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Analysis of Firm-Specific Factors Affecting Capital Structure in Renewable Energy Firms

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Yenilenebilir Enerji Firmalarında Sermaye Yapısını Etkileyen Firmaya Özgü Faktörlerin Analizi

Abstract

The purpose of this study is to investigate firm-level determinants of capital structures of renewable energy firms. For the study, data from the world's top 10 renewable energy firms, ranked in the Reuters Energy 100 report from 2019 to 2023, were used. In the study, multiple linear regression is used to analyse associations among variables. Based on the analysis conducted in the study context, profitability, size, asset structure, tax and liquidity variables, and firm leverage showed strong negative correlations. The relationships among the variables provided evidence that the pecking-order theory holds in renewable energy companies.

Keywords : Sustainability, Capital Structure, Trade-off Theory, Pecking Order Theory, Leverage.

JEL Classification Codes : G30, G32, Q20.

Öz

Bu çalışmanın amacı yenilenebilir enerji firmalarının sermaye yapılarına etki eden firmaya özgü faktörlerin analiz edilmesidir. Çalışma kapsamında, Reuters tarafından hazırlanan Energy 100 raporunda yer alan dünyanın önde gelen 10 yenilenebilir enerji firmasının 2019-2023 yılları arasındaki verileri kullanılmıştır. Araştırmada değişkenler arasındaki ilişkilerin analiz edilebilmesi için çoklu doğrusal regresyon analizi kullanılmıştır. Araştırma kapsamında gerçekleştirilen analiz sonucunda, firma kaldıracı ile kârlılık, büyüklük, varlık yapısı, vergi ve likidite değişkenleri arasında anlamlı ve negatif bir ilişki tespit edilmiştir. Değişkenler arasında tespit edilen bu ilişkiler yenilenebilir enerji firmalarında finansal hiyerarşi teorisinin geçerli olduğuna dair kanıtlar sunmuştur.

Anahtar Sözcükler : Sürdürülebilirlik, Sermaye Yapısı, Dengeleme Teorisi, Finansal Hiyerarşi Teorisi, Kaldıraç.

1. Introduction

Financing decisions are among the key topics of corporate finance research. Financing decisions concern the optimal utilisation of equity and debt to finance firms' assets, ensuring the minimum capital cost. By this method, firm value maximisation will be achieved through liability structures that minimise capital costs. To this end, many studies are conducted, and new approaches are discovered and reported in the literature. Although many variables are covered in the literature, the treatments focus mainly on the leverage effect and liquidity. In these studies, theories of capital structure have been developed to explain firms' optimal capital structures.

Theories explaining capital structure can be classified into classical and modern approaches. Classical approaches focus on the effect of changes in the firm's debt-to-equity composition on firm value. These approaches include the net income approach (Durand, 1952), the net operating income approach (Berges, 2004), the classical approach (Baker & Wurgler, 2002), and the Modigliani-Miller (1958) approach. Some recent capital structure theories, such as this paper, highlight the determinants of capital structure. These are listed as trade-off theory (Bontempi, 2002; Stiglitz, 1972), agency theory (Harris & Raviv, 1991), pecking order theory (Frank & Goyal, 2003), signalling theory (Leland & Pyle, 1977), and asymmetric information theory (Harris & Raviv, 1991).

Among modern theories of capital structure, the trade-off theory (TOT) and the pecking order theory (POT) are among the most widely researched. TOT considers the debt used to finance firm assets by evaluating its pros and cons. According to this theory, the use of debt financing provides benefits by allowing the free flow of information and liquidity to firms and institutions within the company's group, except for its tax advantage. The managers' debt burden is also said to make them more inclined to operate at optimal levels. In line with the trade-off theory, while debt financing provides these benefits, bankruptcy costs increase when a threshold is exceeded. Therefore, TOT argues that debt is to be used optimally (Buferna et al., 2005: 7; Ar & Sakur, 2021: 749; Akkaynak, 2022: 60; Ersoy, 2022: 200). POT argues that firms are to utilise retained earnings, debt, and equity, respectively, in meeting their financing needs. As a result, POT suggests that honouring a specific financing sequence for firm assets will enhance firm value (Frank & Goyal, 2003: 219; Akkaynak, 2022: 60; Ersoy, 2022: 200).

According to TOT and POT, there must be certain relationships between firms' capital structures and the variables that determine or affect this structure. Therefore, the negative relationships among the tangible fixed asset ratio, profitability, and the leverage ratio support the POT theory (Abdioğlu & Deniz, 2015: 200; Engin et al., 2019: 690). Similarly, according to POT, there is a negative relationship between leverage and size (Titman & Wessels, 1988; Frank & Goyal, 2009; Ersoy, 2022). Another important finding for the POT theory is that firms with high liquidity will use less debt. Therefore, while POT expects a negative relationship between liquidity and leverage, TOT expects the opposite relationship (Abdioğlu & Deniz, 2015: 204; Engin et al., 2019: 690). When considering the situation in terms of non-debt tax shields, firms with higher non-debt tax shields, both according to TOT and POT, are expected to use less debt (Cortez & Susanto, 2012: 125). This study tested the TOT and POT theories within this framework within a sample and analysed the findings within this conceptual framework.

