Energy Transition and Financial Distress: Assessing Bankruptcy Risks in Fossil Fuel Companies

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***Abstract*—For fossil fuel companies, it is essential to make strategic moves toward sustainability to avoid potential bankruptcies and ensure long-term success during this critical transition period. In this study, is investigated whether fossil fuel energy companies are influenced by the energy transition represented by four factors that characterize the outlook for a country's zero-carbon economy. A multinomial logit model is applied to investigate financial distress and bankruptcy among fossil fuel energy companies for a nine-year period from 2015 to 2023, utilizing approximately 246 company-year observations drawn from the S&P Europe BMI index (data in dollars). The findings indicate that energy transition metrics impact failure probabilities, both directly and indirectly, depending on whether the firm is in a distressed or healthy financial state. These results suggest that the energy transition metrics may act as a moderator in the relationship between the Current Ratio and the probability of bankruptcy.**

***Index Terms*—Bankruptcy, Energy Transition, Companies, Fossil Fuel, Current Ratio**

I. Introduction

The shift to a zero-carbon world highlights the innovations transforming the manufacturing sector and the policies accelerating this global shift [1]. Corporations worldwide are committing to net-zero carbon transitions by utilizing various tools and pathways, further supporting the growth of renewable companies [2].

In the face of the existential threat posed to businesses, the urgency of the energy transition, driven by climate policies and the need for renewable energy adoption, underscores the importance of adapting business models to mitigate these risks [3]. Adjusting business models to reduce risks requires a thorough understanding of how the energy transition influences financial conditions and the potential for business failure.

Despite extensive research on how energy transition impacts firms and risks related to the transition costs, at the country- level [4] and at the firm level [5], there is very limited conceptualization of how the energy transition is represented in the probability of company bankruptcy.

Perhaps the literature on corporate bankruptcy and energy transition has developed in a diffuse manner because there are different ways of measuring energy transition. Another reason is that the field of bankruptcy prediction has been the subject of research since the 1930s. However, the excessive search for the best bankruptcy model has led to the development of increasingly technically robust bankruptcy prediction models. The predictive capacity of models has become a priority in the face of contemporary problems.

More recent literature review studies of corporate bankruptcy focus exclusively on statistical models [6] while others focus on artificial intelligence models [7], [8], [9]. Another important point is the need for a clear definition. The definition of a bankrupt company varies depending on the criteria set by the researcher [6]. The choice to use one definition over another as an exit strategy is influenced by several factors, including the firm's age, size, labor productivity, and its involvement in research and development (R&D) or advertising activities [10]. Generally, researchers lean towards the concept of legal insolvency, as it allows for a better understanding of the legal characteristics of the bankruptcy process in each country [11]. However, the literature on bankruptcy lacks consistency and does not establish a clear consensus on an appropriate definition. There is limited theoretical development in this area, and many studies make arbitrary decisions.

As a disorderly transition to a low-carbon economy may impose significant costs on both financial and non-financial companies, this research seeks to evaluate the role of the energy transition in moderating the relationship between liquidity and bankruptcy risk. Specifically, we aim to determine whether the energy transition amplifies or mitigates the effects of liquidity on the likelihood of bankruptcy for companies.

Metrics that can represent the effects of energy transition as risk in previous research have focused on environmental, social, and governance (ESG) factors [12], [13], [14], greenhouse gas [15], Technology Investment to total investment (TCAP) [13] and corporate carbon footprints and climate disclosures [16].

Related literature suggests that an increase in ESG (Environmental Social and Governance) scores enhances the predictive capability. Notably, a strong ESG score significantly reduces the likelihood of misclassifying distressed or defaulted banks as healthy [13], [17]. Additionally, ESG reports can act as a new indicator for predicting whether an energy company

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will face financial distress [14]. Indeed, the incorporation of ESG factors in the literature is important. However, there is a strong externality in the relationship between ESG performance and the likelihood of bankruptcy. A better cost leadership strategy has a higher ESG performance that reduce the probability of bankruptcy, increasing the social value of the company [18]. This means that the externality of operational performance contains useful information for predicting corporate bankruptcy indirectly.

Indirect impacts may also be covered by climate risks, namely physical risk and transition risk [13]. Physical risks cover the short-term impacts on business operations and transition risks, which involve the regulations imposed by the energy transition [19]. There is a negative association between technology capital expenditures and default risk, suggesting that companies investing in technology take a proactive approach towards innovation and operational efficiency [13].

