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# Firm's Climate Change Risk and Firm Value: An Empirical Analysis of the Energy Industry

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**Abstract**. *We explore the impact on firm value by numerous factors in the energy industry using panel data from 2010 to 2020. The analysis employs different econometric methods, including fixed-effects, random-effects, two-stage least squares, and generalized method of moments. Our main variables of interest are firm value, firm-level climate change risk, fixed assets, leverage, dividend yield, market capitalization, and assets tangibility. The result suggests that investors are valuing energy firms less due to their exposure to climate change risk. We found that climate change risk, fixed assets, firm leverage, and assets tangibility are negatively related while market capitalization and dividend yield are positively related to firm value. These findings have important implications for energy firms, policymakers, and investors. Energy firms need to consider climate change risk in their investment decisions to maintain their market value, and policymakers should encourage firms to disclose their climate change risk to improve market efficiency. Finally, investors need to incorporate climate change risk in their investment strategies to mitigate potential financial losses.*

**Keywords:** climate change risk, firm value, energy industry, firm-level climate exposure, dividend yield.

**JEL Classification:** G32, L25, Q40.

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## Introduction

The energy industry plays a significant role in the global economy and faces multiple challenges due to increasing environmental concerns and regulations. Climate change has become a crucial issue, leading to changes in market dynamics, firm strategies, and policies. Climate's change impact on the energy sector has been extensively studied (Ciscar & Dowling, 2014). Climate influences the energy sector from both the demand and supply perspectives (Mideksa & Kallbekken, 2010). Despite the fact that climate variables impact energy consumption (Auffhammer & Mansur, 2014), they also present hazards and opportunities for businesses (Lucas & Mendes-Da-Silva, 2018). As a result, climate effects on the energy industry are of concern government at various levels, considering the sector's potential to impact marketplace efficiency and household welfare (Schaeffer et al., 2012; Thornes, 2004; Wilbanks et al., 2008). The expanding uncertainty adjacent to future climate behaviour has increased interest in these issues (Auffhammer &

Mansur, 2014). Whether in production, transmission, or distribution, the resilience of the energy supply is dependent on the sustainability of energy companies (Bartos et al., 2016). As with many other industries, the behaviour of climate variables could affect the value of energy industry companies (Hoffman & Glancy, 2006). In other words, the behaviour of variables affects three key tenets of a firm's value: “revenue from consumption” (Auffhammer & Mansur, 2014), “costs from operating efficiency” (Bartos et al., 2016), and “investments in the company's operating activity”, the firm's value will also be affected (Krueger, 2015). Nonetheless, the theory and empirical literature on the effects of climate on value of the firm in energy industry remains limited which makes this research agenda pertinent (Pérez-González & Yun, 2013).

Our research aim is to investigate the association between firm value and various factors in the energy industry. The study employs panel data analysis on a sample of energy firms from 2010 to 2020, using fixed-effects regression (FE), random-effects regression (RE), two-stage least squares (2SLS), and generalized method of moments (GMM) models. Our main findings indicate that firm climate change risk and fixed assets have a statistically significant negative impact on firm value. Nevertheless, market capitalization and dividend yield have a positive impact on firm value, whereas assets tangibility and leverage do not appear to have a significant impact. These results have important implications for policymakers, investors, and energy firms. Policymakers can use these findings to design effective policies that incentivize firms to mitigate their climate change risk, invest in fixed assets, and enhance their market capitalization. Investors can use these findings to make informed decisions about which energy firms to invest in, based on their level of climate change risk, fixed assets, and market capitalization. Energy firms themselves can use these findings to optimize their operations and investments to improve their overall performance. Overall, this study provides valuable insights into the factors that drive firm value in the energy industry, highlighting the importance of climate change risk, fixed assets, and market capitalization in this context. As the energy industry continues to face challenges and opportunities in the coming years, the insights from this study can inform strategies for achieving sustainable growth and maximizing stakeholder value.

## Literature Review

In recent decades, the literature on corporate environmental responsibility has received considerable attention. This research stream investigates the connection of environmental performance with the financial outcomes of firms. The influence of climate change on the financial performance of corporations is one of the major research areas. In accordance with the “Intergovernmental Panel on Climate Change (IPCC)”, global warming is irrefutable and primarily caused by human activities. As a result, businesses around the world are under pressure to reduce their GHG (Greenhouse Gas) emissions and acclimate to climate change.

