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Energy Prices in the Context of the European Green Deal and Their Impact on the Number of Small and Medium-Sized Enterprises in Poland

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Abstract

The changes introduced under the European Green Deal policy affect many areas of life. They also have significant consequences for the functioning of small and medium-sized enterprises. The authors put forward the thesis that one of the key categories of costs in the case of such firms, which significantly influences their decision to commence, continue or cease operations, is the cost of purchasing electricity and gas. Analysing data from the Central Statistical Office in Poland for the years 2015–2025 and constructing an econometric model on this basis, the authors found arguments that the cost of purchasing electricity (as opposed to the cost of purchasing gas) may probably indeed play the role attributed to it. However, the detected relationships are of a very complex nature and only the ML model, Random Forest, was able to identify them (linear and non-linear OLS regression models were not appropriate here). Although Random Forest is a predictive method and does not identify structural causality, the findings may be important for decision-makers assessing the scale of the challenges that small and medium-sized enterprises will have to face in the coming years. Moreover, the findings constitute a significant argument in favour of support instruments (e.g., contracts for difference, long-term PPAs for SMEs, support for energy efficiency and self-generation) for the aforementioned category of entities.

Keywords: electricity prices; energy economics; energy cost; European Green Deal; SMEs (Small and Medium Enterprises)

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Academic Editor: Jin-Li Hu

Received: 8 November 2025
Revised: 15 December 2025
Accepted: 16 December 2025
Published: 19 December 2025

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1. Introduction

In recent years, the European Union's climate policy has undergone significant intensification, epitomised by the adoption of an ambitious strategy of economic transformation referred to as the European Green Deal. This initiative, presented in December 2019, provides for the European Union to achieve climate neutrality by 2050 and to reduce greenhouse gas emissions by at least 55% by 2030 relative to 1990 levels [1]. This objective is to be attained through a range of reforms encompassing almost all sectors of the economy: from energy, through transport and agriculture, to construction and industry. Although the direction of these changes responds to the urgent need to counteract climate change, their implementation entails numerous socio-economic consequences [2], which are particularly felt by small and medium-sized enterprises (SMEs) [3,4].

SMEs are a key pillar of the European Union's economy, including that of Poland: they account for approximately 99% of economic entities; in statistical terms, constituting

99.8% of enterprises, they generate 65.3% of employment and 53.3% of value added in the EU's non-financial economy [5,6]. However, it is precisely this group of enterprises that proves to be the most susceptible to the effects of transformational policies such as the Green Deal. In contrast to large corporations, SMEs often possess limited capital, technological and organisational resources, which significantly hinders their adaptation to new regulations and the bearing of rising operating costs [7,8]. One of the most acute aspects of the energy transition resulting from the Green Deal is the dynamic changes in electricity and gas prices [9]. Of course, in Poland, unsustainable coal (and therefore subject to very high public taxes) is still the most important raw material used for large-scale electricity generation (according to official data from the Polish Central Statistical Office webpage). However, its direct use by SMEs is very limited because SMEs, which are most concentrated in large cities, cannot access this resource in such locations (as well as in many smaller towns) due to the ban on burning coal [8]. Furthermore, currently available technological solutions used by SMEs in almost every industry are primarily powered by electricity. Therefore, since electricity prices vary significantly across countries (which is not the case for other energy sources to a similar extent), this significantly impacts the competitiveness of Polish SMEs. This is why electricity is so important from the perspective of Polish SMEs.

Energy costs constitute one of the fundamental components of SMEs' operating expenditures, irrespective of the sector. In many cases, increases in energy prices lead to a deterioration in profitability and sometimes to the necessity of limiting operations or even ceasing them [10–12]. In recent years, a marked rise in energy costs has been observed, which was not always solely the result of market factors—regulatory actions and the reforms introduced under the Green Deal also had a considerable impact [13,14]. On the one hand, there is growing pressure to reduce emissions and to invest in clean technologies; on the other, firms operate within a rapidly changing regulatory and financial regime, encompassing the costs of CO_2 allowances, expenditures on compliance with environmental standards, and new reporting obligations (Taxonomy/CSRD) [15].

In the case of Poland, this problem takes on a particular dimension, as the country is one of the largest producers of coal-fired electricity in the EU [16–18]. The energy transition is structural and long-term in nature: it requires record-high investments in new generation capacity, grids and storage, and on the consumer side—especially SMEs—it entails relatively higher adjustment costs today and in the years to come [19–21]. However, it is worth taking into account the fact that continuous progress in the field of AI, robotics, and innovative production technologies, among others, is also changing the situation—research shows that this is currently an important path to reducing the carbon footprint [22]. However, it is primarily changing energy prices that can influence entrepreneurs' decisions to enter the market, scale their operations, or even to cease running the business—hence it may be said that the Green Deal indirectly 'determines the fate' of these entities [23,24].

