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# The Pricing of Climate Risk

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*This study investigates whether corporate climate risk is priced by the capital markets. Using carbon dioxide emission rates of publicly traded U.S. electric companies, we find that climate risk is positively associated with cost of capital measures, more specifically the implied cost of equity and the cost of debt. Additionally, we find that equity and debt investors evaluate corporate climate risk differently. The results show that the cost of debt decreases with the level of capital intensity, suggesting that debt investors value the increase in efficiency resulting from current capital investments. The results also show that the cost of equity decreases and the cost of debt increases with the newness of assets in places. Newer equipment is likely to be operationally and environmentally more efficient. While the results concerning the cost of debt are puzzling, we consider that debt investors may account for other performance indicators. We conclude that equity and debt investors evaluate climate risk differently according to their different payoff functions.*

## INTRODUCTION

This paper investigates whether corporate climate risk is priced by the capital markets. Using a sample of publicly traded U.S. electric companies, we find that firms' implied cost of equity and cost of debt are both positively associated with carbon dioxide emission rates. Our findings support the notion that investors price firms' climate risk.

Given the current social, political and environmental debates which emphasize sustainable development, investors are paying increasing attention to firms' social responsibility performance in general, and to firms' environmental performance in particular. Consequently, more corporate disclosures are called for to facilitate investors' assessment of firms' environmental risk, pollution costs and contingent environmental liabilities. Regulatory bodies are in the process of providing more guidelines regarding the level of environmental disclosures concerning environmental risks at the firm level. For example, following a petition by institutional investors and other organizations [1], the Securities and Exchange Commission (SEC) recently released guidance regarding the application of existing disclosure requirements to climate change matters, more precisely regarding the physical, legislative, regulatory, business and market impacts related to climate change that may have a material effect on a company's business and operations [2]. As stated by the guidance, material information such as emission reduction related capital expenditures and firms' status with respect to cap and trade laws should be conveyed to investors. In addition, information regarding how laws and regulation will potentially affect supply and demand for products and services based on their environmental performance and carbon content may also be material to investors' decisions.

The impact of environmental risk on firm value can be analyzed on two different dimensions, one related to the uncertainty of future cash-flows, and the other related to information uncertainty. The uncertainty of future cash-flows arises from future capital expenditures required to comply with regulation and legislation, clean-up costs and costs with lawsuits related to accidental spill and other uncontrollable events, and contingent environmental liability (Garber and Hammitt, 1998; Cormier, Magnan and Morard, 1993; Hughes, 2000; Conar and Cohen, 2001; Clarkson, Li and Richardson, 2004; Chapple, Clarkson and Gold, 2009). Future cash flows can also be affected by potential shifts in supply and demand, and changes in prices of products and services provided by companies affected by these developments. Moreover, trading markets for emission credits related to "cap and trade" programs might be established in the future and could represent both costs and opportunities for companies.

Information uncertainty or information risk reflects "value ambiguity, or the degree to which a firm's value can be reasonably estimated by even the most knowledgeable investors" (Jiang, Lee and Zhang, 2005). In particular, information uncertainty may be reflected in dispersion of investors' estimates of firms' future performance (Francis, LaFond, Olsson and Schipper, 2004). Information risk, or value ambiguity, is often translated into further discounting in firm valuation. This type of risk can be mitigated through corporate disclosures. The results from studies on environmental disclosure are, however, inconclusive (e.g. Richardson and Welker, 2001; Magness, 2009; Jacobs, Singhal and Subramanian, 2010).

In this study we focus on a single industry, the electric utility industry. Electric companies are subject to comparable regulations and legislation, capital spending requirements, as well as other costs associated with pollution control and reduction. Therefore, information risk is mitigated within our sample. In this way, our findings regarding the pricing of environmental risk can be viewed as while holding information uncertainty risk constant.

Previous studies provide evidence that environmental performance is valued by equity investors (e.g. Hamilton, 1995; Khanna, Quimo and Bojilova, 1998; Konar and Cohen, 2001; King and Lenox, 2002; Clarkson, Li and Richardson, 2004; Clarskon and Li, 2006). However, market prices reflect both changes in the expectations for future cash flows and changes in the risk perception of these cash flows. Empirical studies which test the relationship between environmental performance and market price do not disentangle these effects. This study proposes to estimate the risk perception component of market value assessments.

