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Will the Reduction of CO_2 Emissions Lower the Cost of Debt Financing? The Case of EU Countries

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Abstract: The main objective of this article is to test the relationship between the intensity of CO_2 emissions and company's cost of debt capital. This study fills a gap in the financial literature on this compound by examining a sample of 225 large nonfinancial enterprises operating in 15 EU countries in the years 2018–2021. The fractional logit regression controlling for company's characteristics (assets, profitability, liquidity and leverage) was used. The results show that by reducing the intensity of CO_2 emissions, a company can reduce the cost of debt. This relationship was confirmed for three measures of intensity, i.e., CO_2 emissions in relation to revenues, assets and number of employees. Markets and financial institutions impose an additional risk premium in relation to companies operating in an industry considered to be comprised of strong CO_2 emitters. The use of the latest data for a wide sample of European enterprises provides an up-to-date assessment of the analyzed issues and the results can be used by enterprises and public authorities when analyzing the benefits of implementing a technology that reduces CO_2 emissions.

Keywords: CO_2 emission; cost of debt; nonfinancial companies; EU countries

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1. Introduction

In recent decades, the problem of climate change has become the subject of debates, not only by environmentalists, but also economists. Its scale is evidenced by the significant losses incurred as a result of climate disasters. Between 1980 and 2019, climate-related natural disasters caused economic losses of €446 billion in European Economic Area (EEA) countries [1]. Although the 2015 Paris climate conference indicated the need to reduce GHG emissions in order to lower global temperature below 2, and preferentially 1.5 degrees Celsius compared to pre-industrial levels, the amount of CO_2 emissions to atmosphere continues to rise [2]. According to the International Energy Agency (IEA) data, in the years 2015–2019, CO_2 emissions, as a result of the combustion of fuels for energy production, increased from 33.2 to 34.4 Gt. [3]. In such circumstances, the question arises whether institutions and financial markets notice the negative effects of climate change for the entire economy and whether they penalize high emitters of CO_2 for contributing to a further increase in climate risk.

Climate change affects the state of the economy and financial stability through two channels, i.e., physical risk and transition risk [4]. Physical risk results from the risk of floods, wildfires, water stress and heat stress. The Swiss Re Institute indicates that, in 2020, the value of natural catastrophe losses amounted to USD 190 trillion and 70% of these were caused by severe convective storms and wildfires [5]. Transition risk impacts the incomes of enterprises and households and is a source of financial losses for credit institutions and investors. It affects the economy through investment and productivity channels. The basic measure of transition risk is the size and/or intensity of GHG or CO_2 emissions. Enterprises operating in six sectors—fossil fuel, utility, energy-intensive, construction, transportation and agriculture—are considered to be the most exposed to the climate transition risk [6].

The growing public pressure to limit the consequences of climate change has led financial institutions to include climate risk in their assessment of investment projects. The European Investment Bank decided to stop financing fossil fuel energy projects from the end of 2021 [7] and released the guidelines for the energy lending policy stipulating forms of the EU supports and types of energy projects which are consistent with the bank's objectives [8]. Nordea Bank accepted the guideline to limit and next stop the financing of enterprises using energy from fossil sources. It determined that by the end of 2030 it will reduce CO_2 emissions from its lending and investment portfolios by 40–50%. It also obliged existing financing customers who extract thermal coal or use it to produce energy to discontinue this type of activity by 2030 [9]. However, the decisions of banks are not limited only to reducing the financing of CO_2 emitters, but also supporting projects for their transformation and the introduction of low-emission technologies. In 2021, HSBC Holding plc established a $1 trillion program to finance its clients' projects to decarbonize their production processes [10] and Standard Charter plc launched a Universal Climate Finance Loan to incentivize enterprises to outpace national decarbonization rates and established Transition Acceleration Teams to provide to companies from carbon-intensive sectors expertise on how to accelerate their low-carbon transitions [11].

The decisions to radically reduce the climate risk in the activities of financed corporate clients were made in 2021 by, inter alia, HSBS Holdings plc [10] and Standard Charter plc [11]. Additionally, central banks and financial supervisors recommended commercial banks to increase their attention to the destructive effects of economic activity on the natural environment, to limit the financing of non-ecological projects, and to introduce into the set of risks taken into account when assessing investment projects of a special category, i.e., climate risk [12–14].

The threats of climate change have also become a more frequent subject of academic research. In the area of corporate finance, most studies focused on assessing the benefits from the implementation of environmentally friendly technologies [15], the impact of delayed implementation of green technologies and procedures on financial performance [16,17], or the scale of restrictiveness of credit policies of financial institutions, which referred to the climate risk presented by enterprises operating in sectors that are particularly harmful to the natural environment [18,19]. According to the authors' knowledge, there are few studies on the impact of CO_2 emissions on the cost of debt financing.

