Conference of the Faculty of Management*. Koper Congress Centre Bernardin, Slovenia, 24-26 November.
58. Mulliqi, A., Adnett, N., Hisarciklilar, M., Rizvanolli, A. (2018). Human Capital and International Competitiveness in Europe, with Special Reference to Transition Economies. *Eastern European Economic*, *56(6),* pp. 541-563. doi: https://dx.doi.org/10.1080/00128775.2018.1502612
59. Nabi, M.N., Gao, Q., Rahman, M.T., Britton, S.O., Islam, M.M. (2020). Intellectual Capital and Corporate Performance: Evidence From Banking Industry of Bangladesh. *International Journal of Human Resource Studies*, *10(1),* pp. 234-259. doi: https://doi.org/10.5296/ijhrs.v10i1.16146
60. Nawrocki, T.L., Jonek-Kowalska, I. (2023). Efficiency of Polish Energy Companies in the Context of EU Climate Policy. *Energies*, *16*, 826. doi: https://doi.org/10.3390/en16020826.
61. Nazari, J.A., Herremans, I.M. (2007). Extended VAIC Model: Measuring Intellectual Capital Components. *Journal of Intellectual Capital*, *8,* pp. 595-609. doi: https://doi.org/10.1108/14691930710830774
62. Nelson, R., Phelps, E. (1966). Investment in humans, technological diffusion, and economic growth. *The American Economic Review*, *56(1/2),* pp. 69-75. doi: https://www.jstor.org/stable/1821269
63. Nilsson, C., Ford, D. (2004). Introducing intellectual potential – the case of Alfa Laval. *Journal of Intellectual Capital, 5(3),* pp. 414-425. doi: https://doi.org/10.1108/14691930410550372
64. OECD (1998). *Human Capital Investment*. Retrieved from: https://doi.org/10.1787/9789264162891-en, 2.05.2023.
65. Østergaard, A., Marinova, S.T. (2018). Human Capital in the Entrepreneurship Ecosystem. *International Journal of Entrepreneurship and Small Business*, *35(3),* pp. 371-390. doi: https://doi.org/10.1504/IJESB.2018.095907
66. Ozkan, N., Cakan S., Kayacan, M. (2017). Intellectual capital and financial performance: A study of the Turkish Banking Sector. *Borsa Istanbul Review*, *17(3),* pp. 190-198. doi: https://doi.org/10.1016/j.bir.2016.03.001
67. Pach-Gurgul, A., Ulbrych, M. (2019). Progress of V4 Countries towards the EU's Climate and Energy Targets in the Context of the Energy Supply Security Improvement. *Entrepreneurial Business and Economics Review, 7(2),* pp. 175-197. doi: https://doi.org/10.15678/EBER.2019.070210

68. Pap, E., Petković, M., Simićević, A. (2021). Measuring distribution of intellectual capital components contribution: French context. *The European Journal of Applied Economics, 18(1),* pp. 1-14. doi: https://doi.org/10.5937/EJAE18-28628
69. Pritchett, L. (2001). Where has all the education gone? *World Bank Economic Review, 15(3),* pp. 367-391.
70. Prohorovs, A. (2022). Russia's War in Ukraine: Consequences for European Countries' Businesses and Economies. *Journal of Risk and Financial Management, 15(7),* 295. https://doi.org/10.3390/jrfm15070295
71. Pulic, A. (1998). Measuring the performance of intellectual potential in the knowledge economy. *2nd McMaster World Congress on Measuring and Managing Intellectual Capital by the Austrian Team for Intellectual Potential*. Retrieved from: https://www.academia.edu/8959823, 2.05.2023.
72. Pulic, A. (2000a). MVA and VAIC™ Analysis of Randomly Selected Companies from FTSE 250. *Austrian Intellectual Capital Research Centre*. Graz, Austria/ London: UK. Retrieved from: http://www.measuring-ip.at/Papers/ham99txt.htm, 2.05.2023.
73. Pulic, A. (2000b). VAIC – an accounting tool for IC management. *International Journal of Technology Management, 20,* pp. 702-714. doi: https://doi.org/10.1504/IJTM.2000.002891
74. Pulic, A. (2004). Intellectual capital – does it create or destroy value? *Measuring Business Excellence, 8(1),* pp. 62-68.
75. Pulic, A. (2008). *The Principles of Intellectual Capital Efficiency*. Retrieved from: https://www.scinapse.io/papers/2371185822, 2.05.2023.
76. Puntillo, P. (2009). Intellectual capital and business performance. Evidence from Italian banking industry. *Electronic Journal of Corporate Finance, 4(12),* pp. 97-115.
77. Queirós, A.S.S., Teixeira, A.A.C. (2016). Economic Growth, Human Capital and Structural Change: An Empirical Analysis. *Research Policy, 45,* pp. 1636-1648.
78. Roos, J., Ross, G., Dragonetti, N.C., Edvinsson, L. (1997). *Intellectual Capital. Navigation the New Business Landscape*. Basingtoke: Palgrave Macmillan.
79. Rossi, F. (2020). Human Capital and Macro-Economic Development: A Review of the Evidence. *The World Bank Research Observer, 35(4),* pp. 227-262. doi: 10.1093/wbro/lkaa002
80. Schultheiss, T., Pfister, C., Gnehm, A-S., Backes-Gellner, U., (2023). Education expansion and high-skill job opportunities for workers: Does a rising tide lift all boats? *Labour Economics, 82(C),* pp. 1-23. doi: https://doi.org/10.1016/j.labeco.2023.102354
81. Schultz, T.W. (1961). Investment in human capital. *American Economic Review, 51(1),* pp. 1-17.
82. Segu, Z., Natoli, R. (2012). Human capital: The history, measurement and impact on nations from an economic perspective. *International Journal of Value Chain Management, 6(1),* pp. 61-77. doi: https://doi.org/10.1504/IJVCM.2012.045158