We use carbon emission rates, obtained from the Emissions and Generation Resource Integrated Database (EGRID) issued by the Environmental Protection Agency (EPA), to measure environmental performance. This measurement is based on the assumption that firms with higher carbon emissions rates have greater exposure to climate risk. Most of the existing environmental literature uses Toxics Release Inventory (TRI) data from the EPA to measure environmental performance. Only since January of 2010 the EPA requires large emitters of greenhouse gases to collect and report data with respect to greenhouse gas emissions. Therefore, data on greenhouse gases emissions is available only for companies that have voluntarily disclosed this information through sustainability or standalone environmental reports, or that report to the Carbon Disclosure Project (CDP). The information reported at the individual company level is, however, incomplete, unaudited, and difficult to compare. EGRID provides comprehensive information on emissions for electric companies collected by the EPA, the U.S. Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). Additionally, reporting and regulation of toxic chemical releases and waste management has been effective for several years, while new developments related to disclosure and regulation of greenhouse gases are anticipated in the coming years. Therefore, measures based on greenhouse gases emissions better capture environmental risks faced by companies.

To assess the market pricing of climate risk, we estimate the implied cost of equity and the cost of debt of the companies in our sample. We use the model proposed by Claus and Thomas Model (2001) and a modified version of the Easton model (Easton, 2004; Botosan and Plumlee, 2005) to estimate the implied cost of equity. Implied cost of equity models are expectation models that rely heavily on analysts' projections, and as such are subject to biases and forecast errors. The models we employ require shorter term forecasts, minimizing forecast errors that are likely to increase as the forecasting horizon increases. Moreover, to reduce potential measurement errors, we use the average of the estimates obtained from the two models. Our estimation for the cost of debt is based on yield-to-maturity spreads. For firms with multiple bond issues and different maturities, we select the bonds with the longest maturity.

Our analysis shows that after controlling for firm size, market to book ratio, leverage, cash flow volatility, long-term growth rate, age of assets in place and capital intensity, climate risk is positively associated with the cost of capital measures. Additionally, we find that equity investors and bond investors evaluate corporate investment strategy differently. Our results show that while capital intensity, or overall level of capital investment, does not have a significant effect on the implied cost of equity, it is negatively associated with the cost of debt. Capital spending may represent investments in new equipment and technologies that are operationally and environmentally more efficient. While equity holders' payoff function has a "call-option" imbedded within, i.e. equity holders will capture the potential incremental benefits of investments in future efficiency and pollution costs reductions, bond holders' payoff function is fixed. However, current capital spending also suggests lower future capital expenditures. Therefore, debt investors value the increase in future efficiency resulting from current capital investments, and possibly lower requirements to invest in the future, resulting in less variability in the cash flows available for debt stakeholders, and lower default risk.

Our results also show that the both the cost of debt and the cost of equity are affected by the age of the existing equipment. Equity investors value positively the existence of new equipment in the company. Conversely, the cost of debt seems to increase with the existence of newer equipment. While this result may be puzzling, it may also suggest that bond investors value the existence of newer equipment according to additional performance indicators. For example, the existence of newer equipment and higher carbon emission rates may suggest that past capital investments realized by the company did not result in increased efficiency, and may imply the need for future investments to increase efficiency and performance. Future capital expenditures may reduce future cash flows available for debt payments, and consequently increase the level of default risk.

The remainder of the paper is organized as follows. Section 2 provides a brief literature review and describes the hypothesis. Section 3 describes the data and variables construction. Section 4 presents the empirical analysis and section 5 concludes.

## LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Very few studies empirically investigate the impact of environmental performance on the cost of equity and debt. For example, Garber and Hammitt (1998) examined the effect of Superfund liabilities on the cost of equity measured based on the CAPM and beta, for a sample of companies in the chemical industry. They found no relationship between balance sheet liabilities identified to cover Superfund remediation costs and the cost of equity for small firms, but were able to find a robust positive relationship for large firms. It should be noted that Superfund liabilities reflect cleanup costs for past emissions and spills. As such, Superfund liabilities entail a high level of uncertainty relating to final cleanup costs but may not provide a strong signal of future environmental performance. In another study, Sharfman and Fernando (2008) found a positive and significant relationship between environmental risk management, a measure based on TRI, and cost of equity, measured based on the CAPM and beta.