This paper fills this gap in research by analyzing the relationship between the size of the carbon risk, measured by the intensity of CO_2 emissions, and the cost of financing nonfinancial enterprises with debt. The research covers 225 enterprises operating in 15 countries in the years 2015–2021. Additionally, the study controls this relationship by the industry and the country in which the enterprise operates, as well as the enterprise's own characteristics. The study asked whether, in the absence of a clear reduction in GHG emissions and increasing external pressure on financial institutions to limit financing of environmentally harmful projects, banks and market investors penalize enterprises emitting significant amounts of CO_2 with the increased cost of debt capital.

The remaining part of the paper has the following structure. The next section presents a literature review of the impact of GHG emissions on the company's financial situation, followed by data sources and research methodology, as well as the modelling results and their discussion. The entire study is summarized in the conclusions.

2. Literature Review

While there are distant studies showing that pollution monitoring does not generate additional income, but increases production costs and capital depreciation [20], the prevailing opinion in the current literature indicates a positive relationship between the company's commitment to ecological standards (i.e., adoption of strategies of pollution prevention, environmental management procedures, reduction of CO_2 emission and energy consumption, shift from fossil fuel to renewable energy) and reputation and the financial results obtained [21–27] Maintaining transparency and higher environmental standards allow companies to avoid legal costs and compensation for penalties for environmental pollution, reducing risk and increasing the profitability and financial stability of the company [16,17]. It also creates a buffer for the eventual future environmental shocks [28].

The growing importance of the negative impact of GHG emissions on climate change, and, consequently, on the economy in the macro and micro scale, motivated researchers to assess the impact of carbon risk on the valuation of assets in financial markets, as well as the stability and profitability of non-financial enterprises and financial institutions, including, mainly, banks. Research by Chen and Yang showed that Taiwanese investors were optimistic about positive news about improving environmental standards implemented by enterprises [29]. Siddique et al. showed that companies that disclosed their carbon footprints data had better access to long-term debt markets [24], and Alessi et al. stated that investors on the European equity markets were even willing to earn lower returns by holding stocks of companies which are transparent about their environmental performance [30]. Kim et al. also indicated that maintaining high standards of ESG data publication motivated enterprises not to engage in environmental polluting projects and, as a result, reduce the risk of bankruptcy [31].

Hübel showed that the company's improvement of its environmental standards can reduce future lawsuits and environmental disasters, help to lower credit risk, flatten the implied credit curve of CDS and lower the cost of long-term debt [15]. Moreover, studies by Cerqueti et al. stated that European investment funds with portfolios of companies with high ESG ratings suffered significantly less losses than funds with a lower ESG ranking, and were also characterized by lower price volatility [32]. In turn, Bolton and Kacperczyk showed that carbon emissions had a positive impact on the rates of return on US stocks, which they associated with the imposition of a higher risk premium by investors. Observing these companies in the longer time horizon, they noticed that reducing the intensity of CO_2 emissions in some of them contributed to the reduction of the required rate of return by investors [33].

A certain part of the research focused on the impact of carbon risk on the economic situation of the entire regions and countries. Research of Davidson et al. showed that in Russia, the need to lower the carbon risk forced the industry to use more advanced environmentally friendly technologies, which, in turn, raised the technological and economic level of some regions. In result, this process helped to lower the level of income inequality throughout the country [34]. Reducing carbon risk lowers the sovereign risk, which, in turn, enables the receiving of cheaper funds for the country's development. Natural disasters caused by, for example, GHG emissions introduce uncertainty about the future of production and growth prospects and significantly affect the valuation of market assets [35]. They distort business and trade and damage infrastructure and as a result divert capital from innovation technology to post-catastrophic damage reconstruction and lower the state of the national economy [36]. Chaudhry et al. also pointed to the increased country's risk and deterioration in the valuation of treasury bonds as a result of rising CO_2 emissions [37]. On the other hand, Umar et al. [38] and Wu et al. [39] stated that the increase in CO_2 emissions lowered air quality and became the cause of the deterioration of the health condition of the society, with consequences for the state of the economy throughout the country.

The assessment of the impact of carbon risk on the level of risk in business operations has been the subject of several studies. Sharman and Fernando found that companies that improved environmental risk management lowered the cost of equity capital and shifted their financing to cheaper debt financing, took advantage of the opportunity to reduce the tax burden with finance costs [40]. The reduction in carbon risk was priced in by investors by lowering bond yields. Schneider noted that US chemical companies' bonds achieved a lower bond yield after improving their environmental footprint [41]. Meanwhile, in Korea, Park and Noh found that companies emitting more greenhouse gases or consuming more energy were more exposed to future climate risk, which led to an increase in their bond yield [42].

