ENVIRONMENTAL STRATEGIES OF ENERGY COMPANIES DURING THE COVID-19 PANDEMIC

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Abstract: This paper focuses on the impact of COVID-19 on energy companies in terms of implementing their environmental strategies and continuing the low-emission transformation of their generating units in conditions of their financial results' instability. Nonlinear panel model is estimated for energy companies listed on the Warsaw Stock Exchange, whose generations units have been included in EU ETS in the years 2009-2021. The estimation results indicate the existence of a U-shaped relationship between the CO_2 intensity observed one year earlier and current asset returns, which can be explained by the 'too-little-of-a-good-thing' effect. It indicates that companies with proactive environmental strategies that are intensively involved in the low-carbon transformation processes of energy-generating facilities achieve increasingly better financial performance. The inclusion of pandemic shocks in the modelling has not changed the shape of the CEP-CFP relationship, but it has been observed that during this period, carbon-intensive energy companies achieved lower returns on assets. A new environmental variable was considered, namely the emission to allowances index, which, together with the variable describing the share of renewable energy in energy production, informs about the degree of low-emission transformation of electricity generation.

Key words: environmental strategies, emission intensity, financial performance, panel models, COVID-19 pandemic

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Introduction

The COVID-19 pandemic has become a significant risk factor for the global economy, and the rapid rate of its spread has led most governments to introduce lockdown and social distancing policies to limit the number of infections (Brodeur et al., 2021; Zhang and Fang, 2022). Unfortunately, these policies generated high costs (Basuki et al., 2022; Zulfikar et al., 2021), especially in the corporate sector due to a sharp decline in demand for the goods and services they offered, as well as difficulties in meeting the growing demand for credit (Ding et al., 2021). Difficulties in accessing external sources of financing business activity and poorer operational performance of firms may have led to reduced environmental expenditures during

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the pandemic spread. This, in turn, may have hindered the sustainable development of various groups of firms, the coherence of which is crucial for green economic transformation and climate change counteracting (Zhang, 2022). Given the above, analysis of the impact of the pandemic on corporate environmental performance (CEP) and corporate financial performance (CFP) can be used to assess progress in implementing environmental strategies by companies, but it can also provide important information in the context of designing government anti-crisis programmes. This type of research can alert policymakers to the need for protective packages for firms that would not only stimulate their operations during COVID-19 but also motivate firms to continue a sustainable transformation (He and Harris, 2020; Halmai, 2022; Streimikiene, 2022). This is particularly important for companies from the energy sector, which during the Covid-19 pandemic had to constantly face increasingly stringent requirements in the field of EU climate and energy policy related to the development of renewable energy, improvement of energy efficiency of generating units and the functioning of the EU Emission Trading System (EU ETS). The changeability of national rules for supporting energy production, the withdrawal of financial institutions from financing investments in the energy sector based on fossil fuels, combined with limited access of companies to sources of financing for investments and ongoing operations during the pandemic period, could have weakened the implementation of environmental strategies and slowed down the low-emission transformation of energy companies. For the above reasons, identifying the shape and direction of the relationship between the environmental and financial performance of energy firms during the pandemic will provide important implications for formulating new corporate development strategies that can also consider improving their environmental performance.

Literature Review

The present work aligns with the stream of research dedicated to studying the relationship between firms' environmental performance and financial performance in the context of formulating environmental strategies while influencing the shock impulses generated by COVID-19. Identifying the direction and shape of the relationship between CEP and CFP constitutes a vital research trend in the literature devoted to environmental management and business management theory (Abban and Hasan, 2021; Aragón-Correa and Sharma, 2003; Fujii et al., 2013; Horváthová, 2012; Trumpp and Guenther, 2017; Wahyuni and Ratnatunga, 2015; Seroka-Stolka, 2020). Most works have highlighted the differential impact of the pandemic on firms' environmental performance, which mainly depended on the firms' financial condition and environmental needs. Firms representing energy-intensive sectors of the economy, which were characterised by high emission intensity of pollutants generated by the combustion of organic fuels, addressed some environmental problems by implementing energy conservation practices (Mukanjari and Sterner, 2020). In turn, the increased demand for credit from firms and the periodic economic lockdown introduced may have altered firms' environmental behaviour, which often

depended on their ability to obtain external finance for their green transformation (Ghosh and Dutta, 2022). The need to comply with environmental standards may put additional pressure on firms whose operating performance has deteriorated as a result of the periodic economic lockdown, and the additional financial constraints caused by the pandemic may reduce firms' propensity to invest in low-carbon retrofits (Zhang and Zheng, 2022). The latter, combined with an increase in the scale of production for economic recovery after successive waves of the pandemic, may result in higher emissions, while the effect of the reduction in emissions intensity due to the economic lockdown was rather momentaneous and its relevance for low-carbon economic transformation was not confirmed (Guérin and Suntheim, 2021). It has also been shown that the most environmentally innovative industrial firms before the COVID-19 pandemic were more adversely affected than firms less committed to environmental issues, as environmental innovations are more vulnerable to external shocks due to the high costs and complexity of implementation procedures, as well as the relatively long payback time of these investments (Hermundsdottir et al., 2022). Similarly, it has been observed that companies reducing their carbon footprint (Scherer and Milczarski, 2021) by switching to renewable energy and abandoning fossil fuel-generated energy have been forced to suspend renewable energy technology projects and reduce all additional costs that are not necessary for the survival of the company during the COVID-19 period (Hosseini, 2020). This type of strategic response by firms to pandemic shocks is protective and reactive, usually linked to postponing investments to increase the probability of firm survival (Thorgren and Williams, 2020). These types of firms reduced investment in green production technologies if the investments did not generate direct benefits in the short term, and thus, their environmental performance was worse than before the COVID-19 pandemic (Guérin and Suntheim, 2021).
The second type of strategic response is proactive when a company uses the filter of risks and opportunities to discover innovative business procedures (Ismail et al., 2020; Ab Rahman et al., 2018) or implement new production technologies (Akpan et al., 2020; Morgan et al., 2020). This type of response can be reinforced by green recovery packages aimed at motivating firms to invest in the low-carbon transformation of manufacturing processes and a structural shift in consumer and investor preferences towards environmentally friendly products (Seroka-Stolka, 2020; Guérin and Suntheim, 2021).
This paper focuses on the impact of COVID-19 on firms in the energy sector, given the unique importance of energy as a factor of production for stimulating post-pandemic economic recovery (Huang and Liu, 2021). Few works examine the impact of COVID-19 pandemic on energy companies in terms of implementing their environmental strategies and continuing the low-emission transformation of their generating units in conditions of the financial results' instability. Yoo et al. (2021) assessed the impact of environmental, social and corporate governance (ESG) performance on the market performance and stock price risk of listed companies during COVID-19. They noted that pandemic-induced price shocks in global oil