There are many studies in the literature examining the optimal capital structures of firms. These studies are mostly focused on sectors such as the manufacturing industry and banking. Surprisingly, not many studies have examined the capital structures of renewable energy firms. In the limited number of studies on the capital structures of renewable energy firms, the issue has been examined at the country and industry levels, but firm-level factors have not been examined for similarly sized international firms. In the econometric analysis carried out within the scope of this study, firm-specific factors affecting the capital structure of the world's 10 leading renewable energy firms (First Solar, GCL-Poly Energy, Green Plains, Guodian Nanjing, Inox Wind, Motech, Pacific Ethanol, and Zhejiang Akcome) included in the Energy 100 report published by Reuters (<https://www.thomsonreuters.com/en/products-services/energy/top-100>, 04.02.2025) are used as the data set. Given the scale and capacity of traditional energy companies today, it is extremely important to expand government incentives and financing options to enable renewable energy companies to gain a competitive advantage. This situation becomes even more important given the high initial investment costs of clean and renewable energy. Therefore, it is necessary to analyse the firm-specific factors affecting the capital structures of renewable energy firms.

This study will enable a comparison of whether the TOT or the POT theorem is applicable for driving large-sized companies in this sector. TOT assumes that larger firms use more leverage, whereas POT assumes a negative size-leverage relationship (Titman & Wessels, 1988; Frank & Goyal, 2009; Ersoy, 2022). Therefore, the research seeks to fill a research gap by investigating the capital structures of large renewable energy companies and presenting econometric evidence.

In the second part of the study, the relevant literature is reviewed and the theoretical basis established. In the third part of the study, the data set and methodology are presented, and in the fourth part, the findings are discussed. In the conclusion, the study's results will be discussed.

2. Literature

There are literature review papers that outline firms' capital structures, taking into account macroeconomic and firm-specific determinants. Among the research papers, most explain the capital structures of firms in the energy sector. Research on renewable energy companies has been published in the literature in recent years, however. The majority have chosen country indices or renewable energy companies as their topics. This study differs from others in that it includes the world's leading renewable energy companies featured in

Reuters' Energy 100 report. In this section, the relevant literature on the capital structures of renewable energy companies is reviewed.

Samour et al. (2024) attempted to surface the effects of COVID-19 and capital structure on Chinese listed non-renewable and renewable energy companies. COVID-19 has had unfavourable consequences for non-renewable energy firms, according to the research. With respect to the other situation, financial leverage negatively affects equity and return on assets for both non-renewable and renewable energy companies. Therefore, based on these observations, it is certain that these findings follow the POT method. Irawan and Okimoto (2021) empirically examined the capital structures of renewable and non-renewable energy companies. TOT, POT, and market-timing theorems have been tested using macroeconomic variables in this research. The research concludes that the POT and market-timing theorems hold in describing the capital structures of energy companies. Zhang et al. (2021) examined the relationship between the capital structures of renewable energy companies and Chinese economic performance. The conclusions established from the study are the same as those of Irawan and Okimoto (2021) and Samour et al. (2024).

In Doğan and Erdoğan's (2024) research, capital structure variables of energy companies showed negative correlations with other variables, including the current ratio, return on assets, and the ratio of tangible fixed assets to total assets. In their research, Doğan and Erdoğan (2024) also provided evidence supporting the POT method. In the study by İskenderoğlu et al. (2017) on energy companies in Türkiye, the determinants of capital structure were examined. According to the study, profitability and leverage were negatively related. Evidence from studies supports POT. In Grabinska et al.'s (2021) study, the influence of corporate governance on capital structure in the energy industry was studied. Three proxies for corporate governance were utilised: institutional investors, board size, and government holdings. As the study indicates, institutional investors positively influence debt levels among Polish energy companies. In addition, some studies in the literature focused on the financial performance of electricity companies and examined the impact of capital structure variables on financial performance (Tekin, 2022).

Osiichuk (2023) conducted a comparative study of the financial positions and funding needs of traditional and renewable energy companies in EU countries. The study finds that the financial performance of renewable energy companies is improving over time. The study also offers evidence that renewable energy companies can access cheaper equity capital and easier debt financing. Morina et al. (2021) conducted a study to examine the determinants of profitability of renewable energy companies in European Union member states. The study analyses the profitability of listed renewable energy companies in European Union countries, accounting for firm-, country-, and macroeconomic factors. The research found that firm-specific drivers explain profitability more than macroeconomic factors. The firm size also influences profitability, as the study finds. Leverage also has a direct positive correlation with profitability, as the study finds. The study's findings validate the TOT theorem.

Zhang et al. (2016) reported significant findings in their article for testing both the capital structure and overinvestment hypotheses of Chinese renewable energy companies. The findings of this research showed that there has been overinvestment in China, primarily in the biomass and wind power sectors. The study found that companies' capital structures are funded by corporate bonds and long- and short-term commercial loans. The conclusion stated above follows the TOT model. Wei et al. (2020) examined the effect of capital structure on the performance of Chinese renewable energy firms. Even though the study supported an inverse relationship between profitability and financial leverage among renewable energy firms, it also found that profitability was positively related to sustainable growth.

In general, the literature on the capital structure of renewable energy companies is quite limited. While a significant part of the studies focuses on China (Samour et al., 2024; Zhang et al., 2021; Wei et al., 2020; and Zhang et al., 2016), another part focuses on the EU countries (Osiichuk, 2023; Grabinska et al., 2021; Morina et al., 2021, and Irawan & Okimoto, 2021). Another important finding from the literature review is that studies generally provide supporting evidence for the POT theorem in explaining the capital structures of renewable energy firms. This study contributes to the literature by explaining the capital structures of the world's leading renewable energy companies featured in the Energy 100 report using firm-specific factors. In the next part of the study, six models developed during the research will be introduced, with a focus on the data and methodology.

3. Data & Methodology

3.1. Data

This study aims to determine the firm-specific factors that affect the capital structures of the world's 10 leading renewable energy companies (First Solar, GCL-Poly Energy, Green Plains, Guodian Nanjing, Inox Wind, Motech, Pacific Ethanol, and Zhejiang Akcome), as included in the Energy 100 report published by Reuters. To do this, a multiple regression analysis was performed using financial ratios from the published financial reports of the target firms for the period 2019-2023. Financial statement information for the companies under the study scope was sourced from the Refinitiv Eikon database.