A limited number of studies have focused on the impact of CO_2 emissions on the cost of debt capital. Zhou et al. found a nonlinear—U-shape—relationship between CO_2 emissions and cost of debt in Chinese firms in the years 2011–2015. They explained that the deviation from linearity was significantly impacted by the mitigating influence of the media [43]. On the other hand, Maaloul, while examining the relationship between the amount of GHG emissions and the cost of debt capital of Canadian companies, stated that, when granting loans, banks took into account the intensity of the company's GHG emissions. As a result, the increase in emissions resulted in a rise in the cost of capital [44]. A similar positive correlation between the cost of debt capital and the company's GHG emission intensity was demonstrated by Li and Liu when examining companies listed on the Australian Stock Exchange in the years 2006–2010. However, they did not find a relationship between the volume of GHG emissions and the cost of equity capital [45].

In turn, Kumar and Firoz, while researching Indian companies operating in the years 2011–2014, found a positive correlation between the intensity of CO_2 emissions and the cost of debt capital. In addition, they noticed that the cost of financing was higher in firms that polluted the environment more and lower in firms that were more environmentally friendly [19]. Siamak and Abdullah found that climate risk adversely affected the firm's cost of borrowing [46]. Especially in a case of long-term bank loans, the poorly rated firms operating in locations that were exposed to a higher level of climate risk were charged with higher spreads. Moreover Krueger et al. proved that investors became increasingly concerned about the financial implication of climate risk. Institutional investors specializing in long-term and high-value investments considered climate risk management as essential for their investment profitability [47].

Based on this literature background the following hypotheses were formulated:

Hypothesis 1 (H1). *Lower intensity CO_2 emissions allows European companies to obtain lower financing costs.*

Hypothesis 2 (H2). *The cost of financing enterprises with debt is higher in high-carbon industries than in others.*

3. Materials and Methods

Research on the GHG emission is limited to a large extent due to the lack of related data. Despite the implementation by the Member States of Directive 2014/95/EU of the European Parliament and of the Council in regards to disclosure of non-financial and diversity information by certain large groups [48], as well as the increase in environmental awareness of entrepreneurs, the quantity, quality and consistency of the reported ESG data still remains highly varied between companies [49]. As of the end of October 2021, only 60 out of 114 stock exchanges had adopted ESG reporting guidance for their listed companies [50]. "The Model Guidance on Reporting ESG Information to Investors" was prepared by the United Nations Sustainable Stock Exchanges (SSE) initiative and is to serve as a voluntary technical tool for stock exchanges [51]. In addition, the EBA, conducting a pilot stress-test on climate-related risk on a sample of the 29 largest European banks, indicated that only 17% of the exposures of the tested banks came from enterprises that fully reported ESG data, and for 65% of exposures it was possible to use only the average GHG intensity adopted for NACE (Nomenclature of Economic Activities), level 4 class, to which the parent company belongs [52].

These problems resulted in the fact that, out of several hundred largest non-financial enterprises in Europe, only 225 out of 15 countries had longer series of data on the amount of CO_2 emitted. For assessing the regression model, the study included enterprises that reported data on CO_2 emissions with a quarterly frequency, at least from 2018 onwards. As a result, we concluded with an unbalanced panel with 4370 observations. For each company, the industry in which it operated was assigned based on the profile published by the Refinitiv agency. Table 1 presents the data on the number of surveyed enterprises from individual countries and industries.

Table 1. Distribution of companies by industries and countries.

Industries							
Production	**Energy**	**Utilities**	**Trade**	**Transport**	**Construction**	**ITC**	**Services**
90	22	12	17	14	12	28	30

Countries														
AT	BE	DE	DK	ES	FI	FR	IE	IT	NL	NO	PL	PT	SE	UK
4	10	44	15	23	7	15	4	12	23	23	7	6	6	57

Note: AT—Austria, BE—Belgium, DE—Germany, DK—Denmark, ES—Spain, FI—Finland, FR—France, IE—Ireland, IT—Italy, NL—Netherlands, N—Norway, PL—Poland, PT—Portugal, SE—Sweden, UK—United Kingdom.

Companies from the UK (57) had the largest share in the sample, followed by Germany (44), the Netherlands (23), Spain (23) and Norway (23). Manufacturing (90) was the most strongly represented industry, followed by services (30), ITC (28) and energy (22). Data characterizing enterprises were retrieved from Refinitiv agency, and data on the cost of debt capital was obtained from the Bloomberg agency. Table 2 presents the descriptive statistics and definitions of the variables used in the study.

Table 2. Descriptive statistics for the variables applied in the study.

