Climate Risks Pricing in The Capital Market of South Africa

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Abstract

Climate risk represents an increasing vital issue to countries, companies, and institutional investors, making it a reality but not a distant threat to humanity. Considering the effects of climate risks on firms' financial indices and financing options, the study extends the growing literature to the South African capital market. The study investigates whether climate risk is priced by the capital markets of South Africa. Climate-related financial risks refer to a set of potential risks that may result from climate risk and could potentially impact the safety and soundness of the individual financial institutions and have a broader financial stability implication. Investors are therefore paying attention to a firm's environmental performance due to the ongoing environmental debate that emphasizes sustainable investment. The study therefore used reported carbon emissions as a measure of climate risk of 81 listed companies in the Johannesburg Stock Exchange from 2011 to 2020 to examines whether climate risk is considered and priced by the South Africa capital market. We used the two-step system Generalized Method of Moments to corroborate the effects of climate risk on cost of capital and capital structure. We find that climate risk is priced in both cost of debt capital and cost of equity capital. Specifically, we find that an increase in a firm's exposure to climate risk increases the cost associated with issuing debt and equity capital. We also find that climate risk exposure decreases debt-equity ratio. The study concludes that climate risk is priced in cost of financing in the capital market of South Africa. The study therefore recommends that firms should invest in installing eco-friendly machinery in order to reduce their carbon emissions levels.

Key Words: Climate risk, cost of capital, capital structure, capital markets

JEL: C23; G10, Q50

1. Introduction

Climate risk represents an increasing vital issue to countries, companies, and institutional investors (Ginglinger, 2020), making it a reality but not a distant threat to humanity (Hjort, 2016). Since the inception of the industrial revolution in the 1800s, the magnitude and dimension of climate related risks faced on earth has increased tremendously. Human activities are thought to have contributed to global warming of about 1.0^0C since pre-industrial times. According to the Intergovernmental Panel on Climate Change (IPCC, 2018) report in 2018, if these trends continue, global warming will reach 1.5^0C between 2030 and 2052, and 2 to 4^0C by the end of the century. Hence, increasing the number of severe hot days, heavy rains, droughts, and precipitation shortages as well as sea level rise.

Physical and transitional risks are the two main types of climate risks. Climate change related natural disasters such as hurricanes, storms, floods, among others that can cause damage to assets and interrupt supply chains are termed as physical risks. These event-driven risks are referred to as acute physical risks. Physical dangers can also be chronic; referring to long-term changes in climatic patterns such as rising temperatures or rising sea levels. Transition risks are related to the process of transitioning to a lower-carbon economy, and it includes legal risks (climate-related litigation claims), technology risks (new green technologies may disrupt part of a company's activity), market risks (consumers are turning to green products, shifting their buying habits), and reputation risks (the overall perception of the company may be affected by the transition process). However, climate change may also generate new prospects for companies due to cost savings, access to new markets and the development of new products.

While scientific society has been drawing to climate change for many years, the financial community's commitment is more recent but crucial for the future of our planet. One might think that climate related risk is only a part of a company's business risk, hence the application of traditional financial risk management tools can capture these risks (Ginglinger, 2020). However, climate risk complexity, implications and investors perception could explain why these risks cannot be captured with traditional risk tools. Therefore, climate risk may affect the value of assets, financing options, the cost of equity and debt, and hence valuation of firms. One of the major questions in climate finance research is whether climate risks are already considered by firms and priced by the market.

Investors are currently paying much attention to firms' social, governance and environmental performance due to the ongoing environmental debates that emphasize sustainable development (Chen & Gao, 2012; Mungai, Ndiritu, & Rajwani, 2022). Consequently, to facilitate investor's ability to check the environmental risks, pollution costs, and contingent environmental liabilities of firms, more corporate disclosures are needed. For example (Ilhan, Krueger, Sautner, & Starks, 2019) surveyed institutional investors perception of climate and found that more than half of the surveyed investors indicated that climate risks disclosures are as important as financial reporting. A survey of 900 members of the World Economic Forum (2015) shows that climate risks is ranked second among the top ten global risks with immediate likelihood. This was confirmed by Mercer (2015) that climate risk is a source of portfolio risk to investors over the next 20years.

Due to South Africa's carbon emission levels and its efforts to reduce emissions levels and climate change related risk, firms are supposed to disclose environmental, social, and governmental risks such as carbon emissions level, pollution, among others. These disclosures are aimed towards developing mitigation and adaptation strategies, and investment credibility (Torres-Baumgarten and Rakotobe-Joel, 2022). However, investors and financial regulators have argued that climate risk disclosures are important as financial reporting but not sufficient to attract green investors or risk adverse investors (Ilhan et al., 2019; Braun, Braun, & Weigert, 2021). This assumes that investors would expect climate risk to reflect on firm value and market premium and hence affecting their investment decisions. Expectations of this sought makes investors to either divest their investment portfolio (termed as eco-investing or green investing) or engage management for risk-return trade-offs.

South Africa's recent position as the 1st and 14th largest emitter of carbon in Africa and the world respectively (The Carbon Brief, 2018) and one of the most vulnerable countries to climate change related risks, poses a serious challenge to the capital market as market capitalization continue to decline (Johannesburg Stock Exchange Report, 2018). Although, firms are forced to disclose exposure to environmental risks, these risks can have consequences on stock prices and firm value through cost of equity and debt (Huynh, Nguyen, & Truong, 2020; Ginglinger, 2020 and Chen & Gao, 2012) and performance and financing choices of firms (Huang, Kerstein, & Wang, 2018). Stock prices are affected by expectations of future paths of returns and since climate risk signifies possible disruption in production and consumption possibilities, this effect may imply reduction in future asset values. Expectations of this sort would affect cost of financing and financing options today.

In the fight against climate change, companies are made to discourse these environmental, social and governance risks and policies to aid investors decisions. According to Krueger, Sautner and Starks (2020) and Ilhan et al. (2019), investors value climate risk reporting more than financial risk reporting. They reward firms that care about the environment by investing in those firms. Hence, although environmental risks disclosures are necessary, pricing of environmental risks far outweighs disclosure (Huang et al., 2018). To the best of our knowledge, there is no evidence as to whether firms in South Africa price firms' climate change related risks. Hence, the need to provide answers to the following questions: Does climate risk affect stock prices in South Africa? What is the effect of climate risk on firm value? Does the discount rate (cost of capital) used in calculating firm value reflect climate risk? This study tries to provide answers to these pressing issues of concern to investors and policymakers.