Under the research umbrella, 15 independent variables were used to estimate the effects on 6 dependent variables. Dependent variables, leverage ratios, were used to describe the firm's capital structure. In this study, short-term debt/total asset ratio (S/TA), long-term debt/total asset ratio (L/TA), total debt/total asset ratio (D/TA), short-term debt/equity ratio (S/E), long-term debt/equity ratio (L/E), and total debt/equity ratio (D/E) are utilised as the dependent variables. The independent variables incorporated into the models developed in this study are presented in Table 1.

Table: 1
Dependent and Independent Variables

Variable	Ratios
Profitability	Operating Profit / Sales (O/S) for S/TA, L/TA and L/E models Net Profit / Total Asset (ROA) for D/TA and S/E models Operating Profit / Total Assets (O/TA) for the D/E model
Size	Natural logarithm of capital (LOG_{CAP}) for S/TA, S/E and D/TA models Natural logarithm of sales (LOG_S) for the L/TA model Natural logarithm of total assets (LOG_{TA}) for L/E and D/E models
Asset Structure	Tangible Fixed Assets / Total Assets (TANG)
Growth Opportunities	R&D Expenses/Sales (R&D/S)
Tax	Paid Tax / Profit Before Tax(T/PBT)
Borrowing Cost	Financing Expenses / Total Debt (FE/D)
Liquidity	Current Ratio (CR)
Non-debt tax shields	The ratio between total depreciation expenses and total assets (NDTS)

3.2. Methodology

Multiple linear regression was preferred for the research analysis. Panel data analysis is not used in the research because the sample size is more suited to regression analysis. According to Sekaran (2013), to obtain optimal results from regression analysis, the sample size should be between 30 and 500. According to Baldwin (1989), at least 200 observations are needed in panel data analysis. Given the sample size of 50 in this research, the regression analysis yields optimal results. In this context, 6 models were created and analysed in the study. While creating the models, the firms' asset structures, growth opportunities, taxes, borrowing costs, firm liquidity, and non-debt tax-shield variables were held constant across all models. Model differentiation was achieved using the profitability and firm size variables that most significantly impact capital structure and financial performance. In contrast to this study, many prior studies used different variables for profitability and firm variables in their models (Demirhan, 2009; Dsouza et al., 2023; Gill et al., 2011; Yıldırım & Karabayır, 2024).

$$(S/TA)_{i,t} = \beta_0 + \beta_1 (O/S)_{i,t} + \beta_2 (LOG_{CAP})_{i,t} + \beta_3 (TANG)_{i,t} + \beta_4 (R\&D/S)_{i,t} + \beta_5 (T/PBT)_{i,t} + \beta_6 (FE/D)_{i,t} + \beta_7 (CR)_{i,t} + \beta_8 (NDTS)_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$(L/TA)_{i,t} = \beta_0 + \beta_1 (O/S)_{i,t} + \beta_2 (LOG_S)_{i,t} + \beta_3 (TANG)_{i,t} + \beta_4 (R\&D/S)_{i,t} + \beta_5 (T/PBT)_{i,t} + \beta_6 (FE/D)_{i,t} + \beta_7 (CR)_{i,t} + \beta_8 (NDTS)_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$(D/TA)_{i,t} = \beta_0 + \beta_1 (ROA)_{i,t} + \beta_2 (LOG_{CAP})_{i,t} + \beta_3 (TANG)_{i,t} + \beta_4 (R\&D/S)_{i,t} + \beta_5 (T/PBT)_{i,t} + \beta_6 (FE/D)_{i,t} + \beta_7 (CR)_{i,t} + \beta_8 (NDTS)_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$(S/E)_{i,t} = \beta_0 + \beta_1 (ROA)_{i,t} + \beta_2 (LOG_{CAP})_{i,t} + \beta_3 (TANG)_{i,t} + \beta_4 (R\&D/S)_{i,t} + \beta_5 (T/PBT)_{i,t} + \beta_6 (FE/D)_{i,t} + \beta_7 (CR)_{i,t} + \beta_8 (NDTS)_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$(L/E)_{i,t} = \beta_0 + \beta_1 (O/S)_{i,t} + \beta_2 (LOG_{TA})_{i,t} + \beta_3 (TANG)_{i,t} + \beta_4 (R\&D/S)_{i,t} + \beta_5 (T/PBT)_{i,t} + \beta_6 (FE/D)_{i,t} + \beta_7 (CR)_{i,t} + \beta_8 (NDTS)_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$(D/E)_{i,t} = \beta_0 + \beta_1 (O/TA)_{i,t} + \beta_2 (LOG_{TA})_{i,t} + \beta_3 (TANG)_{i,t} + \beta_4 (R\&D/S)_{i,t} + \beta_5 (T/PBT)_{i,t} + \beta_6 (FE/D)_{i,t} + \beta_7 (CR)_{i,t} + \beta_8 (NDTS)_{i,t} + \varepsilon_{i,t} \quad (6)$$

Explanations regarding the variables included in the six models established here are provided in Table 1. Therefore, explanations regarding the variables will not be repeated. In the next part of the study, the findings will be presented and discussed.

4. Findings and Discussion

Before presenting the findings from time-series analyses, it is necessary to examine descriptive statistics to make a general assessment and remove unsuitable time series from the dataset. In this context, descriptive statistics regarding the variables used in the research are included in ANNEX-1.

The average ratio of total debt to total assets for renewable energy firms' financing is 0.53, as shown in the descriptive statistics in ANNEX-1. However, an examination of the standard deviation of the ratio's volatility shows it is 0,17. As a result, the debt utilisation rate varies across the industry. When analysing debt-to-equity ratios, the industry shows lower volatility. Within these ratios, only the long-term debt-to-equity ratio varies among companies. But this can be considered normal due to the cost of long-term lending.

