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The impact of sectoral and macroeconomic variables on company profitability in the energy sector. Analysis using neural networks

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Abstract

The aim of this empirical study was to determine the relationship between the main sectoral and macroeconomic variables and the profitability of companies in the energy sector. It analysed jointly the macroeconomic variables including: the unemployment rate, changes in gross domestic product, the Consumer Price Index, the Producer Price Index, the sector-level variables covering the share of energy from renewable sources and investment in the sector, and the company-level profitability indicators. The study sample included 300 companies operating in Poland in 2003–2021. For the purpose of data analysis, it employed a neural network. Specifically, a multi-layer perceptron (MLP) with the hyperbolic tangent as the activation function was used. The findings suggest that the changes in both sectoral and macroeconomic variables may have an important effect on the profitability of companies operating in the energy sector. The study proposes several novelties, including the employment of neural networks and a joint analysis of both sectoral and macroeconomic independent variables.

Keywords: profitability, macroeconomic indicators, sectoral indicators, neural network, energy sector

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1. Introduction

While profitability plays a central role in economic analysis, previous scientific research produced differentiated and often unstructured conclusions on its determinants. To schematise the reasoning, this research proposes a framework in which the determinants fall into one of the three groups: endogenous, exogeneous (sector) and exogeneous (macroeconomic). Once classified as such, the striking differentiation of the previous research emerges, where the studies on the endogenous determinants of profitability are abundant and those on the exogeneous ones are distinctly less pronounced. Regarding this imbalance, both sectoral and macroeconomic determinants of profitability will constitute the principal axis of this study.

The overview of the selected research on the subject leaves little doubt on the importance of company environment for its profitability. And yet, both scientists and practitioners notoriously disregard the exogeneous factors in profitability analysis and by focusing on the company data they detach the company from its environment. Moreover, the general conclusion on the importance of exogenous factors for company profitability suffers from severe deficiencies when detailed analysis is needed. First, the spectrum of sectoral and macroeconomic variables studied so far does not seem to be anyhow consistent. Second, previous studies produced often mutually exclusive results, and because of the limited amount of evidence, definitive conclusions could not be reached. Third, most previous studies relied on the repetitive usage of traditional research methods. Therefore, the result obtained could not be discussed against the results obtained with the use of modern methods of data analysis. While addressing all these issues in one study seems neither possible nor required, this research attempts to contribute to the scientific dialogue by selecting the most important sectoral and macroeconomic variables, combining both of these groups of exogenous variables in one comprehensive study, and determining their role in shaping company profitability with the use of a method rarely employed in the field.

With respect to the above considerations, the aim of this paper is to determine the relationship between the main sectoral and macroeconomic variables and the profitability of companies. In order to achieve the purpose, a dedicated empirical investigation was performed. With respect to the previous scientific evidence, it is hypothesised here that all the selected sectoral and macroeconomic variables are important in shaping company profitability in the sector.

As the sector selection is of principal importance from the perspective of the relationship studied, this study targets one of the most prominent ones, i.e. the energy sector. It is currently of particular interest to both scientists and practitioners. Its transformation is the key ingredient of the European decarbonisation policies with feed-in tariffs and certificate systems (Jaraite, Kazukauske 2013), investment subsidies, tax credits, and portfolio requirements (Reuter et al. 2012) being in place.

The empirical study was designed based on the established theoretical foundations and thus combined three perspectives: endogenous, exogeneous (sector) and exogeneous (macroeconomic). It relied on the yearly data for 300 randomly drawn companies. The time frame encompassed 2003–2021. Because of the outliers detected and the missing values on covariates and dependant variables, the final number of observations matched 3,121. Regarding the study design, a sound operationalisation of the variables was needed. As for the macroeconomic factors, four variables were selected: unemployment rate, changes in gross domestic product, Consumer Price Index, and Producer Price Index. With respect to the sectoral variables, the share of energy from renewable sources and investment in the energy

sector were employed. As for company profitability, four different measures were used: ROE, ROA, ROS, and ROIC. In the process of data analysis, a neural network, specifically a multi-layer perceptron (MLP), was used. The input layer consisted of 12 variables representing all the examined sectoral and macroeconomic variables in the given (t) and preceding ($t - 1$) periods. The output layer included the four target profitability variables in a given period (t). There were no restrictions on the number of neurons in the hidden layer. All variables were appropriately rescaled. The rescaling method for the covariates was adjusted normalisation, and for the dependants it was standardisation. The hyperbolic tangent was used as the activation function and the batch learning type was adopted. In order to study variable importance, a sensitivity analysis was performed as it computes the importance of each predictor in determining the neural network.

The obtained results suggest that the changes in both sectoral and macroeconomic variables might have an important effect on the profitability of companies. However, the study challenged the widely recognized analytical principle that sectoral variables are more effective predictors of company performance than those representing the broader economy, indicating the opposite effect. Moreover, the results obtained here partially diverge from previous evidence and imply that a one-year time span is adequate for changes in macroeconomic conditions to notably influence company profitability in the sector. In reference to the variables used, the most important macroeconomic ones were Producer Price Index (t) changes in gross domestic product (t), and Consumer Price Index (t). As for the sectoral factors, investment in the period $t - 1$ ranked highest. At the same time, it was the most important lagged ($t - 1$) variable in the set. The remaining macroeconomic and sectoral variables demonstrated a relatively low importance.

The paper is structured as follows. First, the literature review depicts the role of profitability in economic analysis and presents the current evidence on the sectoral and macroeconomic determinants of profitability. Second, the research methods are depicted with special regard to the neural network built to analyse the data. Third, the results are presented and discussed against the previous evidence in the field. The paper ends with conclusions.

2. Literature review

Profitability remains one of the central elements of the economic analysis. This is because it is crucial from the operational viewpoint and is considered one of the key determinants of company value (Dang et al. 2019). On the other hand, however, profitability itself is affected by a number of determinants. Because scientific evidence here is somehow fragmented, this research proposes a division of these determinants into exogeneous and endogenous, with the former being further divided into two groups: sectoral and macroeconomic. At the same time, the former also constitutes the main focus of this research. Therefore, since profitability is one of the key links between company environment and its value, it is central to financial management and requires a thorough understanding.

In its basic sense, profitability reflects the return earned by the company in a given period in relation to the causative factor. Profitability ratios usually make up financial results with sales, assets, value of equity or total capital employed in the company. Therefore, the profitability analysis makes it possible to evaluate the company's activity on many levels, each of which has its own individual characteristics.

From the financial and managerial viewpoints, profitability is analysed during most operational activities as well as during the development of strategic plans. In most cases rationally managed enterprises strive to improve it. The importance of profitability is also firmly supported by analytical practice: "the ability to generate profit on capital invested is a key determinant of a company's overall value and the value of the securities it issues. Consequently, many equity analysts would consider profitability to be a key focus of their analytical efforts" (Robinson et al. 2020, p. 291).