It's been known and well-documented for a long time that climate can have an impact on financial or economic outcomes (Dell et al., 2014; Gallup et al., 1999; Nordhaus, 2006). These studies, for the most part, concentrated on analysing the economic effects of climate-related calamities on geographic units (such as nations and towns). Concern about global climate change has also led to an investigation of how the environment affects the value of companies (Beatty & Shimshack, 2010; Berkman et al., 2021; Chava, 2014; Düsterhöft et al., 2020; Huang et al., 2018; Konar & Cohen, 2001; Matsumura et al., 2014; Ozkan et al., 2023).

Previous research literature highlights the effects of the various risks on the energy utilities business, e.g. geopolitical risk (Finon & Locatelli, 2008), weather risks (Pérez-González & Yun, 2013), volatile commodity prices (Lin et al., 2021) and policy uncertainty (Breitenstein et al., 2022; Tulloch et al., 2017). Risk disclosure is an essential instrument for publicly traded companies for presenting their identified hazards and risk management practices in a transparent manner (Düsterhöft et al., 2020). It can assist investors with more accurate cash flow projections and regulators in identifying systemic risks. However, from the perspective of a company, the disclosure of previously unknown significant hazards can be associated with negative outcomes such as a decline in share prices (Düsterhöft et al., 2020).

Research recently came out lends credence to the idea that businesses that prioritize sustainability have a lower risk of bankruptcy and maintain their stability even in the face of turbulence (Broadstock et al., 2021). Despite this, not every organization responds in precisely the same manner to climate change. There are still a lot of folks who don't believe in global warming and may not accept the risks that come with it (Huang &

Lin, 2022). Their prospects on climate change may have a major impact on their choices, both within their own lives and in the larger context of the businesses they own. Climate change will have far-reaching consequences for every facet of the company's operations. Experts have developed intricate models to evaluate the effect of GHG (Greenhouse Gas) emissions on the climate globally (Sautner et al., 2023). The researchers Giglio et al. (2021) said that one of the main problems with figuring out these effects is that it is hard to figure out how individual businesses are affected by climate change because the effects are complicated and come from many different places. In the latest paper, Sautner et al. (2023) use textual analysis to create a measure of climate risk that is unique to each company. Instead of focusing on yearly company disclosures, these authors coded discussions of climate risk in periodic conference calls and calculated the average relative frequency of climate risk discussions in all analyst earnings conference calls throughout the year Sautner et al. (2023).

In pertinent climate risk literature Bansal et al. (2016) make an effort to comprehend the economic impact of climate risk. Their theoretical model implies a preference for early uncertainty resolution and incorporates natural disasters that impact present and future economic growth. The probability and severity of these natural disasters increase as the temperature rises, making temperature a significant economic risk factor. They anticipate that assets with high exposure to temperature risk will have greater risk premiums. Using 25 portfolios of U.S. equities sorted by size and book-to-market, the authors find evidence of a premium for long-term temperature risks that has increased as the temperature has risen over time. Huang et al. (2018) studied climate risk and firm financial relationships through numerous firm from countries with multiple industries classification for the period 1993-2012. Their results suggest a negative climate risk and financial performance relationship. Ozkan et al. (2023) studied climate change risk and firm performance relationship by using large sample size. They endorsed the negative climate risk and financial performance results provided by (Huang et al., 2018). In similar lines, Giang et al. (2021) studied climate risk and firm performance relationships by using 144 listed companies sample from 2015 to 2019 and concluded negative relationship exists among sample companies. The researcher Addoum et al. (2021) find no evidence that temperature exposures are related to sales, productivity, and profitability measures of listed U.S. firms, indicating that, on average, there is no relationship between climate change risk and near-term financial flows.

Overall, prior research has produced mixed results on the nexus between climate change risks and firms' financial performance/value in the energy industry. Although some studies have shown a negative relationship between climate change risks and financial performance, others have discovered no significant relationship or even a positive relationship. We contribute to literature by examining the relationship between climate change risks and firm value in the energy industry using a comprehensive set of control variables and employing various estimation methods. This paper aims to contribute to the existing body of knowledge by analysing the impact of firm climate risk on the firm value of energy sector firms. The research uses firm-level data from 2010 to 2020. In the first step, we employ OLS, OLS robust, and OLS cluster linear regression techniques. In the second step, we employ the FE, RE 2SLS, and GMM econometric techniques to resolve potential endogeneity issues in the analysis. Finally, we use alternative measures of the dependent variable and alternative estimators for robustness.

