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Hedging effectiveness in EU energy market: A case study

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ABSTRACT

The current conditions in the European Union energy market are closely linked to significant fluctuations in both demand (due to the marked reduction in economic activity across the EU region due to the implementation of protection measures against COVID-19) and supply (characterized by high volatility in electricity pricing due to irregular fluctuations in fossil fuel prices). Given these challenging conditions, energy companies are forced to adopt hedging strategies to navigate the complexities associated with the extensive market risks. This study empirically examines the impact of the implementation of hedging strategies (measured by the value of financial derivatives relative to the total assets of company values) on financial value (assessed using the Tobin Q ratio) of power generation companies operating in the EU region for 2016 - 2021. The results, derived from an econometric study using panel data analysis, revealed that a potential increase in the value of financial derivatives as a percentage of total assets held by power generation firms in the EU region positively affects the Tobin Q index and, consequently, enhance their financial value. There is no statistically significant evidence to support the relationship between the growth of the domestic forward electricity market and the Tobin's Q index.

Contribution/ Originality: The present study contributes to the academic research of the impact of hedging strategies on firms' financial value, focusing on EU energy-generating companies. The results obtained have particularly significant policy implications for companies due to energy's further upgraded importance in modern times.

1. INTRODUCTION

It is a fact that the efficient functioning of the electricity market plays an important role in the conduct of a variety of economic activities. The price of electricity, which is a tradable commodity, depends on the amount of electricity demanded and supplied.

Girish and Vijayalakshmi (2013) conducted an extensive literature review, and categorized the factors that determine the current price (spot price) of electricity into four (4) sub-categories: basic factors (including but not limited to fossil fuel prices, ambient temperature, weather conditions, production cost/unit of product, seasonal fluctuations in electricity demand), operational factors (including but not limited to electricity distribution network maintenance, congestion in electricity transmission), strategic factors (including but not limited to bilateral power purchase agreements, electricity market structure, existence or non-existence of an energy exchange) and historical factors (e Electricity generating companies, , are required to address the full range of impacts that may be caused to their operating results by the ongoing volatility of the above-mentioned factors. In order to achieve this, they use certain financial derivatives products primarily for hedging and secondarily for speculation.

The level of a company's financial value is an important parameter in order to attract investors who will finance its activity with a view to making a profit. Thus, the main research question of this study is whether and to what extent the implementation of hedging strategies by EU-based electricity generating companies affects their financial value. A sample with quarterly panel data for the period 2016-2021 of 10 electricity generating companies based in 10 EU-27 member states (MS), half of which have a developed forward electricity market and the other half do not, was studied.

As this is the first time such a survey has been carried out for electricity generating companies based in the EU-27, the findings are particularly relevant for the formulation of EU energy autonomy policies, especially in times of crisis, and confirm similar previous studies carried out for electricity generating companies globally.

The present study is structured as follows. At the beginning, empirical results from previously conducted scientific studies with a related question are summarized.

This is followed by a presentation of the variables and the main assumptions concerning the way of collecting the economic data corresponding to the companies under consideration. Then the methodology used to analyze the panel data is presented followed by an evaluative presentation of the descriptive statistics of the sample and a critical analysis of the econometric findings. Finally, the main conclusions of the conducted research are summarized, and suggestions for further extension are presented.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Geyer-Klingeberg, Hang, and Rathgeber (2021) surveyed 71 studies performed during 2001-2018 and concluded that there is a systematically higher effect on the value of a company from the use of derivatives to hedge currency risk, compared to the effect caused by the use of derivatives related to hedging interest rate risk and the risk arising from the price fluctuation of primary commodities.

Tobin's index is being widely used in the recent literature for studying the effect of the application of hedging strategies on the financial value of firms in various industries (indicatively, Ferri, Tron, Colantoni, and Savio (2022) in telecoms; Balasuriya and Bøen (2019) in gold mining), and countries (indicatively, Taipale (2022) for Finland; Hadian and Adaoglu (2020) for Malaysia; Hossain and Gulay (2020) for China; Akpınar and Fettahoğlu (2016) for Turkey; Walker, Kruger, Migiro, and Sulaiman (2014) for South Africa; Ahmed, Azevedo, and Guney (2014) for the UK).

The main studies previously conducted and relevant to the main research question of this study are summarized as follows:

Lookman (2004) studying companies involved in the US oil and gas production and exploration industry, attempted to investigate whether hedging strategies associated with volatility in commodity prices have a positive (or negative) effect on the companies in the industry under consideration. The author separates the companies in the sample by taking into account whether the company's main or secondary activity is oil and gas production and exploration.

Based on the above criterion, the companies which have the above mentioned as their main business activity are obtained. Therefore, these companies are considered to be the main risk. On the other hand, the companies, which are also engaged in other activities, treat the above risk as a secondary risk. The main conclusion of the investigation is that the companies which treat the above mentioned risk as their main risk do not benefit from hedging it. In contrast, the other companies in the sample improve their value by hedging the secondary risk.

Jin and Jorion (2006) by studying US oil and gas producing companies, the authors concluded that there is no statistically significant difference in the financial value of the sample companies that implement hedging strategies compared to other companies. The authors acknowledge that the above conclusion contradicts the findings of other studies. They emphasize that companies depending on their characteristics face the same risks to different degrees. For example, a multinational oil producer faces a higher degree of exposure to commodity risk and/or foreign exchange exposure than a domestic firm.