When the descriptive statistics for the profitability ratios (O/S, ROA, and O/TA) of renewable energy companies are examined, the average values are close to zero, but the volatility is high. The high initial investments and the long time required to turn a profit may affect the sector's average profitability. However, as shown in ANNEX-1, the companies' high profitability rates also indicate the sector's profitability potential.

Another piece of information from ANNEX-1 is that companies have high levels of tangible fixed asset investments (TANG). This situation can also be seen when depreciation is accounted for as a share of total assets. In addition, the sector's average current ratio is quite acceptable at 1,76. Therefore, companies can meet their due liabilities on time.

After the descriptive statistics, the data were subjected to correlation analysis. The correlation results are presented in ANNEX-2. Going through ANNEX-2, it is realised that there exists a strong and significant relationship among capital structure ratios, particularly profitability, asset structure, cost of borrowing, and tax shield ratios, for Models I, II, and III. When the variable for growth opportunities is included, a significant, positive relationship is observed only with short-term debt. In Models IV, V, and VI, strong correlations are observed with profitability, asset structure, debt cost, and non-debt tax shield variables. But there was no correlation between growth opportunity variables and the debt-to-equity ratio. Therefore, based on the initial results of the correlation analysis, it is possible to conclude that the short-term debt ratio variable affects the growth prospects of renewable energy companies. A possible reason is that most of the money spent on R&D is sourced through short-term debt.

In multiple linear regression, stationarity tests are required to assess whether variables are spurious. For this purpose, the Generalised Dickey-Fuller (ADF) test was applied to the time series of the models used in the research (Dickey & Fuller, 1979: 427-431).

Table: 2
ADF Test Results

Variable	Stat.	Prob.	Variable	Stat.	Prob.	Variable	Stat	Prob.
S/TA*	-6,55	0,0000	**O/S**	-3,46	0,0132	**TANG***	-7,21	0,0000
L/TA	-3,31	0,0194	**ROA**	-4,64	0,0004	**R&D/S***	-5,66	0,0000
D/TA*	-6,51	0,0000	**O/TA**	-4,65	0,0004	**T/PBT**	-5,97	0,0000
S/E*	-6,47	0,0000	**LOG_S***	-7,31	0,0000	**FE/D**	-4,23	0,0000
L/E	-3,70	0,0069	**LOG_{CAP}***	-7,25	0,0000	**CR***	-6,65	0,0000
D/E	-3,20	0,0254	**LOG_{TA}***	-7,29	0,0000	**NDTS**	-4,70	0,0004

** Since they are not stationary at the level, their first differences are taken.*

Table 2 reports the outcome of the ADF tests. For the series within the scope of application to possess no stationarity, the $p<0,05$ hypothesis must be fulfilled. As noted in Table 2, all series fulfil the null hypothesis of no unit root. For variables that lacked stationarity at the level, the analysis continued by taking first differences of the series.

For the models established in multiple linear regression analysis to yield accurate results, certain assumptions must be met. These assumptions are: no multicollinearity, no deviation from normality, constant variance assumption, and no autocorrelation in the models (Güriş et al., 2013: 165). For this purpose, the variance inflation factor test was applied to assess multicollinearity in the models developed for the application. When the results of the multiple linear correlation test were examined, the “Centred VIF” values for all models ranged from 1 to 5, indicating no multicollinearity among the variables.

The Jarque-Bera test was used to check the normality assumption of the models examined in the research. For the models to meet the normality assumption, the p-value of the statistic must be greater than 0,05 (Chen & Kuan, 2003:7). It has been determined that Model III and Model VI, among the models within the scope of the study, meet this assumption. However, when the sample sizes of other models are taken into account, there is no problem with performing regression analysis under the central limit theorem. *“The central limit theorem states that the arithmetic mean of a large number of independent and identically distributed random variables, if they have finite variance values, will exhibit an approximately normal distribution; Gaussian distribution.”* Based on this theorem, it is concluded that it is possible to use parametric tests even if the normality assumption is not met in series with 30 or more samples (Artstein et al., 2004: 975-982; Rempala & Wesolowski, 2002: 47-54; Marasinghe et al., 1996).

To test for heteroscedasticity in the models utilised by the study, the Breusch-Pagan-Godfrey test was applied, and to test for autocorrelation, the Breusch-Godfrey test was applied (Yan & Su, 2009: 196, 262-263). The tests showed no evidence of heteroscedasticity in any of the models. It is observed that there is autocorrelation in Models II, V, and VI. To eliminate autocorrelation, the “iterative Cochrane-Orcutt” method was applied to the models (Cochrane & Orcutt, 1949).