Variable	No. of Observations	Average	Standard Deviation	Minimum	Quartile 1	Median	Quartile 3	Maximum	Source
COD	4370	0.90	1.31	−0.92	0.14	0.61	1.34	18.67	BBG
CO2_Rev	4370	332.01	869.77	0.01	9.15	37.25	236.20	8.7 × 103	RTF
CO2_Asset	4370	258.25	862.26	0.02	4.04	21.50	157.30	1.1 × 104	RTF
CO2_Empl	4370	275.50	990.29	0.08	3.79	13.46	139.31	1.4 × 103	RTF
Size	4370	5.1 × 104	9.4 × 104	6.3 × 103	9.3 × 103	1.1 × 104	3.9 × 104	9.8 × 105	RTF
Profitability	4370	6.09	10.13	−1.40	1.58	5.33	9.83	54.59	RTF
Liquidity	4370	169	325	18	90	129	174	765	RTF
Leverage	4370	26.41	16.09	4.78	14.51	24.58	38.02	86.64	RTF

Note: BBG—Bloomberg, RTF—Refinitiv, COD—cost of debt capital (%), CO_2_Rev—CO_2 emissions to revenues (ton/USD mn), CO_2_Asset—CO_2 emissions to assets (tonne/USD mn), CO_2_Empl—CO_2 emissions to number of employees (tonne/person), Size—assets (USD mn), Profitability—return on assets (ROA) before taxes (%), Liquidity—current liquidity ratio (%), Leverage—debt to assets (%).

In terms of size, the composition of the research sample is diverse. More than 75% of the number of enterprises have assets, revenues or a number of employees that is lower than the corresponding average values. Other characteristics indicate a significant differentiation among enterprises, which could be caused by the fact that they operate in various industries. The specificity of running a business in various sectors may affect the size of employment and the scope of digitization. The diversity of the sample refers to most of the characteristics of the analyzed companies, including the size of assets, revenues and employment, as well as profitability and the financial leverage used.

Taking into account the form of the models presented in the literature, to examine the relationship between the cost of debt capital and the intensity of CO_2 emissions, a regression model was used, in which the explained variable is the cost of debt capital, and the explanatory variables are the intensity of CO_2 emissions and company-specific variables [53–56]. The research adopted three measures of the intensity of CO_2 emissions, i.e., the value of emissions in relation to: revenues, assets and a number of employees. The first two measures were proposed by Hoffmann and Busch [57], as well as Capasso et al. [54] and ESRB [58,59], Caragnano et al. [54] The third measure was used in the ECB research conducted by De Haas and Popov [60]. To reduce the impact of heteroscedasticity, these measures have been logarithm.

The research on CO_2 emissions and the cost of debt conducted so far indicates that the form of the relationship between these two values is also influenced by the characteristics of the enterprise [53–56,61]. For this reason, the following measures were adopted as control variables: *Size*, *Profitability*, *Liquidity* and *Leverage*. In the case of *Size*, the natural logarithm of assets was used to reduce the impact of heteroscedasticity.

Size: Large enterprises are characterized by greater transparency and lower information asymmetry, which contributes to charging their financing with a lower risk premium [62]. Due to the lower probability of default [63,64] and the economies of scale, larger enterprises obtain external financing at lower interest rates [56,65]. It can be expected that in the analyzed sample, an increase in the company's assets will contribute to a decrease in the cost of debt capital.

Profitability: Profit-generating enterprises are less likely to fail to pay on time their liabilities arising from the incurred debt or issued debt securities [62,63]. Therefore, we expect ROA growth to be negatively related to the cost of debt capital.

Liquidity: Enterprises with adequate financial liquidity have an adequate amount of assets necessary to meet their current obligations on a regular basis. Therefore, financial institutions and investors charge such companies with a lower liquidity risk premium [66]. We expect the current ratio to be negatively related to the cost of debt capital.

Leverage: Theoretical and experimental evidence shows that increasing the use of leverage increases the risk of a default, which rises the risk premium [56,67]. The activities of such companies are subject to a greater uncertainty, prompting investors to impose an additional premium on risk [68]. Therefore, in the study, we expect a positive relationship between the value of leverage and the level of the cost of debt capital.

Table 3 presents the values of Pearson's correlation indexes between the variables analyzed in the study. It indicates that the cost of debt capital is, at the level of 10%, significantly correlated with all variables analyzed in the study. The signs of the correlation coefficients are consistent with the expectations inferred from the analysis of the literature on the subject. Values of the VIF (variance inflation factor) below the benchmark of 10 indicate the lack of multilinearity between the explanatory variables, as in Matsumura et al. [69] and Griffin et al. [70]. The result of the Shapiro–Wilk test indicated that the null hypothesis, that the distribution of variables is normal, should be rejected.

Table 3. Pearson's correlation matrix.