Pérez-González and Yun (2013) studying US electricity and gas utilities, attempted to investigate whether and how (among other things) the valuation of electricity and gas utilities is affected by the use of so-called weather derivatives.

According to the researchers, the use of these derivative financial products as a hedging tool led to a significant increase in the real value of the companies under investigation.

Panaretou (2014) in her research on large UK companies (other than those engaged in financial activities), attempted to investigate the degree of impact of three (3) main forms of hedging (exchange rate, interest rates, primary commodity prices) on the financial value of large UK companies that do not engage in financial activities. It is important to note that the sample of companies includes (among others) 38 companies active in the provision of utilities.

According to the results, the greatest benefit is derived from hedging exchange rate risk. In addition, there is a positive effect on the value of the companies through the hedging of interest rate risk, while at the same time there is no statistically significant evidence for the effect of hedging of primary commodity prices.

Samitas, Tsakalos, and Eriotis (2011) focus on investigating the extent of the effect of the aforementioned strategies during the recent financial crisis (2007-2009) by studying 50 companies operating in the energy sector globally (analyzing panel data).

Using the Tobin's Q index, they conclude that the subset of companies that apply hedging strategies achieve (during financial crisis' periods) a statistically significant positive effect on their financial value as compared to the subset of companies that declared that they do not use corresponding derivative financial products.

3. METHODS AND MATERIALS

3.1. Data Description

As shown in literature, the capital structure has a significant impact on energy firms' profitability and effectiveness (indicatively (Georgakopoulos, Toudas, Poutos, Kounadeas, & Tsavalias, 2022; Kester, Georgakopoulos, Kalantonis, & Boufounou, 2013; TeRiele, Georgakopoulos, Toudas, & Boufounou, 2022)). The main research question examined in the present study is whether and to what extent the implementation (or not) of hedging strategies by the EU-27 power companies under consideration during the period 2016 - 2021 affects their financial value. The level of a company's financial value is an important parameter to attract investors who will finance its activity with the aim of achieving profit.

It should be noted that the scope of the hedging strategies applied by power generating companies is documented by the value of derivative financial products as valued in the respective published balance sheets. To perform the econometric analysis, the collection of corresponding financial data from the companies comprising the study sample is imperative, using published accounting data.

Financial data serves as the foundation for determining the respective values of the variables under examination. Table 1 provides a brief overview of the basic assumptions applied during the gathering of the study data.

Table 1. Assumptions applied during the collection of financial data.

No	Description
1	The financial data is presented on a quarterly basis. Instances where corresponding availability on a semi-annual basis was present were supplemented by utilizing the numerical average of the available observations. For example, the numerical average of observations for the 12th month of 2020 and the 6th month of 2021 corresponds to the observation for the 3rd quarter of 2021.
2	The fair value of derivative financial instruments pertains to their assessment as financial assets over both short-term and long-term periods.
3	Moreover, the total fair value of derivative financial instruments is considered irrespective of their classification at levels 1, 2, or 3.
4	The total fair value of derivative financial instruments is taken into account regardless of whether they are intended for risk hedging or/And speculative purposes.
5	In cases where published financial statements lack a clear reference to the fair value of derivative financial instruments, the remainder of the "other financial products" account is considered.
6	Certain companies included in the examined sample do not disclose the exact amount of net debt in their financial statements. In such cases, net debt is derived from the formula: Net debt=Short−Term financial liabilities +Long −term financial liabilities−Cash equivalents and other equivalents
7	In cases where the value of cash equivalents surpasses the total financial liabilities, the net debt assumes a negative value.

Table 2 presents the key figures of the power companies included in the sample and the EU Member State where they are based. It should be noted that according to the data published by Eurostat the total available quantity of electrical energy in the EU-27 for 2021 was 2,546,229.48 Giga-Watt-hours (GWh.), Companies were selected on the basis of the availability of their published financial data in the periodicity necessary for this study for the whole of the period under consideration 2016-2021 (as shown in Table 2, 80% of all companies in the sample publish the requested financial data on a quarterly basis).

Table 2. Key information on sample companies.

No.	Company name (Brand)	Country (Headquarters)	Electricity market sector	Financial data reporting frequency	Domestic forward electricity market presence	Electricity generation (GWh) (Sample firms) 2021	Available to internal market electricity (GWh) (Eurostat) 2021	Electricity generation of sample firm to total available to internal market electricity (%) 2021	% Other
1	RWE	Germany	Production/Trade	Quarterly	Developed	101,298.00	468,098.45	21.60%	78.40%
2	EDF group	France	Production/Trade	Semi-annual	Developed	402,500.00	440,282.81	91.40%	8.60%
3	Enel group	Italy	Production/Trade	Quarterly	Developed	47,964.00	318,075.00	15.10%	84.90%
4	Energa group	Poland	Production/Trade	Quarterly	Developed	4,100.00	154,437.98	2.70%	97.30%
5	Fortum	Finland	Production/Trade	Quarterly	Developed	68,800.00	82,738.07	83.20%	16.80%
6	Naturgy energy group	Spain	Production/Trade	Quarterly	Underdeveloped	16,948.00	231,643.27	7.30%	92.70%
7	Cez group	Czech Republic	Production/Trade	Quarterly	Underdeveloped	56,000.00	62,996.30	88.90%	11.10%
8	Ignitis Gamyba	Lithuania	Production/Trade	Quarterly	Underdeveloped	1,760.00	11,493.18	15.30%	84.70%
9	Public power corporation	Greece	Production/Trade	Semi-annual	Underdeveloped	45,550.00	54,906.24	83.00%	17.00%
10	Verbund	Austria	Production/Trade	Quarterly	Underdeveloped	31,306.00	66,069.98	47.40%	52.60%
					Totals	776.226.00	1,890,741.29	41.10%	58.90%

Source: Annual Financial Reports of Companies - (Eurostat, 2022).