markets had a negative impact on the returns and stock price volatility of energy companies. They showed that energy companies could reduce market risk by improving their environmental performance in terms of energy efficiency and increasing the share of renewable energy sources (RES) in their fuel mix. Huang and Liu (2021) showed that the probability of a crash in the energy sector decreased significantly after the pandemic's first waves and that the risk of strong discounting of companies' shares significantly reduced their engagement in CSR activities. Wan et al. (2021), on the other hand, demonstrated that the COVID-19 period affected the deterioration of the financial performance of Chinese energy companies, with companies specialising in clean energy generation and distribution less affected by the negative effects of the pandemic compared to fossil fuel energy companies. Szczygielski et al. (2022) investigated the impact of uncertainty surrounding the spread of COVID-19 on returns and stock market index volatility for companies in the energy sector. They noted that an essential channel for transmitting shocks to the performance of energy companies during the pandemic was the product channel, which was associated with a sharp decline in demand for energy products in response to restrictions on citizens' mobility and the periodic freezing of economies.

Consequently, a growing research interest assesses the ability of energy companies to achieve their financial goals under conditions of solving environmental problems and implementing resource-efficient production technologies, increasingly using renewable energy sources. It is also worth considering that the participation of energy companies in the European Emissions Trading Scheme (EU ETS) may generate additional costs for companies with a high share of conventional fuels in energy production and high CO_2 intensity. The expiring derogation period in the power industry related to the possibility of obtaining free emission allowances (EUAs) in exchange for investments in low-carbon modernisation of generation facilities may reinforce the negative impact of the pandemic on companies' financial performance. This, in turn, may impact the implementation of environmental strategies of energy companies during the pandemic, especially since individual energy companies had carried out the low-carbon transformation of generating units to a different extent in the pre-pandemic period (Włodarczyk and Kadłubek, 2018).

Considering the above, the study aims to examine the impact of the COVID-19 pandemic on the relationship between environmental and financial performance of power corporations in Poland in the context of the environmental strategies' implementation.

Moreover, based on the brief literature review conducted, the following research questions were formulated to expand existing knowledge about the impact of the pandemic on the financial results and pro-environmental behaviour of energy companies in Poland, which play a crucial role in stimulating economic recovery. The research questions are as follows,

Has the COVID-19 pandemic prejudiced the performance of energy companies in Poland, and has the shape of the CEP-CFP relationship changed due to the transmission of shocks generated by the product channel to the energy sector?

Did increasing energy production from renewable sources and the effectiveness of companies in obtaining free CO_2 emission allowances under the derogation for the energy sector have a positive impact on firms' financial results?

Research Methodology

Due to identify the direction and shape of the relationship between environmental and financial performance of energy corporations, the following non-linear panel model is constructed:

$$\mathrm{CFP}_{it} = \alpha_{0\mathrm{i}} + \alpha_1 CEP_{it-k} + \alpha_2 (CEP_{it-k})^2 + \beta' X_{it} + \gamma' Z_{it-k} + u_{it}, \quad (1)$$

A turning point of corporate environmental performance (under the assumption that $\alpha_2 \neq 0$) may be calculated as:

$$TP = \frac{-\alpha_1}{2\alpha_2}, \quad (2)$$

where CFP_{it} – corporate financial variable (i = 1, 2, …, N for company, t = 1, 2, …., T for time), CEP_{it-k} – lagged corporate environmental variable (k=1, 2), X_{it} – vector of control variables referring to the firm's financial characteristics, Z_{it-k} – vector of lagged control variables referring to the firm's environmental characteristics, α_ι (ι=0, 1, 2) – estimated coefficients, β and γ –matrices of estimated parameters, u_{it} – error term.

Model (1) can describe various types of relationships between CEP and CFP, which in the literature on the subject are explained based on various concepts from management theory and may point at different environmental strategies implemented by firms (Aragón-Correa and Sharma, 2003; Fujii et al., 2013; Misani and Pogutz, 2015; Wahyuni and Ratnatunga, 2015; Trumpp and Guenther, 2017):

-the CEP-CFP relationship is linear and negative if $\alpha_1 < 0$ and $\alpha_2 = 0$. This type of relationship corresponds to the neoclassical agency theory and the trade-off theory, which indicate that the financial benefits of the pro-ecological activity of enterprises are lower than the costs generated by it in the short term. It may be observed in companies that have adopted reactive environmental strategies;