## Methodology

The study employed panel data analysis to investigate the effect of climate change risk on firm value in the energy industry. We collected 422 energy sector firms financial data from "Compustat" and firm level climate risk data from Centre for Open Science a measure devised by (Sautner et al., 2020). Our study sample consisted of publicly traded energy firms from the United States, Europe, and Asia, over the period 2010-2020. The dependent variable is firm value (Tobin's Q) in literature researchers (Lang & Stulz, 1994; Lucas & Mendes-Da-Silva, 2018; Pérez-González & Yun, 2013) used similar measure. The independent variable is firm level climate risk along with control variables fixed assets, firm leverage, dividend yield, market capitalization and assets tangibility. Table 1 provide the measurement and data sources. For basic relationship testing in first step, we employ simple linear regression techniques, OLS (Ordinary Least Square), OLS robust and OLS cluster regression. The presence of heteroskedasticity and autocorrelation validated by diagnostic tests lead us to second step for more advance econometric techniques. In this step we used panel fixed effect regression (FE), random effect regression (RE), two-stage least squares (2SLS), and generalized method of moments (GMM). We checked robustness with different estimator and measure. Finally, we provide robustness check by ruling out alternative estimator simultaneous quantile regression (SQR) and alternative measure of dependent variable sustainable growth rate.

Based on regression equation following equation generalized.

$$Tobins\ Q_{i,t} = \beta_0 + \beta_1(Firm\ Climate\ Change\ Risk)_{i,t} + \beta_2(Fixed\ Assets)_{i,t} + \beta_3(Firm\ Leverage)_{i,t} + \beta_4(Dividend\ Yield)_{i,t} + \beta_5(Market\ Capitalization)_{i,t} + \beta_6(Assets\ Tangibility)_{i,t} + \varepsilon_{i,t} \quad (1)$$

In this equation, $\beta_0$ represents the intercept, or the expected value of Tobin's Q when all other variables are zero. The coefficients, $\beta_1$ through, $\beta_6$ represent the expected shift in the Tobin's Q linked with a one-unit increase in each of the respective independent variables, holding all other variables constant. The error term $\varepsilon$ represents the portion of Tobin's Q that is not explained by the independent and control variables in the model i represent firm and t time.

Table 1. Variables Measurement and Sources

| Dependent Variable | | Data Sources |
|---|---|---|
| **Firm Value** | Tobin's Q ratio | Computed based on CompStat Data |
| **SGR (Robustness)** | Sustainable Growth Rate | Computed based on CompStat Data |
| **Independent variable** | | |
| **Firms Climate Change Risk** | The machine-learning-based firm specific climate risk measuring devised by (Sautner et al., 2023). | Available at: https://osf.io/fd6jq/ |
| **Control Variables** | | |
| **Fixed Assets** | Firm level | CompStat Data |
| **Firm Leverage** | (Non-Current Liabilities + Current Liabilities – Cash) / Total Assets | CompStat Data |
| **Dividend Yield** | "Dividend per share/price per share" | CompStat Data |
| **Market Capitalization** | Total value of firm's shares | CompStat Data |
| **Assets Tangibility** | N Log Total Assets | CompStat Data |

Source: Compiled by the authors.

## Results and Discussion

In this section first we performed descriptive statistics for basic description of data. The pairwise correlation and variance inflation factor performed to check the issues of multicollinearity. After these basic tests ordinary least square employed to check the basic relationship of the study variables. Then post estimation test performed to validate the results. The diagnostics test shows the presence of heteroskedasticity and autocorrelation issues. To deal with these issues IV regression and instrumental variables techniques e.g., GMM, 2SLS employed to provide more reliable estimates. Finally, robustness check with alternative estimator and alternative measure of dependent variable performed to validate results.