The results of the association between environmental performance and cost of debt are not conclusive. Graham and Maher (2006) demonstrate that the value of accrued environmental liabilities is positively associated with bond yields. Bauer and Hann (2010) document that environmental concern is associated with higher cost of debt financing and lower credit ratings. Similarly, Schneider (2010) find that the cost of debt increases with poor environmental performance measured based on TRI emissions. The results are justified based on the claim that poor environmental performance represents potential liabilities related to compliance and clean-up costs due to increasingly strict environmental laws and regulations. Conversely, Sharfman and Fernando (2008) show that cost of debt increases with environmental risk management, but attribute this increase to an increase in debt financing in the capital structure of the firm. Kim, Surroca and Tribo (2009) argue that reductions in lending rates may simply be due to the fact that both borrowers and lenders belong to a similar cohort along the social responsibility dimension.

Several arguments can be used to explain the relationship between the cost of capital and environmental performance. Superior environmental performance may be reflected in a reduced cost of equity through a lower systematic risk and equity beta. Sharfman and Fernando (2008) argue that firms with better environmental risk management will have more flexibility to manage economic downturns, for example, by changing its processes. Bansal and Clelland (2004) make a similar argument, but relating to unsystematic risk. They argue that poor environmental performance, through the negative impact on the firm's legitimacy, has long term effects on the share price volatility. Superior social responsibility performance, on the contrary, tends to attract dedicated institutional investors and analyst coverage, hence facilitating the price discovery process (Dhaliwal, Li, Tsang and Yang, 2011).

Environmental risk reduction is associated with good corporate reputation, and good corporate reputation is a valuable intangible asset (Branco and Rodrigues, 2006). It is necessary to point out that the firms "social norms" vary across different industries, geographical areas, and employee characteristics[3]. Thus a strong record of environmental performance may enhance or damage reputation depending on whether a firm's activities 'fits' with environmental concerns in the eyes of stakeholders (Brammer and Pavelin, 2006). Therefore, firms coping strategies can be very different. Other than investing in environmental risk reduction, firms can also choose to invest in other areas to minimize environmental risk exposure, such as lobbying. As a matter of fact, Cho, Patten and Roberts (2006) reveal a significant, inverse relationship between firm environmental performance and political spending.

The impact of environmental risk on cost of equity can also result from a smaller base of investors in high polluting companies and consequent increase in the cost of equity (Merton, 1987). Heinkel, Kraus and Zechner (2001) introduced a theoretical model to show that exclusionary ethical investing leads to polluting firms being held by fewer investors because green investors will not invest in polluting firms' stock. This lack of risk sharing among non-green investors leads to lower stock prices for polluting firms and to an increase in their cost of capital.

This study investigates the effect of firms' environmental risk reduction on firm valuation. Formally, the hypothesis tested is the following:

***Hypothesis:*** *There is a positive association between a firm's climate risk level and the cost of capital.*

We measure firms' cost of capital in terms of implied cost of equity and cost of debt. Since equity and bond investors value corporate risk differently, our analysis studies the relationship between the cost of capital and the level of climate risk separately for equity and debt.

## EMPIRICAL MODEL, DATA, AND VARIABLE CONSTRUCTION

The primary dataset used in this study was obtained from the Emissions and Generation Resource Integrated Database (EGRID) issued by the EPA in 2002, 2006 and 2007. EGRID provides emissions [4], generation resource mix and capacity, ownership and corporate affiliation for almost all U.S. electricity generating plants. EGRID collects information from three federal agencies: The U.S. Environmental Protection Agency (EPA), the U.S. Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). In addition, firms' financial statement data was obtained from the Compustat Database, analyst forecast data was obtained from the Institutional Brokers' Estimate System (I/B/E/S), and corporate bond trading data from the Mergent Fixed Income Securities Database (FISD).

To address the research questions formalized in the hypothesis presented in the previous section, we employ the following model:

$$\begin{aligned} \textit{Cost of Capital}_{i,t} = \; & \beta_0 + \beta_1 \textit{Emissons Rate}_{i,t} + \beta_2 \textit{Size}_{i,t} + \beta_3 \textit{M/B}_{i,t} + \beta_4 \textit{Leverage}_{i,t} + \beta_5 \sigma(\textit{Cash Flows})_{i,t} \\ & + \beta_6 \textit{Growth}_{i,t} + \beta_7 \textit{Newness}_{i,t} + \beta_8 \textit{Capital Intensity}_{i,t} + \varepsilon_{i,t} , \qquad (1) \end{aligned}$$

where

$$\begin{aligned} \textit{Cost of Capital}_{i,t} &= \textit{Implied Cost of Equity}_{it} && \text{for the cost of equity analysis,} \\ &= \textit{YTM\_Spread}_{it} && \text{for the cost of debt analysis.} \end{aligned}$$

The variables construction is discussed in the following sub-sections.