Profitability itself is affected by a wide range of factors, which in this research will be classified into three groups: endogenous, exogeneous (sector) and exogeneous (macroeconomic). While research on the endogenous determinants of profitability is abundant, the evidence on the relation between company profitability and sectoral and macroeconomic variables remains less pronounced and therefore will constitute the principal axis of this study. This inadequacy is especially important in the open economies characterised by the high interdependency between companies, sectors and countries. According to the current evidence, in the global economy companies are especially exposed to numerous threats related to the unstable and uncertain business environment, at the level of individual countries and the global economy (Batra, Kalia 2016).

In line with the logic proposed in this paper, research targeting the relation between exogeneous variables and company profitability may be attributed into one of two principal groups: non-sector--specific and sector-specific. In the first one the focus is placed on macroeconomic variables affecting the entire economy (e.g. inflation, GDP change etc.). In this line of research sectorial specificity is often disregarded. In the second vein, a particular sector is targeted and its specificity is accounted for by the addition of sector-specific variables (e.g. cereal price in the agricultural sector, deposit insurance regulation in the banking sector etc.). This distinction is important as it drives the selection of independent variables.

With regard to the first group of studies – covering only the non-sector-specific variables, affecting the entire economy – the review of literature allows to indicate of the most widely used exogeneous (macroeconomic) variables. While the research is still fragmented, some similarities between particular studies may be identified. In the research conducted in Greece, covering non-financial Greek firms listed in the Athens Exchange, the results indicated that company profitability is positively influenced by its size, sales growth and investment and negatively by leverage and current assets. As for the exogeneous perspective, the research showed that the participation in the European monetary union and the adoption of the euro were negatively related to firm profitability (Asimakopoulos, Samitas, Papadogonas 2009). Further research in this vein offered a clear division into internal and external factors that affect profitability, and then analysed both. One of the most important conclusions was that there is a significant and negative relationship between the return on assets and the change in gross domestic product (GDP) and the inflation rate (Khrawish 2011). Partially supporting these conclusions, later studies indicated that in the case of banks, the rate of economic growth has a negative impact on profitability and higher inflation has a positive one (Sufian 2009; Sufian, Noor 2012). Subsequent research further confirmed the importance of exogeneous (macroeconomic) variables for shaping the profitability of companies. It used the sample of 108 banks from the USA, Great Britain and Germany specializing in real estate financing. The results showed that the Lerner Index, interest rate volatility and GDP level have a significant effect on company profitability (Martins, Serra, Stevenson 2019).

Therefore, the analysis of the previous evidence points to changes in gross domestic product and the inflation rate as the most commonly employed exogeneous factors representing the shape of the overall economy.

The sector-specific studies deepen the considerations by adding the variables related to particular sectors, i.e. exogeneous (sector). Again, while the studies demonstrate important differences, some commonalities may be identified. The results of the research conducted in the banking sector indicated the significance of both exogeneous (sector) and exogeneous (macroeconomic) factors in shaping the profitability of companies. According to the research, the profitability of banks was determined by the following: bank characteristics, macroeconomic conditions, explicit and implicit bank taxation, deposit insurance regulation, overall financial structure, and underlying legal and institutional indicators. In the sample, a larger ratio of bank assets to gross domestic product and a lower market concentration ratio led to lower margins and profits, and this effect was demonstrated by controlling for differences in bank activity, leverage, and the macroeconomic environment (Demirgüç-Kunt, Huizinga 1999). In a similar vein, research on the profitability determinants of Australian manufacturing companies introduced sector-specific considerations. With respect to endogenous variables, the results suggested that the profitability achieved by the company in the previous period is an important determinant of the current level of margins. Regarding the sectoral level, it showed that there is a positive relationship between the degree of industry concentration and the margins realized within it (McDonald 1999). What is especially important here is the introduction of the lagged effects. However, as they were introduced only with respect to the endogenous variables, it appears that the analysis of the lagged effects of the changes in exogeneous variables remains a promising research direction. In the research on profitability conducted in Croatia, a group of four sectors was selected based on their importance for the national economy: agriculture, production, construction and trade. Regarding endogenous variables, the study indicated that the firm's age and labour costs have a significant influence on its profitability. However, it further complemented the conclusion by adding the sectoral variables and showing that industry concentration significantly influences company profitability. As for the exogeneous (macroeconomic) variables, the study demonstrated that both GDP growth and inflation rate are significant factors (Kristic, Druzic, Logarusic 2020). Further research confirmed again the importance of sectoral and macroeconomic variables for the profitability of companies. Based on the sample of 47 banks from 14 European countries in the period 2013–2018, it was found that the GDP growth rate, inflation rate and sector concentration have a positive impact on company profitability (Karadzic, Dalovic 2021). Finally, sector-specific research was also conducted in Poland. It relied on a sample of agricultural distributors in the period of 2006–2016. In the course of the analysis, both endogenous and exogeneous variables were suggested to significantly affect profitability. In the latter group a significant positive impact of macroeconomic factors such as unemployment rate, and sectoral factors such as cereal price was demonstrated (Korneta 2019). The results seem especially important from the perspective of this study because of the overlapping spatial scope.

In the energy sector, the sector-specific research on profitability was also identified. In the study by Wattanatorn and Kanchanapoom (2012), the impact of the exogeneous (sector) variable such as the crude oil price on the profitability performance of the sector was investigated. The study used data on companies in the stock exchange of Thailand from 2001 to 2010 and found that oil prices have a significant impact on the profits realised in the energy and food sectors.

The further study of literature led to the conclusion that in numerous recent studies the main focus is placed on renewable sources of energy. In this context, the study covering the European Union allowed to verify how the implemented renewable electricity promotion systems affected the profitability of the electricity production companies. Thus, it took the sectoral perspective and focused on the

Tradable Green Certificates and Feed-in-Tariffs. The results indicated that the companies operating in EU countries that implemented TGC, were more profitable compared to FIT firms, which partially supported the hypothesis that higher investment risk, higher capital constraints and higher transaction costs result in TGC schemes being associated with excess profits for renewable electricity generating firms (Jaraite, Kazukauske 2013). Subsequent research approached the issue of profitability taking into account the investment made in different technologies in the sector. After stating that the investment in new renewable energy capacities have exceeded funds invested in conventional energy capacity, the leading factors of market profitability were discussed. The results indicated that in the renewable energy sector company profitability depends mainly on the degree of stability and predictability of policies stimulating the development of renewables in particular countries (Chebotareva 2018). What seems especially important here is the introduction of the investment perspective into the analysis. It appears of both crucial scientific and crucial practical importance, as the development of renewables requires substantial investments and is subject to public incentives supporting them such as feed-in tariffs, certificate systems, investment subsidies, tax credits, and portfolio requirements (Reuter et al. 2012; Jaraite, Kazukauske 2013). In the context of renewables, further study attempted to identify the drivers of profitability for renewable energy companies during the period of 2004–2018 in the European Union. The findings suggested that endogenous factors were more important than exogeneous ones in explaining profitability. Nevertheless, the study showed that tradable green certificate schemes enhance long-term profitability and that financial crises hinder the financial performance of renewable energy firms (Morina, Ergun, Hysa 2021).