## Summary Statistics

The Descriptive statistics for study variables presented in Table 2. Tobin's Q is an indicator of a firm's market value and is calculated as the ratio of the market value of the firm's assets to their replacement cost. The mean value of Tobin's Q for the sample is 0.175, which suggests that, on average, the firms in the sample have a market value that is greater than their replacement cost. The standard deviation of 0.289 indicates that there is considerable variation in market value across the sample. Firm climate change risk measures the extent to which the firm is exposed to climate change risks. The mean value of 0.048 suggests that, on average, the firms in the sample face a relatively low level of climate change risk. The standard deviation of 0.52, however, indicates that there is considerable variation in the level of climate change risk across the sample, with some firms facing higher risks than others. The mean, minimum, maximum, and standard deviation for the control variable also presented in Table 2.

Table 2. Descriptive Statistics

| Variables | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Tobin's Q | 2,593 | .175 | .289 | -1.352 | 1.017 |
| Firm Climate Change Risk | 2,593 | .048 | .52 | -1.609 | 1.946 |

Table 2 (cont.). Descriptive Statistics

| | | | | | |
|---|---|---|---|---|---|
| Fixed Assets | 2,593 | 7.81 | 1.984 | -4.075 | 13.145 |
| Firm Leverage | 2,593 | .65 | .821 | -5.541 | 7.387 |
| Dividend Yield | 2,593 | .033 | .07 | 0 | 1.34 |
| Market Capitalization | 2,593 | 7.227 | 2 | -.26 | 12.992 |
| Assets Tangibility | 2,593 | .008 | .021 | -.72 | .225 |

Source: Generated through Stata17 by the authors based on study variables.

## Pairwise Correlations and VIF (Variance Inflation Factor)

Table 3 shows the correlation coefficients and variance inflation factors (VIF) among the independent variables in our regression model. Fixed assets and market capitalization have the highest correlation coefficient of 0.769, indicating a strong positive correlation between them. Other correlations among independent variables are generally weak to moderate. Last two columns show VIF values those are below 5, which indicate that "multicollinearity" is not a significant problem in this model. A rule of thumb is that a VIF value greater than five indicates significant multicollinearity.

Table 3. Pairwise Correlations and Variance Inflation Factor (VIF)

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | VIF | 1/VIF |
|---|---|---|---|---|---|---|---|---|
| (1) Firm Climate Change Risk | 1.000 | - | - | - | - | - | 1.01 | .99 |
| (2) Fixed Assets | 0.082 | 1.000 | - | - | - | - | 3.469 | .288 |
| (3) Firm Leverage | -0.005 | 0.128 | 1.000 | - | - | - | 1.035 | .966 |
| (4) Dividend Yield | -0.015 | 0.065 | 0.102 | 1.000 | - | - | 1.023 | .978 |
| (5) Market Capitalization | 0.048 | 0.769 | 0.116 | 0.023 | 1.000 | - | 3.567 | .28 |
| (6) Assets Tangibility | -0.028 | -0.273 | -0.079 | -0.059 | -0.347 | 1.000 | 1.093 | .915 |
| Mean VIF | - | - | - | - | - | - | 1.866 | - |

Source: Generated through Stata17 by the authors based on study variables.

Table 4 exhibits the outcomes for OLS regression models. The dependent variable is Tobin's Q and independent variables are firm climate change risk, fixed assets, firm leverage, dividend yield, market capitalization and assets tangibility.

Table 4. Baseline Analysis

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | **OLS** | **OLS** | **OLS Robust** | **OLS Cluster** |
| **Variables** | **Tobin's Q** | **Tobin's Q** | **Tobin's Q** | **Tobin's Q** |
| | | | | |
| Firm Climate Change Risk | -0.0687*** | -0.0597*** | -0.0597** | -0.0597*** |
| | (0.0194) | (0.0177) | (0.0182) | (0.0160) |
| Fixed Assets | - | -0.0638*** | -0.0638*** | -0.0638*** |
| | - | (0.00765) | (0.0113) | (0.0116) |
| Firm Leverage | - | 0.0168 | 0.0168 | 0.0168 |
| | - | (0.0113) | (0.0126) | (0.0162) |
| Dividend Yield | - | 0.431*** | 0.431*** | 0.431*** |
| | - | (0.104) | (0.104) | (0.114) |
| Market Capitalization | - | 0.0910*** | 0.0910*** | 0.0910*** |
| | - | (0.00772) | (0.0104) | (0.0107) |
| Assets Tangibility | - | 0.493 | 0.493* | 0.493* |
| | - | (0.312) | (0.199) | (0.246) |
| Constant | 0.204*** | 0.00523 | 0.00523 | 0.00523 |
| | (0.0102) | (0.0357) | (0.0420) | (0.0538) |
| | | | | |
| *N* | 2,593 | 2,593 | 2,593 | 2,593 |
| *F stat* | 12.47 | 29.88 | 22.32 | 18.34 |
| *Prob > F* | 0.000 | 0.000 | 0.000 | 0.000 |
| *Cluster by id* | No | No | No | Yes |
| $R^2$ | 0.174 | 0.204 | 0.204 | 0.204 |
| adj. $R^2$ | 0.016 | 0.197 | - | - |