No.		VIF	1	2	3	4	5	6	7	8
1	COD		1							
2	CO_2_Rev	3.47	0.46 ^{a}	1						
3	CO_2_Asset	2.10	0.12 ^{a}	0.48 ^{a}	1					
4	CO_2_Empl	2.00	0.02 ^{c}	0.37 ^{a}	0.39 ^{c}	1				
5	Size	1.69	−0.06 ^{b}	−0.07 ^{a}	−0.07 ^{c}	−0.05 ^{b}	1			
6	Profitability	1.14	−0.06 ^{a}	−0.04 ^{a}	−0.13 ^{b}	−0.06 ^{c}	−0.13 ^{a}	1		
7	Liquidity	1.09	−0.07 ^{a}	−0.02	−0.01	−0.01	0.05 ^{a}	0.02 ^{b}	1	
8	Leverage	1.08	0.07 ^{a}	−0.08 ^{a}	−0.07 ^{c}	−0.04 ^{b}	−0.07 ^{a}	−0.05 ^{a}	−0.28 ^{a}	1

Note: ^{a}, ^{b}, and ^{c}—significance at, respectively 1%, 5% and 10% level.

In the previous research on the relationship between the cost of debt capital and the risk resulting from CO_2 emissions, the following were used, inter alia, the OLS linear regression method taking into account fixed time and spatial effects [33,46], panel regression with fixed effects for the country and industry of the enterprise's operation [53,56], and the System Generalized Method of Moments (GMM) method [55]. To investigate the relationship between the cost of debt capital and the intensity of CO_2 emissions by companies operating in different countries and different industries, the fractional logit regression was applied. Method proposed by Papke and Wooldridge [71,72] acknowledges the fractional character of the dependent variable that can be applied for both the discrete and continuous variable and is capable of handling the extreme variables of 0 and 1 [73,74]. This method is especially effective when the values of the explained variable are fractional and fall within the range from 0 to 1. This method is often used in the case of credit risk testing [75,76].

$$COD_{i,t} = \alpha_0 + \beta_1 CO2Emissions_{i,t} + \beta_2 Size_{i,t} + \beta_3 Profitability_{i,t} + \beta_4 Liquidity_{i,t} + \beta_5 Leverage_{i,t} + \sum \gamma_j Country_{i,j} + \sum \delta_k Industry_{i,k} + \sum \zeta_n Quarter_n + \varepsilon_{i,t}$$

where, for firm i, quarter t, country j, industry k, quarter n—$COD_{i,t}$—cost of debt capital, $CO2Emissions_{i,t}$natural logarithm of CO_2 emissions to, respectively revenues, assets or number of employees, $Size_{i,t}$—natural logarithm of assets, $Profitability_{i,t}$—ROA before taxes, $Liquidity_{i,t}$—current ratio, $Leverage_{i,t}$—debt to assets, $Country_{i,j}$ and $Industry_{i,k}$—respectively country and industry of operations, $Quarter_n$—quarter, $\varepsilon_{i,t}$—random component, α_0, β_1, β_2, β_3, β_4, β_5, γ_j, δ_k, ζ_n—parameters to be assessed. All of the models considered in the study are estimated in two versions: without taking into account (models marked with the letter A) and taking into account the time effects (models marked with the letter B).

4. Results of Modelling and Discussion

The results of the analysis show that for European companies there exists a positive relationship between the CO_2 emission intensity and the cost of debt capital, which is in line with research Hypothesis 1. These results are also consistent with the results obtained by Caragnano et al. [53] and Pizzutilo et al. [56] for a similar group of European enterprises in 2010–2017. This relationship is controlled by the companies' characteristics, i.e., size, profitability, liquidity and financial leverage. The coefficients of these control variables are statistically significant and indicate that large and profitable companies obtain cheaper financing, as well as those characterized by high liquidity. On the contrary, companies with high leverage have to bear higher debt capital costs due to the higher risk of default. The signs of relationships are consistent with the expectations and classic principles of corporate finance [67,77].

Table 4 presents the results of the model estimation for three CO_2 emission intensity measures based on revenues, assets and the number of employees, including the time fixed effects. On average, by reducing the intensity of CO_2 emissions, measured with these measures by 100 basis points (bps) enterprises can reduce the cost of financing by, respectively, 10 bps, 11 bps and 8 bps. These results are consistent with the results obtained by Capasso et al. [54], Caragnano et al. [53] and Pizzutillo et al. [56]. This means that investors and credit institutions in their investment decisions penalize companies emitting CO_2 with a higher cost of debt. Thus, firms which are strong emitters of CO_2 must take this dependency into account when planning to apply for bank loans or issuance of long- or short-term debt securities.

Table 4. The estimation results of basic regression models.