The energy transition path is associated with a lower probability of default and, consequently, a reduced risk of bankruptcy. The available evidence indicates that this transition involves a shift towards more sustainable practices by companies, which may indirectly enhance financial performance. These findings have important implications for companies and their external stakeholders. This study aims to fill this gap by proposing a model that explores the different metrics for corporate energy transition, the ability of these metrics to predict corporate bankruptcy, and how these metrics relate to financial ratios. The metrics used in this study are ESG score, Emissions Score, CO_2 Emissions (Total) and Energy Transition Index, and companies are classified as bankrupt, financial distress and healthy according to Altman's Z score[20].

The potential marginal contributions are as follows. First, the independent variable is categorized into three levels, distinguishing financial difficulties from bankruptcies and healthy companies. Unlike previous work, this study builds a data set combining information from eleven countries (Austria, Belgium, Finland, France, Greece, Italy, Netherlands, Norway, Portugal, Spain and United Kingdom) widely used in academia as a case study.

Second, the study tests whether including energy transition variables (ESG Score, Emissions Score, CO2 Emissions (total) and Energy Transition Index) influences the probability of bankruptcy predictive models. This study demonstrates ways to incorporate the energy transition into bankruptcy models, highlighting the important role of sustainability in assessing companies' financial risk.

Finally, comprehensive elucidations of potential adverse future transition scenarios can facilitate comprehension and mitigation of a "disorderly" transition, which denotes a technological evolution characterized by substantial socioeconomic repercussions and financial instability. In this framework, the survival of fossil fuel enterprises is rendered critical for orchestrated transformation. Consequently, analyzing the sector's bankruptcy probability reflects a future orientation towards a low-carbon economy.

This study investigated whether fossil fuel energy companies are influenced by the energy transition represented by four factors that characterize the outlook for a country's zero-carbon economy: ESG score [14], Emissions score, CO_2 Emissions (total) [21], [22] and energy transition index [23]. Furthermore, the study explores whether the energy transition directly or indirectly affects company bankruptcy [18].

II. METHODOLOGY

A. Multinomial logit model

A multinomial logit model is applied [24] to investigate financial distress and bankruptcy among fossil fuel energy companies. The multinomial model is situation in which a dependent variable involves more than two qualitative states. In this study, the states are bankrupt, healthy and in financial distress. For J states, the probabilities are specified as:

$$P_{tj} = \frac{\exp\left(\alpha_j + \beta_j X_t\right)}{\sum_{k=1}^{J} \exp\left(\alpha_k + \beta_k X_t\right)} \quad (1)$$

where $\alpha_1 = 0$ and $\beta_1 = 0$ are normalized.

For the specific case of three states—bankrupt ($J=0$) , financial distress ($J=1$) , and healthy ($J=2$) —the equations are:

$$\begin{aligned} Log\left(\frac{P_{t2}}{P_{t1}}\right) &= \alpha_2 + \beta_2 X_t \\ Log\left(\frac{P_{t3}}{P_{t1}}\right) &= \alpha_3 + \beta_3 X_t \end{aligned} \quad (2)$$

with $P_{t1} = 1 - P_{t2} - P_{t3}$

The log of the odds ratio between states remains a linear function of the independent variables. However, the model is constrained by the requirement that the sum of the individual probabilities equals 1. Four multinomial logistic regression models were developed to evaluate the likelihood of company bankruptcy to identify various indicators related to the energy transition. The predictive variables were selected based on a literature review [25]. To summarize the firms' situations, a set of 17 financial ratios (Independent variables) was analyzed. The dependent variable was categorized into three groups: Category 0 (Bankruptcy), Category 1 (Financial Distress), and Category 2 (Healthy). The definition is based on Altman's Z score [20]. Each model incorporates a range of accounting and market ratios. The models also include variables representing the energy transition, such as the ESG score, Emissions Score, CO_2 Emissions (total), and the Energy Transition Index. The initial number of variables considered in the analysis was subsequently reduced. This reduction was necessary to mitigate issues related to collinearity, which often arises from computing ratios using figures from the same financial statements. This process resulted in a final set of five financial ratios plus four energy transition metrics for our analysis. All statistical analyses were performed using Stata 18.Table I presents this final set of ratios.

TABLE I. FINANCIAL RATIOS AND ENERGY TRANSITION METRICS

Variable code	Model factors	
	Metric	**Group of indicators**
R01	Current Ratio[a]	Liquidity Ratio
R02	Total Liabilities/Total Assets[a]	Leverage Ratio
R03	Current Assets/Total Incomes Ratio[a]	Activity Ratio
R04	Return on Assets (ROA)[a]	Profitability Ratio
R05	Market Capitalization/Total Liabilities[a]	Market Ratio
R06	ESG Score[a]	Energy Transition Metrics
R07	Emissions Score[a]	
R08	CO_2 Emissions (total)[a]	
R09	Energy Transition Index (ETI)[b]	

a. Data are from Eikon/Datastream. b. Data are from [23].