### Climate Risk Measure

We use carbon emission rates to proxy for climate risk exposure. This measurement is based on the assumption that firms with lower emission rates, and better environmental performance, have less exposure to climate risk. Firms with better environmental performance have a strategic competitive advantage in anticipation of future regulations or legislation. Superior environmental performers may over-comply with existing regulations, and benefit from the flexibility inherent to voluntary environmental initiatives, as they have more time to invest in innovative pollution technologies and process improvements without the threat of non-compliance penalties (Boyd, 1998; Khanna and Damon, 1999). In addition, firms may pursue a pollution reduction strategy to benefit from green consumerism, reduce the risk of future environmental liabilities and lawsuits, and increase productivity and efficiency in production (Porter and van der Linde, 1995; Epstein, 1996; Reinhart, 1999). Carbon dioxide emissions rate is calculated as total emissions divided by electricity generation in MWh.

One limitation regarding the EGRID database is the unavailability of data for some years. EGRID was released in the years 2002, 2006 and 2007. EGRID 2002 reports emissions for the years from 1996 to 2000, EGRID 2006 reports emissions for 2004, and EGRID 2007 reports emissions for 2005. For the purpose of this study, we considered emissions in the year of release of the database, not the year that the emissions occurred. This construct is based on the assumption that the information was made available to investors on the year of release of EGRID. Additionally, we consider the values of emissions also for the year subsequent to the release of the data. Therefore, we consider emissions that occurred in 2000 in the years 2002 and 2003, emissions that occurred in 2004 are considered in 2006, and emissions that occurred in 2005 are considered in 2007 and 2008. In this way, our study includes data for the years 2002, 2003, 2006, 2007 and 2008.

In a related study, Matsumura, Prakash, and Vera-Munoz (2010) rely on hand-collected carbon-emissions data for 2006-2008 that S&P 500 firms voluntarily disclosed to the Carbon Disclosure Project (CDP) and find that increases in carbon emissions are associated with decreases in firm value. However, studies based on voluntarily disclosed information suffer from self-selection bias, as firms with better environmental performance are more likely to disclose (Clarkson, Li, Richardson and Vasvari, 2008).

After merging EGRID with I/B/E/S and Compustat data, we obtain a sample size of 182 company/year observations for the analysis related to the cost of equity. There are total of 44 companies represented in the sample. Merging EGRID with Compustat and the FISD databases, results in a sample of 117 company/year observations for the analysis pertaining to the cost of debt, including information related to 35 companies. Table 1 presents descriptive statistics for the two samples. The samples are comparable in terms of carbon emission rates. The average is 1,643 tons/MWh for companies in the equity sample and 1,564 tons/MWH for companies in the bonds sample.

**Cost of Capital Measures**

We estimate two measures of cost of capital, the implied cost of equity and the bond yield-to-maturity spread. The construction of these measures is described below.

***Implied Cost of Equity Measures***

Several recent papers examine empirical methods for computing the implied cost of equity capital given stock prices and expectations of future earnings (e.g., Botosan 1997; Gebhardt et al. 2001; Claus and Thomas 2001; Botosan and Plumlee 2002; Easton 2004; Easton and Monahan 2005; Ohlson and Juettner-Nauroth 2005). These models use analysts' forecasts of future earnings and the current stock price to estimate the implied cost of capital. Analysts' forecasts are often subject to biases and forecast errors that may translate into the implied cost of equity measures, making these measures very noisy. The longer the forecasting horizon, the greater are these forecast errors. For this reason, we use the Claus and Thomas (2001) model and the modified Easton Model (Easton, 2004; Botosan and Plumlee, 2005), which rely on relatively shorter time horizons. To further reduce the measurement error, our implied cost of equity measure (*Cost of Equity*) is the average of the Claus and Thomas (2001) model and the modified Easton Model.