Existing studies on climate risks pricing are conducted in other parts of the world, there is little or no empirical study on climate risk pricing in South Africa. For instance, Chen and Gao Silva (2012), Huynh et al. (2020) and Baldauf, Garlappi and Yannelis (2020) examined climate risk pricing in United States, while Braun et al. (2021), Faccini, Matin, Skiadopoulos (2021), and Bansal, Kiku and Ochoa (2019) examined climates risk pricing in other parts of the world except Africa. The only study that considers South Africa is Huang et al. (2018); they examined the effects of climate risk on firm performance and financing choices using 55 countries of which South Africa is part. They used 121 firms, of which only two are from South Africa. Therefore, there is the need for a study that uses as representative sample of firms in South Africa. Also, Huang et al. (2018) only focused on firm performance and financing choices, while the main focus of this study is to assess whether cost of capital (equity and debt) considers climate risks faced by the company. Secondly, many empirical studies on climate risk pricing have ignored the endogenous nature of firm's climate risk (see Palea and Drogo, 2020; Bansal, Kiku, & Yaron., 2010; Bansal et al., 2019). Climate risk at the firm level is determined by many firm level variables which cannot be measured empirically and are therefore captured in the error term that are likely to be correlated with climate risk, and hence the endogeneity problem. Bansal, Kiku and Ochoa (2019) also emphasized on the importance of including a lag dependent variable in empirical cost of capital models.

Therefore, to close the gap in the climate risk pricing research, the study examines the effects of climate risk on stock prices, firm value and cost of equity and debt. This study differs from earlier ones in the following ways: First, following studies by Chen and Silva Gao (2012), Huynh et al. (2020), Bansal et al. (2019), and Berkman, Jona and Soderstrom (2019), the study examines the effects of climate risk on cost of equity and debt using firm level information among companies listed on the Johannesburg Stock Exchange. Secondly, the study examines the effects of climate risk on capital structure of listed companies. The study resolves the endogeneity problem in the models by adopting a dynamic panel estimation technique by Arellano and Bover (1995) and Blundell and Bond (1998). We introduced a lagged dependent variable in our models to allow for the use of dynamic panel technique and in estimating we treat the lagged dependent variable and climate risk as endogenous.

The remainder of the study is structured as follows: Section 2 discusses the theoretical and empirical review on risk pricing and capital structure. Section 3 reports the econometric methodology employed for the study whereas Section 4 presents and discusses the results. Section 5 reports the conclusion and policy recommendation of the study.

2. Literature Review

2.1 Climate Risk and Cost of Capital

The Capital Asset Pricing Model (CAPM) by Sharpe (1963), Lintner (1965), and Mossin (1966) is the basic asset pricing model used in describing the relationship between expected returns and systematic risk. In finance the CAPM is widely used in pricing risky assets and generating returns for assets/portfolios given the level of risk and the cost of capital. The CAPM is supported by many empirical studies such as Fried and Blume (1970), Black, Jensen and Scholes (1972), and

Fama and Macbeth (1973). Other studies have argued that beta is not the only factor that affects asset prices or stock return. For instance, Basu (1977) reported that earning price ratio explains returns on risky assets, Banz (1981) proved that size factor and market capitalization are important in explaining asset prices and returns of risky assets. Also, Bhandari (1988) explains that debt-equity ratio is relevant in explaining returns of risky assets. These empirical studies led to theoretical augmentations of the capital asset pricing model. Fama and French (1993; 1995) in their three-factor asset pricing model argued that beta is not the only factor that influence asset pricing or return of risky asset. However, Fama and French (1993; 1995) reported that the size factor and the book-to-market value factor are two other important factors that affect asset pricing or returns of risky assets. Fama and French (2015) in one of their most important research "A Five Factor Asset Pricing Model" augmented the three-factor model by adding two additional variables: the investment factor and the profitability factor, after observing that the three-factor model is redundant in explaining average returns of risky assets.

Recently, augmentation to the capital asset pricing model is focused on how climate change related risk affects stock return, risk premiums, cost of capital and stock prices. Climate risk is currently posing serious risk to various sectors of the economy, and the financial sector/equity market is not an exception. To the extent that majority of investors are ranking risk as more important than financial risk (Ginglinger, 2020; Ilhan et al., 2019). Studies by Ginglinger (2020), Huynh et al. (2020), Gregory (2021), Berkman et al. (2019), Agliardi and Agliardi (2021), among others have found that climate risk is a factor that explains stock return, risk premiums, cost of capital, and stock prices under the capital asset pricing framework. Therefore, the capital asset pricing framework can be used to establish the relationship between climate risk and cost of capital.

Many empirical studies have examined climate change related risk pricing in financial institutions. For instance, Chen and Silva Gao (2012) examined climate risk pricing among US electrical firms. Using a pooled panel regression approach and firm reported carbon emission as a measure of climate risk, the authors found that climate risk is priced by US electrical firms. That is, the cost of equity capital and debt reflects climate risks. Berkman, Jona and Soderstrom(2019) use a firm-specific climate risk measure based on textual analysis and find that firm value is negatively related to climate risk. Beirne, Renzhi and Volz (2021) examined the link between climate risk vulnerability and resilience to climate risks and cost of sovereign bonds. Using data from 40 advanced and emerging economies that are vulnerable to climate change, the study found a positive relationship between climate risk and cost of sovereign bonds but a negative relationship for resilience to climate risks. However, vulnerability to the direct effects of climate change matters most for sovereign borrowing costs than climate risk resilience. Moreover, the effects are more intensive for countries highly vulnerable to climate change.

Huynh, Nguyen and Truong (2020) examined the relationship between drought and cost of capital in the United States agricultural sector. Drought data is sourced from the Palmer Drought Severity Index (PDSI) from 1968 to 2015. A 12-month average was used as the PDSI yearly value for each state. Two dummies were created to capture the severity of the drought and the intensity. Applying panel fixed effect method of analysis, the study found that costs of capital (debt and equity) are positively affected by drought. The analysis also revealed that drought intensity is positively associated with costs of capital equity implied in stock prices. Moreover, the severity and duration of drought are more damaging to firms' cost of capital. Hong, Karolyi and Scheinkman (2020) used the PDSI to estimate countries' vulnerability to droughts as a result of climate change. The authors examine food industry stock returns across countries over the sample period of 1985 to 2014 and find that equity markets do not anticipate the effects of predictably worsening droughts on agricultural firms until after they materialize. This is inconsistent with the findings of Bansal and Ochoa (2009) that rises in global temperature lowers equity valuation and raise risk premiums. Bansal and Ochoa (2009) also indicated that a current increase in temperature can negatively affect future growth up to ten years and it will cost about 104% of GDP to completely insure against temperature variations.

Bansal, Kiku and Ochoa (2019) established that long-run temperature shifts have a significant negative effect on equity valuation. Hence, the temperature beta of equity return is negative for almost all equity portfolios. Huynh, Nguyen and Truong (2020) also examined the effect of climate risks (measured as drought) on cost of equity capital among agricultural firms. Applying the dummy variable fixed effect panel model, they found that implied cost of equity capital in stock prices are positively affected by drought severity and intensity. They also found that longer droughts pose more danger to economic activities as compared to short term droughts. Sautner and Starks (2021) confirm that climate risks are priced in the US financial markets. The authors also argue that investors prefer to employ risk management and engagement strategies rather than divestment to address climate risks in their portfolios. But divest if their portfolio managers do not put in the necessary actions. However, Griffin and Hammond (2019) demonstrate that equity markets recognize but underprice physical climate risk, consistent with forming biased expectations of future equity returns. This is consistent with Bertolotti, Basu, Akallal and Deese (2019), which show that the physical climate risks of 269 publicly listed U.S. utilities, based on the physical location of their plants, property, and equipment, are underpriced in equity markets.