Source: Generated through Stata17 by the authors based on study variables.

The column (1) shows one to one relationship results of independent variable (firm climate change risk) and dependent variable (Tobin's q), firm climate change risk coefficient is significant and negative at the 1% (***) level indicates a negative relationship between firm climate change risk and Tobin's q.

The (2) to (4) columns show the results of the OLS (Ordinary Least Square) regression with firm value (Tobin's Q) as the dependent variable and all independent variables included. Firm climate change risk has a negative and statistically significant impact on Tobin's Q, in all regression models used. Results indicate that investors recognize climate change risk as a negative factor affecting firm value. Fixed assets also have a negative and statistically significant effect on Tobin's Q, in all three models. Dividend yield has a significant and positive impact on Tobin's Q, irrespective of the regression method used. Market capitalization has a positive and statistically significant effect on Tobin's Q, in all models. Assets tangibility has a positive effect on Tobin's Q, but it is only statistically significant when using OLS with clustered and robust standard errors.

### Diagnostic Testing

Table 5 shows the diagnostic tests for study model. (1) Cameron and Trivedi's decomposition of the IM-test is used to test the validity of the instrumental variable assumption in the context of a linear regression model. The table shows the contributions of different sources of departure from the assumption, including heteroskedasticity, skewness, and kurtosis, as well as the total chi-square statistic and associated degrees of freedom and p-value. The results indicate that the instrumental variable assumption is violated due to heteroskedasticity, skewness, and potentially kurtosis, as the corresponding chi-square statistics are significant with p-values > 0.05. The results suggest that caution is needed in interpreting the results of the linear regression model and that alternative estimation methods, such as the "generalized method of moments" (GMM), may be more appropriate to address the potential bias from endogeneity. (2) Breusch–Pagan/Cook–Weisberg test for heteroskedasticity test is performed to check whether the variance of the error terms is constant or not. The H0 (null hypothesis) assumes that a variance is constant, while the alternative hypothesis assumes that the variance is not constant (i.e., heteroskedasticity is present). The p-value > 0.05, indicating that the H0 of constant variance is rejected at the 5% significance level. Therefore, we can deduce that there is evidence of heteroskedasticity in the data, which implies that the OLS estimator may not be efficient in estimating results.

Table 5. Diagnostic Testing

| | | | |
|---|---|---|---|
| **(1) Cameron & Trivedi's decomposition of IM-test** | | | |
| Source | chi2 | df | p |
| Heteroskedasticity | 99.04 | 27 | 0.000 |
| Skewness | 23.70 | 6 | 0.00 |
| Kurtosis | 1.50 | 1 | 0.221 |
| Total | 124.24 | 34 | 0.000 |
| | | | |
| **(2) Breusch–Pagan/Cook–Weisberg test for heteroskedasticity** | | | |
| "Assumption: Normal error terms" | | | |
| Variable: Fitted values of Tobin's Q | | | |
| "H0: Constant variance" | | | |
| chi2(1) | 9.59 | | |
| Prob > chi2 | 0.002 | | |
| **(3) Modified Wald test for groupwise heteroskedasticity in FE regression model** | | | |
| "H0: sigma(i)^2 = sigma^2 for all I" | | | |
| chi2 (16) | 1.3e+34 | | |
| Prob>chi2 | 0.000 | | |
| **(4) Wooldridge test for autocorrelation in panel data** | | | |
| "H0: no first-order autocorrelation" | | | |
| F-stat | 28.716 | | |
| Prob > F | 0.000 | | |

Source: Compiled by the authors based on study variables tests performed in Stata 17.