Therefore, in the studies targeting directly the energy sector one issue seems to dominate the scientific discussion, i.e. energy production from renewable sources. In addition to that, the issue of the investments needed and made in the sector appears to be of both scientific and practical importance, especially in developed countries seeking to decarbonize the energy mix.

3. Research methods

This section explains the specific methods by which the data was collected and the research techniques that were used to achieve the research objective. The purpose of this section is to describe the materials and methods so that the study could be repeated and the validity of results and conclusions be judged.

The study design built on the theoretical foundations provided in the previous section and allowed for an analysis of the relationship between the main sectoral and macroeconomic variables and the profitability of companies. For this reason, the empirical investigation needed to be specifically tailored. First, it combined three perspectives: endogenous, exogeneous (sector) and exogeneous (macroeconomic). Such an approach entailed the complementary usage of a wide spectrum of variables ranging from economy-wide variables to specific company-level measures of profitability. Second, because of the relatively low variability of macroeconomic and sectoral indicators, it needed to cover a reasonably long time frame. In the present research it encompassed 2003–2021. Third, since the exogeneous and endogenous dynamics diverge, and the transmission of changes in sectoral and macroeconomic conditions to companies is dependent on intersectoral business linkages and may take a substantial amount of time (Nguyen, Chevapatrakul, Mateut 2022), this time offset needed to be addressed. Because of that, lagged variables were incorporated into the network.

The research targeted the energy sector, in which 300 companies were randomly drawn. It used yearly data. The sample size was determined based on the statistical principles, where adapting z-alpha of 1.65 and the estimation error of 5% results in the sample size matching 272 observations. This number was rounded up. The study covered companies operating in Poland. The final number of observations matched 3,121, and was substantially smaller than the expected sample size of 5,700 (300 companies · 19 years). This was due to two reasons. First, outliers were eliminated from the sample (n = 27). Second, all the cases with user-missing values on covariates and dependant variables were excluded (n = 2,552).[1]

Regarding the combination of endogenous, exogeneous (sector) and exogeneous (macroeconomic) perspectives, a sound operationalisation was needed. The operationalisation required the selection of the main variables and derived from the study of literature. In the case of the macroeconomic factors, four variables were selected: unemployment rate, changes in gross domestic product (hereafter: changes in GDP), Consumer Price Index (hereafter: CPI), and Producer Price Index (hereafter: PPI).[2] As such, the variables corresponded to those used in most of the analysed studies and in the ones conducted specifically in Poland. With respect to the exogeneous (sector) variables, the share of energy from renewable sources (hereafter: Renewables) and the investment in the energy sector (hereafter: Investment) were selected. As for the company profitability, since it is a complex concept on its own, adopting a single measure as its proxy was considered inadequate. Because of that, four different profitability measures were used: ROE, ROA, ROS, and ROIC. In this regard, as there is no single, universally accepted set of exact formulas for calculating indicators, and calculation formulas often differ depending on the choice of a particular researcher or data source, calculation formulas had to be precisely determined. This article uses what seems to be one of the most methodologically sound approaches, where:

$$ROE = \frac{\text{net profit}}{\text{average total equity}};\ ROA = \frac{\text{net profit}}{\text{average total assets}}$$

$$ROS = \frac{\text{net profit}}{\text{revenues}};\qquad ROIC = \frac{\text{EBIT} \cdot (1-t)}{\text{total equity} + \text{ interest bea}}$$

Such formulas are thoroughly analysed in the literature (Mikołajewicz, Nowicki 2021) and supported by the specialised bodies such as the CFA Institute (Robinson et al. 2020).

Examining solely exogenous independent variables enabled the mitigation of potential endogeneity issues by isolating factors independent of the company's internal processes. Consequently, this approach facilitated the comparison of the relative importance of exogenous variables among themselves. Such an analytical strategy held particular significance for the external stakeholders of the company. These stakeholders, lacking insight into internal processes but possessing knowledge of the company's external environment, are tasked with making informed investment decisions. Given the study's objective to

[1] This was especially important, as for numerous companies no data on interest bearing debt was available.

[2] More accurately, Statistics Poland calculates the price indices of sold production of industry, which cover four industries: "Mining and quarrying", "Industrial processing", "Electricity, gas, steam and hot water production and supply" and "Water supply, sewage and waste management, reclamation" (Statistics Poland 2023b).

comprehend the external determinants of profitability, variables pertaining to the interaction between the company's profitability and its environment were deliberately selected.

In the process of data analysis, a neural network, specifically a multi-layer perceptron (MLP), was used. This method was rarely employed in this context but tested in preliminary studies (Szutowski 2023). The initial tests suggested higher MLP network performance over the radial basis function. As for the network structure – the input layer consisted of 12 variables representing all the examined sectoral and macroeconomic variables in the given (t) and preceding ($t - 1$) periods. As such, it corresponded to the previously characterised research direction consisting of analysing the lagged effects of the changes in exogeneous variables. The variables used included: unemployment rate (t and $t - 1$), changes in gross domestic product (t and $t - 1$), CPI (t and $t - 1$), PPI (t and $t - 1$), share of energy from renewable sources (t and $t - 1$) and investment in the energy sector (t and $t - 1$). The output layer included the four target profitability variables in a given period (t), i.e. ROE, ROA, ROS and ROIC. There were no restrictions on the number of neurons in the hidden layer.

One of the methodological dilemmas in this study was the choice between using one neural network with four outputs or four separate perceptrons. Utilizing a single neural network with four outputs has emerged as the preferred methodology for forecasting profitability metrics. This preference arose from the potential inclusion of intricate patterns and interdependencies within the dataset. Employing a singular neural network with four outputs enabled the capture of these potential dependencies effectively. Such an approach is particularly advantageous when forecasting multiple indicators that are interrelated, a characteristic commonly observed in profitability metrics (Mikołajewicz, Nowicki 2021). Furthermore, this approach mitigated the risk of perceptron over-specialization, a concern that would be exacerbated if separate perceptrons were employed to predict each of the four profitability variables. The utilization of distinct perceptrons would be preferred mainly if the data used for forecasting individual profitability indicators exhibited significant differences in nature or range of values. However, such a scenario was not manifested in the present study.

In line with the theoretical considerations, all variables were appropriately rescaled (IBM 2023). The rescaling method for the covariates was adjusted normalisation, and for the dependants it was standardisation. The adjusted normalisation was selected as it is advised for the hyperbolic tangent activation function used in this research. The division into training and test sets was made automatically. The summary of the case processing, including the division into training and testing samples is provided in Table 1.