The overall amount of electricity produced (2021) by the sampled companies represents around 30% of the total quantity available for consumption in the EU-27 during the same year, and 41.1% of the total quantity available for consumption (including imports) in the 10 EU Member States where the companies in question are based. Figure 1 below illustrates the share of electricity produced by the sampled companies of the total amount of electricity available for consumption in the country where each company is headquartered for 2021.

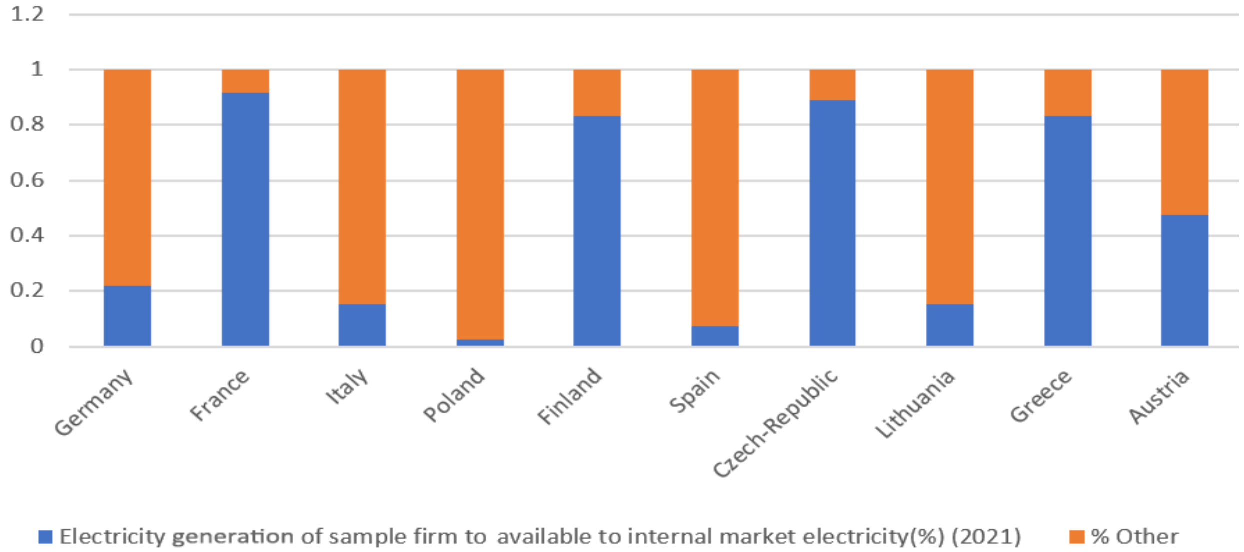

Figure 1. Share of electricity produced by the sampled companies in the total amount of electricity available in the country of the company's headquarters (2021).

In the analysis, the total sample is also divided into two (2) subgroups, each comprising five (5) companies: The first sub-group includes companies based in EU Member States with a developed forward electricity market, while the second sub-group consists of companies based in EU Member States with a non-developed forward electricity market. In the econometric model developed, an assessment of this parameter (whether and to what extent the developed domestic forward market has a positive effect on the financial value of the companies under consideration) is performed. Data regarding the development level, in terms of liquidity, of forward markets for electricity in EU Member States were obtained from the European Agency for the Cooperation of Energy Regulators (EU-ACER). Specifically, the EU-ACER's report monitoring the wholesale electricity market in the EU for the year 2020 includes statistical data on the historical evolution of liquidity levels (per Member State) of the respective domestic forward market for the years 2016 – 2020. According to the EU-ACER, liquidity levels are measured by considering the tradable volume of electricity subject to negotiation either on an organized financial market or between two contracting parties, expressed as a multiple of the actual consumed quantity of electricity during the reference year. This measure serves as an indicator of the size of the respective forward market. The chronological evolution (2016 – 2020) of this measure for the main forward electricity markets in the EU (including the UK) is illustrated in the following Figure 2 from which it is apparent that the three (3) most developed forward electricity markets in the EU-27 are in Germany, France, and the Scandinavian countries (specifically Sweden and Finland as EU Member States). Conversely, markets with the lowest liquidity levels are identified in Bulgaria, Belgium, and Hungary. It is important to note, however, that some Member States have not developed a forward electricity market with sufficient liquidity and, as a result, are not represented in the relevant Figure 2.