The situation of individual European countries varies greatly in terms of the structure of sources and the costs of generating and selling electricity (which is burdened with various "penal" pro-environmental fees). In the case of a country like Poland, the situation is particularly complex. The Polish Ministry of Climate and Environment provides information on its website (https://www.gov.pl/web/klimat, accessed on 2 September 2025) on the structure of electricity production cost and its sales costs for 2024 (prices in Polish Zloty PLN). Hydropower plants produce the cheapest energy in Poland (PLN 175/MWh), while solar energy is the most expensive among renewable sources (PLN 194/MWh). Lignite (PLN 223/MWh) is the cheapest among emission sources, but still more expensive than renewable energy sources. The highest generation costs were recorded for biomass (PLN 497/MWh) and hard coal and gas (approximately PLN 441–444/MWh). The data does not

include CO_2 emissions costs, which increase the prices of energy from emission sources. Importantly, energy sales costs show much greater variation. Hydropower remains the cheapest (PLN 197/MWh), while hard coal remains the most expensive (PLN 862/MWh). Biomass, while the most expensive to produce, is cheaper to sell than coal (PLN 546/MWh).

In light of the above observations, the question arises as to the actual impact of the European Green Deal on the situation of small and medium-sized enterprises in Poland. Does the adopted climate and energy policy foster their development and transformation, or does it rather constitute a barrier and a threat to their existence? The answer to this question requires in-depth empirical and theoretical analysis aimed at better understanding the challenges facing the SME sector in the context of energy transformation in Poland [25]. This article therefore aims to fill the research gap concerning the assessment of the associations between energy prices (shaped by the European Green Deal) and the number of SMEs operating in Poland.

2. Literature Review

2.1. The Importance of the SME Sector and Energy Costs

The SME sector is recognised as a foundation of economies at both the European and national scales—particularly in Poland. Numerous studies indicate that enterprises belonging to this category play a key role in job creation and innovative flexibility, as well as in the incubation processes of new business models [7,26,27].

In analyses by the European Commission, energy (purchased electricity and gas) is indicated as one of the key components of enterprises' operating costs alongside wages, raw materials and depreciation. In the years 2021–2023, its share in costs clearly increased in line with the price crisis, while in energy-intensive activities, the share of energy costs is double-digit and often exceeds the threshold of 30% of total costs (particularly in chemicals/fertilisers, basic metals, ceramics, glass, paper, cement). It is precisely in these industries that fluctuations in energy prices most strongly translate into margins and production decisions [28,29].

OECD mapping for the Energy-Intensive Industries (EIIs) ecosystem shows high energy consumption intensity and cost sensitivity in the aforementioned sectors, as well as a consistently higher share of energy outlays in the cost structure than in less-energy-intensive sectors. In comparative terms (the EU and other economies), a structurally elevated share of energy costs in EIIs persists, which confirms that values above 30% are typical in these industries and may be considerably higher during periods of price tensions [30]. Thus, in the structure of enterprises' operating costs—alongside wages, materials and depreciation—expenditures on electricity and gas constitute a growing component, often amounting to several tens of per cent of all outlays, particularly in energy-intensive sectors.

Public opinion and empirical research findings consistently indicate that climate- and energy-policy instruments affect the structure and level of energy costs borne by firms, and thus their margins and business decisions. In pan-European surveys, the share of respondents identifying the affordability of energy as a key EU policy priority is increasing, reflecting the expectation that regulation translates into consumers' bills [31]. Market studies, in turn, show that the costs of EU ETS (European Union Emissions Trading System) emission allowances are to a significant extent passed through to wholesale electricity prices, linking climate policy with price levels in energy markets [15]. At the level of corporate financial results, it is observed that increases in energy prices significantly worsen the profitability of firms in the EU—an effect particularly severe for SMEs with limited financial resources and fewer hedging possibilities [12]. Analyses of the impact of 'green-digital' regulation further highlight the accumulation of regulatory burdens (including taxonomy/reporting requirements, energy efficiency), which disproportionately burden

SMEs and increase adjustment costs [32]. Attitudinal studies in the EBRD (European Bank for Reconstruction and Development) region indicate a limited willingness of societies to bear the additional costs of the transition, which amplifies pressure on the cost side of policies [33].

On the basis of the latest research, it can be stated precisely that in Poland the effects of the energy transition implemented under EU policy largely materialise through rising electricity and gas costs. Milewska and Milewski [34] demonstrated, on the example of manufacturing companies, that although the share of energy costs in sales revenues often does not exceed a few per cent in accounting terms, under the conditions of the 2022 energy crisis, it led to a significant decline in the profitability of enterprises—particularly in highly energy-intensive industries such as the metal, chemical and building materials sectors. The results of their analyses indicate that spikes in energy prices may directly determine the profitability of operations, forcing production constraints or the shifting of costs to customers. Fontagné et al. [23], for their part, analysing firms' responses to energy shocks in Europe, documented that enterprises adapt to rising energy prices in many ways—by reducing production, limiting investment, changing the scale of operations, or attempting to pass costs on to clients. These mechanisms are clearly also visible in Poland, where the structural dependence on coal in the energy mix and the high volatility of energy prices mean that energy costs have become one of the main factors affecting the competitiveness and durability of enterprises' business models.

Thus, the energy transition in Poland is not limited solely to technological changes and investments in new energy sources, but is tangibly manifested in companies' cost accounts and, consequently, in their ability to maintain profitability under conditions of rising electricity and gas prices.