The batch learning type was adopted, in which the weights are updated based on the information obtained from the entire data set. This type of learning is recommended because it minimizes the total error and is especially appropriate for small and medium data sets like the one under investigation here.

As one of the principal characteristics of neural networks is that they do not provide the regression--like coefficients for the independent variables, a separate independent variable importance analysis was administered. For this purpose, a sensitivity analysis was performed as it computes the importance of each predictor in determining the neural network (IBM 2019). Because the number of predictors was not overly large, the sensitivity analysis was neither computationally expensive nor time-consuming. In order to build the neural network, IBM SPSS software was used.

This study exploited two main sources of data. First, sectoral and macroeconomic data was obtained from the Macroeconomic Data Bank, a service offered by Statistics Poland. In line with the source information, "it is a statistical database gathering indicators characterizing the macroeconomic

and social situation of Poland. The database allows access to long time series for basic macroeconomic data in various thematic areas" (Statistics Poland 2023b). Second, the endogenous financial data used to calculate profitability ratios was gathered from the EMIS (Emerging Markets Information Service) database. According to the database provider, it provides access to financial data for 682 thousand companies registered in Poland, including all large, medium and small companies (EMIS 2022).

4. Results and discussion

With respect to the purpose of the study, which consisted in determining the relationship between the main sectoral and macroeconomic variables and the profitability of companies, this study suggests that the changes in both sectoral and macroeconomic variables may have an important effect on the profitability of companies operating in the energy sector.

First, the specific network information, summarising the input, hidden and output layers, is presented. It provides the general information on the shape of the created network, including the variables used, the rescaling methods, and the activation and error functions. For the clarity of presentation, it takes a tabular form (Table 2).

Next, the summary of the model is presented. The results calculated for the training sample are comparable to the testing one. The rule for stopping the network learning process was to perform one consecutive step with no decrease in error. As a result, the relative error for the training sample matched 0.999, and for the test sample 1.001. As specified in Table 3, in the testing sample ROS had the highest relative error, while ROA had the smallest. The exact characteristics of the estimated parameters are presented in the Appendix.

The quality of the model was assessed with the use of both mean absolute error (MAE) and mean squared error (MSE). To avoid bias, the standard MSE formula was altered in such a way that the denominator took the form of N – 1 – p, where p stands for the number of input variables (Karłowska-Pik 2022). Both errors were the smallest for ROA. The results for each of the dependent variables are stated in Table 4.

The overall result of the analysis is presented in the Figure 1. As stated previously, the network, apart from the input and output layers, consisted of a single hidden layer with six neurons. Both the input and the hidden layers had a bias unit. Figure 1 shows a diagram of the network, in which grey lines indicate synaptic weights greater than zero, and blue lines indicate synaptic weights less than zero.

Due to the fact that the results obtained do not directly indicate the relationship between the variables of the input layer and the variables of the output layer, a sensitivity analysis was performed. This analysis allowed to indicate the importance of individual variables of the input layer. The results are presented in Table 5 and discussed below.

The theoretical contribution of this research primarily focuses on sectoral specificity and time lags. In this context, the study challenges the widely recognized analytical principle that variables closely linked to the company serve as superior predictors of its profitability compared to those less directly related. This commonly leads to the perception that sectoral variables are more effective predictors of company performance than those representing the broader economy. Additionally, the study aims to enrich the theoretical discourse within the theory of cycles, particularly regarding the temporal delay through which changes in a company's environment permeate and impact its profitability.

To facilitate clear visualization, the findings regarding the significance of exogenous (sectoral) and exogenous (macroeconomic) variables in both the current period (t) and the previous period ($t - 1$) will be presented graphically (refer to Figure 2). Subsequently, these results will be deliberated in the context of the theoretical framework provided.

From a theoretical standpoint, various concepts are employed to evaluate the determinants of company performance. The resource-based view underscores company-specific factors (Galbreath, Galvin 2008), while organizational theory emphasizes the structural characteristics of the industry (Bain 1968) and can be extended to encompass features of the entire economy. This research aligns with the latter perspective. The findings indicate that exogenous (macroeconomic) variables hold more significance than endogenous (sectoral) variables concerning company profitability (the three most crucial variables being PPI, changes in GDP, and CPI). Consequently, these results partially deviate from the existing body of knowledge, suggesting the need for an alternative explanatory framework.

This study may contribute to a relatively less-recognized research trajectory, which could, in part, elucidate prior evidence highlighting the elevated importance of sectoral variables compared to macroeconomic ones. Considering the outcomes of previous research (Hawawini, Subramanian, Verdin 2001), one might hypothesize that a portion of the absolute estimates of the variance in profitability variables is attributable to a few exceptional industries, both outperforming and underperforming in comparison to the rest. Put differently, endogenous factors outweigh the exogenous ones only for a selected few value-creating and value-destroying industries. For the majority of sectors, particularly those that do not markedly outperform or lag behind in the entire economy, the influence of macroeconomic variables tends to exert a greater impact on performance compared to industry--specific ones. The explanation of this phenomenon lies in the extraordinary position of the particular sector, which correlates with improved (or diminished) financial outcomes for firms within the sector, irrespective of the macroeconomic situation. On the other hand, macroeconomic dynamics primarily matter for the firms operating in the sectors "stuck in the middle", i.e. neither leading nor lagging behind the average economy-wide performance levels.

As this explanation is hypothetical, the potential interplay between the endogenous and exogenous factors calls for further studies. Nevertheless, some previous evidence provided a similar logic while studying the importance of sectoral factors against the company-specific ones (Hawawini, Subramanian, Verdin 2001).

In terms of the specific variables analysed, the study identified that the most crucial macroeconomic factor influencing the profitability of companies in the energy sector is the Producer Price Index (PPI) in the current period. The pronounced significance of this factor in shaping enterprise profitability appears substantively justified, because the PPI variable – as operationalised in this study – represents changes in base prices in industry (including electricity, gas, steam and hot water production and supply) which in turn has a direct effect on company financial performance. This finding is also robustly aligned with prior research indicating a correlation between corporate profitability and inflation (Khrawish 2011; Sangkyun 2022; Sufian 2009; Sufian, Noor 2012). Moreover, changes in gross domestic product (GDP) emerged as the second most critical macroeconomic factor. Energy consumption intricately intertwines with economic performance, where increased electricity usage correlates positively with higher GDP levels (Stern, Burke, Burns 2017). This in turn, in the presence of fixed and variable costs, leads to improved profitability, which was firmly established in the energy sector based on the relationship between full load hours (FLH; expressing generation per capacity) and

levelized cost of electricity (LCOE). In line with empirical evidence, higher FLH lowers LCOE exactly because the fixed costs are spread over a greater number of production units,[3] which in turn allows companies in the sector to improve profitability. The third most significant macroeconomic factor is the Consumer Price Index (CPI). Once more, this result reinforces earlier findings that highlight a robust relationship between inflation and company profitability (Khrawish 2011; Sufian 2009; Sufian, Noor 2012). The subtle variance in importance between the PPI and CPI variables may stem from the fact that one of the components of the former variable, as calculated by Statistics Poland, directly reflects the price index attributed to the energy sector.