The Claus and Thomas model is represented by the following equation:

$$P_t = B_t + \sum_{i=1}^{5} \frac{FEPS_{t+i} - r_{ct} B_{t+i-1}}{(1+r_{ct})^i} B_{t+i-1} + \frac{(FEPS_5 - r_{ct} B_4)(1+g)}{(r_{ct} - g)(1+r_{ct})^5}, \quad (2)$$

where

$r_{ct}$= implied cost of equity,

$P_t$ = price per share of common stock in June of year *t* as reported by I/B/E/S,

$B_t$ = book value at the beginning of the year divided by the number of common share outstanding in June of year *t*,

$FEPS_{t+i}$= I/B/E/S consensus for the first two years, for years three, four, five, consensus forecasts if available, otherwise, $FEPS_{t+i} = FEPS_{t+i-1} \cdot (1+LTG)$,

*LTG*= consensus long-term growth forecast reported in June of year *t*,

$B_{t+i}$= $B_{t+i-1} + 0.5 \cdot FEPS_{t+1}$,

*g*= $r_{rf} - 0.03$

$r_{rf}$= risk-free rate equal to the yield on a 10-year Treasury note in June of year *t*.

Easton (2004) shows that under the assumption of zero dividends and no growth in abnormal earnings beyond the forecast horizon (after year 2), the cost of capital is proportional to the inverse of the PEG ratio. The resulting formula is given in Equation (3):

$$r_{peg} = \sqrt{\frac{FEPS_2 - FEPS_1}{P_0}} \quad (3)$$

We follow Botosan and Plumlee (2005) and use *FEPS3* and *FEPS2* in place of *FEPS2* and *FEPS1*. Botosan and Plumlee (2005) justify this procedure based on two reasons. First, when *FEPS2* is less than *FEPS1* the model cannot be solved, which limits the sample size. In our sample *FEPS3* always exceeds *FEPS2*. Second, changes in abnormal earnings beyond the forecast horizon are likely to be smaller when using earnings forecasts for periods further away in time. Therefore, we employ the following equation:

$$r_{peg} = \sqrt{\frac{FEPS_3 - FEPS_2}{P_0}} \quad (4)$$

The implied cost of equity variables are multiplied by 100 and are used in percentage terms. Our *Cost of Equity* measure is the average of the implied cost of equity measures based on the Claus and Thomas Model (2004) and the modified Easton Model. Therefore, *Cost of Equity* = ($r_{ct} + r_{peg}$)/2.

Summary statistics for the *Cost of Equity* measure are reported in Table 1, Panel A. The mean for the *Cost of Equity* is 4.598%. This value is consistent with values presented in previous literature.

***Bond Yield to Maturity Spread Measure***

The bond yield-to-maturity spread (*YTM_Spread*) is calculated as follows:

$$YTM\_Spread_{it} = Bond\ Yield\ to\ Maturity_{it} - Benchmark\ Yield_t. \quad (6)$$

*Bond Yield to Maturity* is calculated by solving the following equation:

$$P_0 = \frac{Par\ Value}{(1+YTM)^T} + \sum_{t=1}^{T} \frac{Coupon\ Payment}{(1+YTM)^t} \quad (7)$$

where

$P_0$ = bond price at time 0,

$YTM$ = estimated yield to maturity,
$T$ = maturity.

We obtain corporate bond trading data from the FISD database and include bonds with at least 1800 days (five years) to maturity. The yield-to-maturity measure for each bond issue is calculated on days when there are transactions. If a corporate bond has more than 60 months and less than 84 months to maturity, then *YTM_Spread* is the difference between the corporate bond's yield-to-maturity and the seven-year Treasury bond rate. Treasury bond yield data is obtained from the Federal Reserve website. All treasury yield data is based on constant maturity. Carrying out similar grouping criteria, we grouped corporate bonds into four different maturity groups, more specifically seven, ten, twenty, and thirty year-to-maturity groups. Corporate bonds' *YTM_Spread* is calculated based on the respective benchmark treasury bonds' yields. For firms that have multiple bonds outstanding with different maturities, we choose the observation that has the longest maturity period. Many utility bonds are thinly traded and, therefore, bond pricing is a combination of firms' credit risk and transaction costs. Inevitably using the yield-to-maturity measure to proxy for cost of debt can be too noisy and may affect our results. The summary statistics for *YTM_Spread* are reported in Table 1, Panel B. The average *YTM_Spread* is 2.383%.

**Control Variables Construction**

The control variables included in our analyses are firm size, market to book ratio, leverage, cash flow volatility, long term growth rate, asset newness, and capital intensity, all of which have be shown in previous literature to be associated with firms' cost of capital (e.g. Botosan and Plumlee, 2005).