Variable	Model 1A	Model 1B	Model 2A	Model 2B	Model 3A	Model 3B
CO2_Rev	0.109 *** (8.82)	0.095 *** (7.84)				
CO2_Asset			0.127 *** (8.24)	0.112 *** (7.38)		
CO2_Empl					0.085 *** (6.76)	0.076 *** (5.57)
Size	−0.021 (−0.94)	−0.035 ** (−2.12)	−0.000 (−0.12)	−0.013 (−0.91)	−0.030 * (−1.75)	−0.041 *** (−2.71)
Profitability	−0.016 *** (−6.81)	−0.019 *** (−6.81)	−0.016 *** (−5.71)	−0.019 *** (−7.71)	−0.016 *** (−6.71)	−0.019 *** (−7.71)
Liquidity	−0.057 ** (−2.52)	−0.042 * (−1.86)	−0.056 *** (−4.76)	−0.047 *** (−3.76)	−0.077 *** (−5.76)	−0.065 *** (−5.76)
Leverage	0.001 (1.39)	0.004 *** (3.78)	0.003 *** (2.85)	0.006 *** (5.21)	0.001 (0.38)	0.003 *** (2.78)
Constant	1.085 *** (2.95)	2.340 *** (5.95)	2.287 ** (4.25)	3.353 *** (6.95)	3.353 *** (3.84)	2.735 *** (6.47)
Time effects	N	Y	N	Y	N	Y
N	4370	4370	4370	4370	4370	4370
F−statistic	43.26	37.26	56.98	26.98	36.74	19.74
Prob > F	0.00	0.00	0.00	0.00	0.00	0.00

Note: ***, **, *—significance at 1%, 5%, 10% level.

In order to check whether the relationship between CO_2 emission intensity and the cost of debt capital is shaped by the location of the business, the basic models that are additionally controlled by country dummy variables (1 when the country in which the enterprise operates and 0 otherwise) were estimated, while taking into account the time effects. The estimation results presented in Table 5 show that the coefficients at the variables of CO_2 emission intensity and company characteristics are still statistically significant and with the same sign and similar to the value. Coefficients for the country dummy variables indicate that the financial markets in each country individually evaluate companies that emit more CO_2 and, thus, increase their own credit risk in alignment with carbon risk. Positive signs of the coefficients for Norway, Poland, Portugal and the UK and negative for the other countries of the sample indicate that banks and the markets impose, respectively, a higher and a lower carbon risk premium in the case of both of these groups of European countries. These results are in line with the results obtained by Caragnano et al. as to the countries and directions of changes in the amount of the premium imposed for carbon risk [53].

Table 5. The estimation results of regression models with country dummy variables.

Variable	Model 4A	Model 4B	Model 5A	Model 5B	Model 6A	Model 6B
CO2_Rev	0.062 *** (4.52)	0.047 *** (3.56)				
CO2_Asset			0.087 *** (5.57)	0.071 *** (2.27)		
CO2_Empl					0.070 *** (4.95)	0.060 *** (4.39)
Size	−0.035 (−1.42)	−0.026 (−1.12)	−0.051 (−1.21)	−0.043 (−0.42)	−0.019 (−0.87)	−0.013 (−0.69)
Profitability	−0.010 *** (−2.99)	−0.013 *** (−3.47)	−0.006 *** (−2.28)	−0.009 *** (−6.81)	−0.005 ** (−1.99)	−0.008 *** (−3.14)
Liquidity	0.018 (1.09)	0.034 (0.94)	0.007 (0.69)	−0.020 * (−1.69)	−0.011 * (−1.69)	0.004 (1.02)
Leverage	0.002 (1.39)	0.002* (1.76)	0.001 (0.61)	0.003 *** (3.53)	0.002 (1.31)	0.002 * (1.71)
AT	−0.647 *** (−7.42)	−1.575 *** (−3.42)	−0.657 *** (−5.22)	−1.535 *** (−7.42)	−0.847 *** (−5.52)	−1.417 *** (−7.42)
BE	−0.298 *** (−3.42)	−1.264 *** (−8.42)	−0.187 * (−1.91)	−1.178 *** (−10.72)	−0.446 *** (−3.34)	−1.298 *** (−4.61)
CZ	0.035 (0.42)	−0.805 *** (−5.26)	0.115 (0.29)	−0.855 *** (−5.12)	−0.719 *** (−3.42)	0.721 *** (−4.45)
DE	−0.591 *** (−6.42)	−1.591 *** (−9.42)	−0.487 *** (−4.54)	−1.397 *** (−9.15)	−0.691 *** (−2.94)	−1.357 *** (−5.94)
DK	−0.545 *** (−3.42)	−1.475 *** (−6.72)	−0.423 *** (−4.81)	−1.359 *** (−14.25)	−0.731 *** (−6.65)	−1.149 *** (−8.42)
ES	0.101 (1.42)	0.821 (0.92)	0.225 (0.92)	−0.784 *** (−7.31)	0.061 (1.29)	−0.651 *** (−7.25)
FI	−0.473 *** (−5.42)	−1.373 *** (−5.96)	−0.379 *** (−3.95)	−1.134 *** (−5.78)	−0.558 *** (−4.41)	−1.263 *** (−6.29)
FR	0.050 (0.45)	−0.860 *** (−4.47)	0.241 (1.29)	−0.547 *** (3.12)	−0.047 (−0.64)	−0.665 *** (−8.72)
IE	−0.941 (−0.81)	−0.987 *** (−8.22)	−0.798 *** (−5.44)	−0.971 *** (−8.95)	−0.084 (−0.44)	−0.841 *** (−8.12)
IT	0.094 (0.42)	−0.084 *** (−5.42)	0.094 (−0.49)	0.0974 *** (−7.02)	0.041 (0.31)	−0.695 *** (−6.42)
NL	−0.171 * (−1.75)	−1.194 *** (−9.79)	−0.171 (−1.32)	−0.951 *** (−9.01)	−0.194 (−1.14)	−0.171 (−0.42)