Regarding the time lag, consistent with the classical tenets of the theory of cycles, company profitability demonstrates procyclical behaviour: it ascends during favourable economic conditions and declines during unfavourable ones (Machin, Reenen 1993). While this principle is widely acknowledged and supported by empirical data (Pattitoni, Petracci, Spisni 2014), a particular focus lies on the duration required for company profitability to be impacted. Although some studies have controlled for the economic cycle by incorporating control variables (Pattitoni, Petracci, Spisni 2014), much of the evidence neglects the time lag between changes in economic conditions and company profitability (Khrawish 2011; Korneta 2019; Sufian 2009; Sufian, Noor 2012). However, existing research suggests a delayed transmission, as alterations in external conditions manifest effects on company profitability only after a certain period. This delay is evident in phenomena such as inflation (Albertazzi, Gambacorta 2009) and GDP growth (Acaravci, Çalim 2013; Bonaccorsi di Patti, Palazzo 2018).

The results obtained here suggest that while delayed effects are indeed present, those observable within a given period carry more significance. The relative importance of all variables – except for investment and renewables – was greater in period t than in period $t - 1$. In this regard, the findings partially diverge from previous evidence and imply that a one-year time span is adequate for changes in macroeconomic conditions to notably influence company profitability. At the company level, these results evoke the theory of short-termism (Palley 1997), the potential revival of which presents an enticing avenue for future research.

Furthermore, two of the studied variables (Investment and Renewables) exhibited notable lagged effects, distinguishing them from the rest of the variables, thus warranting a more detailed discussion. This outcome appears to be driven by sectoral specificity. Previous studies have suggested that investment projects in energy, aerospace, and pharmaceuticals typically entail the longest durations (Bar-Ilan, Strange 1996). Hence, it is reasonable to infer that the effects of an investment become apparent only after a certain period. However, what may be considered surprising is that a one-year span suffices to observe the effect. Given that large-scale energy investments often require several years to complete, a one-year time lag between the investment and the profitability change appears relatively short. This discrepancy might be potentially elucidated by: (1) the structure of the sample, encompassing large, medium, and small companies, with long-lasting investments predominantly associated with the former, and (2) the fact that the preceding ($t - 1$) period's investment captures, in some instances, the final year before the investment's completion. Nonetheless, as these explanations remain speculative, further research on the lag between investment and profitability change in the sector appears to be a promising avenue for exploration.

[3] Open Power System Data, Data Package Time series. Version 2020-10-06, DOI: 10.25832/time_series/2020-10-06.

Lastly, the Renewables variable exhibited relatively low importance, marginally higher in period $t - 1$ than in period t, which came as an unexpected finding. Current evidence in the field indicates that in recent years, two-thirds of the total generation capacity added comprised renewable power sources (Painuly, Wohlgemuth 2021). Given that renewable energy development is a pivotal component of European decarbonization policies, coupled with a wide array of public incentives supporting investments in renewables (Jaraite, Kazukauske 2013; Reuter et al. 2012), one might anticipate a substantial impact of the share of energy from renewables on company profitability. As it is not the case here, this study might partially support the explanatory logic based on uncertainty. Drawing on examples such as wind farms, previous research has employed the concept of uncertainty regarding wind loads. Comparing the distributions of yearly profits when constant and variable loads were simulated revealed higher profit variability when confronted with variable wind loads. Moreover, when the wind load was modelled as uncertain, the expected profit was smaller than in situations where the load was modelled as constant (Reuter et al. 2012). Consequently, this uncertainty in wind loads needed to be accounted for, as it adversely affected wind farm profitability and its competitiveness versus conventional plants powered by combusting fossil fuels.

5. Conclusions and recommendations

Because of the crucial role of profitability in economic analysis and the differentiated existing evidence on the role of exogenous factors in shaping it, the aim of this study was to determine the relationship between the main sectoral and macroeconomic variables and the profitability of companies. The study focused on the energy sector. Regarding the hypothesised importance of all the selected sectoral and macroeconomic variables in shaping company profitability, the research turned out to be partially supportive. The results suggested that the changes in both sectoral and macroeconomic variables might have an important effect on the profitability of companies operating in the sector. The research questioned the commonly accepted analytical notion suggesting that sectoral variables hold greater predictive power for company performance compared to indicators representing the overall economy, presenting contrasting findings. Additionally, the findings from this study partially deviate from prior evidence, suggesting that a one-year duration is sufficient for macroeconomic changes to significantly impact a company's profitability within the sector. More specifically, for the macroeconomic factors the analysis indicated that the most important variable is the Producer Price Index in the current period. Furthermore, changes in gross domestic product (t) ranked as the second and Consumer Price Index (t) as the third most important macroeconomic factors. Regarding the sectoral factors, investment in the period $t - 1$ ranked highest. Also, it was the most important lagged ($t - 1$) variable in the set. The remaining sectoral variables demonstrated a relatively low importance, which was especially surprising in the case of the share of energy from renewable sources.

The results apply strongly to the world of practice. On the one hand, profitability analysis is an important element of numerous analytical works (valuation, transactional analysis, financial analysis, operational and strategic analysis, bankruptcy prediction etc.), on the other hand, expertise, expert opinions and judicial opinions notoriously disregard the exogeneous factors. By analysing only the company data, they detach the subject of analysis from its environment and formulate unreliable conclusions. The results obtained in this research advocate strongly for the crucial importance of exogenous factors and their compulsory inclusion in the analysis of company profitability.

Despite the above general conclusion, the research left room for more detailed studies in the field. During the research, two promising directions for further research were identified, both of which derived from the limitations of this study. First, the specificity of the energy sector is that the large--scale investments may take several years to completion. While this research included a variable covering investment in the energy sector, its limitation was that as an aggregate measure it did not provide any cross-sectional data on investments that would allow for more detailed analysis. Consequently, in-depth investigation on the lags between the investments made and the resulting changes in profitability seems a promising research path. Second, different effects of energy production from renewable sources on company profitability are theoretically possible. Again, while this research incorporated the share of energy from renewable sources into the analysis, its limitation was that it only allowed for the formulation of general conclusions as no cross-sectional data on renewables was accessible. Therefore, in-depth research focusing on renewables seems a promising direction for future research.

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Appendix

Table 1
Case processing summary

		N	Percent
Sample	Training	2,156	69.1
	Testing	965	30.9
Valid		3,121	100.0
Excluded		2,552	
Total		5,673	

Source: own development.