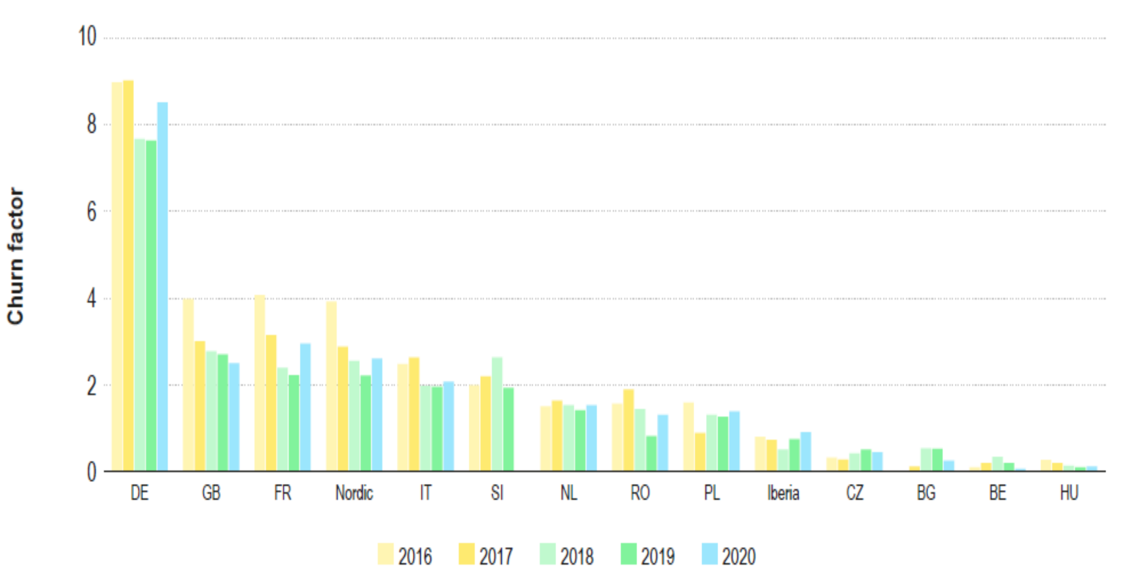

Figure 2. Temporal evolution of liquidity levels in forward electricity markets in the EU (2016 – 2020).

Source: EU-ACER (2022).

3.2. Model Specification

The main research of this study revolves around examining the impact, or lack thereof, of the implemented risk mitigation strategies on the valuation of EU-27 power companies throughout the period from 2016 to 2021. Addressing this question requires a dependent variable measuring the market value of a company. Consequently, at least one independent variable should quantify the extent to which derivative financial products, which serve as the main instruments for implementing risk mitigation strategies, are used.

In accordance with the outlined considerations, the formulated econometric model encompasses one dependent variable and three independent variables, each associated with specific magnitudes presented as follows:

- Dependent Variable (Y): The firms' value is measured using the Tobin's Q index. In literature there are many different definitions of Tobin's Q; indicatively (Panaretou, 2014; Samitas et al., 2011). In the present study we adopt the Market Value to Book value (MV/BV) approach, also used by Samitas et al. (2011).
- Independent variable (X1): This variable corresponds to the following calculation formula:

$$\text{X1} = \frac{Fair\ value\ of\ financial\ derivatives}{Accounting\ value\ of\ assets}$$

Considering that the sum of assets reflects the valuation of resources utilized by each respective company for the efficient execution of its activities, the aforementioned ratio underscores the importance assigned to the adoption of hedging (and/or speculative) strategies. The ratio, as encapsulated by Tobin's Q index, serves as a metric that encapsulates the interplay between market value, debt, and replacement value of assets. Importantly, it signifies the proportion of the market value of the company's circulating stocks and debt relative to the replacement value of its assets.

- Independent variable (X2): This variable corresponds to the following formula:

$$X2 = \frac{Net\ debt}{Total\ Liabilities}$$

The net debt serves as an evaluation metric for a company's financial liquidity and according to the Corporate Financial Institute is computed according to the following equation :

$$Net\ debt = Short - term\ \&\ Long - term\ Debt - Cash\ and\ Equivalents$$

Where:

Short-term & Long-term Debt: It pertains to the financial obligations that become due within the next twelve (12) months or beyond that period, respectively (e.g., bank loans, bonds, promissory notes, etc.).

Cash and Equivalents: It encompasses the elements of current assets with the highest degree of liquidity (e.g., bank accounts, cash, etc.).

It is important to note that the net debt value, calculated as the difference between short-term and long-term debt and cash and equivalents, serves as a crucial measure of a company's liquidity. Specifically, a higher net debt value corresponds to a lower liquidity level of the respective company. Furthermore, a negative net debt value indicates that the total financial obligations of a company are covered by its liquidable assets.

The use of the independent variables X1 and X2 in the form of ratios is driven by two (2) key reasons:

1. *Currency Disparity:* Given that the financial statement figures of the sample companies are expressed in different currencies, the use of ratios was deemed expedient to derive unit-free numbers.
2. *Size-Independent Comparison:* The use of ratios enables the comparison of the examined companies with respect to these variables, irrespective of their size. This approach facilitates a meaningful analysis of the impact of risk mitigation strategies and market characteristics on electricity-producing companies within the EU-27, offering insights that transcend the inherent variations in company sizes and currencies.

- Independent variable (X3): A binary pseudo-variable assumes the values:

0: Assigned to companies in the sample based in EU Member States with either no organized forward market for electricity or a forward market characterized by low liquidity.

1: Assigned to companies in the sample based in EU Member States with an organized forward market for electricity characterized by high levels of liquidity.