Braun, Braun and Weigert (2021) examined hurricane exposure as a systematic risk factor in the US stock market from 1995 to 2020. The study showed that stocks with low hurricane losses sensitivity outperformed stocks with high hurricane losses sensitive. The study emphasized the importance of climate risks for firm's cost of capital as hurricane premium is not explained by standard asset pricing risk factors nor stock characteristics. Allman (2020) also confirmed that firm's exposure to higher seal level rise across US branch locations pay a premium when issuing bonds. This effect is more pronounced for firms in industries vulnerable to weather conditions. Similarly, Kim, An and Kim (2015) studied the effects of carbon risk on cost of equity of 379 Korean firms from 2007 to 2011. The results indicate that carbon intensity is positively related to cost of capital. The study recommends that companies' efforts to improve carbon productivity are suggestively compensated by the reduction in the cost of capital, which increases firm value. Javadi and Al-Masum (2020) studied the impact of climate change on the cost of bank loans. Firms in locations with higher exposure to climate risk pay significantly higher spreads on their bank loans. To alleviate the concern related to using firm's headquarters in determining climate risk exposure, they exploit the economic link between a firm and its customers and find that the exposure of a firm's customers to climate risk also adversely affect that firm's cost of borrowing. They find that the long-term loans of poorly rated firms drive the effects. Their evidence suggests that lenders increasingly view climate change as a relevant risk factor.

In conclusion, studies on the effects of climate risks on cost of capital (equity and debt) are still scanty since most climate risks pricing literature are focused on few developed and emerging economies. There is therefore the need to expand existing studies to various financial markets across the world. Hence, this study to the best of our knowledge is the first to extend these studies to South Africa.

2.2 Climate Risk and Capital Structure

The starting point of capital structure theories is the Modigliani and Miller (1958) capital structure irrelevant theory. They demonstrated that firm value is unaffected by the level of leverage to equity ratio under some assumptions related to optimal investor behavior and capital market behavior. The assumptions under the their capital structure irrelevant theory are that securities of firms are traded in perfect markets, and that insiders and outsiders have all relevant information at the time of making decisions (no asymmetry information). That implies that there is no transaction cost, bankruptcy cost, and personal taxation. Hence, individuals and firms can borrow unlimitedly at the same rate, which permits homemade leverage. Therefore, they propose that managers should not be concerned about the capital structure, and they can freely select the composition of debt to equity.

However, trade-off theory proposed by Myers (1977) argued that firms trade the associated cost of debt (financial distress cost) for marginal benefits of debt (tax shield) up to the point where the marginal benefits of debt (tax shield) is equal to the marginal cost of debt (financial distress cost). Unlike the Modigliani and Miller (1958) capital structure irrelevance theory, firms can achieve an optimal capital structure (debt to equity ratio) that maximizes firm value by balancing the benefits of tax shield and financial distress cost associated to leverage. Myers and Majluf (1984) proposed the pecking order theory, which hypothesizes that management of firms prefer internally generated capital than externally generated source of capital. The pecking order theory suggests that firms first resort to internal source of capital before resorting to debt capital and lastly to issuing equities as the last resort of raising capital when the cost of debt (bankruptcy cost and agency cost) is higher than the tax shield of issuing debt.

The credit rating–capital structure hypothesis by Kisgen (2006) is an extension of the trade-off theory of capital structure. Kisgen (2006) hypothesized that the cost and benefits of different ratings levels affect capital structure decisions. However, his hypothesis only considers credit rating, therefore extending the hypothesis to cover other essential ratings that likely affect capital structure decisions is of paramount importance. According to Krueger et al. (2020) and Ilhan et al.

(2019) investors value climate risk reporting more than financial risk reporting. Climate risk rating is one of the current ratings that tell how firms' activities affect the natural environment. Investors and debtors are becoming more concerned about climate risk rating due to the huge associated risk. Although climate risk is a cost to firms on its own, it has the potential of affecting credit ratings and financial distress cost of firms. Therefore, the study uses the trade-off theory and its extension (credit rating–capital structure hypothesis) to link climate risk and capital structure decisions theoretically. The expectation is that a higher climate risk level would worsen financial distress cost and credit ratings and hence affect the level of debt used by the firm.

Leaving aside the theoretical reasoning, there exist a growing empirical literature on the effects of climate risk on capital structure. Huang, Kerstein and Wang (2018) studied the impact of climate risk on firm performance and financing choices. Applying a panel fixed effect approach, they found that climate risk is negatively associated with firm earnings and positively associated with earnings volatility. They also showed that countries characterized by severe climate risk tend to hold more cash, rely less on short term loans and more on long term loans, and pay low cash dividends. Using firm level data from 14400 firms in 77 countries, Bolton and Kacperczyk (2021) finds that the impact of climate transitioning risk on stock return is greater for firms located in lower economic development, greater reliance on fossil fuel and less inclusive political systems. Long term climate transitioning risk is higher for countries with strict domestic but not international climate policies.

Sun, Yang, Huang and Zou (2020) examined the impacts of climate change risks on financial performance of listed mining companies in China. The study found that rain waterlogging, and flooding risks have negative impacts on financial performance of mining companies in China, but drought risk have a positive impact on the financial performance of mining companies in China. While Hugon and Law (2018) find that firms' earnings on average are negatively impacted by an abnormally warm climate, Berkman et al. (2019) found that climate risk negatively affects firm value. Similarly, Ginglinger and Moreau (2018) found that greater climate risk leads to lower leverage in the post 2015 period. Specifically, the study found that acute risks (risks that lead to natural disasters such as storms, hat waves, and heavy rainfalls) and sea level rise risks have a significant negative effect on leverage. Also, the authors further proved that the reduction in leverage as a result of higher climate risk can be separated into two: the demand side effect (where firms decrease their optimal leverage ratio as a result of climate risk) and supply side effect (where debtors increase the spreads on loans as a result of climate risk).

Nguyen and Phan (2020) examined the effects of climate risk on corporate capital structure in Australia. Classifying companies into heavy emitters and low emitters, the study examined how leverage of companies responded to the Kyoto protocol ratification (KPR). The study first examined market reaction to the announcement of KPR by measuring the cumulative abnormal stock return (CAR) around the announcement day. The study found a negative CAR for the average firm. But the subsamples showed that negative market reaction is concentrated among heavy emitters while it is insignificant for light emitters. Further analysis using the difference in difference framework also showed that book and market value of leverage of heavy emitters decreased after the announcement. Kovacs, Latif, Yuan and Zhang (2021) examined the effects of climate regulatory risk on capital structure. The results show that firms located in states with finalized climate adaptation plans increase their net market leverage by 3.3% more compared to firms located in neighboring states without such plans. Capasso, Gianfrate and Spinelli (2020) investigated the relationship between exposure to climate change and credit risk of European companies. The study showed that the distance-to-default, a widely used market-based-measure of credit risk or default risk, is negatively associated to firm's carbon emissions and carbon intensity. Therefore, companies with higher carbon emissions level are more likely to default as compared to firms with low carbon emissions.