-the CEP-CFP relationship is linear and positive if $\alpha_1 > 0$ and $\alpha_2 = 0$. This type of relationship corresponds to the win-win hypothesis and the resource-based theory, which point to more efficient use of environmental resources and a reduction in pollutant emissions as a result of investments in cleaner production technologies, which in turn may strengthen the competitive advantage of companies in the long term. It refers to companies that have implemented proactive environmental strategies;

-the CEP-CFP relationship is nonlinear and U-shaped if $\alpha_1 < 0$ and $\alpha_2 > 0$. This type of relationship can be explained by the "too-little-of-a-good-thing" (TLGT) effect, as the initial efforts of companies focused on improving their environmental impact cause a deterioration in their profitability, and only after exceeding the turning point for the CEP - corresponding to the minimum value of CFP - an increase in environmental performance can have improved their financial results. This describes a situation where companies initially adopted reactive environmental strategies, but they can acquire knowledge and skills enabling them to use cleaner production technologies in the future, which leads to changing their environmental strategies into proactive ones;

-the CEP-CFP relationship is nonlinear and inverted U-shaped if $\alpha_1 > 0$ and $\alpha_2 < 0$. This type of relationship can be explained by the "too-much-of-a-good-thing" (TMGT) effect, as initially, the increase in the environmental performance of enterprises can improve their financial results, but after reaching the turning point of CEP - corresponding to the maximum value of CFP - further expenditures incurred for the implementation of ecological goals lead to the deterioration of financial results. This describes a situation where companies are implementing proactive environmental strategies, and their continued research on implementing innovative technological solutions in the production process and acquiring specialist knowledge in this area may generate very high costs in the short term.

In order to avoid the endogeneity problem in modelling the CEP-CFP relationship, the lagged independent variables describing the environmental performance of companies and lagged environmental control variables are included in panel regression. This is in line with the suggestions of (Horváthová, 2012), who showed that the improvement in the environmental performance of companies might generate profits and lead to higher profitability ratios not immediately but after some time.

In addition, the COVID-19 dummy variable and interactive variables describing the impact of environmental factors on financial variables only during the pandemic spread in Poland were included in the panel model:

$$\mathrm{CFP}_{it} = \alpha_{0\mathrm{i}} + \alpha_1 CEP_{it-k} + \alpha_2 (CEP_{it-k})^2 + \delta_1 CEP_{it} \cdot \mathrm{COV19}_t + \delta_2 EA_{it} \cdot \mathrm{COV19}_t + \delta_3 RES_{it} \cdot \mathrm{COV19}_t + \delta_4 \mathrm{COV19}_t + \beta' X_{it} + \gamma' Z_{it-k} + u_{it} \quad (3)$$

where $\mathrm{COV19}_t$ – dummy variable taking value 1 in the years 2020-2021 and 0 in other years, $\mathrm{CEP}_{it} \cdot \mathrm{COV19}_t$ – interactive terms describing the indirect impact of firm's environmental performance on financial performance during the COVID period, $\mathrm{EA}_{it} \cdot \mathrm{COV19}_t$ – interactive factor indicating the disparity between the EUAs allocated free of charge and the company's CO_2 emissions during the pandemic period, $\mathrm{RES}_{it} \cdot \mathrm{COV19}_t$ – interactive factor showing the share of renewable energy in the total production of energy companies during the pandemic period, δ_k (k=1,…, 4) – estimated coefficients.

The return on assets (ROA) is the most often used accounting-based measure of financial performance in research as it points out the ratio of the net income to the beginning-of-the-year total assets (Horváthová, 2012; Lahouel et al., 2019). Taking into account the aforementioned effect of transmission of pandemic shocks through the product channel, what is reflected in the generated revenues by firms, the return on assets indicator plays the role of the dependent variable in this paper. Furthermore, given the new changes in the EU climate policy to achieve carbon neutrality by 2050, the focus is on carbon performance as an important dimension of environmental performance (Busch et al., 2022). For this reason, the independent variable will be the CO_2 emission intensity (CEI), which informs about the amount of carbon dioxide emissions per unit of energy produced by a given energy corporation. Additional control variables are also included in the panel model to reduce the omitted variable bias, which contributes to partially solving the endogeneity problem (Lahouel et al., 2019). A control variable that is very often used to explain the nature of the CEP-CFP relationship is firm size, estimated as the natural logarithm of total assets. Big firms are expected to be more profitable than smaller ones due to the economies of scale and easier access to credit (Abban and Hasan, 2021). Another control variable is leverage (LEV), indicating the ratio of a firm's total debt to its total assets. This variable helps identify firms with high exposure to financial risk due to high debt levels. Cash flow return on sales (CF) is the control variable pointing to the net cash flow ratio to revenues from sales. According to Trumpp and Guenther (2017), high levels of free cash flow might improve corporate financial performance.

A control variable characterizing the environmental performance of companies is the emission to allowances index (EA), which compares the value of verified carbon dioxide emissions to the number of free allocated allowances that electricity producers in Poland could have received under the derogation system. EA values not exceeding one confirm the surplus of free allowances in a given energy group against its actual demand for covering its emissions (Segura et al., 2018; Włodarczyk, 2019). The last control variable affecting the environmental performance of companies is the renewable energy sources index (RES), indicating what proportion of the energy produced by installations owned by energy corporations comes from renewable sources.

Data Description

The panel model is estimated for the group of the energy sector companies listed on the Warsaw Stock Exchange and included in the WIG-Energia index before the Covid-19 pandemic. Due to their activities in producing electricity and heat from conventional fuels, all the analysed companies were included in EU ETS before 2013. The database constructed for this study includes information on the companies' financial performance for the period 2009 - 2021, which comes from the Notoria database. Non-financial data providing information on energy production volume from renewable sources and conventional fuels comes from the CSR reports and interim reports of the listed companies studied. Information on annual carbon dioxide emissions and the number of EUAs allocated free of charge for each generating facility owned by a given power company comes from the EU registry available in the European Union Transaction Log database. In order to mitigate the impact of extreme values on the estimation results, all variables were winsorized at the 5 and 95 percentiles (Misani and Pogutz, 2015).