Table 5. *Cont.*

Variable	Model 4A	Model 4B	Model 5A	Model 5B	Model 6A	Model 6B
NO	1.016 ***	0.116	1.217 ***	0.327**	1.016 ***	0.487 ***
	(5.92)	(1.02)	(6.57)	(2.16)	(3.59)	(2.95)
PL	1.075 ***	0.875**	1.083 ***	0.3175	0.921 ***	0.226*
	(8.42)	(1.98)	(9.21)	(1.03)	(5.31)	(1.86)
PT	0.665 ***	0.665 ***	0.818 ***	0.665	0.593 ***	−0.665
	(4.42)	(3.91)	(6.57)	(056)	(4.03)	(−0.42)
SE	−0.364 ***	−0.364	−0.222 ***	−1.197 ***	−1.387 ***	−0.364
	(−3.12)	(−0.62)	(−2.24)	(−3.82)	(−3.65)	(−1.42)
UK	0.921 ***	0.872	0.716 ***	0.978 ***	0.512 ***	0.921 ***
	(6.47)	(0.98)	(4.68)	(6.93)	(3.85)	(2.84)
Constant	−0.103	1.954 ***	0.418	2.754 ***	0.351	2.153 ***
	(−0.34)	(6.24)	(1.51)	(6.54)	(1.12)	(6.28)
Time effects	N	Y	N	Y	N	Y
N	4370	4370	4370	4370	4370	4370
F-statistic	79.14	56.84	80.78	53.65	79.04	54.92
Prob > F	0.00	0.00	0.00	0.00	0.00	0.00

Note: ***, **, *—significance at 1%, 5%, 10% level, t-statistics in parentheses.

In turn, Table 6 presents the results of the estimation of basic models supplemented with industry dummy variables (1 when the industry in which the enterprise operates and 0 otherwise). The results indicate that enterprises from industries with increased CO_2 emissions: construction, energy, production, transportation and utilities, obtain external financing at a higher cost than in the case of other industries, which is consistent with the research Hypothesis 2. This means that financial markets perceive increased CO_2 emissions as a source of possible increased charges for CO_2 emissions or penalties for environmental pollution. The obtained results are consistent with the results presented by Carangano et al. [53]. This means that these companies, as well as the authorities of the countries in which they operate, should be particularly motivated to implement public programs to reduce CO_2 emissions, which is in line with the priority of the EU Multiannual Financial Framework (MFF 2021–2027), directing funds to all climate-relevant sectors and catalyzing the transition towards a net-zero greenhouse gas emission economy [78]. Due to the restrictive approach of the markets increasing the interest rates on funds for high-emitters, public programs would enable such companies to obtain cheaper funds for emission-reduction investments.

Table 6. The estimation results of regression models with industry dummy variables.

Variable	Model 7A	Model 7B	Model 8A	Model 8B	Model 9A	Model 9B
CO2_Rev	0.119 ***	0.103 ***				
	(7.91)	(7.01)				
CO2_Asset			0.144 ***	0.124 ***		
			(7.44)	(6.27)		
CO2_Empl					0.089 ***	0.078 ***
					(5.23)	(4.71)
Size	−0.024	−0.039 **	−0.004	−0.010	0.033 **	0.044
	(−1.41)	(−2.42)	(−0.12)	(−0.42)	(1.99)	(1.75)
Profitability	−0.016 ***	−0.019 ***	−0.016 ***	−0.019 ***	−0.017 ***	−0.020 ***
	(−5.43)	(−6.23)	(−6.81)	(−6.81)	(−6.52)	(−7.81)
Liquidity	−0.054 **	−0.042 *	−0.045 ***	−0.038 ***	−0.080 ***	0.068 ***
	(−2.21)	(−1.69)	(−3.31)	(−2.78)	(−5.41)	(−4.78)
Leverage	0.001	0.003 ***	0.001	0.004 ***	0.001	0.003 **
	(0.39)	(2.98)	(1.39)	(4.24)	(1.01)	(2.45)