The literature reviewed afore clearly shows that there exist a theoretical link between climate risk and capital structure. However, there are no empirical studies on this relationship in Africa, to the best of the researchers' knowledge. Therefore, the study spices up the empirical literature on the climate risk–capital structure relationship by being the first to explore this relationship among South African firms.

3. Methodology

3.1 Data

The study covers eighty-one (81) companies listed on the Johannesburg Stock Exchange market over 10years. Data on all variables were sourced from Data Stream database. DataStream database is a global financial and macroeconomic time-series database, providing data on equities, stock market indices, currencies, company fundamentals, fixed income securities, and key economic indicators for 175 countries and 60 markets. The Johannesburg Stock Exchange currently lists 442 firms, however only a few of these firms were required to report on the environmental performance such as carbon emissions levels. Due to this limitation, the study resorts to using a non-probability sampling technique in acquiring the data for the analyses. The study used a purposive sampling technique in selecting the firms for the study, here firms that report their carbon emissions from 2011 and 2020 were selected. And this forms a sample of eighty-one firms over 10years.

3.2 Model Specification

The study used the risk pricing model of Bansal and Yaron (2004) to investigate the effects of climate risk on cost of capital. According to Bansal et al. (2010), the model can jointly account for the equity premium, and the risk-free rate puzzles, among others. The model also explains the observed credit spread, term structure of interest rates, option prices, and cross-section of expected returns across assets. The study augments the model of Bansal and Yaron (2004) to capture the pricing of climate risk in the expected risky return. The augmented model can be express as follows:

$$E\left(R_c - R_f\right) = \beta_\mu \lambda_\mu + \beta_x \lambda_x + \beta_c \lambda_c \quad (1)$$

Here $E(R_c - R_f)$ is the expected risk premium, in this study the expected risk premium is used as the expected cost of capital for each instrument in the market. And $\lambda_\mu, \lambda_x, and\ \lambda_c$ are the market prices of risks. Importantly, expected risk premium rise with climate risk – the term $\beta_c\lambda_c$ reflects the compensation related to climate risk, and this rises with climate risk as λ_c increases with climate risk. The functional form of equation 1 can be expressed as:

$$Cost\ of\ capital_{it} = f(climate\ risk, size, lev, roa, turnover, mrktcap) \quad (2)$$

Where, $cost\ of\ capital$ is cost of acquiring equity or debt instruments (measured as cost of equity capital and cost of debt capital), climate risk is proxied with carbon emission (following Chen & Silva Gao (2012). This measure assumes that firms with lower emission rates and high environmental performance have lower exposure to climate risk. According to Chen and Silva Gao (2012) these firms have a strategic competitive advantage in anticipation of future legislation or regulations. Superior environmental performers may either over-comply with existing pollution regulations or engage in voluntary investment in innovative pollution technologies without any threat of non-compliance levies. Firms may pursue strategies to reduce emissions to benefit from green consumerism, reduce future environmental restriction penalties and lawsuits, and improve productivity and efficiency. Carbon emissions measured as the total direct and indirect levels of emissions. Therefore, equation 2 can be written in the specific form as follows:

$$\begin{aligned} Cost\ of\ capital_{it} &= \varphi + \beta cost\ of\ capital_{it-1} + \gamma climate\ risk_{it} + \eta Size_{it} + \delta Lev_{it} + \theta roa_{it} \\ &+ \delta turnover_{it} + \vartheta mrktcap_{it} + \psi_i + \varphi_t + \varepsilon_{it} \quad (3) \end{aligned}$$

Among which, $Size$ is the firm size measured as the log of total assets of the firm, Lev is the leverage ratio of the firm measured as total leverage divided by total assets, roa is the profitability of the firm measured as the return on asset, and $turnover$ and $mrktcap$ are market turnover and market capitalization, respectively.

In analyzing the effects of climate risk on capital structure, we adopt the theoretical model by Kisgen (2006), which hypothesized that the cost and benefits of different ratings level affects capital structure decisions. Various ratings directly affect capital structure decisions thus when a firm is closer to a poor rating reduces it debt to equity ratio and increases debt when it is closer to a good rating. Generally, Kisgen (2006) model can be expressed as follows:

$$Debt\ to\ Equity\ ratio = f(ratings, X) \quad (4)$$

Among which $Debt\ to\ equity\ ratio$ is the ratio of total debt to total equity, $ratings$ can either be environmental performance rating, and credit rating, among others, and X are other variables that affect capital structure. The study deviates from pervious literature that used credit rating to using environmental performance rating as an important rating affecting financing decisions as indicated by Krueger et al. (2020) and Ilhan et al. (2019). Hence, the specific form of equation 4 can be written as follows:

$$DER_{it} = \alpha + \vartheta DER_{it-1} + \beta Climate\ risk_{it} + \gamma Size_{it} + \delta ROA_{it} + \eta Mktcap_{it} + \varphi Turnover_{it} + \psi Lev_{it} + \phi_i + \phi_t + \varepsilon_{it} \quad (5)$$

Where, $DER, Size, Mktcap, turnover$ and Lev are debt to equity ratio, firm size, market capitalization, market turnover, and leverage ratio.

4. Results and Discussion

4.1 Climate Risk and Cost of Capital

Here we present the results of the analysis with discussions on major findings. The lagged coefficient is insignificant suggesting there is no financing inertia and market signaling in the debt market. This also implies market participants' perception of firms' creditworthiness and risk factors does not persist over time. It also implies market conditions and competitions do not affect cost of debt capital in South Africa.

Insert Table 1 here

Table 1 presents the results of the effects of climate risk on cost of debt capital. The results show that increases in a firm's exposure to climate risk are associated with an increase in the cost of debt capital. That is a percentage increase in carbon emissions is associated with a 0.2 percent increase in the cost of debt. Thus, increases in carbon emissions increase the firm's exposure to climate risk, higher risk derives risk premiums higher. A higher risk premium would drive up investors' appetite for higher return on their debt holding as a trade-off for higher risk, an increase in the return from debt holding increases the cost of debt capital. The results are consistent with the findings of Chen and Silva Gao (2012), Huynh et al. (2020), Bansal et al. (2019), Kim et al. (2015), and Sautner and Starks (2021) who also found a positive relationship between climate risk and cost of debt capital.

Also, increases in firm size are associated with an increase in the cost of debt capital. Larger firms have more capital and might take on large proportions of debt, increasing their leverage risk and hence further debt comes with a higher risk and should be compensated with higher return on debt instrument. A higher return on debt instruments causes the average cost of debt to rise. However, Modigliani and Miller (1956, 1959) argued that increases in firm size reduces the total risk associated with that firm and hence reduces the cost of raising capital. But recent studies have found that larger firms take large and long-term debts while smaller firms take short term debt with shorter yields (Myers and Majluf, 1984), thus these firms issue debt at a higher cost than smaller firms.