Berk (1995) demonstrates that size exhibits a negative relation with expected returns, as a residual risk factor, in an incomplete model of expected returns. Therefore, we expect that the implied cost of equity is negatively associated with firm size. Also, as the firm size increases, more collateral assets and longer firms' history are likely translated into lower cost of debt. Thus, we expect size to be negatively associated with the cost of debt as well. *Size* is the value of total assets at the beginning of the fiscal year. As shown in Table 1, the average value of *Size* is \$17,814 and \$18,913 million for the implied cost of equity sample and the bond yield to maturity spread sample, respectively. In order to reduce the type I error caused by heteroskedasticity, we use *ln(Size)* in the regression analyses.

Fama and French (1993) develop a three factor asset pricing model that includes beta, size and market-to-book, and show that this asset-pricing model outperforms the CAPM. Fama and French (2004) use Ohlson's (1995) residual income framework to formalize the valuation role of the market-to-book ratio (*M/B*) in expected returns and predict a negative relation between *M/B* and expected return. Therefore, *M/B* should be negatively associated with the cost of equity. *M/B* is the ratio of market value of common equity to book value of common equity. As shown in Table 1, the mean *M/B* is 1.874 and 1.909 for the implied cost of equity sample and the bond yield to maturity spread sample, respectively.

According to Modigliani and Miller (1958), the risk of equity capital increases as a firm's leverage increases. In addition, increased leverage increases the probability of bankruptcy. Thus, we expect that both the cost of equity and cost of debt are positively associated with leverage. *Leverage* is the ratio of long-term debt to market value of common equity. As shown in Table 1, the average value for *Leverage* is 1.874 and 1.909 for the implied cost of equity sample and the bond yield to maturity spread sample, respectively.

Cash flow volatility captures the fluctuation of firms' cash flows from operation. High cash flow volatility means higher uncertainty about firms' cash flows. Therefore, this measure should be negatively associated with cost of capital (Francis et al. 2004). *σ(Cash Flows)* is the standard deviation of a firm's *Cash Flows* over the prior five years. *Cash Flows* is cash flow from operations scaled by total assets at the beginning of the year. As shown in Table 1, the average of *σ(Cash Flows)* is 0.019 and 0.020 for the implied cost of equity sample and the bond yield to maturity spread sample, respectively. The values are very low, suggesting that electricity generating firms' cash flows from operations are very steady.

La Porta (1996) shows empirically that high expected-growth stocks have higher standard deviations of returns and higher betas when compared with low expected-growth stocks. *Growth* is the mean I/B/E/S analyst long-term growth in earnings per share forecast for each year of estimation. We expect the coefficient of *Growth* to be positive.

Firms with newer equipment, with newer and less polluting technologies, are likely to have superior environmental performance relatively to their industry peers (Clarkson, Li, Richardson and Vasvari, 2008). *Newness* is the ratio of Net Property, Plant and Equipment to Property, Plant and Equipment at cost.

Firms with higher capital expenditures are investing in new equipment. These upgrades and investments should improve environmental efficiency (Clarkson, Li, Richardson and Vasvari, 2008). *Capital Intensity* is the ratio of capital expenditures for the year divided by total sales revenues at the end of the previous year.

## EMPIRICAL ANALYSIS AND DISCUSSION

Table 2 presents the correlation coefficients between the variables included in our model. Panel A shows that *Cost of Equity* is positively correlated with cash flow volatility (*σ(Cash Flows)*) and firms' growth prospect (*Growth*), and negatively correlated with market to book ratio (*M/B*) and newness of fixed assets (*Newness*). *Emissions Rate* is negatively correlated with *Size* and, as expected, with *Newness*. Panel B shows that *YTM_Spread* is positively correlated with *Emissions Rate, σ(Cash Flows),* and *Newness*, and negatively correlated with *M/B* and *Capital Intensity*.