Table: 3
Regression Results

	Model (I)	Model (II)	Model (III)	Model (IV)	Model (V)	Model (VI)
O/S	-0,0084 (0,1340)	0,0432 (0,9975)			-0,0801 (0,3925)	
O/TA						-1,3034 (-1,8607)***
ROA			-0,2291 (-1,6931)***	-0,3237 (0,3949)		
LOG_S		0,0191 (1,2276)				
LOG_{CAP}	-0,0313 (-2,0706)**		0,0144 (0,7347)	-0,1848 (-1,5527)		
LOG_{TA}					0,0261 (0,3606)	0,1756 (1,4595)
TANG	-0,6129 (-8,3799)*	0,1420 (1,6814)	-0,2376 (-2,1816)**	-1,9562 (-2,9653)*	0,5761 (1,7329)	-0,9948 (-1,0203)
R&D/S	-0,4588 (0,5842)	0,4358 (0,5835)	-0,8277 (-1,0527)	-2,8050 (0,5889)	1,7163 (0,5979)	-8,3921 (-1,5346)
T/PBT	-0,0239 (-1,1212)	-0,0260 (0,8125)	-0,0889 (-2,4301)**	-0,2826 (-1,2748)	-0,0043 (0,0430)	-0,3537 (-2,3824)**
FE/D	-0,2279 (0,7161)	1,2307 (1,9063)	-0,6445 (-1,2921)	-1,2218 (0,4043)	3,1963 (1,1682)	-3,2318 (-1,3196)
CR	-0,1282 (-7,9413)*	-0,0358 (-3,9345)*	-0,1435 (-9,3204)*	-0,5685 (-6,0952)*	-0,1852 (-3,5019)*	-0,7142 (-4,8042)*
NDTS	0,1312 (0,2754)	1,9345 (2,7188)*	0,8569 (1,3876)	3,1855 (0,8515)	5,2946 (2,0417)**	7,6453 (1,6495)
Constant	0,0021 (0,1082)	0,0679 (1,9162)	-0,0143 (0,5894)	-0,0773 (0,5241)	0,1474 (1,5138)	-0,1709 (0,9210)
Breusch- Pagan-Godfrey	0,6509	0,9689	0,3241	0,5802	0,9975	0,9030
R^2	0,8092	0,4465	0,7432	0,5673	0,4110	0,6056
F-Stat.	(0,0000)	(0,0000)	(0,0000)	(0,0000)	(0,0000)	(0,0000)

** Indicates statistically significant relationship at 1%, ** 5%, *** 10% level.*

Table 3 exhibits the outcome of six other models in the context of the research. The regression analysis was carried out using ordinary least squares (OLS). O/S, O/TA, and ROA variables were used to investigate the effect of profitability on the firm's leverage. Results from Models III and VI indicate negative, significant relationships between profitability and firm leverage. These results would indicate that successful firms derive less advantage from borrowing. Yet, if one examines the significance levels of the results, it is evident that they should be supported by other research. Analysis of other studies in the literature revealed an inverse correlation between profitability and firm leverage, consistent with the findings of this research (Samour et al., 2024; Doğan & Erdoğan, 2024; Irawan & Okimoto, 2021; Zhang et al., 2021; İskenderoğlu et al., 2017).

Within the scope of the study, the relationship between firm leverage and size was analysed using the variables sales (LOGS), capital (LOGCAP), and total assets (LOGTA). When the empirical findings in Table 3 are examined, a negative relationship between leverage and size is detected only within Model I. This provides evidence that firms need less short-term debt as their capital size increases. The findings of the model established within the scope of the research regarding the relationship between leverage and size align with those in the literature (Samour et al., 2024; Osiichuk, 2023; Zhang et al., 2021; Grabinska et al., 2021).

Firm asset structure and leverage were investigated through the ratio of tangible fixed assets to total assets. The variable has to be analysed due to its high installation cost for renewable energy companies and their high tangible fixed assets. Negative and strong relationships between firms' leverage and asset structure were found in Models I, III, and IV of this study. This setting provides evidence that renewable energy firms with higher levels of tangible fixed assets are likely to rely on equity capital components rather than short-term debt. These findings are corroborated by Osiichuk (2023) and Grabinska et al. (2021).

In the empirical analysis conducted in this study, the sales-to-research-and-development-expenses ratio was used as the growth-opportunity variable across all models. However, no model supports the contention that leverage is related to growth opportunities. The relationship between leverage and tax was also explored in the study. Here, a negative relationship between firm leverage and tax was found under the scope of Models III and VI. It is important in the context of showing the tax effect of leverage. It is uncommon in the literature to find research on the tax variable for renewable energy firms. However, findings on the leverage-tax relationship are as much as those of Irawan and Okimoto (2021).

In this study, the association between the leverage levels of renewable energy companies and their cost of borrowing was investigated. However, in this study, no significant association was found between these two variables. The current ratio variable was used to investigate the association between leverage and liquidity. The findings reveal negative, significant relationships between leverage and liquidity. There is a negative relationship between leverage and liquidity across all models constructed within the study's framework. This situation shows that firms with less liquid assets tend to borrow more. These findings align with the literature (Osiichuk, 2023; Grabinska et al., 2021). In addition, the negative and robust correlation between liquidity and leverage across all specifications indicates that renewable energy firms prefer to utilise internal sources of funds rather than debt, thereby reducing their external financing requirements by maintaining high liquidity.

Throughout the research, the relationship between leverage and the non-debt tax shield was also investigated. Empirical results confirmed a positive relationship between leverage and the non-debt tax shield. The findings indicate a relationship between non-debt tax shields and high leverage. The positive impact of the non-debt tax shield on leverage indicates that components such as depreciation have a significant financial leverage effect, alongside the tax benefit of firms' debt utilisation. The literature review found that prior research had not examined the impact of non-debt tax shields and leverage on renewable energy firms. Nevertheless, in other sectors, results have been similar to those of this paper (Ersoy, 2022; Söylemez, 2019; Mirza et al., 2017).

After determining the relationships among all variables and leverage, it would be appropriate to draw a general conclusion about the regression outcome. In this study, the analysis found negative relationships between leverage and profitability, size, asset structure, tax variables, and liquidity variables among renewable energy companies. These findings between the variables indicate the relevance of the POT theorem in this sector.

Moreover, for the first time in this study, the relationship between leverage and non-debt tax shields in renewable energy firms was examined, and a positive relationship was found. Conversely, in the research topic, no relationship was observed among the leverage, growth opportunities, and financing cost variables.

5. Conclusion

The world's need for clean, renewable energy is increasing by the day. However, the relative cost advantage of traditional energy sources necessitates subsidies and other credit incentives for investments in renewable energy. Looking at the development of the energy sector, the number and size of renewable and clean energy companies are increasing. In this regard, the literature discusses the capital structures of renewable energy firms.