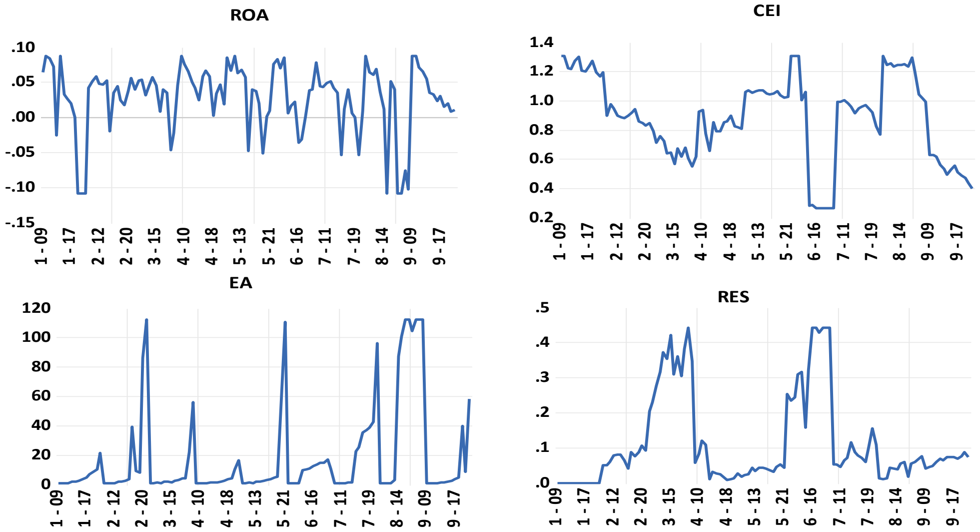

Figure 1: Financial and environmental indicators for the surveyed group of energy companies in the years 2009-2021
Source: Own elaboration

While analysing Figure 1, it can be seen that the studied group of companies was heterogeneous regarding the efficiency of utilising the total assets and the intensity of carbon dioxide emissions. ROA values ranged from -0.1082 to 0.0875; however, this indicator describing the financial performance of energy companies most often took negative values in 2015 and 2019-2020. The CEI values typically hesitated between 0.4371 and 1.3103 Mg/MWh, depending on the structure of fuels used for energy production by individual energy companies. The lower panel presents the values of two control environmental variables that are associated with the ability of companies to obtain free emission permits in connection with their investments in low-emission modernization of generating units and development of the RES electricity generation. Values of the EA index indicate significant differences between the second (2008-2012) and third (2013-2020) trading periods, which were caused by the different rules of the EUAs allocation as well as uneven distribution of allowances under the derogation for electricity producers in Poland.

Table 1. Cross-section dependences and unit root tests for financial and environmental variables

Test	ROA	CEI	SIZE	LEV	CF	EA	RES
Pesaran scaled LM	11.77^{***} [0.000]	15.52^{***} [0.000]	25.38^{***} [0.000]	15.44^{***} [0.000]	1.18 [0.239]	27.40^{***} [0.000]	31.07^{***} [0.000]
Pesaran – CIPS	-2.85^{*}	-2.96^{*}	-2.88^{*}	-3.31^{**}	-4.39^{***}	-2.19^{*}	-3.25^{**}

Source: Own calculation in Eviews
Note: Akaike Information Criterion (AIC) is used for lag selection; p-values in brackets; ***, **, * indicate significant statistics at the level respectively 1%, 5%, 10%.

An important step in constructing panel models is to check the stationarity of all variables. For this purpose, the second-generation panel unit root test was used due to the presence of significant cross-sectional dependencies that were confirmed based on Pesaran LM test (see Table 1). The null hypothesis about no cross-section dependencies in the panel of surveyed energy firms was rejected at the significance level of 0.01 for all environmental and financial variables except the CF (cf. Pesaran, 2021). When analysing the results of the Pesaran CIPS test presented in Table 1, the null hypothesis, assuming a common unit root process, had to be rejected at a significance level of 0.1 for all analysed variables, confirming their stationarity.

Empirical Results

Parameters of the panel regressions were estimated employing the Generalized Least Squares method (GLS) as it accounts for various correlation patterns among residuals: cross-section specific heteroskedasticity, period-specific heteroskedasticity, contemporaneous covariances, and between-period covariances. Following Trumpp and Guenther (2017), White's period standard errors were implemented in order to obtain the robust calculation of the covariance matrix elements. Table 2 shows the estimation results of linear and nonlinear model specification (1) in which CO_2 intensity and control environmental variables (EA and RES) with a one-year lag affect the return on assets.

Table 2. Estimation results of panel regression (1) for energy companies

Coefficient	Model 1 linear	Model 2 nonlinear	Coefficient	Model 1 linear	Model 2 nonlinear
α_0 constant	0.0219 (0.0280)	0.0630 (0.0393)	γ_2 (RES)	-0.0001 (0.0002)	-0.0002 (0.0002)
α_1 (CEP)	-0.0065 (0.0104)	-0.1311^{*} (0.0667)	β_1 (SIZE)	0.0018^{*} (0.0009)	0.0031^{*} (0.0016)
α_2 (CEP^2)	-	0.0718^{*} (0.0341)	β_2 (LEV)	-0.0059^{*} (0.0028)	-0.0088^{*} (0.0042)
γ_1 (EA)	-0.0006^{***} (0.0001)	-0.0007^{***} (0.0001)	β_3 (CF)	0.0773^{**} (0.0249)	0.0740^{***} (0.0180)
Diagnostic tests					