Since we use panel data, all models are estimated using pooled cross-sectional regressions with robust standard errors clustered at the firm level. Table 3 reports the results of multivariate regressions of *Cost of Equity* on *Emissions Rate* and control variables. While the univariate regression represented in Model 1 does not reveal a significant relationship between *Cost of Equity* and *Emissions Rate*, the results of Model 2 show that the coefficient of the variable *Emissions Rate* becomes significant at the 5% level (t-stat.=2.214, p<0.05) after controlling for firm size, market to book, leverage, volatility of cash flows and growth. Model 3 introduces two more variables to control for the age of the equipment and capital investment intensity. Additionally, Model 3 shows that *Cost of Equity* is positively associated with *Growth* (t-stat.= 4.210, p<0.01) and *σ(Cash Flows)* (t-stat.=1.945, P<0.1), which are likely indicators of current and future risk. *Cost of Equity* is negatively associated with *M/B* (t-stat=-4.051,p<0.01), which proxies for intangible good will. Environmental risk management may result in corporate goodwill, and goodwill may reduce the cost of equity.

Table 4 shows that there is a positive and significant association between *Emissions Rate* and *YTM_Spread* (t-stat.=2.506, p <0.01). Therefore, our results point to the direction that cost of debt is positively associated with climate risk. Furthermore, as shown in Model 3, we find that *YTM_Spread* is also positively related with *Leverage* (t-stat.=2.109,p<0.05) and *σ(Cash Flows)* (t-stat.=2.136,p<0.05), which are likely to be associated to default risk. Cost of debt decreases with the value of *M/B* (t-stat.=-2.289, p<0.05).

The results regarding the effect of the age of the firm's assets in place and capital intensity on the cost of equity and debt are somewhat intriguing. We analyze the results based on the different payoff functions of equity and debt investors. While equity holders' payoff function has a "call-option" imbedded within, i.e. equity holders will capture the potential incremental benefits of investments in future efficiency and pollution costs reductions, bond holders' payoff function is fixed and as such bond investors will not benefit from the potential incremental value from these investments. Additionally, the debt holders' stake is better protected with lower levels of cash outflow, and consequent decrease in the level of default risk and bankruptcy costs.

In the regression relating to the cost of equity (Table 3, Model 3), the coefficient of the variable *Newness* is negative and significant at the 10% level (t-stat.=-1.851). Newer equipment is likely to be operationally and environmentally more efficient. Therefore, *Newness* might be associated with a lower level of exposure to climate risk. *Newness* might also signal lower requirements for future investments in the company.

On the contrary of the results obtained for the cost of equity, the cost of debt is inversely related to the age of assets in place in the company. While this result may seem puzzling, it may also suggest that bond investors value the existence of newer equipment according to additional performance indicators. For example, newer equipment might be associated with operational and environmental performance, but if the company emits relatively high carbon emission rates it may imply that past capital investments realized by the company did not result in increased efficiency. It may also suggest that the company needs to invest in new equipment and efficiency in the near future. Future capital expenditures may imply lower cash flows available for debt payments, and consequently higher default risk.

The coefficient of *Capital Intensity* is statistically insignificant in our sample for the cost of equity analysis, although we would expect that equity investors benefit from future improvements in efficiency from capital spending.

The coefficient of *Capital Intensity* is statistically significant at the 5% level in the bonds sample (t-stat.=-1.982, $p<0.05$). This result suggests that risk of debt investment decreases with capital spending. It may also imply lower future capital expenditures requirements, higher future cash flows available for debt payments, and consequently lower default risk.

## CONCLUSION

This paper investigates whether corporate climate risk is priced by the capital market. Using carbon dioxide emission rates of publicly traded U.S. electric companies, we conclude that the cost of equity and debt financing increase with the level of exposure to climate risk. The results hold after controlling for firm size, market to book ratio, leverage, cash flow volatility, long-term growth rate, asset newness and capital intensity.

Additionally, our results suggest that equity investors and bond investors evaluate corporate climate risk from different lights. While the effect of capital intensity on implied cost of equity is not statistically significant, the cost of debt decreases with new capital investments. We argue that debt investors value the increase in future efficiency resulting from current capital investments, and possibly lower requirements to invest in the future, resulting in less variability in the cash flows available for debt stakeholders.

The results concerning the relationship between the cost of capital and the age of assets in place are rather puzzling. While the cost of equity decreases, the cost of debt increases with newer assets in place. Newer equipment is likely to be operationally and environmentally more efficient. Therefore, we expect firms with newer equipment to have a lower level of exposure to climate risk. We consider that the results from the debt analysis may be due to bond investors' valuation according to additional performance indicators. The main variable in our analysis is carbon emissions rates. Companies with newer equipment but relatively high carbon emission rates may still require future capital investments in pollution reduction technologies and, consequently, there will be lower cash flows available for debt payments, and higher levels of default risk.