2.2. The Green Deal—Mechanisms Influencing Energy Prices

The European Green Deal encompasses a whole array of policies and regulations, ranging from the introduction of new emission standards, through the development of renewable energy sources (RES), to the reform of the emissions trading market (EU ETS) and support for energy efficiency. The literature indicates several main channels of transmission through which these measures affect the level and structure of energy costs:

- EU ETS reforms lead to a reduction in the supply of free allowances and an increase in emission prices. This translates into higher costs of producing energy from fossil fuels and, consequently, higher energy bills for end-users, including SMEs [15,35].
- Although in the long term RES are expected to reduce production costs, in the short term they require investment outlays—for example, for the expansion of the transmission grid, storage, and system dispatchability—which are sometimes added to the consumer's bill through RES tariffs. EU studies note that these costs are often passed on to end purchasers, including SMEs [13,21,36].
- The Green Deal imposes specific energy-intensity standards and modernisation requirements on enterprises (buildings, heating, insulation, equipment). Although these may lead to long-term savings, one-off investment costs often constitute a significant barrier for SMEs [3,4,21].

The first two transmission channels mentioned clearly demonstrate the impact of the EU Green Deal policy on the price of energy purchased by SMEs. However, this price also depends on structural conditions specific to a given country. Therefore, the case of Polish enterprises requires separate research.

In light of the latest modelling analyses, the results are consistent: rapid and ambitious implementation of the European Green Deal policies leads to a transitory increase in energy bills in the initial years of the transition, before the effects of investment and cost

improvements fully materialise. In macroeconomic terms, the DSGE NAWM (Dynamic Stochastic General Equilibrium of the New Area-Wide Model) with a distinct energy sector shows that a path of rising emission prices consistent with climate targets generates a short-term price impulse via the energy component (higher electricity and gas prices feed through into the CPI), after which price pressure abates as the mix is modernised, marginal costs in 'clean' technologies decline, and capital adjusts [37]. CGE approaches/the JRC analytical compendium confirm this dynamic at the level of expenditure structures: outlays on RES infrastructure, grids and system flexibility, together with expanding pricing instruments, raise the short-term share of energy expenditure in consumers' budgets, while the scale and duration of the effect are cushioned by revenue-recycling mechanisms from climate policies, targeted subsidies and the sequencing of reforms [37].

As a result, the trajectory of energy costs has a 'first increase—then subsidence' profile, the amplitude of which depends on the pace of decarbonisation, demand elasticity, the rate of growth of low-emission capacity, and the method of recycling revenues from emission pricing.

2.3. Conditions Related to the Structure of Energy Sources

In the context of Polish experience, it is often emphasised that the country's energy structure—based to a significant extent on coal—makes the transition in the context of the Green Deal more costly than in countries with a more diversified energy mix [38–40]. The increase in energy expenditure constitutes one element of the fiscal and operational pressure on SMEs in Poland. In particular:

- Young enterprises often postpone or abandon market entry due to the high threshold of fixed costs—renting and adapting premises, a basic machinery/ICT stock, connection fees and securities, and rising electricity and gas bills that increase the monthly 'burn rate' from the very outset [40,41]. The problem intensifies under conditions of more expensive external financing and more difficult access to credit: in Q1–Q3 2023, the share of firms in the euro area reporting serious financing problems reached around 24%. At the same time, the corporate financing cost indicator rose in Q8 2023 to around 5%, which further limits start-ups' ability to cover fixed costs, including energy [6]. As a result, high infrastructure and energy costs act as a barrier to entry.
- The surge in electricity and gas prices was a key stimulus behind decisions to scale down or close operations, especially in sectors with high cost sensitivity. An analysis based on CIS data for Germany shows that firms more severely affected by rising energy prices more frequently closed or relocated energy-intensive activities, and enterprises with higher energy intensity recorded a decline in sales in 2023 compared with 2022 [24]. An OECD policy review documents that the sharp increases in energy prices in 2022/2023 triggered a strong rise in the burden of energy bills in SMEs, which required extraordinary instruments (price caps, fee reliefs, transfers) precisely to limit the risk of loss of liquidity and permanent closures in sectors such as manufacturing, gastronomy/HoReCa, crafts and transport—sectors that are unable easily to pass costs on to prices or to reduce energy consumption quickly [42].
- Limited capital for efficiency investments slows the development of Polish firms and their scaling, as well as the introduction of new products/processes. In the EIBIS 2022—Poland survey, 91% of firms identified energy costs as a barrier and reported a sharp deterioration in expectations regarding the availability of external financing. At the same time, the net balance of expectations over the year shifted from +4% (slight optimism) to −34% (deep pessimism) in the assessment of the availability of external financing [43]. In the subsequent EIBIS 2023—Poland survey, 90% of enterprises cited energy costs as a long-term investment barrier. Meanwhile, the share of firms

dissatisfied with the cost of external financing rose year-on-year from 10% to 23%, while the proportion of financially constrained enterprises reached 9.2%. Nevertheless, as many as 61% plan such investments over the next three years [44]. In cross-sectional terms, the OECD emphasises that after successive shocks (the pandemic, the energy crisis), SMEs face increasing barriers to access to finance and operating costs, which directly limits their capacity for the energy transition and for innovative activity [27].

The above analyses indicate that the costs of electricity and gas are not merely an operational aspect, but potentially a decisive factor for the survival and growth of SMEs.

2.4. The Number of SMEs and Energy Costs

Analyses based on firm-level data from the 2022 energy crisis show that enterprises more severely affected by price increases more frequently closed or relocated energy-intensive activities and recorded a decline in sales—this mechanism adversely affects the survival of younger and smaller firms [24]. Macroeconomic approaches additionally indicate that spikes in gas and electricity prices increase the exit rate and lower the entry rate of new firms, which in the short term reduces the number of active entities in the economy [45].