F-statistic	7.7832 [0.000]	7.7410 [0.000]	Adj. R-squared	0.5239	0.5338
Redundant fixed effect	4.7208 [0.000]	4.9006 [0.000]	Hausman test decision	Fixed effect preferred	Fixed effect preferred
Pesaran scaled LM	1.6892 [0.091]	1.6956 [0.090]	Jarque-Bera test	2.2171 [0.330]	5.3065 [0.068]

Source: Own calculation in Eviews
Note: p-values in brackets and standard errors in parentheses

For linear model 1, the parameter of the CEP variable is negative, so increasing carbon intensity in a given year will ceteris paribus decrease ROA in the following year. It is worth stressing that an increase in carbon intensity means a decrease in the corporate environmental performance of energy companies. Therefore, the sign of alpha 1 parameter is consistent with the win-win hypothesis. Unfortunately, this parameter is statistically insignificant, so linear model is not suitable for identifying the investigated relationship. For non-linear model 2, the parameters assigned to the CEP and CEP^2 variable are statistically significant at the 0.1, and their signs ($\alpha_2 > 0$, $\alpha_1 < 0$) indicate the existence of a U-shaped relationship between the CO_2 intensity observed one year earlier and the current ROA values (see Table 2). This means that higher financial ratios correspond to two groups of energy companies: the group owning the generation installations characterized by the worst environmental performance and the group managing the installations with the lowest carbon intensity in the previous year. It is worth noting that the turning point for the carbon dioxide intensity, calculated from equation (2), is 0.913 Mg/MWh. It has been assigned a minimum ROA value located on a U-shaped curve. At the same time, it is close to the median value of the variable describing the volume of CO_2 emissions per unit of energy produced, which is 0.9215 Mg/MWh for the analysed group of companies.

The identified shape of the relationship relates to the 'too-little-of-a-good-thing' effect, which explains the direction of the correlation between firms' financial efficiency and their reduction of the negative environmental impacts of manufacturing processes in the context of the environmental strategies used, the manufacturing technologies and the degree of commitment to low-carbon modernisation. In particular, companies characterised by low emissions intensity and high returns on assets among the surveyed companies had already implemented proactive environmental strategies several years before the pandemic outbreak (Wodarczyk and Kadłubek, 2018). This is indicated not only by the CSR activity reports available on the websites of these companies but also by their involvement in research and development projects focused on low-carbon energy generation technologies, which are implemented in cooperation with academic centres. The U-shaped relationship between CEP-CFP was also confirmed by Trumpp and Guenther (2017), who studied the efficiency of manufacturing firms in terms of CO_2 emissions reduction and return on assets. Also, Misani and Pogutz (2015), studying carbon-intensive firms, emphasised the non-linear relationship between carbon performance and financial performance measured by Tobin's q and ROA. According to their analysis, the relationship is shaped like an inverted U and the best market performance is achieved by firms with average carbon performance, which corresponds to the 'too-much-of-a-good-thing' effect. However, proactive environmental strategies might positively moderate the CEP-CFP relationship, as stakeholders simultaneously evaluated a firm's carbon performance and its efforts to reduce its environmental impact. Due to this, the relationship between carbon performance and Tobin's q might change into the U-shape curve (Misani and Pogutz, 2015).

In each model, the parameter next to the EA variable is statistically significant at the 0.01 level, and the sign of the parameter indicates a negative impact of this variable on ROA. An increase in the emission to allowances index value, indicating a large disparity between companies' emissions and the number of emission allowances allocated to companies under the derogation, will ceteris paribus cause a deterioration in asset returns in the following year. Increasingly higher EUA prices and the ending derogation period for electricity producers in Poland further strengthen the negative relationship between EA and ROA. The RES variable is statistically insignificant, and the negative sign of the parameter may indicate the costs accompanying RES development, which in the short term cause a deterioration in the financial performance of companies.

The size of the company significantly affects returns on assets, and the sign of this parameter shows that large energy corporations utilise economies of scale in their operations. A negative and statistically significant parameter next to the LEV variable shows that companies with a high total debt-to-asset ratio achieve worse financial results. In contrast, a high level of free cash flow significantly improves the financial performance of the surveyed companies, which is in line with the research of Trumpp and Guenther (2017).

The relatively high values of the coefficient of determination (0.5338) for model 2 and the significance of the F-statistic at the 0.01 level indicate that the independent variable and the set of control variables explain the changes in dependent variable quite well.

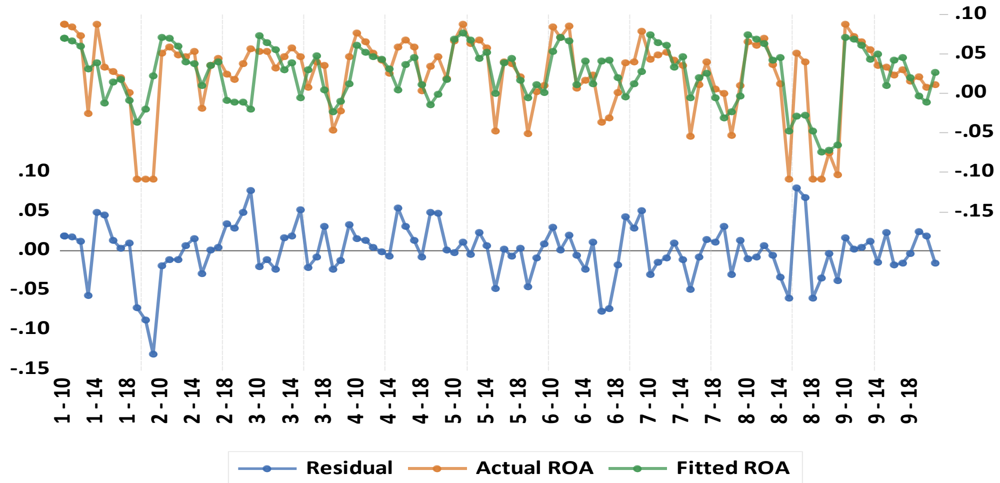

Figure 2: Actual and fitted values of returns on assets calculated for model 2
Source: Own elaboration