Table 2
Network information

Input layer	Covariates	1	Unemployment rate
		2	Changes in GDP
		3	CPI
		4	PPI
		5	Unemployment rate (t – 1)
		6	Changes in GDP (t – 1)
		7	CPI (t – 1)
		8	PPI (t – 1)
		9	Investment
		10	Investment (t – 1)
		11	Renewables
		12	Renewables (t – 1)
	Number of units[a]		12
	Rescaling method for covariates		Adjusted normalized
Hidden layer(s)	Number of hidden layers		1
	Number of units in hidden layer 1[a]		6
	Activation function		Hyperbolic tangent
Output layer	Dependent variables	1	ROS
		2	ROA
		3	ROE
		4	ROIC
	Number of units		4
	Rescaling method for scale dependents		Standardized
	Activation function		Identity
	Error function		Sum of squares

[a] Excluding the bias unit.

Source: own development.

Table 3
Model summary

Training	Average overall relative error		0.999
	Relative error for scale dependents	ROS	1.008
		ROA	0.990
		ROE	0.999
		ROIC	0.997
	Stopping rule used		1 consecutive step(s) with no decrease in error[a]
	Training time		0:00:00.51
Testing	Average overall relative error		1.001
	Relative error for scale dependents	ROS	1.271
		ROA	0.992
		ROE	1.002
		ROIC	0.996

[a] Error computations are based on the testing sample.

Source: own development.

Table 4
Mean absolute error and mean squared error

	ROS	ROA	ROE	ROIC
MAE	0.31	0.06	0.11	0.66
MSE	1.08	0.13	0.26	0.79

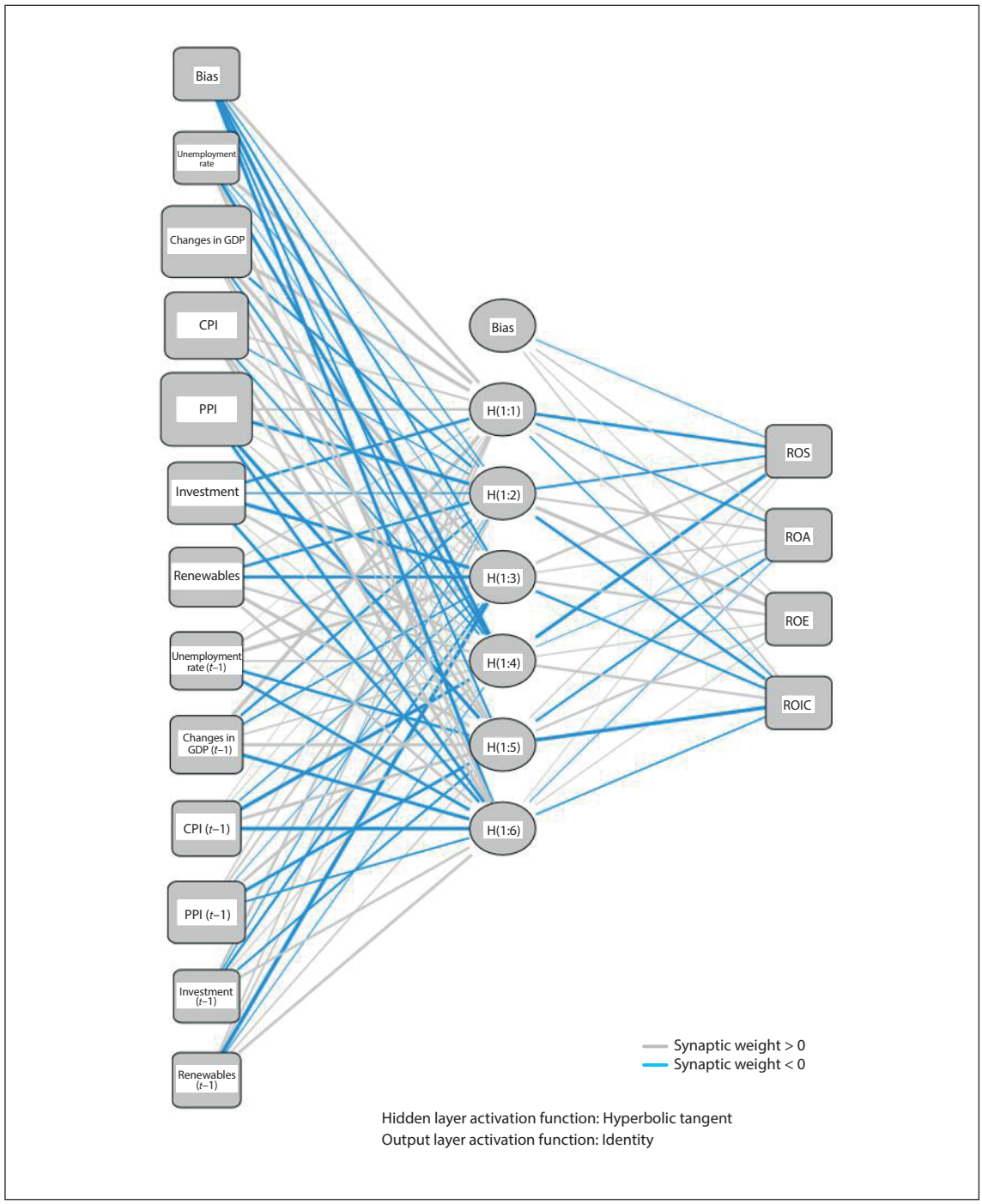
Source: own development.

Table 5
Independent variable importance

	Importance	Normalized importance (%)
Unemployment rate	0.059	72.5
Changes in GDP	0.117	96.3
CPI	0.102	84.1
PPI	0.121	100.0
Unemployment rate (t – 1)	0.088	48.9
Changes in GDP (t – 1)	0.080	65.9
CPI (t – 1)	0.075	62.2
PPI (t – 1)	0.076	63.1
Investment	0.067	55.4
Investment (t – 1)	0.088	72.5
Renewables	0.061	50.1
Renewables (t – 1)	0.066	54.7