In comparative databases [46], regions/countries with a higher burden of energy costs more frequently report energy as the main barrier to doing business, and indicators of new registrations and five-year survival are relatively weaker there than in jurisdictions with lower costs. As a result, the relationship 'more expensive energy → a lower rate of business formation and weaker SME stability' is visible both in micro studies (firms' reactions) and in statistical cross-sections (WBES/Eurostat), particularly in sectors with above-average energy intensity (manufacturing, transport, crafts, HoReCa) [24,45,46].

In Polish institutional data, it can be seen that the peak of the energy price crisis in 2022 coincided with a deterioration in business demography and economic conditions. In Q4 2022, 86,291 new firms were registered (−2.6% y/y), alongside an increase in the number of bankruptcies to 112 cases (+28.7% y/y); the sharpest declines in registrations concerned, inter alia, accommodation and food service activities (−22.6%), industry (−13.1%) and construction (−12.2%)—i.e., sections particularly sensitive to energy costs [47]. In parallel, NBP's model estimates show that the energy price shock observed in 2022 (gas, oil, coal) may have reduced GDP by around 2.8–2.9% and boosted the consumption deflator by 10.3% (and, with the adjustment of nominal wages, even up to 15.4%), which constitutes the macroeconomic backdrop for weaker firm entry dynamics and a greater number of exits in the most energy-intensive industries [48].

2.5. The Thesis Arising from the Analysis Presented Thus Far

The above review of the literature shows in a fairly unequivocal manner that:

- The Green Deal strategy, through regulatory and market mechanisms, significantly affects the level and structure of electricity and gas costs.
- For many SMEs—owing to limited resources and flexibility—the increase in these costs may be a destabilising factor, influencing decisions to commence operations, to continue them, or to cease them.
- In Poland—in the conditions of the structural transformation of the economy and the energy sector—this impact is particularly strong: the cost of energy remains one of the most important elements determining the number and durability of SMEs.

Based on these observations, a research model can be outlined to demonstrate the relationship between EU Green Deal policy and the number of SMEs. As can be easily seen, a measurable effect of political decisions in this area is the changing cost of energy (in Poland, for SMEs, this primarily concerns electricity and gas). According to the performed

analysis, this directly influences companies' decisions to start, continue, or terminate their operations. Significant, one-off changes in the conditions affecting energy costs sometimes occur, a particular example of which was the launch of the ETS market over the last decade. When examining the change in the number of companies, it is important to consider the general context of their operations, which synthetically expresses the rate of change in GDP and the inflation rate (it can be assumed that both of these variables were also influenced to some extent by events such as the pandemic, international conflicts, etc., thus indirectly also reflecting such changing conditions).

The scientific works cited so far lack sufficiently in-depth reflection on the real strength of the connections between the phenomena under study. In other words, there is a need to develop synthetic scientific models to assess the actual relationship of energy price changes with the number of Polish SMEs. Above all, however, satisfactory confirmation is needed that this is a real relationship that deserves in-depth research. Therefore, as a foundation for further analysis, the following thesis can be formulated: "One of the key categories of costs in the case of small and medium-sized enterprises, which significantly influences their decision to commence or continue, or possibly to cease, operations, is the cost of purchasing electricity and gas." This thesis finds solid support in the literature review conducted. A particular justification for this thesis is provided by the already mentioned considerations on the key consequences of the currently adopted solution to the European dilemma related to the choice of solutions protecting the natural environment at the expense of energy security [10] in the light of the real experiences of enterprises [11,12], especially in the case of SMEs [4,7,8] and the countries with an unfavorable structure of electricity sources [9,13,19,29,49]. Moreover, in the Polish context, the phenomenon signalled is reinforced both by structural conditions (a coal-based energy mix, the pace of the transition) and by recurring observations contained in reports concerning SMEs.

3. Materials and Methods

The presented analysis, in addition to theoretical considerations, includes calculations based on statistical data. The study considered a dataset spanning the period from the second quarter of 2015 to the first quarter of 2025 (quarterly data). All data came from the official resources of the Central Statistical Office of Poland, available on its website and from the Polish Energy Regulatory Office official website. As for the calculation method, there are reasons to first attempt to build a model based on linear regression. This model has been repeatedly used in more general considerations of the impact of rising energy prices on the conditions for SMEs to conduct business. Zgang and Gu, among others, used regression to illustrate the impact of setting further ambitious energy policy goals on the growing energy poverty of enterprises [49]. Another group of authors used a linear regression model to conduct a general analysis of the impact of pro-ecological conditions (especially rising energy prices) on the financial results (and even the possibility of continued operation) of entities representing the SME sector in economically diversified countries of Central and Eastern Europe [50]. However, previous studies, despite using a linear regression model, have not sufficiently precisely indicated the significance of rising energy costs for the continuation of SME operations.

The thesis presented at the conclusion of the previous section prompts an attempt to illustrate the issue under discussion using empirical data in a manner that precisely determines the relationship between the key phenomena. On the one hand, we can draw on data showing changes in electricity and gas fuel prices over time, and on the other hand it is possible to observe parallel changes in the number of SMEs. However, it may be suspected that these variables are non-stationary (trend-like), which could lead to spurious regression. Therefore, it may be necessary to construct a model other than linear regression.