Analysing Figure 2, which shows actual and fitted values of returns on assets for the panel of surveyed energy companies in the years 2010-2021, one can also notice relatively small differences between them, which indicates a good fit of the theoretical model to the empirical data. According to Trumpp and Guenther (2017), the explanatory power of the non-linear regression was compared with the linear specification using the partial F-test. The significance of F statistics (F = 3.4066*) confirms that the relationship between CEP and CFP is non-linear. It is worth stressing that various specifications of panel models were estimated that considered the occurrence of cross-section fixed effect or period fixed effect, as well as cross-section random effect or period random effect. Based on the results of the estimation of these models and the Hausman's test, a period fixed effect specification has been finally selected, which has led to the removal of period specific means from endogenous and exogenous variables and performing a regression analysis based on demeaned data (Baltagi, 2005). The common assumption that may be often broken in panel samples is the lack of correlations between the disturbances in different cross-section units. This assumption has been verified utilizing the Pesaran test, and the null hypothesis about no cross-section dependencies has not been rejected at the significance level of 0.05 (see Tables 2 and 3).

A comparison of models (1) and (3) will provide answers to the research questions that have been formulated in the previous section, so Table 3 shows the estimation results of panel models (3) in which an interactive variable was included to describe the COVID-19 pandemic effect on the CEP-CFP relationship.

Table 3. Estimation results of panel regression (3) for energy companies

Coefficient	Model 3 linear	Model 4 non-linear	Coefficient	Model 3 linear	Model 4 non-linear
α_0 constant	0.0373 (0.0339)	0.0613 (0.0405)	δ_1 CEP*COV19	-0.1511** (0.0617)	-0.1380* (0.0656)
α_1 (CEP)	-0.0024 (0.0124)	-0.0857* (0.0455)	β_1 (SIZE)	0.0014 (0.0011)	0.0021 (0.0017)
α_2 (CEP^2)	-	0.0478* (0.0247)	β_2 (LEV)	-0.007 (0.0049)	-0.0093* (0.0045)
γ_1 (EA)	-0.0004** (0.0001)	-0.0005*** (0.0001)	β_3 (CF)	0.080** (0.0244)	0.0778*** (0.0203)
γ_2 (RES)	-0.0002 (0.0001)	-0.0003 (0.0001)	TP CEP	-	0.8964
Diagnostic tests					
F-statistic	7.5827*** [0.000]	7.3474*** [0.000]	Adj. R-squared	0.5255	0.5299
Pesaran scaled LM	1.3216 [0.186]	1.4101 [0.159]	Redundant fixed effect test	5.4509*** [0.000]	5.3429*** [0.000]

Source: Own calculation in Eviews

The equation (3) additionally includes interactive variables describing the impact of environmental factors on the returns on assets of energy companies in the period of impact of shocks generated by COVID-19, i.e. in 2020-2021. Of all the interactive variables considered, only the variable describing CO_2 emission intensity during the spread of successive pandemic waves in Poland significantly affected the financial performance of energy companies. The negative value of the parameter at the CEI*COV19 variable indicates that, in 2020-2021, energy companies characterised by high CO_2 emission intensities had lower returns on assets compared to companies with lower carbon emissions per unit of energy produced. The inclusion of this additional interactive variable, relating to the spread of shocks generated by the pandemic, did not change the shape of the CEP-CFP relationship. In contrast, the emission to allowances index still significantly shaped the returns on energy company assets, but its values deteriorated significantly during the pandemic period, as the median EAs in 2020 and 2021 were 22.02 and 58.30, respectively. Such high index values indicate that the companies' annual CO_2 emissions could only, to a small extent, be accounted for by freely allocated EUAs, while the majority of emission allowances had to be purchased by the companies in the auction system. At the same time, speculative action in the financial markets during the pandemic caused the price of EUAs at the beginning of 2021 to increase by 135% compared to the same period in 2020. Taking the above into account and the negative sign of the parameter at the EA variable, it can be inferred that the returns on the assets of the surveyed companies deteriorated during the COVID-19 period under the influence of shocks affecting financial markets and the tightening of EU climate policy. Zhang and Zheng (2022) also stress that environmental policies may amplify the negative impact of the pandemic on firms' financial performance. In addition, the parameter of RES is still statistically insignificant, and its negative value may indicate that investment in increasing the share of RES in the fuel mix of energy companies could generate additional costs, reducing their profitability. Moreover, as highlighted by Hermundsdottir et al. (2022), the shocks generated by the pandemic may periodically slow down investment in renewable energy development, as power companies during this period had to adjust the operation of coal-fired units to the reduced energy demand from the industry.

Conclusion

This paper examines the impact of the COVID-19 pandemic on the relationship between the environmental and financial performance of power corporations in Poland in the context of the environmental strategies' implementation. The presented results of panel model estimation indicate the existence of a U-shaped relationship between the CO_2 intensity observed one year earlier and current asset returns, which can be explained by the 'too-little-of-a-good-thing' effect. It indicates that companies with proactive environmental strategies that are intensively involved in the low-carbon transformation processes of energy-generating facilities achieve increasingly better financial performance. It has also been shown that the share of renewable energy in the companies' production structure did not significantly impact asset returns, although the negative correlation between the two indicates the high costs accompanying RES development, worsening the companies' financial performance in the short term. The lower scale of allocation of free emission allowances compared to previous years contributed significantly to the deterioration of financial performance in surveyed energy companies that had to buy most of their allowances on the secondary market, where EUA prices increased due to the uncertainty surrounding the pandemic.