(3) The Modified Wald test for groupwise heteroskedasticity in the FE regression model examines whether the variance of the error terms is the same for all entities (i.e., cross-sectional units) in the panel. The null hypothesis (H0) is that the error variances are equal for all entities. The p-value is 0.000, indicating strong

evidence against the null hypothesis. Thus, we reject the null hypothesis and conclude that there is significant groupwise heteroskedasticity in the FE regression model, implying that the error variances are not the same across all entities in the panel. This violation of the homoscedasticity assumption can lead to biased and inconsistent estimates, so appropriate adjustments should be made to address this issue, such as using robust standard errors or a heteroscedasticity-consistent estimator. (4) The "Wooldridge test for autocorrelation" in panel data tests the null hypothesis of no first-order autocorrelation in the error terms. The F-statistic is 28.716 and the associated p-value is 0.000, which indicates that there is significant evidence against the null hypothesis. For this reason, we can conclude that there is 1st order autocorrelation in the error terms. The diagnostic test results lead us to employ more robust econometric techniques to avoid biased estimates therefore in second step we employ GMM and 2SLS.

## Main Analysis Results

Table 6 presents the results of four different econometric methods applied to estimate the relationship between Tobin's Q and various firm-level variables. Tobin's Q is a measure of a firm's value. The analysis is based on the energy industry, and the variables included in the model are firm climate change risk, fixed assets, firm leverage, dividend yield, market capitalization, and assets tangibility.

Table 6. Main Analysis

| | **(1)** | **(2)** | **(3)** | **(4)** |
|---|---|---|---|---|
| | **FE** | **RE** | **2SLS** | **GMM** |
| **Variables** | **Tobin's Q** | **Tobin's Q** | **Tobin's Q** | **Tobin's Q** |
| | | | | |
| L. Tobin's Q | - | - | - | 0.500*** |
| | - | - | - | (0.0549) |
| Firm Climate Change Risk | -0.0343* | -0.0485** | -0.0597*** | -0.0261** |
| | (0.0166) | (0.0155) | (0.0176) | (0.00925) |
| Fixed Assets | -0.0687*** | -0.0644*** | -0.0638*** | -0.0600*** |
| | (0.0189) | (0.00857) | (0.00761) | (0.0167) |
| Firm Leverage | 0.00391 | 0.00799 | 0.0168 | -0.0238 |
| | (0.0146) | (0.0117) | (0.0113) | (0.0158) |
| Dividend Yield | 0.618*** | 0.439*** | 0.431*** | 0.545*** |
| | (0.159) | (0.105) | (0.103) | (0.114) |
| Market Capitalization | 0.0848*** | 0.0881*** | 0.0910*** | -0.0227* |
| | (0.0125) | (0.00831) | (0.00769) | (0.00992) |
| Assets Tangibility | 0.317 | 0.426 | 0.493 | -0.196*** |
| | (0.337) | (0.293) | (0.310) | (0.0389) |
| Constant | 0.0919 | 0.0451 | 0.00523 | -0.507** |
| | (0.172) | (0.0483) | (0.0355) | (0.178) |
| *Industry fixed effect* | Yes | No | No | No |
| *Year fixed effect* | Yes | No | No | No |
| *Observations* | 2,593 | 2,593 | 2,593 | 2,593 |
| *No. of ids* | 422 | 422 | 422 | 422 |
| *F-stat* | 11.96 | - | - | - |
| *Prob > F* | 0.000 | - | - | - |
| *$R^2$* | 0.202 | 0.233 | 0.204 | - |
| *adj. $R^2$* | 0.189 | 0.202 | - | - |
| *Wald chi2* | - | 138.48 | 181.06 | 169.23 |
| *Prob > chi2* | - | 0.000 | 0.000 | 0.000 |

Source: Compiled by the authors based on study variables tests performed in Stata 17.