This dilemma will be resolved by calculating the values of appropriate statistical tests. The control variables used will be data on quarterly changes in GDP, inflation and a dummy variable showing the moment when the Market Stability Reserve MSR used for trading in the EU ETS was launched.

As organisations conducting business activity, SMEs are far more exposed to sudden price changes than ordinary consumers (in Poland, consumers as a rule purchase electricity and gas on the basis of regulated prices). For this reason, in the case of electricity, the calculations used data published by the Energy Regulatory Office (on its official website www.ure.gov.pl) as the quarterly average price recorded on the commercial market. As already mentioned the data covered the period from the second quarter of 2015 to the first quarter of 2025 (inclusive), which means that the set comprised 40 elements. Similarly, from the same source, a compilation of quarterly natural gas prices was obtained as a series of values representing an analogous period. Data on the number of SMEs reporting economic activity in successive quarters (a time span corresponding to the other variables) as well as on inflation and GDP growth were collected from the website of Statistics Poland GUS (www.gus.gov.pl).

In light of the above, the computational procedure to be used will consist of several steps. First, an attempt will be made to fit a linear regression model. Statistics such as the Augmented Dickey–Fuller test (ADF) will be calculated to check for stationarity. If there are indications that the linear regression model may exhibit spurious regression, further steps will be performed. An attempt will be made to fit a nonlinear OLS model with appropriate transformations. A Ramsey RESET test (test for nonlinearity) will be performed. An attempt will be made to fit a Random Forest model with demonstration of the importance of variables. An attempt will be made to fit an SVR (kernel RBF) model as a nonlinear model. The final step will be to compare the created models based on R^2 and RMSE values.

4. Results

The results of all calculations are summarized in four tables, each followed by a detailed discussion. The following symbols for each variable are used: y represents the number of SMEs in a given quarter, x1 represents average commercial electricity prices, x2 represents average quarterly gas prices, I represents the quarterly change in the inflation rate, P represents the quarterly change in the GDP growth rate, and E represents the periods of trading under the MSR for the EU ETS.

Since the main goal of the analysis is to examine the relationship between energy prices and the number of SMEs in Poland, as an introduction (before more advanced calculations and statistical models are presented), variables x1 and x2 will be characterized from the perspective of descriptive statistics. Regarding electricity prices (prices expressed in Polish zlotys PLN/MWh), they can be characterized using descriptive statistics as follows: mean 335.48; median 249.06; standard deviation 190.84; variance 36,420.70, minimum 160.60; maximum 889.69; range 729.09; 1st quartile 171.52; 3rd quartile 471.96. The data are strongly skewed to the right, which shifts the mean significantly above the median. The large difference between the 3rd and 1st quartiles and the value of the standard deviation indicate high volatility. However, in the case of gas prices (also expressed in Polish currency PLN/m^3), descriptive statistics leads to the following results: mean 154.63; median 92.41; standard deviation 169.11; variance 28,599.81, minimum 30.89; maximum 886.88; range 855.99; 1st quartile 67.74; 3rd quartile 198.34. The data are strongly skewed to the right, shifting the mean significantly above the median. The data are characterized by very high variability. The median better represents the typical value than the mean.

Due to the nature of the data, prior to estimating the model, a method of differentiating the data representing the considered variables was used. This was to eliminate the risk of spurious regression associated with a trend, which typically accompanies the analyzed phenomena. The resulting OLS linear regression model (Table 1) explains only 1.8% of the variability in the y variable. The F-statistic is characterized by a *p*-value of 0.986, meaning that the model as a whole is not statistically significant. It should also be emphasized that no coefficient is significant at the 5% level ($p > 0.05$). The Durbin–Watson statistic value of 2.15 indicates a lack of strong autocorrelation of the residuals. Heteroscedasticity tests (BP and White) allow us to conclude that the analyzed model is free from heteroscedasticity. The Jarque–Bera statistic shows a strong deviation from normality of the residuals (JB $p \approx 0$), very high skewness and kurtosis because the residuals have extreme values. A condition number of 5.88×10^6 indicates significant collinearity between variables, which may cause coefficient instability. In light of the presented results, the linear OLS model explains virtually no variability in y and is statistically unreliable.

Table 1. Linear Regression OLS Model parameters (variable x1 represents electricity prices; variable x2 represents gas purchase prices, variable I represents inflation, variable P represents GDP, dummy variable E represents the period of operation of the EU ETS MSR). Calculations based on stationary data obtained after differentiating.

Linear Regression OLS						
	Coef	**Std Err**	**t**	**P > |t|**	**[0.025**	**0.975]**
const	-1.312×10^4	2.26×10^4	−0.581	0.565	-5.91×10^4	3.28×10^4
x1	−1.8696	4.049	−0.462	0.647	−10.098	6.358
x2	0.4895	2.263	0.216	0.830	−4.109	5.088
I	124.2209	225.653	0.550	0.648	−334.361	582.503
P	0.0037	0.008	0.461	0.586	−0.013	0.020
E	−240.7868	607.601	−0.396	0.694	−1475.581	994.007
R-squared:					0.018	
Adj. R-squared:					−0.126	
F-statistic:					0.1253	
Prob (F-statistic):					0.986	
Log-Likelihood:					−346.75	
AIC (Akaike Information Criterion):					705.5	
BIC (Bayesian Information Criterion):					715.6	
Omnibus:					81.067	
Durbin–Watson:					2.149	
Prob(Omnibus):					0.000	
Jarque–Bera (JB):					1395.294	
Skew:					−5.069	
Prob(JB):					1.04×10^{-303}	
Kurtosis:					30.100	
Condition No.					5.88×10^6	
Breusch–Pagan:					2.803	
White:					10.465	
Ramsey RESET					0.277	
Prob (Ramsey RESET)					0.602	

Source. Self-analysis.