B. Data

All data used in this paper are presented annually for the period from 2015 to 2023. This timeframe was selected because it includes the most recent data available and coincides with the Paris Agreement established in 2015. The data for this study were obtained from two main sources. First, most of the data were collected from Eikon/Datastream, specifically the S&P Europe BMI index, with figures reported in US dollars. The focus was placed on all active and inactive fossil fuel energy companies from European countries, resulting in 246 firm-year observations. Second, the data on energy transition index have been collected from [23]. This index reflects two main trends: (a) the shift from fossil fuels to renewable energy sources and (b) the development of more efficient energy solutions. Together, these trends indicate an upward movement on the energy ladder. In this study, the Energy Transition Index was tested to determine whether there is any effect, although it is a country-level index.

All variables were winsorized at the 1% and 99% levels to mitigate the impact of outliers. However, the variable R26, which represents CO_2 emissions (total), underwent a more aggressive winsorization at the 10% and 90% levels due to its significant dispersion. Additionally, all companies with null or zero book values were excluded from dataset.

III. RESULTS AND DISCUSSION

A. Results of Multinomial Logit Models

The evaluation starts with the findings from four multinomial logistic models. Each model varies in the environmental variable used while keeping the financial controls (R01, R02, R03, R04 and R05) and the interaction between R01 (Current Ratio) and the energy transition metric (R06, R07, R08 or R09). For instance, model 1 is represented by the ESG Score variable (R06), financial indicators, and the interaction between the ESG Score and the Current Ratio (R01xR06).

As shown in Table II, Model 1 (using ESG score) and Model 4 (using ETI) present the best fit among the four specifications, pseudo R^2 values range from approximately 0.403 to 0.458 across the 4 models. Additionally, Model 1 and Model 4 yield the most consistent and statistically reliable results. Model 1 demonstrates a positive and significant effect of the interaction between ESG Score and Current Ratio on the probability of a firm being classified as healthy.

This suggests that there is an indirect effect on the chances of a company being considered healthy, the ESG Score may be acting as a moderator, and liquidity risks may be amplified by ESG performance. In fact, these results corroborate the current literature. The better the environmental performance, the better the financial performance tends to be [14], [26]. However, this study highlights that this trend may be related to liquidity. The higher the ESG score, the greater the chances of companies meeting their short-term financial obligations.

Model 4, on the other hand, reveals an impact for both significant coefficients related to the probability of bankruptcy which means that liquidity risks for fuel companies may be associated with a country's transition policies to a low-carbon economy. Government regulatory pressures related to the energy transition increase liquidity risks, affecting the likelihood of the company being classified as in financial distress or deemed healthy [4], [5], [27]. The analyzes of results for models 2 (using Emissions Score) and 3 (using CO_2 Emissions) were discarded due to their lower predictive power and the insignificance of the interaction term.

TABLE II. SUMMARY OF MULTINOMIAL LOGIT MODELS FOR FINANCIAL DISTRESS

Model	Base outcome (Dummy =0)[a]				
	Moderate Variable	**Coefficient (Dummy =1)[b]**	**Coefficient (Dummy =2)[c]**	**Pseudo R^2**	**Total[d]**
Model 1	R01xR06	-0.006 (0.007)	0.028 (0.011)**	0.458	246
Model 2	R01xR07	-0.004 (0.006)	0.010 (0 .008)	0.412	246
Model 3	R01xR08	$-1.07*10^{-9}$ ($1.34*10^{-8}$)	$1.10*10^{-8}$ ($3.26*10^{-8}$)	0.403	246
Model 4	R01xR09	3.078 (1.429)**	-3.065 (1.744)*	0.423	246

a. The Base outcome is "Bankrupt" (Dummy =0). b. The category 1 is "Financial Distress" (Dummy =1). c. The category 2 is "Healthy" (Dummy =2). . d. Number of observations. *Significant at the 10% level, **Significant at the 5% level and ***Significant at the 1% level. Standard errors are reported in parentheses.

B. Results of Model 1 and Model 4

In Table III, all the complete results for Model 1 and Model 4 can be found. Based on the results of Model 4 for Current Ratio, a higher R01 indicates a greater likelihood of a company being healthy and a lower likelihood of facing bankruptcy [28]. Liquidity for healthy companies is, on average, better [29]. The results from Model 4 align with existing literature [30], [31], [32] and are statistically significant: the coefficient for companies in financial difficulties is significant at the 5 percent level, while the coefficient for healthy companies is significant at the 10 percent level. Conversely, Model 1 presents the opposite perspective.

Regarding the other financial variables, R02, R03, R04 and R05, they all present the same signs for both models (1 and 4), which correspond to the expected signs for all respective variables. It is important to note that the variable, R02, represented by Total Liabilities/Total Assets contradicts financial theory. More leveraged companies have a higher risk of insolvency[32], [33]. While the results for R02 do not align with existing literature and theory, there may be a non-linear relationship between R02 and the probability of bankruptcy for fossil fuel companies. It is important to investigate this relationship to determine whether such a possibility exists.