Based on these results, it is possible to tentatively formulate important implications for climate policy and sustainable transformation processes of energy companies in the period of slowing down the spread of the pandemic. The government, when designing solutions within the framework of anti-crisis support programs for companies, should also take into account GHG emission reduction targets by encouraging companies to improve energy efficiency, invest in new production technologies, replace fossil fuels with less carbon-intensive energy carriers (Abban and Hasan, 2021; Fujii et al.,2013). Companies can be recommended to maintain proactive environmental strategies that fit the individual company's needs and allow the company not only to comply with new carbon-constraint regulations but also to profit from its CO2 emission intensity decrease (Wahyuni and Ratnatunga, 2015). To make this possible, companies should have access to external support through government or EU programs to stimulate a sustainable economic recovery.

The limitation of this study is an estimation of panel models for aggregated data describing the consolidated financial performance and environmental behavior of large energy corporations, as well as the method of measuring unobservable and complex phenomena such as the financial and environmental performance of manufacturing companies. These limitations also indicate directions for further research, which will be continued for financial and operational data disaggregated to the level of generating units. It seems interesting to conduct studies for multidimensional variables describing various areas of impact of the environmental strategies of energy companies, including the issues of renewable energy development and the functioning of generating units within the EU ETS.

References

Abban, A. R., Hasan, M. Z., (2021). The causality direction between environmental performance and financial performance in Australian mining companies - A panel data analysis. *Resources Policy*, *70*, 101894.

Ab Rahman, Z. N., Ismail, N. and Rajiani, I., (2018). Challenges for managing non-technological innovation: a case from Malaysian public sector. *Polish Journal of Management Studies*, *17*(1), 7-16.

Akpan, I. J., Udoh, E. A. P. and Adebisi, B., (2020). Small business awareness and adoption of state-of-the-art technologies in emerging and developing markets, and lessons from the COVID-19 pandemic. *Journal of Small Business & Entrepreneurship*, *34*(2), 123–140.

Aragón-Correa, J. A., Sharma, S., (2003). A Contingent Resource-Based View of Proactive Corporate Environmental Strategy. *The Academy of Management Review*, *28*(1), 71-88.

Baltagi, B.H., (2005). *Econometric Analysis of Panel Data*. 3rd Edition, John Wiley & Sons Inc., New York.

Basuki, B., Szczepańska-Woszczyna, K., Rajiani, I., Widyanti, R. and Kot, S., (2022). Working from home arrangement in delivering public service during the COVID-19 pandemic: innovation or irritation? *Administratie si Management Public*, *39*, 26-39.

Brodeur, A., Gray, D., Islam, A. and Bhuiyan, S., (2021). A literature review of the economics of COVID-19. *Journal of Economic Surveys*, *35*(4), 1007–1044.

Busch, T., Bassen, A., Lewandowski, S. and Sump, F., (2022). Corporate Carbon and Financial Performance Revisited. *Organization and Environment*, *35*(1), 154–171.

Ding, W., Levine, R., Lin, C. and Xie, W., (2021). Corporate immunity to the COVID-19 pandemic. *Journal of Financial Economics*, *141*(2), 802–830.

Fujii, H., Iwata, K., Kaneko, S. and Managi, S., (2013). Corporate Environmental and Economic Performance of Japanese Manufacturing Firms: Empirical Study for Sustainable Development. *Business Strategy and the Environment*, *22*(3), 187–201.

Ghosh, D., Dutta, M., (2022). Environmental behaviour under credit constraints – Evidence from panel of Indian manufacturing firms. *Structural Change and Economic Dynamics*, *63*, 490–500.

Guérin, P., Suntheim, F., (2021). Firms' environmental performance and the COVID-19 crisis. *Economics Letters*, *205*, 109956.

Halmai, P., (2022). COVID-19 Crisis and Supply Side Bottlenecks in the EU. Shorter and Longer Term Prospects. *Montenegrin Journal of Economics*, *18*(4), 19-30.

He, H., Harris, L., (2020). The impact of Covid-19 pandemic on corporate social responsibility and marketing philosophy. *Journal of Business Research*, *116*, 176–182.

Hermundsdottir, F., Haneberg, D. H. and Aspelund, A., (2022). Analyzing the impact of COVID-19 on environmental innovations in manufacturing firms. *Technology in Society*, *68*, 101918.

Horváthová, E., (2012). The impact of environmental performance on firm performance: Short-term costs and long-term benefits? *Ecological Economics*, *84*, 91–97.

Hosseini, S. E., (2020). An outlook on the global development of renewable and sustainable energy at the time of COVID-19. *Energy Research and Social Science*, *68*, 101633.

Huang, S., Liu, H., (2021). Impact of COVID-19 on stock price crash risk: Evidence from Chinese energy firms. *Energy Economics*, *101*, 105431.

Ismail, N., Kot, S., Abd Aziz, A. S. and Rajiani, I., (2020). From innovation to market: Integrating university and industry perspectives towards commercialising research output. *Forum Scientiae Oeconomia*, *8*(4), 99-115.

Lahouel, B., Gaies, B., Zaied, Y. and Jahmane, A., (2019). Accounting for endogeneity and the dynamics of corporate social – Corporate financial performance relationship. *Journal of Cleaner Production*, *230*, 352–364.

Misani, N., Pogutz, S., (2015). Unraveling the effects of environmental outcomes and processes on financial performance: A non-linear approach. *Ecological Economics*, *109*, 150–160.