The study also found that an increase in profitability of the firm is associated with a decrease in the cost of debt capital. The finding suggests that increases in a firm's profits makes firms prefer other low risk forms of financing (retained earnings) to debt financing which is relatively riskier (Miller and Modigliani, 1959). This would reduce the pressure on debt demand and cause the cost of debt to fall. This empirical finding is consistent with the empirical studies of Allman (2020), Beirne et al. (2021), and Chen and Silva Gao (2012), among other studies.

Moreover, as expected leverage ratio has a significant positive effect on the cost of debt capital. According to Miller and Modigliani (1959), Myers and Majluf (1984), Chen and Silva Gao (2012) and Beirne et al. (2021), higher leverage is associated with a higher risk (leverage risk), which causes the risk premium associated with debt to increase. Hence, an increase in the risk premiums of debt increases the cost of debt, making leverage ratio to be positively priced in the cost of debt.

Lastly, Table 1 shows that market capitalization and market turnover have negative effects on the cost of debt. These results are expected because an increase in the performance of shares reduces the demand for debt instruments and hence lowers the cost of debt instruments. Therefore, we conclude that climate risk, leverage, and firm size are positively priced in the cost of debt instruments, while profitability, capitalization, and turnover are negatively priced.

Insert Table 2 here

Table 2 presents the results for the effects of climate risk on cost of equity capital. The results show that cost of equity capital tends to persist over time, implying that investors' perceptions of risk, market conditions, or firm-specific factors that contribute to the cost of equity do not change rapidly. Therefore, the lagged cost of equity capital serves as an indicator of the persistence of investors' expectations and the influence of past risk perceptions on the current cost of equity. Moreover, we believe the lagged coefficient relates to market efficiency and information processing, suggests that the market is not fully efficient in incorporating new information into the cost of equity. It implies that market participants may not fully and immediately adjust their expectations in response to new information.

The results also show that increases in a firm's exposure to climate risk are associated with an increase in the cost of equity capital. That is a percentage increase in carbon emissions is associated with a 0.088 percent increase in the cost of equity. Thus, increases in carbon emissions increase the firm's exposure to climate risk, higher risk derives risk premiums higher. A higher risk premium would drive up investors' appetite for higher return on their equity holding as a trade-off for higher risk, an increase in the return from equity holding increases the cost of equity capital. The results are consistent with the findings of Chen and Silva Gao (2012), Huynh et al. (2020), Bansal et al. (2019), Kim et al. (2015), and Sautner and Starks (2021) who also found a positive relationship between climate risk and cost of equity capital.

Similar to the discussion about the effects of climate risk on cost of debt presented in Table 1, firm size is positively priced in cost of equity capital. This result is consistent with Chen and Silva Gao (2012), Huynh et al. (2020), Bansal et al. (2019), Kim et al. (2015), and Sautner and Starks (2021) who found that firm size is positively priced in cost of equity. However, the results also show that leverage ratio and market capitalization are not significant in explaining cost of equity. Moreover, the study found that increases in profitability is associated with an increase in cost of equity. This implies that firms engage in retained earnings instead of paying profitability to investors as dividends, hence firms would have to compensate investors in the future in the form of higher return on equity for unpaid dividends. Lastly, market turnover is found to exhibit a positive influence on the cost of equity. This implies that increases in turnover are associated with an increase in the cost of equity.

In conclusion, the results in Table 2 reveals that climate risk, firm size, profitability, and turnover are positively priced in the cost of equity capital. However, market capitalization and leverage ratio are negative priced, but these two variables are statistically insignificant in this study.

4.2 Climate Risk and Capital Structure

Here we present the results of the analysis with discussions on major findings. We present three static panel regression estimates and a dynamic panel which accounts for the endogeneity issues in the data. The lagged dependent variable (debt-equity ratio) has a positive significant effect on the current debt-equity ratio. This implies that firms tend to maintain a relatively stable capital structure over time (we refer to this as persistence of capital structure). This aligns with the notion of capital structure inertia, where firms maintain their previous financing choices due to financial constraints, informational asymmetries, or managerial preferences. Positive lagged term can also be interpreted in the context of market timing theory, where firms time their financing decisions based on their perception of market conditions and availability of external financing. The positive coefficient indicates favorable markets and hence firms increase their leverage over time.

Insert Table 3 here

Table 3 presents the results on the effects of climate risk on capital structure. The study found a negative relationship between climate risk and debt-equity ratio. This suggests that a percentage increase in carbon emissions would cause the debt-to-equity ratio to fall by 0.00885 (0.89%). Consistent with Ginglinger and Moreau (2018) that greater climate risk leads to lower leverage in the post 2015 period. Specifically, the study found that acute risks (risks that lead to natural disasters such as storms, heat waves, and heavy rainfalls) and sea level rise risks have a significant negative effect on leverage. This also confirms the Modigliani and Miller (1956, 1959) preposition that leverage decreases with perceived risk.

Table 3 also shows that leverage ratio positively affects debt-to-equity ratio. This implies that an increase in leverage as a proportion of total assets would cause debt-to-equity ratio to increase. Leverage ratio is defined as the total debt instruments (long and short terms) issued by the firm as a fraction of total assets, hence an increase in the total debt should automatically increase the debt-equity ratio used by the firm. This is consistent with Ginglinger and Moreau (2018) who argued that an increase in the leverage ratio of a firm increases the debt-equity ratio when all other factors are held constant. Theoretically, this is consistent with the prepositions of Modigliani and Miller (1956, 1959).

Moreover, the study found that increases in firm size is associated with an increase in debt-equity ratio. Myers (1984) hypothesis states that larger firms use more debt instruments especially long-term debt, small firms use less debt mostly short-term debt and hybrids. This suggests that large firms prefer debt to equity because of higher cost of equity (floatation, underpricing), agency cost of equity, dilution of control, and signaling. Current studies such as Ginglinger and Moreau (2018), Nguyen and Phan (2020), Kovacs et al. (2021) also found that increases in firm size is associated with an increase in the debt-equity ratio, similar to the findings of this study.

In addition, the study also found that firm profitability has a significant negative effect on the debt-equity ratio. This implies that a percentage increase in the return on assets of a firm would cause the firm's debt-equity ratio to fall. Myer (1984) argues that profitable firms tend to have lower debt levels despite their high debt capacity and tax shield advantages. This might be due to the fact that firms prefer retained earnings and hybrid securities to larger debts and equities. Firms prefer retained earnings to debts and equities because of the potential cost or risk associated with debt and equity financing.

Lastly, the study found that increases in market capitalization decreases debt-equity ratio. According to Baker and Wurgler (2002), firms issue shares when shares are overvalued or overrated in the market; and buy-off shares when the value of shares are underrated or undervalued. Hence, higher market capitalization would make firms issue more shares and reduce their debt holding, and hence a reduction in the debt-equity ratio. However, market turnover has a positive effect on debt-equity ratio but statistically insignificant, suggesting turnover does not influence firms' capital allocation decisions. Therefore, we conclude that climate risk, firm size, profitability, and capitalization are important factors firms consider before choosing their capital allocations.