Current Assets to Total Income (R03) is an activity ratio that primarily focuses on current accounts, illustrating how effectively a company manages its operating cycle [34]. Higher Activity ratio tend to be associated with healthy companies [30], [35]. Therefore, this result is consistent with the literature and theory. The results of studies R04 and R05 also support previous findings [30], [31].

About Model 1, which uses the ESG score as an independent variable, it is expected that companies adopting ESG criteria are less likely to go bankrupt [14], [17], [26]. However, in the fossil fuel sector, this relationship may be more complex due to variations in ESG measurement criteria, a lack of transparency, and significant heterogeneity within the sector[36]. This study presented a counterintuitive result in the relationship between healthy and bankrupt companies.

Concerning Model 4, which uses the Energy Transition Index as an energy transition proxy. These results revealed that countries that have better energy transition rates tend to have companies with lower chances of bankruptcy. This is a surprising result because fossil fuel companies are expected to face larger challenges related to revenues and operating costs. However, these companies can see the transition to a low-carbon economy as a market opportunity and potentially increase their revenues through greenwashing [37].

It is crucial to note that while R01 and R09 alone show positive signs, the interaction between R01 and R09 presents a negative coefficient for healthy companies. This highlights the moderating effect of the energy transition index on bankruptcy probability which may be further explored in more details in future research.

TABLE III. RESULTS OF MODEL 1 AND MODEL 4

Variable	Model 1[a]		Model 4[a]	
	Coefficient (Dummy =1)[b]	**Coefficient (Dummy =2)[c]**	**Coefficient (Dummy =1)[b]**	**Coefficient (Dummy =2)[c]**
R01	0.320 (0.365)	-1.039 (0.503)**	-2.843 (1.314)**	2.953 (1.587)*
R02	-2.006 (1.965)	13.254 (3.040)***	-1.292 (1.887)	11.587 (2.670)***
R03	0.052 (0.024)**	0 .081 (0.028)***	0.067 (0.025)***	0.071 (0.028)**
R04	0.098 (0.028)***	0.225 (0.047)***	0.120 (0.031)***	0.263 (0.054)***
R05	1.681 (0.575)***	5.115 (0 .843)***	1.730 (0.557)***	4.326 (0.711)***
R06	0.035 (0.018)*	-0.118 (0.032)***	-	-
R01xR06	-0.006 (0.007)	0.028 (0.011)**	-	-
R09	-	-	-3.708 (2.572)	8.320 (3.588)**
R01xR09	-	-	3.078 (1.429)**	-3.065 (1.744)*
Intercept	-3.564 (1.673)**	-9.450 (2.372)***	1.558 (2.770)	-21.178 (4.552)***
Pseudo R^2	0.458		0.423	
Number of observations	246		246	

a. The Base outcome is "Bankrupt" (Dummy =0). b. The category 1 is "Financial Distress" (Dummy =1). c. The category 2 is "Healthy" (Dummy =2). *Significant at the 10% level, **Significant at the 5% level and ***Significant at the 1% level. Standard errors are reported in parentheses

IV. CONCLUSION

This paper examines the connection between the literature on energy transition and the literature on company bankruptcy. The focus is on the fossil fuel subsector of the energy sector, as this allows us to more effectively assess the sensitivity to changes toward a low-carbon world. However, it is necessary to move forward to clarify the relationship between energy transition and company bankruptcy, as well as to develop more robust predictive models. The incorporation of energy transition metrics into bankruptcy prediction models is extremely important; the focus on understanding the short-term and long-term components of bankruptcy probability models represents opportunities for future improvements as well as understanding the moderating effect of the energy transition on other financial components. These effects prevent a disorderly and financially unstable energy transition. Therefore, this study is an essential contribution for policymakers, investors, and industry stakeholders, to developing strategies that mitigate the bankruptcy risk of the companies. To mitigate these risks, innovative financial mechanisms like "climate bailout bonds" or new legal frameworks such as environmental earnouts could be proposed to manage liabilities and support transitions to renewable energy while avoiding abrupt bankruptcies.

The results show a positive relationship between environmental performance, financial performance, and corporate liquidity. However, they also show that countries' decarbonization path may increase liquidity risks for fossil fuel companies since energy transition indicators are moderators of the relationship between liquidity and financial health.

Moreover, future research must be conducted to gain a deeper insight into the financial implications for the fossil fuel industry as it undergoes a structured transition, utilizing extensive data sets. At the same time, qualitative aspects can be included to assess the managerial capacity and management skills of directors in the face of these changes.

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