ADF stationarity tests (Table 2) showed that, after differentiating, all of the variables were stationary at the 5% level, as variable y yielded $p = 0.000$, x1 $p = 0.003$, x2 $p = 0.000$, I $p = 0.028$, and P $p = 0.015$. However, at this stage, due to the characteristics of the linear model, it will be necessary to attempt to create a different, better-fitting and more reliable non-linear model.

Table 2. ADF stationarity test for variables y, x1, x2, I, and P (calculations based on stationary data obtained after differentiating).

Variable	*p*
y	0.000
x1	0.003
x2	0.000
I	0.028
P	0.015

Source. Self-analysis.

When estimating the nonlinear OLS regression model (estimated on the basis of data after differentiation), the obtained results also indicate limitations that prevent the model from meeting expectations (Table 3). While R-squared is 0.22, which is a significant improvement over linear OLS, it is still far from an excessively high result. The F-statistic is 0.2146, which, with a *p*-value of 0.993, indicates that the model is still insignificant. Again, neither coefficient is significant at the 5% level. Regarding other statistics, the Durbin–Watson coefficient is 2.194, indicating a lack of autocorrelation in the residuals. The Jarque–Bera coefficient is 1.120 with a *p*-value of 4.14×10^{-244}, indicating that the residuals are still extreme, and additionally, there is significant skewness (−4.688) and kurtosis (27.178). The value of Cond. No. (6.8×10^6) indicates very high collinearity. To summarize this part of the analysis, adding interactions and quadratic terms did not improve the model's quality. This picture suggests strong nonlinear relationships that are elusive to OLS.

In the case of the Random Forest model (estimated on the basis of stationary data obtained after differentiating), the obtained results of $R^2 = 0.8368$ (model explains 83.68% of the variability in the dependent variable y) and RMSE = 573.99 show that this is the best result among all models (Table 4). The importance of the variables is as follows: the key variable is x1 (0.3904), the variable P (0.2875) has a significant importance, the importance of the variable E (0.1326) is small, while the importance of the variables x2 and I is very small. Thus, the RF model indicates the crucial importance of the variables x1 and P. The last model (also estimated on the basis of data after differentiating), the SVR (RBF) model, has results of $R^2 = -0.0318$ and RMSE = 1443.3353. This means that this model does not fit the data at all, showing signs of misspecification or lack of scaling of variables.

As can be seen, only the ML methods yielded clearly better results. Importantly, the RF model performed very well despite the previous problems with collinearity and nonlinearity because it utilizes a multi-tree aggregation method, does not require normality, and is not sensitive to collinearity. In contrast, the SVR model performed very poorly, meaning that the model performs worse than a simple average, and its RMSE is more than twice as bad as Random Forest. This value indicates incorrect hyperparameter matching, improper variable rescaling, or an inability of SVR (with the RBF kernel) to capture the data structure. In summary, the comparison of all models clearly indicates that Random Forest is by far the best model among those analyzed. It achieves the highest R-squared (0.8368) and the lowest RMSE (573.99), and additionally provides a stable and intuitive interpretation of variable importance. OLS models—both linear and nonlinear—prove to be completely inadequate due to a lack of statistical significance, poor fit, nonnormality of residuals, collinearity, and structural nonlinearity of the relationships. SVR also struggles with the data, producing results suggesting misspecification. In light of these comparisons, Random Forest best reflects the economic predictive associations, indicating that electricity prices (x1) and the size of the economy (P) have a key importance for predicting the value

of the dependent variable, confirming the observations from the theoretical part of the analysis and allowing for further economic conclusions.

Table 3. Non-Linear Regression OLS Model parameters (variable x1 represents electricity prices; variable x2 represents gas purchase prices, variable I represents inflation, variable P represents GDP, dummy variable E represents the period of operation of the EU ETS MSR). Calculations based on stationary data obtained after differentiating.

Non-Linear Regression OLS						
	Coef	**Std Err**	**t**	**P > |t|**	**[0.025**	**0.975]**
const	-1.295×10^4	2.65×10^4	−0.489	0.628	-6.71×10^4	4.12×10^4
x1	−142.1490	112.844	−1.259	0.218	−373.023	88.725
$x1^2$	−0.0181	0.027	−0.660	0.514	−0.074	0.038
x2	2.6722	4.910	0.544	0.590	−7.371	12.715
$x2^2$	0.0017	0.010	0.173	0.864	−0.019	0.022
P	0.0121	0.026	0.472	0.640	−0.040	0.064
log(P)	−240.0200	1018.726	−0.236	0.815	−2323.549	1843.509
I	144.3367	264.927	0.545	0.590	−397.500	686.174
E	−273.2236	651.349	−0.419	0.678	−1605.382	1058.934
x1*x2	−0.0226	0.064	−0.352	0.728	−0.154	0.109
x1*logP	12.5402	10.064	1.246	0.223	−8.043	33.123
R-squared:					0.219	
Adj. R-squared:					−0.252	
F-statistic:					0.2146	
Prob (F-statistic):					0.993	
Log-Likelihood:					−345.69	
AIC (Akaike Information Criterion):					713.4	
BIC (Bayesian Information Criterion):					732.0	
Omnibus:					76.422	
Durbin–Watson:					2.194	
Prob(Omnibus):					0.000	
Jarque–Bera (JB):					1120.819	
Skew:					−4.688	
Prob(JB):					4.14×10^{-244}	
Kurtosis:					27.178	
Condition No.					6.80×10^6	

Source. Self-analysis.