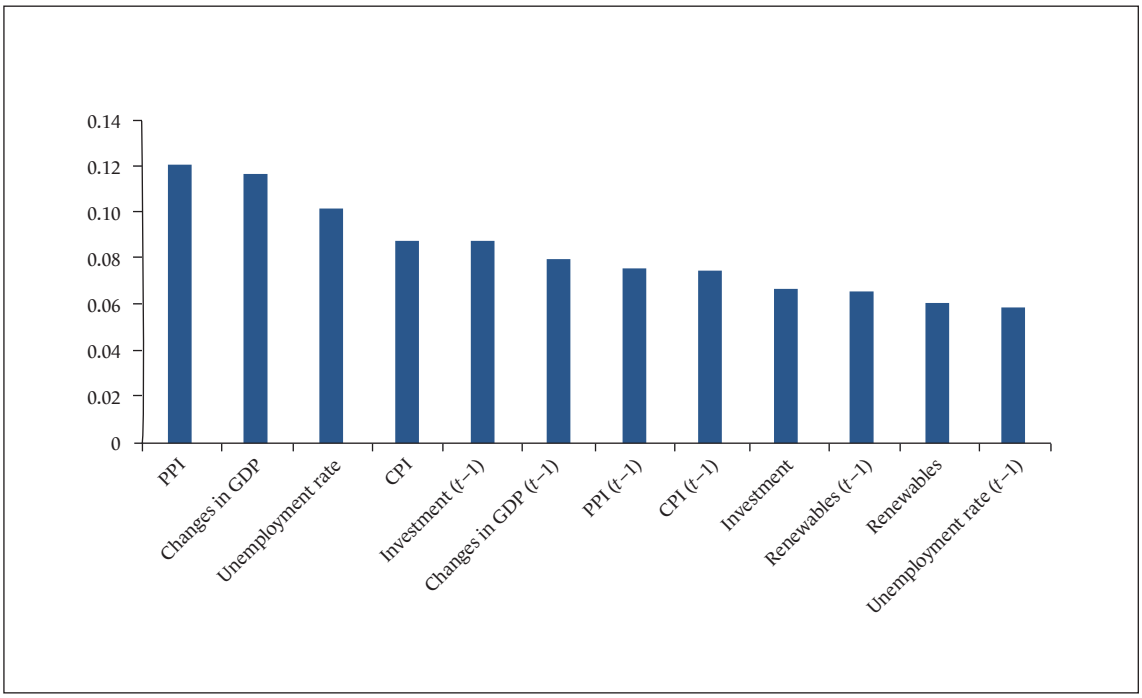
Source: own development.

Figure 1
Synaptic weights



Source: own study.

Figure 2
Importance of endogenous (sector) and exogeneous (macroeconomic) variables in t and $t - 1$



Source: own study.

Table 6
Parameter estimates

Predictor		Predicted									
		Hidden layer 1						Output layer			
		H(1:1)	H(1:2)	H(1:3)	H(1:4)	H(1:5)	H(1:6)	ROS	ROA	ROE	ROIC
Input layer	(Bias)	0.330	-0.103	-0.190	-0.481	-0.172	-0.384				
	Unemployment rate	0.455	-0.083	-0.008	-0.341	0.023	0.409				
	Changes in GDP	0.478	-0.214	0.502	-0.169	0.340	0.134				
	CPI	0.165	-0.109	0.204	-0.154	0.334	0.463				
	PPI	0.236	-0.380	0.087	0.143	-0.408	-0.293				
	Unemployment rate ($t-1$)	-0.268	-0.123	-0.394	0.310	0.069	-0.284				
	Changes in GDP ($t-1$)	0.147	-0.258	-0.312	0.258	0.468	0.260				
	CPI ($t-1$)	0.001	0.234	0.444	0.167	-0.258	-0.284				
	PPI ($t-1$)	0.506	-0.234	-0.156	0.154	0.312	-0.339				
	Investment	0.011	0.048	-0.124	-0.430	0.327	-0.437				
	Investment ($t-1$)	0.131	0.171	-0.018	0.300	-0.302	-0.160				
	Renewables	0.266	-0.097	-0.211	0.077	-0.176	0.238				
	Renewables ($t-1$)	0.156	0.167	-0.604	-0.063	0.138	0.280				
Hidden layer 1	(Bias)							0-.060	0.152	0.051	0.136
	H(1:1)							-0.295	-0.162	0.188	-0.131
	H(1:2)							-0.177	0.181	0.461	-0.269
	H(1:3)							0.239	0.121	0.250	-0.198
	H(1:4)							-0.379	-0.014	0.103	0.227
	H(1:5)							0.113	-0.184	0.190	-0.450
	H(1:6)							0.036	-0.049	0.069	-0.145

Source: own study.

Wpływ zmiennych sektorowych i makroekonomicznych na rentowność przedsiębiorstw w sektorze energetycznym. Analiza z wykorzystaniem sieci neuronowych

Streszczenie

Pomimo tego, że rentowność odgrywa kluczową rolę w analizie ekonomicznej, dotychczasowe badania naukowe oferują zróżnicowane i często nieusystematyzowane wnioski dotyczące jej determinant. Aby uschematyzować podejście do determinant rentowności, w niniejszym badaniu zaproponowano klasyfikację, w której determinanty muszą przynależeć do jednej z trzech grup: endogenicznych, egzogenicznych sektorowych lub egzogenicznych makroekonomicznych. Po przyjęciu powyższej klasyfikacji widać dysproporcję w poprzednich badaniach, w których dociekania nad endogenicznymi determinantami rentowności są niezwykle liczne w przeciwieństwie do opracowań poświęconych determinantom egzogenicznym. Ze względu na tę nierównowagę główną osią niniejszego badania będą sektorowe i makroekonomiczne determinanty rentowności.

Przegląd wybranych badań naukowych nie pozostawia wątpliwości co do tego, jakie znaczenie dla rentowności firmy ma jej otoczenie. Pomimo tego zarówno naukowcy, jak i praktycy notorycznie pomijają czynniki egzogeniczne w analizie rentowności, a przez skupienie się wyłącznie na zmiennych na poziomie przedsiębiorstwa abstrahują od ich otoczenia. Co więcej, ogólny wniosek dotyczący znaczenia czynników egzogenicznych dla rentowności firmy wykazuje koncepcyjne niedostatki, kiedy wymagana jest szczegółowa analiza rentowności. Po pierwsze, spektrum zmiennych sektorowych i makroekonomicznych wykorzystywanych w dotychczasowych badaniach nie jest spójne. Po drugie, wyniki tych analiz często wzajemnie się wykluczają, a ich ograniczona liczba nie pozwala na wyciągnięcie spójnych wniosków. Po trzecie, w większości wcześniejszych analiz wykorzystano tradycyjne metody badawcze. W związku z tym uzyskane wyniki nie mogły być zestawione z wynikami uzyskanymi przy użyciu nowoczesnych metod analizy danych. Ominięcie wszystkich tych ograniczeń w jednym badaniu nie wydaje się ani możliwe, ani konieczne, jednak podjęto próbę wzbogacenia dialogu naukowego przez: wybór najważniejszych zmiennych sektorowych i makroekonomicznych, przeanalizowanie obu tych grup zmiennych w jednym kompleksowym badaniu empirycznym i określenie roli zmiennych egzogenicznych w kształtowaniu rentowności przedsiębiorstw za pomocą rzadko stosowanej w tym obszarze metody.

Celem niniejszego opracowania jest określenie zależności pomiędzy głównymi zmiennymi sektorowymi i makroekonomicznymi a rentownością przedsiębiorstw. Aby osiągnąć ten cel, przeprowadzono badanie empiryczne. Bazując na wcześniejszych dowodach naukowych, sformułowano hipotezę, że wszystkie wybrane zmienne sektorowe i makroekonomiczne są ważne dla kształtowania się rentowności przedsiębiorstw w sektorze energetycznym.