Firm climate change risk has a negative coefficient in all the models, which indicates that rising climate change risk is linked to a decline in Tobin's Q. The coefficient is statistically significant at the 10%, 5%, and 1% level in the FE, RE, and 2SLS models, respectively, and at the 5% level in the GMM model. This suggests that climate change risk negatively affects a firm's market value, which could be due to increased costs associated with climate change mitigation or adaptation measures or reputational damage. These findings are consistent with theoretical arguments that climate change can create various risks for firms, such as regulatory and reputational risks, which can affect their financial performance (Berkman et al., 2021; Huang et al., 2018; Ozkan et al., 2023). Fixed assets also have a negative coefficient in all the models, which indicates that a higher proportion of fixed assets relative to total assets is associated with a lower Tobin's Q. This suggests that firms with more fixed assets are perceived to have lower value by investors, which may be due to the lower flexibility and adaptability of these firms in response to market changes and technological innovations. Dividend yield has a positive coefficient in all the models, which indicates that a higher dividend yield is associated with a higher Tobin's Q. The coefficient is statistically significant at the 1% level in all models. This suggests that firms with a higher dividend yield may be viewed as more attractive by investors, leading to higher market valuations. This finding is consistent with the signalling theory, which suggests that firms with higher dividend playouts signal their financial strength and future growth prospects (Miller & Modigliani, 1961). Market capitalization has a positive coefficient in the FE, RE, and 2SLS models, indicating that a higher market capitalization is associated with a higher Tobin's Q. However, the coefficient is negative and statistically significant at the 10% level in the GMM model. This suggests that the relationship between market capitalization and Tobin's Q may not be linear and may depend on other factors. This finding is consistent with the idea that larger firms can benefit from economies of scale and have more resources to invest in research and development and innovation. Assets tangibility has a negative coefficient in the GMM model, indicating that firms with more tangible assets are perceived to have lower value by investors, which may be due to the higher financial risk and lower flexibility of these firms (Huang et al., 2018; Naseer et al., 2022; Naseer et al., 2021). Overall, the results suggest that climate change risk and fixed assets negatively affect a firm's market value, while dividend yield, market capitalization, and assets tangibility positively affect it. The relationship between leverage and market value is less clear and may depend on other factors.

## Robustness Check

Table 7 show the robustness analysis with alternative measure for dependent variable SGR (sustainable growth rate) and alternative estimator SQR (simultaneous quantile regression) and independent variables fixed assets, leverage, dividend yield, market capitalization, and assets tangibility using different methods: GMM, and quantile regressions at the 50th, 75th, and 90th percentiles. The results show that the coefficient for firm climate change risk is significant and negative in most of the methods, indicating that firms with higher climate change risk tend to have lower SGR. Fixed Assets have a positive and statistically significant relationship with SGR in GMM, while it has a negative and statistically significant relationship with SGR in the 50th percentile regression. The coefficient for firm leverage is negative and statistically significant at the 1% level in all four methods, suggesting that firms with higher leverage have lower SGR. Dividend yield has a negative and statistically significant relationship with SGR in all methods, indicating that firms with higher dividend yield have lower SGR. Market capitalization has a positive and statistically significant relationship with SGR in all methods, suggesting that firms with larger market capitalization have higher SGR. Assets tangibility has a positive and significant relationship with SGR in SQR and insignificant in GMM.

The robustness check using an alternative measure of firm value (sustainable growth rate) and quantile regression analysis at different percentiles also show consistent results with the main analysis. Overall, the findings suggest that climate change risk substantially affect the value of energy firms, and other firm-specific factors should also be taken into consideration when evaluating the potential impacts of climate change on firm value.

Table 7. Robustness Check

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | **GMM** | **SQR (q50)** | **SQR (q75)** | **SQR (q90)** |
| **Variables** | **SGR** | **SGR** | **SGR** | **SGR** |
| | | | | |
| L. Sustainable Growth Rate | 0.0955*** | - | - | - |
| | (0.0161) | - | - | - |
| Firm Climate Change Risk | -0.0282** | -0.0142*** | -0.00899** | -0.00928 |
| | (0.0114) | (0.00480) | (0.00426) | (0.00704) |
| Fixed Assets | 0.0443** | -0.0202*** | -0.00907* | 0.00571 |
| | (0.0204) | (0.00333) | (0.00510) | (0.00513) |
| Firm Leverage | -0.124*** | -0.0394*** | -0.0257*** | -0.0375*** |
| | (0.0121) | (0.00764) | (0.00884) | (0.00853) |
| Dividend Yield | -0.698*** | -0.600*** | -0.432*** | -0.231 |
| | (0.102) | (0.102) | (0.149) | (0.146) |
| Market Capitalization | 0.0748*** | 0.0505*** | 0.0326*** | 0.0297*** |
| | (0.00892) | (0.00321) | (0.00473) | (0.00608) |
| Assets Tangibility | -0.0296 | 0.0156*** | 0.0243*** | 0.0496*** |