Using this independent variable, a secondary investigation is conducted into whether the existence of a domestic organized forward market for electricity with high liquidity influences the value of electricity-producing companies in the EU-27.

3.3. Method of Analysis

The data utilized in the context of this research exhibit two (2) primary characteristics:

a) They pertain to financial data from various entities, specifically electricity-producing companies.
b) They showcase the temporal evolution of economic data for each entity, presented on a quarterly basis spanning the years 2016 – 2021.

Given these characteristics, it is evident that econometric analysis within the framework of this study necessitates the use of the panel data analysis method. Typically, panel data observations encompass at least two (2) individual dimensions, as denoted by the Cross-sectional dimension (i) and the Time-series dimension (j). It is important to highlight that the typical form of data mentioned above can become highly intricate when additional dimensions are considered. According to Hsiao (2007) one of the primary advantages of this method lies in its capability to offer a more detailed approach to complex behavior. This level of granularity would not be attainable through the exclusive study of either cross-sectional data or time series data. The use of panel data analysis, by incorporating both dimensions, enables a more comprehensive understanding of the dynamics and nuances present in the economic performance of electricity-producing companies over the specified period.

As noted by Zulfikar and STp (2018) there are three (3) approaches to panel data analysis:

a) *Common Effect Model:* It represents the simplest form of integrating cross-sectional and time-series data. The model operates under the assumption that the behavior of the data is consistent both among different entities and over time. It is illustrated as follows:

$$Y_{it} = \alpha + \beta \cdot X_{it} + \varepsilon_{it} \quad (1)$$

Where:

α: Regression constant.

β: Coefficient for each independent variable.

i: Entity index (1 to N, number of entities).

j: Time index (1 to T, time periods).

εit: Regression error term.

b) *Fixed Effect Model:* This approach operates under the assumption that each individual entity may possess distinct statistical characteristics, and these differences are captured by entity-specific fixed effects. In this regression, dummy variables are automatically introduced (as many as the entities included in the analysis), taking each the value of 1 for observations related to specific entity and 0 for the rest. It is illustrated as follows:

$$Y_{it} = a_i + \beta \cdot X_{it} + \varepsilon_{it} \qquad (2)$$

Where:

ai: Entity-specific intercept (regression constant).

β: Coefficient for each independent variable.

i: Entity index (1 to N, number of entities).

j: Time index (1 to T, time periods).

εit: Regression error term.

c) *Random Effect Model:* Like the fixed effect model, this method assumes that the data concerning each entity exhibit different statistical characteristics. In this case, the variation is expressed through a random variable, specifically in the form of the residual of the individual regression.

$$Y_{it} = a_i + \beta \cdot X_{it} + \varepsilon_{it} + u_i \qquad (3)$$

Where:

ai: Entity-specific intercept (regression constant).

β: Coefficient for each independent variable.

i: Entity index (1 to N, number of entities).

j: Time index (1 to T, time periods).

εit: Regression error term

ui: Entity-specific error term

In the present study, the Hausman test was used for selecting the appropriate form (fixed or random effect) of the panel data approach, defining the testing hypotheses as follows:

H_0: Do not reject (accept) the random effect model.

H_1: Reject the random effect.

4. EMPIRICAL RESULTS - DISCUSSION

In this section the findings from the statistical and econometric analysis, conducted using EVIEWS 7 software are presented structured as follows: Initially, the primary Descriptive Statistics of the variables included in the econometric model are presented in two distinct dimensions:

i. Cross-Sectional Analysis: Descriptive statistics are analyzed across entities.

ii. Based on the Characteristic of Developed or Undeveloped Domestic Forward Market for Electricity: The statistics are also delineated based on whether the entities operate in a developed or undeveloped domestic forward market for electricity.

In addition, the temporal evolution of the values of the variables under examination is depicted through appropriate charts.

Secondly, the principal results of the econometric analysis are outlined, encompassing the outcomes of the corresponding statistical test concerning the selection of the appropriate approach for handling the data in panel format.

This structured presentation ensures a comprehensive understanding of the statistical and econometric outcomes, offering insights into both the descriptive characteristics of the variables and the substantive results of the applied econometric analysis.

4.1. Descriptive Analysis

Table 3 presents the descriptive statistical analysis of the variables included in the econometric model based on cross-sectional analysis.

Table 3. Descriptive statistics for the dependent and the independent variables by sample company.