83. Sheveleva, L., Jones, M., Harris, I. (2023). It does not matter how hard you work: The importance of task allocation for worker productivity. *Economics Letters, 227(C),* pp. 1-4. doi: https://doi.org/10.1016/j.econlet.2023.111115
84. Shiu, H. (2006). The application of the value added intellectual coefficient to measure corporate performance: evidence from technological firms. *International Journal of Management, 23(2),* pp. 356-65.
85. Škare, M., Lacmanović, S. (2015). Human capital and economic growth: a review essay. *Amfiteatru Economic Journal, 17(39),* pp. 735-760.
86. Son, H.H. (2010). *Human Capital Development*. Retrieved from: https://www.adb.org/sites/default/files/publication/28427/economics-wp225.pdf, 4.05.2023.
87. Ståhle, P., Ståhle, S., Aho, S. (2011). Value Added Intellectual Coefficient (VAIC): a critical analysis. *Journal of Intellectual Capital, 12(4),* pp. 247-268. doi: https://doi.org/10.1108/14691931111181715
88. Stewart, T.A. (1997). *Intellectual capital: the new wealth of organizations*. New York: Doubleday Dell Publishing Group.
89. Storberg-Walker, J. (2004). *Towards a Theory of Human Capital Transformation Through Human Resource Development*. Retrieved from: https://files.eric.ed.gov/fulltext/ED492359.pdf, 2.05.2023.
90. Swoczyna, B. (2024). *Węglowe podsumowanie roku 2023*. Retrieved from: https://energy.instrat.pl/weglowe-podsumowanie-2024-02-22/, 18 August 2024.
91. Szczepankiewicz, E.I.; Mućko, Q. (2016). CSR Reporting Practices of Polish Energy and Mining Companies. *Sustainability, 8, 126*. doi:10.3390/su8020126
92. Tan, H.P., Plowman, D., Hancock, P. (2007). Intellectual capital and financial returns of companies. *Journal of Intellectual Capital, 8(1),* pp. 76-94. doi: https://doi.org/10.1108/14691930710715079
93. Unger, J.M., Rauch, A., Frese, M., Rosenbusch, N. (2011). Human capital and entrepreneurial success: a meta-analytical review. *Journal of Business Venturing, 26(3),* pp. 341-358.
94. Urząd Regulacji Energetyki (2024). *Charakterystyka rynku energii elektrycznej*. Retrieved from: https://www.ure.gov.pl/pl/energia-elektryczna/charakterystyka-rynku/10372,2021.html, 4 August 2024.
95. van Beurden, Q., Goessling, T. (2008). The worth of values - A literature review on the relation between corporate social and financial performance. *Journal of Business Ethics, 82*, pp. 407-424. doi: https://doi.org/10.1007/s10551-008-9894-x
96. Wang, H, Hao, L., Wang, W., Chen, X. (2023). Natural resources lineage, high technology exports and economic performance: RCEP economies perspective of human capital and energy resources efficiency. *Resources Policy, 87A*, 104297. doi: https://doi.org/10.1016/j.resourpol.2023.104297

97. Wielechowski, M., Cherevyk, D., Czech, K., Kotyza, P., Grzęda, Ł., Smutka, L. (2021). Interdependence between human capital determinants and economic development: K-means regional clustering approach for Czechia and Poland. *Entrepreneurial Business and Economics Review*, *9(4)*, pp.173-194. https://doi.org/10.15678/EBER.2021.090411
98. Wosiek, M. (2020). Rural–urban divide in human capital in Poland after 1988. *Oeconomia Copernicana, 11(1),* pp. 183-201. doi: https://doi.org/10.24136/oc.2020.008
99. Young, C.S., Su, H.Y., Fang, S.C., Fang, S.R. (2009). Cross-country comparison of intellectual capital performance of commercial banks in Asian economics. *The Service Industries Journal*, *29(11),* pp. 1565-1579. doi: https://doi.org/10.1080/02642060902793284
100. Zhang, H., Liu, O., Lu, D., Wang, X., Fan, H. (2023). Sustainable development perspective of linking natural re-sources and human capital development: An overview of resources utilization. *Resources Policy*, *86B,* 104097. doi: https://doi.org/10.1016/j.resourpol.2023.104097
101. Zieliński, M., Adamska, M. (2022). ESG Assessment from the Perspective of the Management Board and Trade Unions on the Example of the Opole Power Plant. *Energies*, *15*, 8066. doi: https://doi.org/10.3390/en15218066.