5. Conclusion and Policy Recommendations

Motivated by the devasting impacts of climate change on economic activities in South Africa, this study extends the climate risk pricing literature to the South African Capital market. Specifically, the study examined the effects of climate risk on cost of capital (for both debt and equity capitals) and capital structure of firms listed in the Johannesburg Stock Exchange. The empirical models are derived from the risk pricing model of Bansal and Yaron (2004) and the credit rating capital structure hypothesis of Kisgen (2006). The study applied static panel data analysis to eighty-one listed companies from 2011 to 2020. We employed the two-step system generalized method of moments in estimating the three equations of the study. The two-step system GMM controls for the endogeneity problems in the models and the introduction of the lagged terms aid us to measure the persistence, efficiency, and timing of the equity and debt markets of South Africa.

We found that climate risk positively affect cost of debt and equity capital among listed companies in South Africa. Also, climate risk affects debt-equity ratio negatively as expected. The study also showed that firm size, leverage ratio, capitalization, profitability, and turnover affect both cost of capital and capital structure of listed firms. Based on these findings, the study concludes that the dire effects of climate risk have already been realized in South Africa's capital market.

The practical implications of climate risk on the cost of capital and capital structure can be significant and wide-ranging. Here are some practical implications our analysis has revealed: the first is the higher cost of capital (debt and equity). Lenders and investors have perceived climate risks as potential threats to a company's financial performance and long-term sustainability. As a result, they demand higher returns to compensate for the increased uncertainty and potential losses associated with climate-related risks. This has led to higher borrowing costs and a higher cost of equity, impacting a company's overall cost of capital.

Secondly, our study revealed that climate risk influence capital allocation decisions. This implies that companies may need to prioritize investments in climate-resilient infrastructure, energy efficiency initiatives, or low-carbon technologies to mitigate risks and align with changing market expectations. This may require allocating resources away from more carbon-intensive or climate-vulnerable sectors, impacting a company’s capital structure and investment strategies. Another implication of our findings is related to firm’s reputation and brand risk. Consumers, investors, and other stakeholders have become more conscious of environmental sustainability and may evaluate a company’s commitment to addressing climate risks when making purchasing or investment decisions. Failure to address or mitigate climate risks can lead to reputational damage, loss of market share, and a decline in the company’s overall value.

The study also revealed that Environmental, Social, and Governance (ESG) factors, including climate risk considerations, are gaining prominence in investment decision-making. Investors, particularly those focused on sustainable investing, may incorporate climate risk assessments into their investment processes. This can influence a company's access to capital and cost of capital, as investors may prefer companies with robust climate risk management strategies and lower exposure to climate-related risks. Companies facing higher climate-related risks may experience increased insurance costs or challenges in obtaining adequate coverage. Insurance providers may reassess premiums or coverage terms based on climate risk assessments, potentially impacting a company’s overall cost structure.

These practical implications highlight the need for companies to proactively assess and manage climate risks, incorporate climate considerations into their strategic decision-making, and enhance their resilience to climate-related challenges. It is essential to stay informed about evolving regulatory frameworks, investor expectations, and market trends related to climate risk to make informed decisions regarding capital structure and cost of capital.

Although the study is the first in South Africa, our study is limited by small sample size and reduced statistical power of the analysis. The 2010 carbon disclosure framework was meant for only some firms; however, the 2018 and 2022 carbon disclosure frameworks require all firms to disclosure the carbon emissions levels. Hence, carbon emissions data will be available in the near future, therefore future studies would expand the sample size.

REFERNCES

Agliardi, E., & Agliardi, R. (2021). Pricing climate-related risks in the bond market. *Journal of Financial Stability*, *54*, 100868. https://doi.org/10.1016/j.jfs.2021.100868

Allman, E. (2020). Pricing Climate Change Risk in Corporate Bonds. *Journal of Asset Management 23,* 596-618. https://doi.org/10.1057/s41260-022-00294-w

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, *68*(1), 29-51. DOI: 10.1016/0304-4076(94)01642-D

Baker, M., & Wurgler, J. (2002). Market timing and capital structure. *The journal of finance*, *57*(1), 1-32.

Baldauf, M., Garlappi, L., & Yannelis, C. (2020). Does climate change affect real estate prices? only if you believe in it. In *Review of Financial Studies*, *33*(3), 1256-1295. https://doi.org/10.1093/rfs/hhz073

Bansal, R., and Yaron, A. (2004) Risks for the Long Run: A Potential Resolution of Asset Pricing Puzzles, Journal of Finance *59*, 1481–1509.

Bansal, R., Kiku, D., & Yaron, A. (2010). Long run risks, the macroeconomy, and asset prices. *American Economic Review*, *100*(2), 542-546. DOI: 10.1257/aer.100.2.542

Bansal, R., Kiku, D., & Ochoa, M. (2019). Climate change risk. *Federal Reserve Bank of San Francisco*.

Bansal, R., & Ochoa, M. (2012). Temperature, aggregate risk, and expected returns. *NBER Working Paper*, *17575*, 10-11.

Bansal, R., & Yaron, A. (2004). Risks for the long run: A potential resolution of asset pricing puzzles. In *Journal of Finance*, *59*(4), 1481–1509. https://doi.org/10.1111/j.1540-6261.2004.00670.x

Banz, R. W. (1981). The relationship between return and market value of common stocks. *Journal of financial economics*, *9*(1), 3-18.

Basu, S. (1977). Investment performance of common stocks in relation to their price-earnings ratios: A test of the efficient market hypothesis. *The journal of Finance*, *32*(3), 663-682.

Beirne, J., Renzhi, N., & Volz, U. (2021). Feeling the heat: Climate risks and the cost of sovereign borrowing. *International Review of Economics and Finance*, *76*(April), 920–936. https://doi.org/10.1016/j.iref.2021.06.019

Berkman, H., Jona, J., & Soderstrom, N. S. (2019). Firm-specific climate risk and market valuation. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2775552

Bertolotti, A., Basu, D., Akallal, K., & Deese, B. (2019). Climate Risk in the US Electric Utility Sector: A Case Study. *SSRN Electronic Journal*, 2020 (March), 1–27. https://doi.org/10.2139/ssrn.3347746

Bhandari, L. C. (1988). Debt/equity ratio and expected common stock returns: Empirical evidence. *The journal of finance*, *43*(2), 507-528.