Descriptive statistics for TOBIN_S_Q Categorized by values of COMPANY_ID Sample: 2016Q1 2021Q4 Included observations: 240						
Company_ID	**Mean**	**Median**	**Max.**	**Min.**	**Std. dev.**	**Obs.**
1	1.067	1.065	1.546	0.780	0.193	24
2	0.591	0.569	0.859	0.407	0.109	24
3	1.256	1.114	1.986	0.741	0.411	24
4	0.394	0.359	0.614	0.248	0.094	24
5	1.212	1.156	1.770	0.700	0.294	24
6	1.454	1.407	3.129	0.941	0.497	24
7	1.166	1.078	2.732	0.790	0.443	24
8	1.046	1.041	1.312	0.824	0.128	24
9	0.286	0.119	1.086	0.074	0.308	24
10	2.186	2.134	5.400	0.762	1.238	24
All	1.066	0.987	5.400	0.074	0.713	240
Descriptive statistics for X1 Categorized by values of COMPANY_ID Sample: 2016Q1 2021Q4 Included observations: 240						
Company_ID	Mean	Median	Max.	Min.	Std. dev.	Obs.
1	0.148	0.103	0.458	0.048	0.104	24
2	0.019	0.018	0.027	0.013	0.004	24
3	0.052	0.040	0.190	0.019	0.038	24
4	0.004	0.003	0.013	0.000	0.003	24
5	0.135	0.028	0.640	0.013	0.187	24
6	0.032	0.032	0.049	0.016	0.010	24
7	0.145	0.105	0.475	0.065	0.106	24
8	0.009	0.008	0.028	0.000	0.008	24
9	0.001	0.000	0.004	0.000	0.001	24
10	0.032	0.022	0.136	0.012	0.031	24
All	0.058	0.024	0.640	0.000	0.095	240
Descriptive statistics for X2 Categorized by values of COMPANY_ID Sample: 2016Q1 2021Q4 Included observations: 240						
Company_ID	Mean	Median	Max.	Min.	Std. dev.	Obs.
1	0.263	0.297	0.585	-0.003	0.150	24
2	0.153	0.155	0.169	0.135	0.010	24
3	0.367	0.366	0.409	0.316	0.021	24
4	0.466	0.471	0.549	0.351	0.059	24
5	0.189	0.133	0.533	-0.244	0.235	24
6	0.525	0.536	0.589	0.437	0.042	24
7	0.334	0.351	0.451	0.109	0.090	24
8	-0.152	-0.139	0.111	-0.526	0.193	24
9	0.349	0.368	0.413	0.149	0.067	24
10	0.451	0.441	0.559	0.326	0.073	24
All	0.294	0.363	0.589	-0.526	0.220	240

It is evident that:

- Concerning the Tobin's Q index, companies within the examined sample, on average, present an index value greater than one (1.0658). This suggests that, during the studied period, the market perceives electric power production companies to have a market value exceeding their corresponding accounting value. However, a significant range is observed in the index value, spanning approximately 5.32 units.

- Regarding the independent variable X1, it is observed that companies in the sample allocate, on average, 5% of their assets for strategic hedging or speculation. However, 50% of the companies allocate, on average, up to 2.3% of their assets for these purposes.
- Concerning the net debt value (as a percentage of total liabilities), an average value of 29.42% is observed. It is noteworthy that one out of ten companies in the sample presents, on average, a negative value for this coefficient, indicating that this specific company had a high degree of liquidity during the examined period.

Table 4 presents the descriptive statistical analysis of the variables included in the econometric model based the level of development of the domestic forward electricity market. It is evident that:

- Companies headquartered in EU member states with an undeveloped domestic forward market for electricity exhibit, on average, a higher Tobin's Q index (1.227) compared to other companies in the sample (0.904). Consequently, the existence of a domestic forward market does not substantially impact the financial value of the sample companies. This indication is further confirmed by the empirical results of the econometric analysis, which will be presented in detail in a subsequent section.
- The (average) values of variables X1 and X2 remain consistent across the development (or lack thereof) of the domestic forward market.

Table 4. Descriptive statistics for the dependent and the independent variables based on the level of development of the domestic forward electricity market.

Descriptive statistics for TOBIN_S_Q Categorized by values of X3 Sample: 2016Q1 2021Q4 Included observations: 240						
Tobin's Q by values of X3	**Mean**	**Median**	**Max.**	**Min.**	**Std. dev.**	**Obs.**
0	1.228	1.060	5.400	0.074	0.886	120
1	0.904	0.882	1.986	0.248	0.427	120
All	1.066	0.987	5.400	0.074	0.713	240
Descriptive statistics for X1 Categorized by values of X3 Sample: 2016Q1 2021Q4 Included observations: 240						
X1 by values of X3	Mean	Median	Max.	Min.	Std. dev.	Obs.
0	0.044	0.021	0.475	0.000	0.071	120
1	0.072	0.027	0.640	0.000	0.112	120
All	0.058	0.024	0.640	0.000	0.095	240
Descriptive statistics for X2 Categorized by values of X3 Sample: 2016Q1 2021Q4 Included observations: 240						
X2 by values of X3	Mean	Median	Max.	Min.	Std. dev.	Obs.
0	0.301	0.386	0.589	-0.526	0.260	120
1	0.287	0.349	0.585	-0.244	0.171	120
All	0.294	0.363	0.589	-0.526	0.220	240

The temporal evolution of the model variables, calculated as the average per period, as presented in the Figure 3 reveals the following characteristics:

- First, for the period 2016-2019, values show insignificant variability.
- Furthermore, from Q1 2020 (spread of Covid-19 in the EU) to the end of 2021, a mixed trend is observed. Specifically, both the dependent variable Y (Tobin's Q index) and the independent variable X1 exhibit a pronounced upward trend, while the dependent variable X2 shows a declining trend.