This study investigates firm-level determinants of the capital structure of renewable energy firms. In the context of the study, the world's top 10 renewable energy firms, as presented in the Reuters Energy 100 report, were used as the dataset. The study differs from other studies found in the literature in terms of the variables and scope. The analysis revealed that firm leverage and profitability, size, asset structure, tax variables, and liquidity variables were strongly negatively correlated. This correlation between variables provided evidence that the POT theorem holds for renewable energy companies.

The study's findings indicate that internal financial factors, including profitability, size, asset structure, and liquidity, influence the leverage ratios of renewable energy companies. It would therefore be beneficial to establish tax incentives, policy support for the use of equity, and low-cost green financing programs to improve firms' internal financing options. Additionally, long-term fixed-rate credit lines must be offered to firms with high levels of tangible fixed asset investment. The tax burden on firms can be reduced by encouraging practices that create non-debt tax shields, such as depreciation. Existing asset-based support policies must be put in place with the consideration that firms with high liquidity need to minimise their borrowing requirements. Lastly, instruments such as publicly supported green bonds and credit guarantees must be scaled up to mitigate sector-specific risks, and sectoral data collection and monitoring mechanisms must be put in place. Within the scope of this study, no relationship was found between leverage, growth opportunities, and financing costs. The reason for this may be the variables used or the data set. Therefore, it is recommended that future studies expand the dataset and test unused variables to yield new findings.

This research has significant findings on identifying capital structure factors for renewable energy companies, but it also faces limitations. Firstly, the investigation relies only on financial ratios and the OLS regression method. This reduces the information about the direction of causality and dynamic impacts. Secondly, the study dataset is restricted to a particular period and sample, making it difficult to generalise to other geographical locations or timeframes. Further research could develop the impact of macroeconomic and institutional factors in cross-country comparative studies. Comparing with other sectors would provide a better understanding of the dynamics of the renewable energy sector. Moreover, the model could be expanded by integrating variables such as institutional governance structures, environmental performance metrics, and the extent of green finance use.

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ANNEX-1
Descriptive Statistics

Variable	Obs.	Mean	Median	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis
S/TA	50	0,3729	0,3974	0,6668	0,0980	0,1804	0,0079	1,5851
L/TA	50	0,1614	0,1614	0,3675	0,0197	0,0913	0,3823	2,2236
D/TA	50	0,5343	0,5852	0,7614	0,1961	0,1744	-0,5232	1,9541
S/E	50	1,0465	0,9431	2,7680	0,1219	0,7461	0,4047	1,9426
L/E	50	0,4088	0,3270	1,3315	0,0560	0,3028	0,9573	3,3217
D/E	50	1,4553	1,4109	3,1924	0,2440	0,8825	0,3217	1,9703
O/S	50	-0,0080	0,0407	0,5132	-0,6812	0,2085	-0,9907	5,2754
O/TA	50	0,0082	0,0235	0,2422	-0,4012	0,0980	-1,0457	7,9777
ROA	50	-0,0080	0,0057	0,1877	-0,4364	0,0971	-1,5401	9,0664
LOG_S	50	6,9718	7,0958	8,9376	4,4091	1,2147	-0,5914	2,4921
LOG_{CAP}	50	6,6666	6,4338	8,8079	4,6424	1,2154	0,3090	2,0600
LOG_{TA}	50	7,4988	7,2775	9,7022	5,6017	1,2120	0,3648	1,8823
TANG	50	0,3596	0,3414	0,6311	0,0906	0,1530	0,0315	1,9883
R&D/S	50	0,0197	0,0103	0,0684	0,0000	0,0214	0,8920	2,4307
T/PBT	50	0,0359	0,0196	1,4428	-0,6274	0,3020	1,8159	11,1053
FE/D	50	0,0228	0,0144	0,0991	-0,0271	0,0239	0,8049	3,5857
CR	50	1,7627	1,2865	4,3901	0,5243	0,9525	0,9065	2,8047
NDTS	50	0,0342	0,0323	0,1039	0,0083	0,0191	1,1863	5,0311

ANNEX-2
Correlation Coefficients

Model I

	S/TA	O/S	LOG_{CAP}	TANG	R&D/S	T/PBT	FE/D	CR	NDTS
S/TA	1,00								
O/S	-0,31**	1,00							
LOG_{CAP}	-0,17	0,53*	1,00						
TANG	-0,73*	0,14	0,17	1,00					
R&D/S	0,29**	0,31**	0,37*	-0,36*	1,00				
T/PBT	-0,05	0,30**	0,12	-0,08	0,06	1,00			
FE/D	0,04	-0,48*	-0,23	0,30**	-0,35**	-0,35**	1,00		
CR	-0,85*	0,29**	0,16	0,38*	-0,13	0,04	-0,26**	1,00	
NDTS	-0,51*	-0,04	-0,11	0,63*	-0,27	0,07	0,21	0,31**	1,00

*Indicates statistically significant relationship at * 1%, ** 5%, *** 10% level.*

Model II

	L/TA	O/S	LOG_{S}	TANG	R&D/S	T/PBT	FE/D	CR	NDTS
L/TA	1,00								
O/S	-0,12	1,00							
LOG_{S}	0,12	0,61*	1,00						
TANG	0,55*	0,14	0,32**	1,00					
R&D/S	-0,21	0,31**	0,15	-0,36*	1,00				
T/PBT	-0,17	0,30**	0,21	-0,08	0,06	1,00			
FE/D	0,38*	-0,48*	-0,24**	0,30**	-0,35**	-0,35**	1,00		
CR	-0,01	0,29**	0,18	0,38*	-0,13	0,04	-0,26**	1,00	
NDTS	0,47*	-0,04	0,21	0,63*	-0,27	0,07	0,21	0,31**	1,00