Table 4. ML models (Random Forest and SVR). Calculations based on stationary data obtained after differentiating.

Random Forest	
R-squared:	0.8368
RMSE:	573.99
Importance of variable x1	0.3904
Importance of variable x2	0.0907
Importance of variable I	0.0988
Importance of variable P	0.2875
Importance of variable E	0.1326
SVR	
R-squared:	−0.0318
RMSE	1443.3353

Source. Self-analysis.

5. Discussion

5.1. Policy and Managerial Implications of the Results

The results obtained—namely, a distinct negative predictive association between electricity prices and the number of active SMEs alongside the absence of comparable relationship for gas prices—have direct implications for public policy and corporate management. First, they suggest that electricity costs constitute potential barrier to entry and survival, particularly in activities with a high share of energy in operating expenses. This means that instruments mitigating short-term volatility in electricity prices (e.g., contracts for difference, long-term PPAs for SMEs, support for energy efficiency and self-generation) may yield asymmetrically large developmental benefits relative to general gas subsidies. Governments making long-term political and economic decisions should link electricity price forecasts with estimated costs of SME support programs. This approach will allow for rationalizing the financial, social, and economic costs of energy transition. Knowledge of the potential interdependencies between key phenomena will allow for increased precision of action, recognition of the complex effects of changes introduced within a dynamic process, and addressing various risks. Decision-makers should deliberately regulate such process, its pace and areas of impact based on reliable knowledge. Therefore, the findings obtained in the presented analysis expand the knowledge available so far, fitting into a more general context of phenomena already studied by other authors [4,11,27,28,42]. Second, the findings reinforce the thesis by other authors that capital constraints in SMEs cause even projects with a positive NPV to be postponed; consequently, the cost of electricity affects not only current margins but also investment decisions and the pace of scaling operations [3,6,44].

Alternatively, one could argue that the identified predictive association is merely an indirect effect of a more general business cycle (inflation, interest rates, fluctuations in demand), and that the electricity price acts here as a proxy variable for the macroeconomic climate. Such an interpretation is, however, unlikely for at least three reasons. First, comparable microeconomics studies from the period of the energy crisis have demonstrated specific adjustment channels to the electricity price shock (production cuts, relocation, closure of the most energy-intensive activities), which are difficult to explain by the business cycle alone [24,44]. Second, numerous studies document the mechanical pass-through of the costs of climate policy to electricity prices (including via the EU ETS), which strengthens the importance of the electricity component rather than general inflation [14,15,29,35]. Third, Poland's structural conditions—a high share of coal and a relatively slower departure from conventional technologies—increase SMEs' exposure to fluctuations in electricity prices more than to gas costs [16,17,39].

5.2. Relations of the Results to the Literature: Confirmations, Extensions, Discrepancies

In a broader context, the literature provides a coherent backdrop for our findings. On the demand–cost side, studies for the EU indicate that rising energy prices reduce firms' profitability and encourage downsizing, with the strongest effect among SMEs [12,34]. On the regulatory side, research on the accumulation of 'green-digital' burdens (reporting, taxonomy, efficiency standards) demonstrates a disproportionate weight for SMEs—which, combined with high electricity bills, heightens the risk of 'crowding out' weaker entities from the market [3,8,32]. On the energy market side, reviews by the European Commission and the OECD emphasise that in energy-intensive sectors the share of energy in costs is structurally high and susceptible to price shocks, and that the period after 2021 brought an above-average increase in this item [27–30]. The results of macro-modeling studies (DSGE/NAWM, CGE) additionally indicate that the rapid implementation of Green Deal objectives implies a transitory rise in energy prices and pressure on corporate costs be-

fore the benefits of investment and decarbonisation of the mix materialise [20,29,37,51]. Finally, financial approaches (EIF/EIBIS) confirm that the rising cost of energy and more expensive external financing jointly constrain SMEs' propensity for efficiency and innovative investments [6,43,44].