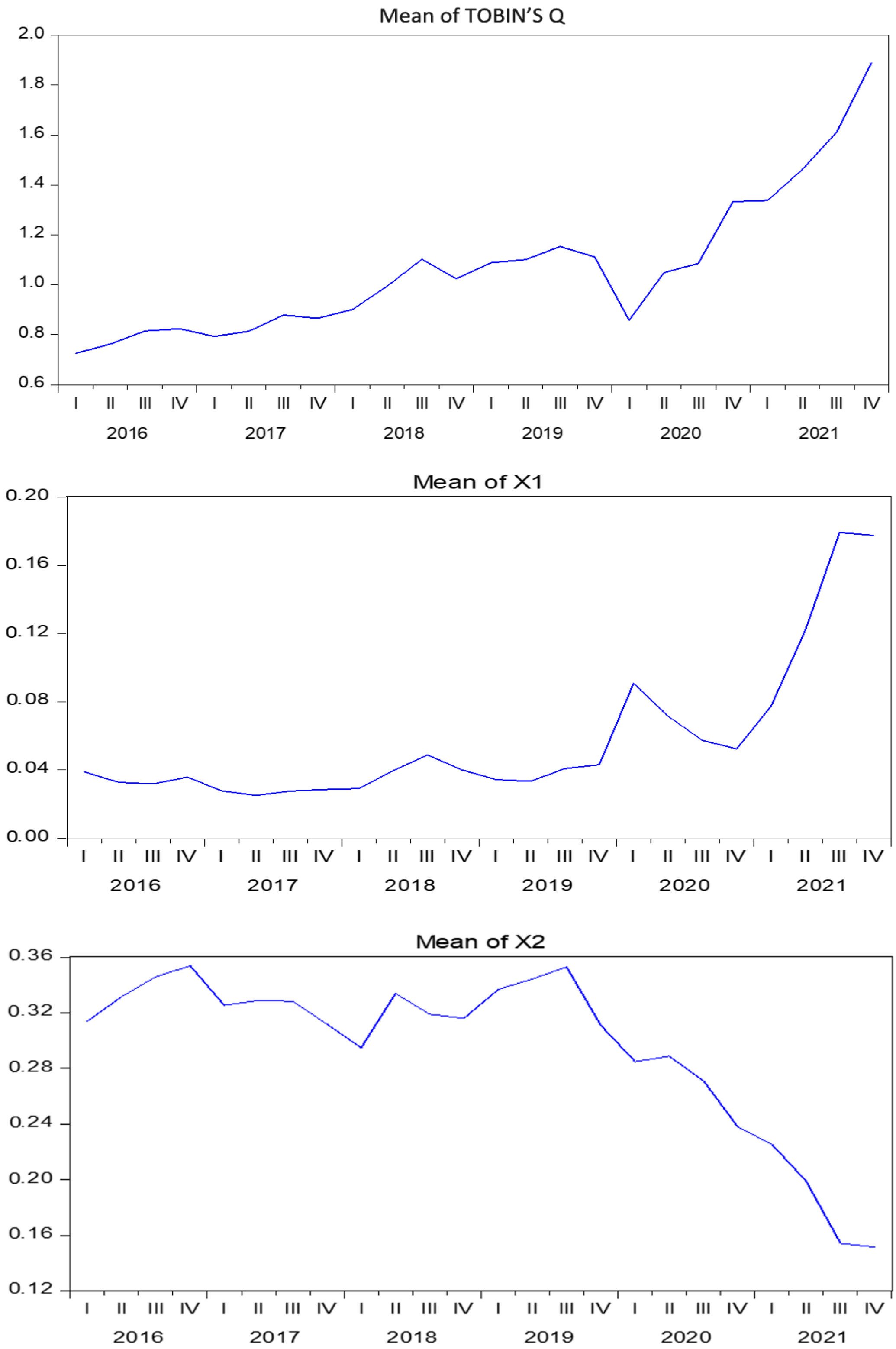

Figure 3. Dependent variable and independent variables (Total sample - common mean for 2016-2021).

In order to deal (To some extent) with the skewness in the distribution of the observations of the dependent variable Y, the logarithm of the Tobin index values was used, and as shown in Table 5 which presents the descriptive statistics of the dependent variable Y, a reduction in the coefficient of skewness (in absolute values) from 2.19 to 1.14 was achieved.

Table 5. Descriptive statistics of dependent variable in normal and logarithmic scale.

Sample: 2016Q1 2021Q4		
	TOBIN_S_Q	**Y**
Mean	1.066	-0.169
Median	0.987	-0.013
Maximum	5.399	1.686
Minimum	0.074	-2.606
Std. dev.	0.713	0.768
Skewness	2.192	-1.143
Kurtosis	11.593	4.854
Jarque-Bera	930.693	86.670
Probability	0.000	0.000
Sum	255.799	-40.677
Sum sq. dev.	121.392	140.972
Observations	240	240

Table 6. Econometric analysis results.

Dependent variable: Y
Method: Panel least squares (Common effect model)
Sample: 2016Q1 2021Q4
Periods included: 24
Cross-sections included: 10
Total panel (Balanced) observations: 240

Variable	**Coefficient**	**Std. error**	**t-statistic**	**Prob.**
C	-0.223	0.099	-2.253	0.025
X1	2.608	0.511	5.106	0.000
X2	-0.030	0.218	-0.137	0.891
X3	-0.177	0.095	-1.856	0.065
R-squared	0.107	Mean dependent var		-0.169
Adjusted R-squared	0.096	S.D. dependent var		0.768
S.E. of regression	0.730	Akaike info criterion		2.225
Sum squared resid	125.829	Schwarz criterion		2.284
Log likelihood	-263.060	Hannan-Quinn criter.		2.249
F-statistic	9.467	Durbin-Watson stat		0.089
Prob(F-statistic)	0.000			