Black, F., Jensen, M. C., & Scholes, M. (1972). *The Capital Asset Pricing Model: Some Empirical Tests*.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115-143. DOI: 10.1016/S0304-4076(98)00009-8

Bolton, P., & Kacperczyk, M. T. (2021). Global Pricing of Carbon-Transition Risk. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3795029

Braun, A., Braun, J., & Weigert, F. (2021). Hurricane Risk and Asset Prices. *SSRN Electronic Journal*, *2020*. https://doi.org/10.2139/ssrn.3952620

Capasso, G., Gianfrate, G., & Spinelli, M. (2020). Climate change and credit risk. *Journal of Cleaner Production*, *266*, 121634. DOI: 10.1016/j.jclepro.2020.121634

Chen, L. H., & Silva Gao, L. (2012). The Pricing of Climate Risk. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1940727

Faccini, R., Matin, R., & Skiadopoulos, G. (2021). Dissecting Climate Risks: Are they Reflected in Stock Prices? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3795964

Fama, E. F., & French, K. R. (1995). Size and Book-to-Market Factors in Earnings and Returns. *The journal of finance*, *50*(1), 131-155.

Fama, E. F., & French, K. R. (2015). A five-factor asset pricing model $. *Journal of Financial Economics*, *116*(1), 1–22. https://doi.org/10.1016/j.jfineco.2014.10.010

Fama, E. F., & Macbeth, J. D. (1973). *Risk, Return, and Equilibrium: Empirical Tests Author (s): Eugene F. Fama and James D. MacBeth Source: Journal of Political Economy, May - Jun., 1973, Vol. 81, No. 3 (May - Jun., Published by: The University of Chicago Press Stable URL:81*(3), 607–636.

Fama, F., & French, R. (1993). *Common risk factors in the returns stocks and bonds. 33*, 3–56.

Fried, I. & Blume, M. (1970). *Measurement of Portfolio Performance Under Uncertainty Measurement of Portfolio Performance Un er Uncertainty*. *60*(4), 561–575.

Ginglinger, E. (2020). *Climate risk and finance to cite this version: HAL Id: halshs-02975207*.

Ginglinger, E., & Moreau, Q. (2019). Climate risk and capital structure. *Université Paris-Dauphine Research Paper*, (3327185).

Gregory, R. P. (2021). Climate disasters, carbon dioxide, and financial fundamentals. *Quarterly Review of Economics and Finance*, *79*, 45–58. https://doi.org/10.1016/j.qref.2020.12.008

Griffin, P. W., & Hammond, G. P. (2019). Industrial energy use and carbon emissions reduction in the iron and steel sector: A UK perspective. *Applied Energy*, *249*(May), 109–125. https://doi.org/10.1016/j.apenergy.2019.04.148

Hong, H., Karolyi, G. A., & Scheinkman, J. A. (2020). Climate finance. *Review of Financial Studies*, *33*(3), 1011–1023. https://doi.org/10.1093/rfs/hhz146

Huang, H. H., Kerstein, J., & Wang, C. (2018). The impact of climate risk on firm performance and financing choices: An international comparison. *Journal of International Business Studies*, *49*(5), 633–656. https://doi.org/10.1057/s41267-017-0125-5

Hugon, A., & Law, K. (2019). Impact of Climate Change on Firm Earnings: Evidence from Temperature Anomalies. *Available at SSRN 3271386*.

Huynh, T. D., Nguyen, T. H., & Truong, C. (2020). Climate risk: The price of drought. *Journal of Corporate Finance*, *65*(June 2019), 101750. https://doi.org/10.1016/j.jcorpfin.2020.101750

Hjort, I. (2016). Potential Climate Risks in Financial Markets: A Literature Overview, Memorandum, No. 01/2016, University of Oslo, Department of Economics, Oslo http://hdl.handle.net/10419/165944

Ilhan, E., Krueger, P., Sautner, Z., & Starks, L. T. (2019). Institutional Investors' Views and Preferences on Climate Risk Disclosure. *SSRN Electronic Journal*, *March*. https://doi.org/10.2139/ssrn.3437178

Javadi, S., & Masum, A. A. (2021). The impact of climate change on the cost of bank loans. *Journal of Corporate Finance*, *69*, 102019. DOI: 10.1016/j.jcorpfin.2021.102019

Kim, Y. B., An, H. T., & Kim, J. D. (2015). The effect of carbon risk on the cost of equity capital. *Journal of Cleaner Production*, *93*, 279-287. DOI: 10.1016/j.jclepro.2015.01.006

Kisgen, D. J. (2006). Credit ratings and capital structure. *The Journal of Finance*, *61*(3), 1035-1072.

Kitsikopoulos, C., Schwaibold, U., & Taylor, D. (2018). Limited progress in sustainable development: Factors influencing the environmental management and reporting of South African JSE-listed companies. *Business Strategy and the Environment*, *27*(8), 1295-1301.

Kovacs, T., Latif, S., Yuan, X., & Zhang, C. (2021). *Climate Regulatory Risk and Capital Structure: Evidence from State Climate Adaptation Plans*. Working Paper.

Krueger, P., Sautner, Z., & Starks, L. T. (2020). The importance of climate risks for institutional investors. *Review of Financial Studies*, *33*(3), 1067–1111. https://doi.org/10.1093/rfs/hhz137

Lintner, J. (1965). Security prices, risk, and maximal gains from diversification. *The journal of finance*, *20*(4), 587-615. https://doi-org.lib-e2.lib.ttu.edu/10.2307/2977249

Mercer *(2015*) Global Insights on ESG in Alternative Investing. http://www.mercer.com/content/dam/mercer/attachments/global/investments/responsible-investment/Global-Insights-ESG-in-Alternative-Investing-2015-Mercer-LGT.pdf

Miller, M. H. (1988). The Modigliani-Miller propositions after thirty years. *Journal of Economic perspectives*, *2*(4), 99-120.

Modigliani, F., & Miller, M. H. (1958). The cost of capital, corporation finance and the theory of investment. *The American economic review*, *48*(3), 261-297. ISSN: 0002-8282, 1944-7981

Mossin, J. (1966). Equilibrium in a capital asset market. *Econometrica: Journal of the Econometric Society*, 768-783.

Mungai, M. E., Ndiritu, W. S., & Rajwani, T. (2022) Environmental Dilemma? Explicating Stakeholder Engagement in Kenyan Firms, Journal of African Business, DOI: 10.1080/15228916.2022.2100745

Myers, S. C., & Majluf, N. S. (1984). Corporate financing and investment decisions when firms have information that investors do not have. *Journal of financial economics*, *13*(2), 187-221.

Myers, S. C. (1984). Capital structure puzzle, NBER Working Paper Series, Working Paper No. 1393.