Ponieważ z perspektywy badanej relacji wybór sektora miał zasadnicze znaczenie, zdecydowano się na jeden z najważniejszych sektorów gospodarki, tj. sektor energetyczny. Jest on obecnie przedmiotem szczególnego zainteresowania zarówno naukowców, jak i praktyków. Jego transformacja jest kluczowym składnikiem europejskiej polityki dekarbonizacji, a w jego funkcjonowaniu stosuje się liczne instrumenty wspierające, takie jak: taryfy gwarantowane i systemy certyfikatów (Jaraite, Kazukauske 2013), dotacje inwestycyjne, ulgi podatkowe i wymagania portfelowe (Reuter i in. 2012).

Badanie empiryczne oparto na ustalonych podstawach teoretycznych. Połączyło ono trzy perspektywy: endogeniczną, egzogeniczną sektorową i egzogeniczną makroekonomiczną. Opierało się na danych rocznych dla 300 losowo wybranych spółek energetycznych. Ramy czasowe obejmowały lata 2003–2021. Z powodu wykrytych wartości odstających oraz niewstarczających danych ostateczna liczba obserwacji wyniosła 3121. Ze względu na przyjęte ramy teoretyczne istotną kwestią była operacjonalizacja zmiennych. Jako czynniki makroekonomiczne wybrano cztery zmienne: stopę bezrobocia, zmianę produktu krajowego brutto, wskaźnik cen towarów i usług konsumpcyjnych oraz wskaźnik cen produkcji sprzedanej przemysłu. Jako zmienne sektorowe wykorzystano udział energii ze źródeł odnawialnych i nakłady inwestycyjne w sektorze energetycznym. Jeśli chodzi o rentowność przedsiębiorstw, zastosowano cztery wskaźniki: ROE, ROA, ROS i ROIC. W analizie danych wykorzystano sieć neuronową, a konkretnie perceptron wielowarstwowy (MLP). Warstwa wejściowa sieci składała się z dwunastu zmiennych obejmujących wszystkie badane zmienne sektorowe i makroekonomiczne w danym (t) i poprzedzającym ($t - 1$) okresie. Warstwa wyjściowa zawierała cztery wskaźniki rentowności w danym okresie (t). Nie ustanowiono ograniczeń co do liczby neuronów w warstwie ukrytej. Wszystkie zmienne zostały odpowiednio przeskalowane. Metodą przeskalowania dla zmiennych niezależnych była skorygowana normalizacja, a dla zmiennych zależnych – standaryzacja. Jako funkcję aktywacji zastosowano tangens hiperboliczny. Przyjęto typ uczenia wsadowego (ang. *batch learning*). W celu zbadania znaczenia zmiennych niezależnych dla rentowności przedsiębiorstw przeprowadzono analizę wrażliwości. Zastosowanie sieci neuronowych – rzadko wykorzystywanych w tym zakresie – oraz łączna analiza sektorowych i makroekonomicznych zmiennych niezależnych stanowią oryginalny wkład niniejszego badania.

Uzyskane wyniki jedynie częściowo potwierdziły hipotezę badawczą. Sugerują one, że zmiany zarówno zmiennych sektorowych, jak i makroekonomicznych mogą istotnie wpływać na rentowność spółek działających w sektorze energetycznym. Badanie nie potwierdziło jednak powszechnego poglądu, że zmienne sektorowe są skuteczniejszymi predyktorami rentowności przedsiębiorstw niż zmienne reprezentujące sytuację makroekonomiczną – jest odwrotnie. Ponadto uzyskane wyniki częściowo odbiegają od wcześniejszych dowodów naukowych i sugerują, że roczny okres wystarcza, aby zmiany warunków makroekonomicznych istotnie wpłynęły na rentowność spółek z analizowanej branży.

W przypadku czynników makroekonomicznych analiza wykazała, że najważniejszą zmienną był wskaźnik cen produkcji sprzedanej przemysłu w bieżącym okresie. Zmiana produktu krajowego brutto (t) uplasowała się na drugim miejscu, a wskaźnik cen towarów i usług konsumpcyjnych (t) na trzecim. Wśród zmiennych sektorowych najwyższą pozycję zajęły nakłady inwestycyjne w sektorze w okresie $t - 1$. Była to również najważniejsza zmienna reprezentująca okres poprzedzający ($t - 1$). Pozostałe zmienne sektorowe miały relatywnie małe znaczenie, co było szczególnie zaskakujące w przypadku udziału energii ze źródeł odnawialnych.

Pomimo powyższych wniosków badanie może stanowić punkt wyjścia do bardziej szczegółowych dociekań w tym obszarze. Zidentyfikowano dwa potencjalnie istotne kierunki dalszych badań, oba wynikające z ograniczeń niniejszej analizy. Po pierwsze, specyfika sektora energetycznego sprawia, że ukończenie dużych projektów inwestycyjnych jest wysoce czasochłonne. Wprawdzie niniejsze badanie obejmowało zmienne dotyczące nakładów inwestycyjnych w sektorze w okresach t oraz $t - 1$, jednak jako zmienne zagregowane nie dostarczały one żadnych przekrojowych danych na temat inwestycji, pozwalających na uszczegółowienie analizy. W związku z tym ograniczeniem pogłębiona analiza opóźnień występujących pomiędzy dokonywanymi inwestycjami a wynikającymi z nich zmianami rentow-

ności wydaje się obiecującym kierunkiem badań. Po drugie, istniejąca podstawa teoretyczna umożliwia uargumentowanie skrajnie różnego wpływu produkcji energii ze źródeł odnawialnych na rentowność przedsiębiorstw. Podobnie jak wcześniej – mimo że badanie uwzględniało udział energii ze źródeł odnawialnych, ograniczeniem tej zmiennej był jej agregatowy charakter. W konsekwencji badanie pozwoliło na sformułowanie jedynie ogólnych wniosków, ponieważ nie były dostępne żadne dane przekrojowe dotyczące odnawialnych źródeł energii. Pogłębione analizy koncentrujące się na odnawialnych źródłach energii wydają się kolejnym obiecującym kierunkiem przyszłych badań.

Struktura artykułu jest następująca. Przegląd literatury przedstawia rolę rentowności w analizie ekonomicznej i przybliża aktualne dowody naukowe dotyczące sektorowych i makroekonomicznych determinant rentowności. Rozdział poświęcony metodom badawczym prezentuje źródła danych i przyjętą metodykę, ze szczególnym uwzględnieniem sieci neuronowej zbudowanej w celu analizy danych. W części poświęconej wynikom zaprezentowano rezultaty analizy na tle wyników wcześniejszych badań. Artykuł kończy się wnioskami.

Słowa kluczowe: rentowność, wskaźniki makroekonomiczne, wskaźniki sektorowe, sieć neuronowa, sektor energetyczny