Mukanjari, S., Sterner, T., (2020). *Charting a "Green Path" for Recovery from COVID-19*. *76*, 825–853.

Pesaran, M. H., (2021). General diagnostic tests for cross-sectional dependence in panels. *Empirical Economics*, *60*(1), 13–50.

Scherer, M., Milczarski, P., (2021). Machine-learning-based carbon footprint management in the frozen vegetable processing industry. *Energies*, *14*(22), 7778.

Segura, S., Ferruz, L., Gargallo, P. and Salvador, M., (2018). Environmental versus economic performance in the EU ETS from the point of view of policy makers: A statistical analysis based on copulas. *Journal of Cleaner Production*, *176*, 1111–1132.

Seroka-Stolka, O., (2020). How Does Stakeholder Pressure Affect Strategic Environmental Types. The Evidence from Polish Companies. [in:] Education Excellence and Innovation Management: a 2025 Vision to Sustain Development during Global Challenges, Soliman Khalid S. (eds.), International Business Information Management Association, Norristown, 8267-8278.

Streimikiene, D. (2022). COVID-19 effect on energy poverty: Lithuanian case study. *Montenegrin Journal of Economics*, 17(4), 215-223.

Szczygielski, J. J., Brzeszczyński, J., Charteris, A. and Bwanya, P. R., (2022). The COVID-19 storm and the energy sector: The impact and role of uncertainty. *Energy Economics*, *109*.

Thorgren, S.,Williams, T. A., (2020). Staying alive during an unfolding crisis: How SMEs ward off impending disaster. *Journal of Business Venturing Insights*, *14*, 1-11.

Trumpp, C., Guenther, T., (2017). Too Little or too much? Exploring U-shaped Relationships between Corporate Environmental Performance and Corporate Financial Performance. *Business Strategy and the Environment*, *26*(1), 49–68.

Wahyuni, D., Ratnatunga, J., (2015). Carbon strategies and management practices in an uncertain

carbonomic environment - lessons learned from the coal-face. *Journal of Cleaner Production*, 96, 397-406.

Wan, D., Xue, R., Linnenluecke, M., Tian, J. and Shan, Y., (2021). The impact of investor

attention during COVID-19 on investment in clean energy versus fossil fuel firms. *Finance Research Letters*, *43*,101955.
Włodarczyk, A., (2019). Economic and environmental performance analysis of Polish energy companies. *Global Journal of Environmental Science and Management*, *5*(SI), 1–11.
Włodarczyk, A., Kadłubek, M., (2018). Use of multifactor models with GARCH structure in carbon emissions risk management, [in:] Multidisciplinary Aspects of Production Engineering 2018, Panova, Zabrze, 1(1), 407-413.
Yoo, S., Keeley, A. R. and Managi, S., (2021). Does sustainability activities performance matter during financial crises? Investigating the case of COVID-19. *Energy Policy*, *155*, 112330.
Zhang, D., (2022). Capacity utilization under credit constraints: A firm-level study of Latin American manufacturing. *International Journal of Finance and Economics*, *27*(1), 1367–1386.
Zhang, D., Fang, Y., (2022). Are environmentally friendly firms more vulnerable during the COVID-19 pandemic? *Journal of Cleaner Production*, *355*, 131781.
Zhang, D., Zheng, W., (2022). Does COVID-19 make the firms' performance worse? Evidence from the Chinese listed companies. *Economic Analysis and Policy*, *74*, 560–570.
Zulfikar, R. Z., Widyanti, R. W., Basuki, B., Mayvita, P. A. and Purboyo, P., (2021). Encourage SMEs sustainable behavior during Covid-19 pandemic through competitive advantages and corporate culture. *Serbian Journal of Management*, *16*(2), 405-417.

STRATEGIE ŚRODOWISKOWE SPÓŁEK ENERGETYCZNYCH W CZASIE PANDEMII COVID-19

Streszczenie: W artykule oceniono wpływ pandemii COVID-19 na przedsiębiorstwa energetyczne w zakresie realizacji strategii środowiskowych i kontynuacji niskoemisyjnej transformacji jednostek wytwórczych w warunkach niestabilności ich wyników finansowych. Skonstruowano i oszacowano nieliniowy model panelowy dla spółek energetycznych notowanych na Giełdzie Papierów Wartościowych w Warszawie, których jednostki wytwórcze zostały objęte systemem EU ETS w latach 2009-2021. Wyniki estymacji wskazują na istnienie zależności w kształcie litery U pomiędzy obserwowaną rok wcześniej intensywnością emisji CO_2 a bieżącą stopą zwrotu z aktywów, co można wytłumaczyć efektem „za mało dobrych rzeczy” ('too-little-of-a-good-thing'). Wskazuje on, że firmy posiadające proaktywne strategie środowiskowe, intensywnie angażujące się w procesy niskoemisyjnej transformacji jednostek wytwórczych, osiągają coraz lepsze wyniki finansowe. Uwzględnienie w modelowaniu oddziaływania szoków pandemicznych nie zmieniło kształtu relacji CEP-CFP, jednak zaobserwowano, że w tym okresie przedsiębiorstwa energetyczne o wysokiej intensywności emisji CO_2 osiągały niższe zwroty z aktywów. Do badania zaproponowano nową zmienną środowiskową, opisującą relację między rzeczywistą emisją spółek a przyznanymi darmowymi uprawnieniami do emisji, która wraz ze zmienną opisującą udział energii odnawialnej w produkcji energii, informuje o stopniu niskoemisyjnej transformacji przedsiębiorstw.

Słowa kluczowe: strategie środowiskowe, intensywność emisji, wyniki finansowe, modele panelowe, pandemia Covid-19