*Indicates statistically significant relationship at * 1%, ** 5%, *** 10% level.*

Model III

	D/TA	ROA	LOG_{CAP}	TANG	R&D/S	T/PBT	FE/D	CR	NDTS
D/TA	1,00								
ROA	-0,43*	1,00							
LOG_{CAP}	-0,21	0,41*	1,00						
TANG	-0,46*	-0,04	0,17	1,00					
R&D/S	0,18	0,14	0,37*	-0,36*	1,00				
T/PBT	-0,14	0,26***	0,12	-0,08	0,06	1,00			
FE/D	0,24***	-0,47*	-0,23	0,30**	-0,35**	-0,35**	1,00		
CR	-0,88*	0,31**	0,16	0,38*	-0,13	0,04	-0,26**	1,00	
NDTS	-0,28**	-0,42*	-0,11	0,63*	-0,27	0,07	0,21	0,31**	1,00

*Indicates statistically significant relationship at * 1%, ** 5%, *** 10% level.*

Model IV

	S/E	ROA	LOG_{CAP}	TANG	R&D/S	T/PBT	FE/D	CR	NDTS
S/E	1,00								
ROA	-0,25***	1,00							
LOG_{CAP}	-0,10	0,41*	1,00						
TANG	-0,57*	-0,04	0,17	1,00					
R&D/S	0,23	0,14	0,37*	-0,36*	1,00				
T/PBT	-0,09	0,26***	0,12	-0,08	0,06	1,00			
FE/D	0,10	-0,47*	-0,23	0,30**	-0,35**	-0,35**	1,00		
CR	-0,80*	0,31**	0,16	0,38*	-0,13	0,04	-0,26**	1,00	
NDTS	-0,38*	-0,42*	-0,11	0,63*	-0,27	0,07	0,21	0,31**	1,00

*Indicates statistically significant relationship at * 1%, ** 5%, *** 10% level.*

Model V

	L/E	O/S	LOG_{TA}	TANG	R&D/S	T/PBT	FE/D	CR	NDTS
L/E	1,00								
O/S	-0,20	1,00							
LOG_{TA}	0,14	0,41*	1,00						
TANG	0,31**	0,14	0,04	1,00					
R&D/S	-0,04	0,31**	0,43*	-0,36*	1,00				
T/PBT	-0,13	0,30**	0,07	-0,08	0,06	1,00			
FE/D	0,34**	-0,48*	-0,16	0,30**	-0,35**	-0,35**	1,00		
CR	-0,36*	0,29**	-0,09	0,38*	-0,13	0,04	-0,26**	1,00	
NDTS	0,33**	-0,04	-0,19	0,63*	-0,27	0,07	0,21	0,31**	1,00

*Indicates statistically significant relationship at * 1%, ** 5%, *** 10% level.*

Model VI

	D/E	O/TA	LOG_{TA}	TANG	R&D/S	T/PBT	FE/D	CR	NDTS
D/E	1,00								
O/TA	-0,38*	1,00							
LOG_{TA}	0,20	0,28**	1,00						
TANG	-0,38*	0,01	0,04	1,00					
R&D/S	0,18	0,10	0,43*	-0,36*	1,00				
T/PBT	-0,12	0,28**	0,07	-0,08	0,06	1,00			
FE/D	0,20	-0,40*	-0,16	0,30**	-0,35**	-0,35**	1,00		
CR	-0,80*	0,31**	-0,09	0,38*	-0,13	0,04	-0,26**	1,00	
NDTS	-0,21	-0,35**	-0,19	0,63*	-0,27	0,07	0,21	0,31**	1,00

*Indicates statistically significant relationship at * 1%, ** 5%, *** 10% level.*

ANNEX-3
Variance Inflation Factors Test Results

MODEL I		MODEL II		MODEL III	
Variable	**VIF**	**Variable**	**VIF**	**Variable**	**VIF**
O/S	1,475	O/S	1,475	ROA	1,840
LOG_{CAP}	1,321	LOG_{S}	1,321	LOG_{CAP}	1,364
TANG	1,714	TANG	1,714	TANG	1,729
R&D/S	1,828	R&D/S	1,828	R&D/S	1,902
T/PBT	1,275	T/PBT	1,275	T/PBT	1,297
FE/D	1,610	FE/D	1,610	FE/D	1,524
CR	1,079	CR	1,079	CR	1,115
NDTS	1,374	NDTS	1,374	NDTS	1,491
C	NA	C	NA	C	NA
MODEL IV		**MODEL V**		**MODEL VI**	
Variable	**VIF**	**Variable**	**VIF**	**Variable**	**VIF**
ROA	1,840	O/S	1,440	O/TA	1,593
LOG_{CAP}	1,364	LOG_{TA}	1,557	LOG_{TA}	1,581
TANG	1,729	TANG	1,741	TANG	1,763
R&D/S	1,902	R&D/S	1,767	R&D/S	1,838
T/PBT	1,297	T/PBT	1,324	T/PBT	1,371
FE/D	1,524	FE/D	1,593	FE/D	1,413
CR	1,115	CR	1,278	CR	1,344
NDTS	1,491	NDTS	1,330	NDTS	1,410
C	NA	C	NA	C	NA