Dependent variable: Y
Method: Panel EGLS (Cross-section random effects model)
Sample: 2016Q1 2021Q4
Periods included: 24
Cross-sections included: 10
Total panel (Balanced) observations: 240
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. error	t-statistic	Prob.
C	-0.029	0.342	-0.085	0.932
X1	0.762	0.361	2.109	0.036
X2	-0.405	0.233	-1.733	0.084
X3	-0.131	0.471	-0.277	0.782
Effects specification				
			S.D.	Rho
Cross-section random			0.740982	0.7822
Idiosyncratic random			0.390975	0.2178
Weighted statistics				
R-squared	0.049	Mean dependent var		-0.018
Adjusted R-squared	0.037	S.D. dependent var		0.398
S.E. of regression	0.390	Sum squared resid		35.985
F-statistic	4.045	Durbin-Watson stat		0.241
Prob(F-statistic)	0.008			

Correlated random effects - Hausman test
Equation: Untitled
Test cross-section random effects

Test summary	Chi-sq. statistic	Chi-sq. d.f.	Prob.
Cross-section random	1.411	2	0.494

4.2. Findings

Table 6 presents the results of the econometric analysis for the common effect model and the random effect model) as well as the relative statistical test Hausman test which shows that the random effect model is the most appropriate for the present study. The main findings are summarized as follows:

The econometric analysis yields conclusive results indicating the statistical significance of variable X1 at a 5% level of significance (p-value: 0.036 < 0.05), accompanied by an estimated coefficient of 0.76. These findings suggest a positive association between the implementation of risk mitigation strategies and the financial value of electricity-producing companies. Importantly, the coefficient is intricately tied to the logarithmic transformation of Tobin's index. Assuming a 1% increase in the X1 variable (representing a 1% rise in the proportion of financial derivatives to total assets), the Tobin's index would increment by

$$e^{0.76*0.01} = e^{0.0076} = 1.0076 \text{ or } 0.76\%$$

The statistical analysis reaffirms the non-significant status of variable X3. Consequently, there is a lack of evidence indicating that the presence of a developed domestic forward market significantly impacts the value of electricity-producing companies in the EU-27. This observation may be rationalized by the flexibility of EU electricity production companies to engage in forward markets of other nations, facilitating agreements for the delivery/receipt of electrical energy with external contracting parties. Variable X2 is ascertained to be statistically non-significant at a 5% level of significance (p-value: 0.0843 > 0.05).

Choosing the random effect model took into account the results of the Hausman test (not rejecting the null hypothesis of using a random effect model) at the 5% significance level (p-value 0.4938 > 0.05).The selection of the random effect model is substantiated by the results of the Hausman test, where the null hypothesis for the use of the random effect model is not rejected at a 5% significance level (p-value 0.4938 > 0.05).

The adjusted coefficient of determination for the model is approximately 3.7%, indicating that around 3.7% of the variability in the dependent variable is explained by the estimated model. This outcome is deemed reasonable, given the dependence of Tobin's index on a multitude of other variables.

5. CONCLUSION AND POLICY RECOMMENTATIONS

This research aims to empirically examine the impact of implementing hedging strategies on the financial value of electricity firms within the EU region, utilizing economic data spanning from 2016 to 2021. The financial value of the firms is evaluated through the Tobin (Q) index, while the degree of hedging strategy implementation is measured by the value of financial derivatives relative to the total assets value of the firms. The criterion for selecting electricity generation firms for inclusion in the dataset is based on the development of the domestic forward electricity market, taking into account its liquidity level.

The determination of the final price of electrical energy involves a multitude of parameters, with one significant factor being the fluctuation in the values of fossil fuels, crucial for electricity production. In 2021, about 30% of the EU-27's electrical energy was generated from fossil fuels, comprising coal, natural gas, and oil. Entities engaged in business activities encounter specific risks that may disrupt their operations, prompting the use of derivative financial products, including forward contracts, futures contracts, and financial options, as widely adopted risk mitigation tools. The electricity market comprises four main segments: generation, distribution, transmission, and retail. Statistical data on the EU-27's electricity market highlights the industrial sector and households as primary consumers, along with a deficit in the balance of imports and exports, emphasizing the region's dependence on third countries to meet internal market demands. Additionally, there has been an upward price trend for residential (or non-residential) consumers since the first half of 2021.

The empirical results from the econometric analysis using panel data demonstrate a statistically significant relationship between the value of derivative financial products used by electricity-producing companies in the EU-27 (as a percentage of their total assets) and the financial value of these companies, as expressed through the Tobin's Q ratio. This finding aligns with previous research by Samitas et al. (2011) that examined the impact of hedging strategies in 50 electric power producing companies (internationally) during the financial crisis 2007-2009.

However, the study indicates that the development of the domestic forward electricity market in the respective regions does not significantly impact the Tobin's Q ratio, possibly due to the high degree of interconnection among forward electricity markets in the EU.

Further exploration of the main research question would include actions such as expanding the sample of electricity companies, focusing on more reliable levels of derivative financial products, segregating products based on their purpose, and incorporating new variables to enhance the interpretive level of the dependent variable. This suggests further refining the research methodology and delving deeper into the intricate relationship between hedging strategies, financial values, and market dynamics in the EU electricity sector.

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