Table 6. *Cont.*

Variable	Model 7A	Model 7B	Model 8A	Model 8B	Model 9A	Model 9B
Production	0.371 *** (2.74)	0.417 *** (4.02)	0.467 (0.52)	1.657 * (1.78)	0.519 (1.51)	0.578 *** (4.55)
Energy	−0.298 *** (3.024)	0.491 *** (4.83)	0.098 (0.62)	0.165 * (1.85)	0.548 *** (4.23)	0.623 *** (6.11)
Utilities	0.742 *** (5.68)	0.795 *** (7.61)	0.519 *** (4.08)	0.595 *** (3.84)	0.846 *** (6.23)	0.088 (0.38)
Trade	0.515 (0.72)	0.591 (1.41)	1.211 (1.06)	0.264 (1.54)	0.651 (1.48)	0.751 (091)
Transport	0.165 (1.28)	0.278 *** (2.82)	−1.545 (−1.23)	0.009 (0.07)	0.347 (1.23)	0.454 (1.28)
Construction	0.278 ** (2.06)	0.302 *** (2.84)	0.121 (0.96)	0.101 (−0.42)	0.372 (1.53)	0.389 (1.17)
ITC	0.631 (1.17)	0.712 (1.19)	0.473 (0.92)	0.167 (1.61)	0.747 (1.23)	0.778 (1.16)
Services	0.101 (0.81)	0.221 (1.56)	−0.132 (−0.85)	0.468 (1.26)	0.244 (0.75)	0.333 (1.45)
Constant	0.769 ** (2.05)	1.924 *** (5.14)	2.304 *** (4.87)	3.206 *** (6.47)	1.066 *** (2.93)	2.114 *** (5.79)
Time effects	N	Y	N	Y	N	Y
N	4370	4370	4370	4370	4370	4370
F-statistic	33.14	29.84	35.78	25.65	30.04	22.92
Prob > F	0.00	0.00	0.00	0.00	0.00	0.00

Note: ***, **, *—significance at 1%, 5%, 10% level, t-statistics in parentheses.

5. Conclusions

In this study, we investigated how the intensity of CO_2 emissions affects the cost of debt capital. This relationship was examined using the fractional logit model, taking into account the time, country and industry effects on the sample of 225 large non-financial enterprises operating in 15 EU countries in 2018–2021. The obtained results indicate a positive and statistically significant relationship between the analyzed values, which allows for the formulation of a forecast that reducing the intensity of CO_2 emissions by 100 bps will allow for a reduction in the cost of debt capital by about 10 bps. The positive relationship was confirmed using three different measures of CO_2 emission intensity. The country and the industry in which the enterprise operates has a significant impact on the total cost of debt. The fact that the company belongs to an industry recognized as a strong CO_2 emitter, including production, energy, utilities, transport and construction, additionally increases the cost of debt capital.

The study expands the financial literature on the impact of carbon risk on the financing conditions of companies that emit significant amounts of GHG. It confirms, and at the same time extends, the results obtained by Caragnano et al. [53] and Pizzutillo et al. [56] for large European nonfinancial companies operating in the years 2010–2017, showing that market investors and financial institutions penalize enterprises for their exposure to carbon risk, including risks that are due to the possibility of deteriorating the reputation and incurring charges for contributing to the process of environmental erosion. The obtained results could be applied by enterprises in the formation of business plans for projects of the implementation of a technology reducing the intensity of CO_2 emissions for improving environmental rating and assessment of financial markets. The results can also be used by public authorities to start governmental programs supporting high-CO_2 emitters in their efforts to reduce CO_2 emission and improve their public reputation.

It should be noted that the quality of the delineated relationship between carbon risk and the cost of debt capital can be improved by using data from more companies as well as by using longer time series of CO_2 emissions data in the calculations. The quality of the estimates may also be affected by the uncertainty about the quality of the CO_2 emissions data published by companies. Some of them, for example, record identical emission values over several years. The upward trend in the number of companies publishing data on CO_2 emissions, as well as the longer period of reporting these data, give hope for an improvement in the quality of the data and the possibility of obtaining more accurate estimates.

The significance of the investigated issues motivates their further analysis. The results of the research obtained so far and the analysis of the literature on the subject indicate that in the next stages it is necessary to examine how the level of firms' CO_2 emission intensity affects their risk of bankruptcy and the cost of equity capital.

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