ANNEX-4
Autocorrelation Test Results

Date: 07/31/25 Time: 14:38
Sample (adjusted): 2 50
Included observations: 49 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.118	-0.118	0.7195	0.396
		2	-0.028	-0.043	0.7619	0.683
		3	-0.079	-0.089	1.1048	0.776
		4	-0.144	-0.170	2.2618	0.688
		5	0.151	0.108	3.5618	0.614
		6	-0.193	-0.194	5.7305	0.454
		7	-0.129	-0.209	6.7220	0.458
		8	0.051	-0.010	6.8785	0.550
		9	0.018	0.002	6.8999	0.648
		10	0.226	0.134	10.159	0.427
		11	-0.094	-0.054	10.739	0.465
		12	-0.036	-0.031	10.825	0.544
		13	-0.046	-0.096	10.974	0.613
		14	0.020	0.023	11.003	0.686
		15	0.036	-0.013	11.097	0.746
		16	-0.005	0.074	11.099	0.803
		17	-0.041	-0.012	11.232	0.844
		18	0.067	0.049	11.596	0.867
		19	-0.011	-0.039	11.606	0.902
		20	0.113	0.095	12.701	0.890

Date: 07/31/25 Time: 14:54
Sample (adjusted): 2 50
Included observations: 49 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.214	-0.214	2.3881	0.122
		2	0.072	0.027	2.6638	0.264
		3	0.078	0.103	2.9923	0.393
		4	-0.173	-0.146	4.6548	0.325
		5	0.088	0.014	5.0913	0.405
		6	0.072	0.115	5.3934	0.494
		7	-0.139	-0.095	6.5366	0.479
		8	-0.021	-0.124	6.5642	0.584
		9	-0.076	-0.085	6.9231	0.645
		10	-0.036	-0.015	7.0049	0.725
		11	-0.081	-0.136	7.4364	0.763
		12	-0.006	-0.062	7.4387	0.827
		13	0.110	0.148	8.2750	0.825
		14	-0.106	-0.052	9.0781	0.826
		15	0.083	-0.011	9.5850	0.845
		16	-0.089	-0.090	10.189	0.857
		17	-0.071	-0.072	10.588	0.877
		18	0.106	0.007	11.502	0.872
		19	-0.047	-0.040	11.688	0.899
		20	0.099	0.095	12.528	0.897

Date: 07/31/25 Time: 14:58
Sample (adjusted): 2 50
Included observations: 49 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.108	-0.108	0.6017	0.438
		2	-0.089	-0.102	1.0208	0.600
		3	0.079	0.059	1.3570	0.716
		4	-0.151	-0.148	2.6270	0.622
		5	0.057	0.039	2.8094	0.729
		6	-0.144	-0.176	4.0206	0.674
		7	-0.044	-0.049	4.1333	0.764
		8	-0.061	-0.146	4.3631	0.823
		9	0.017	0.021	4.3818	0.885
		10	0.144	0.082	5.7150	0.839
		11	-0.133	-0.104	6.8845	0.808
		12	-0.005	-0.063	6.8865	0.865
		13	-0.091	-0.164	7.4554	0.877
		14	-0.078	-0.112	7.8930	0.895
		15	0.098	-0.002	8.6059	0.897
		16	-0.081	-0.065	9.1086	0.909
		17	0.135	0.097	10.523	0.880
		18	0.065	0.040	10.865	0.900
		19	-0.034	-0.043	10.962	0.925
		20	0.146	0.066	12.797	0.886

Date: 07/31/25 Time: 14:54
Sample (adjusted): 2 50
Included observations: 49 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.214	-0.214	2.3881	0.122
		2	0.072	0.027	2.6638	0.264
		3	0.078	0.103	2.9923	0.393
		4	-0.173	-0.146	4.6548	0.325
		5	0.088	0.014	5.0913	0.405
		6	0.072	0.115	5.3934	0.494
		7	-0.139	-0.095	6.5366	0.479
		8	-0.021	-0.124	6.5642	0.584
		9	-0.076	-0.085	6.9231	0.645
		10	-0.036	-0.015	7.0049	0.725
		11	-0.081	-0.136	7.4364	0.763
		12	-0.006	-0.062	7.4387	0.827
		13	0.110	0.148	8.2750	0.825
		14	-0.106	-0.052	9.0781	0.826
		15	0.083	-0.011	9.5850	0.845
		16	-0.089	-0.090	10.189	0.857
		17	-0.071	-0.072	10.588	0.877
		18	0.106	0.007	11.502	0.872
		19	-0.047	-0.040	11.688	0.899
		20	0.099	0.095	12.528	0.897

Date: 07/31/25 Time: 14:38
Sample (adjusted): 2 50
Included observations: 49 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.118	-0.118	0.7195	0.396
		2	-0.028	-0.043	0.7619	0.683
		3	-0.079	-0.089	1.1048	0.776
		4	-0.144	-0.170	2.2618	0.688
		5	0.151	0.108	3.5618	0.614
		6	-0.193	-0.194	5.7305	0.454
		7	-0.129	-0.209	6.7220	0.458
		8	0.051	-0.010	6.8785	0.550
		9	0.018	0.002	6.8999	0.648
		10	0.226	0.134	10.159	0.427
		11	-0.094	-0.054	10.739	0.465
		12	-0.036	-0.031	10.825	0.544
		13	-0.046	-0.096	10.974	0.613
		14	0.020	0.023	11.003	0.686
		15	0.036	-0.013	11.097	0.746
		16	-0.005	0.074	11.099	0.803
		17	-0.041	-0.012	11.232	0.844
		18	0.067	0.049	11.596	0.867
		19	-0.011	-0.039	11.606	0.902
		20	0.113	0.095	12.701	0.890

Date: 07/31/25 Time: 14:38
Sample (adjusted): 2 50
Included observations: 49 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.118	-0.118	0.7195	0.396
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		4	-0.144	-0.170	2.2618	0.688
		5	0.151	0.108	3.5618	0.614
		6	-0.193	-0.194	5.7305	0.454
		7	-0.129	-0.209	6.7220	0.458
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		17	-0.041	-0.012	11.232	0.844
		18	0.067	0.049	11.596	0.867
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