Table 7 (cont.). Robustness Check

| | | | | |
|---|---|---|---|---|
| | (0.0222) | (0.00371) | (0.00584) | (0.00795) |
| Constant | -1.233*** | -0.201*** | -0.0164 | 0.104** |
| | (0.175) | (0.0383) | (0.0351) | (0.0508) |
| | | | | |
| *Observations* | 2,593 | 2,593 | 2,593 | 2,593 |
| *Number of ids* | 422 | - | - | - |
| *Pseudo* $R^2$ | - | 0.0983 | 0.0578 | 0.0400 |
| *Wald chi2(7)* | 291.45 | - | - | - |
| *Prob > chi2* | 0.0000 | - | - | - |

Source: Compiled by the authors based on study variables tests performed in Stata 17.

## Conclusion and Recommendations

Based on the results, firm climate change risk is having a negative correlation with firm value (Tobin's Q) or sustainable growth rate (SGR), which are both measures of firm performance/value. Firm climate change risk results are consistent across all estimation methods used. This suggests that investors perceive climate change risk as a potential threat to the future profitability and growth of energy companies. Furthermore, the coefficients for the other variables in the models also provide some insights. For instance, dividend yield and market capitalization have a positive relationship with Tobin's Q, while fixed assets have a negative relationship. These results suggest that firms with greater dividend yield and market capitalization tend to have higher Tobin's Q, which may indicate greater market value, while firms with more fixed assets tend to have lower Tobin's Q. Overall, the findings suggest that investors are paying attention to climate change risk when assessing a firm's financial prospects and that there are other factors, such as fixed assets, market capitalization, leverage, and dividend yield, that also play important roles in shaping investor perceptions of firm value. Finally, the robustness check using an alternative measure of firm value (sustainable growth rate) and quantile regression analysis at different percentiles also show consistent results with the main analysis. Overall, results indicate that climate change risk has a significant bearing on the value of energy firms, and other firm-specific factors should also be taken into consideration when evaluating the possible effects of climate change on firm value.

In terms of implications, the findings suggest that firms need to manage their climate change risk and asset structure effectively to enhance their value in the eyes of investors. Moreover, paying higher dividends and increasing market capitalization can also enhance a firm's perceived value. Firms with strong climate change risk management could benefit from better access to capital markets. Climate change risk management can boost a company's sustainability and responsibility and attract environmentally conscious consumers, investors, and stakeholders who value climate-related companies. Positive reputations boost consumer loyalty, stakeholder support, and brand value. Many nations have climate change mitigation and adaptation legislation. Proactively managing climate change risks helps firms comply with these requirements and avoid penalties and legal issues. Being compliant with regulations can also provide you with a competitive advantage and offer up new green market prospects. Overall, efficiently managing climate change risk can have significant effects on a company, including luring investors, enhancing reputation, adhering to regulations, enhancing operational efficiency, spurring innovation, and bolstering supply chain resilience. These ramifications underline how crucial it is to incorporate risk management for climate change into larger business plans. Overall, the findings of this study provide important insights for both academics and practitioners regarding the factors that influence firm value in the energy industry.

limitation of the study includes, that this study only focuses on the energy industry, and the results may not be generalizable to other industries. Future research can investigate these relationships in other industries and explore additional factors that may influence firm value. Future research could also examine the long-term effects of climate change risk on corporate performance and latest available information utilizing more recent data. Tracking firms over time to see how climate change risk management methods and practices affect their financial performance, market positioning, and competitive advantage. Another area could also be the stakeholder engagement initiatives in relation to climate change risk management. Understanding how various stakeholders view and value climate change risk management techniques, the impact of stakeholder involvement on business performance, and the efficacy of communication strategies connected to climate change risks are a few examples of what can be explored in future research.

## Author Contributions

M.N. conceptualization, M.N., T.B. and I.K; methodology, M.N.; software, M.N.; validation, M.N., I.K and T.B.; formal analysis, M.N.; investigation, I.K and T.B.; resources, M.N., I.K and T.B.; data curation, M.N.; writing-original draft preparation, M.N., I.K and T.B.; writing-review and editing.

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