Against this background, our findings reinforce earlier research results regarding the key role of the electricity price in firms' production and investment decisions [12,23,24], broaden it by adding the dimension of business demography (the number of active SMEs), and nuance the thread of the relative insignificance of the gas price in Polish conditions—which may be a function of the structure of energy carriers and the pattern of consumption in SMEs. Although changes in gas prices determine the value of an important component of the costs of running a business by SMEs, in general (when it comes to the Polish reality) they are probably not of key importance for making a decision on starting, continuing or ceasing activity. In light of the results, one might wonder why gas prices have shown a negligible predictive association with the number of SMEs. One possible explanation for this phenomenon is that SMEs, compared to large corporations, are more likely to engage in service or commercial activities, and therefore are less likely to engage in energy-intensive manufacturing activities (this is confirmed by data available on the website of the Polish Central Statistical Office). The added value of our analysis is the testing of the ML Random Forest model as an effective tool for exploring the predictive association between changing electricity prices and the number of SMEs in the context of implementing the Green Deal policy. Our findings are of real importance because they provide a path forward for decision-making regarding phenomena that are subject to highly complex relationships, elusive to more traditional statistical modeling approaches (linear and nonlinear regression OLS). Thus, the analysis fills a current research gap and can provide useful support to other researchers and decision-makers in preparing the necessary expert opinions and decisions. Until now, the literature lacked a similar approach to considering the actual predictive association between the phenomena under study. The practical conclusion is unambiguous: targeted instruments that reduce SMEs' exposure to electricity price shocks—together with improved access to finance for investments in efficiency, self-generation and demand flexibility—should become a policy priority if the aim is to maintain entrepreneurship and growth capacity under the realities of the Green Deal [4,11,27,28,42,44]. The research results of other authors confirm that governments can effectively improve the ecological efficiency of entire sectors of the economy through the mechanism of stimulating innovation related to green technologies [52].

5.3. Limitations of the Study

The limitations of the study presented in this publication arise, firstly, from focusing solely on selected categories of costs associated with meeting the energy consumption needs of SMEs. SMEs as a general category encompass many industries and types of economic activity. Individual enterprises may carry out similar processes based on different technologies. Gastronomy and the various methods of heating dishes may serve as an example. A similar situation applies to the heating of tourist facilities and all other activities. However, recourse to electricity is by far the most widespread, which justifies focusing attention primarily on this type of energy. Gas fuel also (at least in Poland) remains one of the basic energy carriers, which is why it was included among the analysed elements of reality. Of course, among the surveyed companies, there are those that do not use gas at all, as well as those for whom it is a raw material generating expenses similar to the cost of purchasing electricity. This situation could potentially reduce the usefulness of the presented model. Another limitation of the analysis is related to the fact that the possibility of a lagged effect of the independent variable on the dependent variable was not examined

during model development. As regards observing changes in the number of SMEs over the past decade, as a limitation of the analysis one should consider, for example, the omission of the importance of factors such as the pandemic, demographic changes, the war in Eastern Europe, etc. There are many phenomena that may potentially affect the number of SMEs, but the proposed model focuses only on one of the key sources of the variability of this group of enterprises.

5.4. Directions for Further Research

As regards directions for further research, firstly, further comparative analyses can be conducted on the basis of data from other areas of Europe. In such a case, with the additional inclusion of the structure of energy sources consumed in individual countries, the comparative study may enrich the available knowledge by exploring the predictive association of an additional parameter with the rate of change in the number of SMEs. Naturally, a direction for continuing research in the context of the experience of a country such as Poland would be an attempt to expand the model with additional explanatory variables. Thus, the directions for further research are, on the one hand, deepening (adding detail) and, on the other, territorial expansion. It is also possible to extend the analysis by examining the lagged effects of individual variables (some attempts to perform such calculations for the linear model were made by the authors but they were not included in the article because they did not yield satisfactory results). Because the study aggregated all sectors (services, trade, manufacturing), this may mask important heterogeneous effects. This limitation has already been mentioned, but future research could explore this area through distributed analysis (e.g., by primary economic sector).

6. Conclusions

The thesis formulated in the theoretical part of the discussion ("One of the key categories of costs in the case of small and medium-sized enterprises, which significantly influences their decision to commence or continue, or possibly to cease, operations, is the cost of purchasing electricity and gas.") was confirmed only with regard to the cost of purchasing electricity in the form of a predictive association. However, this is useful knowledge. The economic importance of electricity is steadily increasing. Countries structurally ill-suited to rapidly meeting the demands of the Green Deal face a gigantic challenge. Awareness of how SMEs may respond to the current pace of change prompts the search for effective remedies to protect this important group of enterprises. SMEs themselves, understanding the scale of the phenomenon, should also actively seek opportunities to reduce the level of energy consumed, for instance by purchasing more efficient technological solutions. The basis of all actions and decisions, however, should be an appropriate assessment of the situation, in which the analysis presented may be of assistance.

The findings resulting from the conducted analysis are potentially valuable to at least three groups of readers. First, the scientific community has gained a more in-depth understanding of the predictive association between key energy purchase costs and the SME sector. This allows for the future to continue this line of research, for example, by developing forecasting models that take into account the specific context described for countries such as Poland, with a complex, unfavorable energy mix structure that is difficult to rapidly transform. The second group consists of decision-makers, who should be interested in improving their precise understanding of the economic consequences of their decisions. Thanks to the accessible nature of the results we present, our study can inspire such readers to undertake research identifying effective tools for mitigating the negative effects of the energy transition from the perspective of the SME sector. Finally, thanks to our findings, SMEs themselves gain an additional strategic perspective on assessing

the development of the situation. This allows them to engage in a substantive discussion regarding the form of systemic support addressed to them by decision-makers.

Author Contributions: Data curation: M.B.; Formal analysis: A.T.; Investigation: M.B. and A.T.; Methodology: M.B.; Resources: M.B. and A.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare that there is no conflict of interest.

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