Myers, S. C. (1977). Determinants of corporate borrowing. *Journal of financial economics*, *5*(2), 147-175. DOI: 10.1016/0304-405X(77)90015-0

Nguyen, J. H., & Phan, H. V. (2020). Carbon risk and corporate capital structure. *Journal of Corporate Finance*, *64*, 101713. DOI: 10.1016/j.jcorpfin.2020.101713

Palea, V., & Drogo, F. (2020). Carbon emissions and the cost of debt in the eurozone: The role of public policies, climate-related disclosure and corporate governance. *Business Strategy and the Environment*, *29*(8), 2953-2972. DOI: 10.1002/bse.2550

Sautner, Z., & Starks, L. T. (2021). ESG and Downside Risks: Implications for Pension Funds. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3879170

Sharpe, W. F. (1963). A simplified model for portfolio analysis. *Management science*, *9*(2), 277-293. DOI: 10.1287/mnsc.9.2.277

Sun, Y., Yang, Y., Huang, N., & Zou, X. (2020). The impacts of climate change risks on financial performance of mining industry: Evidence from listed companies in China. *Resources Policy*, *69*, 101828. DOI: 10.1016/j.resourpol.2020.101828

Torres-Baumgarten, G. & Rakotobe-Joel, T. (2022) Sustainability Discourse in Emerging Market multinationals: The Case of South Africa's Largest Firms, Journal of African Business, 1-26, DOI: 10.1080/15228916.2022.2048513

Ziervogel, G., New, M., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., Stuart-Hill, S., Myers, J., & Warburton, M. (2014). Climate change impacts and adaptation in South Africa. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(5), 605–620. https://doi.org/10.1002/wcc.295

Tables

Table 1. Climate Risk and Cost of Debt

Variable	Pooled OLS	Random Effect	Fixed Effect	GMM (System)
Cost of Debt (-1)				0.0186
				(0.0469)
Climate Risk	0.0731	0.1959**	0.7434***	0.0028**
	(0.0523)	(0.0892)	(0.1768)	(0.012)
Firm Size	0.9986***	1.0514***	1.0225***	-0.0098***
	(0.1197)	(0.1573)	(0.2241)	(0.0021)
Profitability	-2.1866*	-1.9377	-2.0934	-0.0944***
	(1.1622)	(1.2439)	(1.3326)	(0.0222)
Turnover	-0.0414	-0.1622**	-0.1948**	-0.0212***
	(0.0687)	(0.0733)	(0.0783)	(0.0017)
Capitalization	-0.7479***	-0.4012**	-0.1069	0.0152***
	(0.1415)	(0.1599)	(0.1848)	(0.0003)
Leverage Ratio	0.0287	0.2112	0.1393	0.0025
	(0.3099)	(0.2917)	(0.2939)	(0.0239)
_cons	-1.8541	-10.3651***	-35.2828***	-0.0243***
	(1.7991)	(2.7919)	(5.1962)	(0.0362)
Breusch and Pagan LM test for Random effects			129.37(0.000)	
Hausman test			3.02(0.8057)	
Number of groups				81
Number of Instruments				47

Arellano-Bond test for AR(1) in first difference	-3.62(0.000)
Arellano-Bond test for AR(2) in first difference	0.13(0.187)
Sargan test for over-identification restriction	47.24(0.145)
Hansen test for over-identification restriction	45.53(0.187)

Note: *, ** & *** denote significance at 10%, 5% and 1% respectively. The coefficients in the parentheses are the standard errors. However, for those of the Breusch and Pagan LM test for Random effects, the Hausman test, the Arellano-Bond test, Sargan test, and Hansen test are p-values. Due to the endogeneity problem, our discussions are focused on the two-step system GMM estimation results. These results are robust and consistent after accounting for the endogeneity effects in the model. However, we also present static panel regression results from pooled, random effect, and fixed effect estimation strategies.

Table 2: Climate Risk and Cost of Equity

Variable	Pooled OLS	Random Effect	Fixed Effect	GMM (System)
Cost of Equity (-1)				0.8845***
				(0.0098)
Climate Risk	0.2275***	0.1844*	0.1692***	0.0884***
	(0.0599)	(0.1056)	(0.0199)	(0.0185)
Firm size	0.2562*	0.5157***	0.8734***	0.1091***
	(0.1374)	(0.1808)	(0.2525)	(0.0362)
Profitability	4.4709***	4.3186***	4.2052***	1.5964***
	(1.3307)	(1.3966)	(1.5016)	(0.1989)
Turnover	0.0735	0.1628**	0.1937**	-0.0271
	(0.0786)	(0.0827)	(0.0882)	(0.0189)
Capitalization	0.1472	-0.1406	-0.2902	0.0281*
	(0.1621)	(0.1806)	(0.2082)	(0.0163)
Leverage ratio	-1.1375***	-0.3612	-0.2166	-0.6098***
	(0.3548)	(0.3249)	(0.3312)	(0.1352)
_cons	-4.6309**	-4.8435*	-7.6689*	-1.8161**
	(2.0598)	(3.2814)	(5.8550)	(0.7628)
Breusch and Pagan LM test for Random effects			194.74(0.0000)	
Hausman test			26.59(0.0002)	
Number of groups				81
Number of instruments				47
Arellano-Bond test for AR(1) for first difference				-5.23 (0.000)

Arellano-Bond test for AR(2) for first difference	1.43 (0.154)
Sargen test for over-identification restriction	68.32 (0.941)
Hansen test for over-identification restriction	37.25 (0.764)

Note: *, ** & *** denote significance at 10%, 5% and 1% respectively. The coefficients in the parentheses are the standard errors. However, for those of the Breusch and Pagan LM test for Random effects and the Hausman test are p-values. Our discussions are based on the two-step system GMM estimates. These results are robust and consistent after accounting for the endogeneity effects in the model.

Table 3. Climate Risk and Capital Structure

Variable	Pooled OLS	Random effect	Fixed effect	GMM (System)
Debt-Equity ratio (-1)				0.0317***
				(0.0088)
Climate Risk	-0.0125***	-0.0161***	-0.0123***	-0.0084***
	(0.0042)	(0.0062)	(0.0018)	(0.0023)
Firm Size	0.0823***	0.0991***	0.1164***	0.0052**
	(0.0095)	(0.0105)	(0.0136)	(0.0023)
Profitability	-0.1449	-0.2965***	-0.3919***	-0.1425***
	(0.0921)	(0.0816)	(0.0805)	(0.0378)
Capitalization	-0.0773***	-0.0748***	-0.0701***	-0.0003
	(0.0112)	(0.0105)	(0.0112)	(0.0021)
Turnover	0.0114**	0.0053	0.0028	-0.0017
	(0.0054)	(0.0048)	(0.0047)	(0.0013)
Leverage Ratio	0.3210***	0.1726***	0.1281***	1.7623***
	(0.0246)	(0.0191)	(0.0179)	(0.0261)
_cons	0.1559	-0.0884	-0.5574*	0.1621
	(0.1435)	(0.1916)	(0.3155)	(0.1221)
Breusch and Pagan test for Random Effects			720.28(0.0000)	
Hausman test			99.43(0.000)	
Number of groups				81
Number of instruments				49
Arellano-Bond test for AR(1) in first difference				-2.37 (0.02)

Arellano-Bond test for AR(2) in first difference	-0.03 (0.971)
Sargan test for over-identification restriction	108.04 (0.068)
Hansen test for over-identification restriction	34.87 (0.700)

Note: *, ** & *** denote significance at 10%, 5% and 1% respectively. The coefficients in the parentheses are the standard errors. However, for those of the Breusch and Pagan LM test for Random effects and the Hausman test are p-values. Our discussions are based on the two-step system GMM estimates. These results are robust and consistent after accounting for the endogeneity effects in the model.