By focusing on one industry we are able to control for industry-wide factors. However, our study is limited by the small sample size and reduced statistical power of the analysis. Since large emitters of greenhouse gases are required to collect and report data with respect to greenhouse gas emissions to the EPA since 2010, carbon data will be available in the near future. Future research could extend this study to other industries.

## NOTES

[1] On September 18, 2007, a group of investors, state officials and non-profit organizations requested that the SEC issue guidance clarifying that corporations must disclose material climate risks under existing law. A copy of the

Petition is available at http://www.sec.gov/rules/petitions/2007/petn4-547.pdf and http://www.ceres.org//Document.Doc?id=358

[2] http://www.sec.gov/rules/interp/2010/33-9106.pdf

[3] For example, external constituents such as customers, regulators, legislators, local communities, and environmental activist organizations, are more likely dictate corporate environmental risk reduction strategy (Delmas and Toffel, 2008).

[4] EGRID reports emissions resulting from the generation for carbon dioxide, methane, nitrous oxide, nitrogen oxides, sulfur dioxide and mercury. For the purpose of this study, we focus on carbon emissions rates.

**Table 1 - Descriptive statistics**

Panel A – The Implied Cost of Equity Sample (2002, 2003, 2006, 2008, 182 firm-year observations)

| | Mean | Std. Dev. | 25% Quartile | Median | 75% Quartile |
|---|---|---|---|---|---|
| *Cost of Equity (%)* | 4.598 | 1.284 | 3.906 | 4.335 | 4.975 |
| *Size** | 17,814 | 13,498 | 6,271 | 14,059 | 28,271 |
| *Market Value Equity** | 2,460 | 2,691 | 509 | 1,482 | 3,590 |
| *Log(M/B)* | 1.874 | 0.924 | 1.340 | 1.688 | 2.122 |
| *Leverage* | 0.310 | 0.074 | 0.272 | 0.308 | 0.349 |
| *σ(Cash Flows)* | 0.019 | 0.012 | 0.011 | 0.017 | 0.022 |
| *Growth* | 6.912 | 3.230 | 4.680 | 6.140 | 8.140 |
| *Newness* | 0.644 | 0.070 | 0.595 | 0.638 | 0.689 |
| *Capital Intensity* | 0.065 | 0.026 | 0.047 | 0.064 | 0.082 |
| *Emissions Rate* | 1643 | 676 | 1216 | 1696 | 1998 |

Panel B – The Cost of Debt Sample (2002, 2003, 2006, 2008, 117 firm-year observations)

| | Mean | Std. Dev. | 25% Quartile | Median | 75% Quartile |
|---|---|---|---|---|---|
| *YTM Spread (%)* | 2.383 | 2.453 | 1.155 | 1.833 | 2.485 |
| *Size** | 18,913 | 13,893 | 7,361 | 14,901 | 29,873 |
| *Market Value Equity** | 2,615 | 3,097 | 465 | 1,416 | 3,600 |
| *M/B* | 1.909 | 1.080 | 1.299 | 1.677 | 2.118 |
| *Leverage* | 0.334 | 0.087 | 0.277 | 0.326 | 0.371 |
| *σ(Cash Flows)* | 0.020 | 0.014 | 0.009 | 0.017 | 0.024 |
| *Growth* | 6.811 | 2.874 | 4.850 | 6.240 | 7.935 |
| *Newness* | 0.650 | 0.073 | 0.598 | 0.647 | 0.699 |
| *Capital Intensity* | 0.066 | 0.028 | 0.047 | 0.061 | 0.085 |
| *Emissions Rate* | 1564 | 588 | 1208 | 1689 | 1984 |

*In Millions of dollars.

**Table 2 - Pearson Correlation Coefficients**

Panel A – The Implied Cost of Equity Sample

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| *Cost of Equity* (1) | 1 | | | | | | | | |
| *Emissions Rate* (2) | 0.076 | 1 | | | | | | | |
| *Size* (3) | 0.009 | -0.564$^{***}$ | 1 | | | | | | |
| *M/B* (4) | -0.313$^{***}$ | -0.004 | 0.122 | 1 | | | | | |
| *Leverage* (5) | -0.125$^{*}$ | 0.019 | 0.140$^{*}$ | 0.257$^{***}$ | 1 | | | | |
| *σ(Cash Flows)* (6) | 0.193$^{***}$ | 0.104 | -0.143$^{*}$ | -0.038 | -0.007 | 1 | | | |
| *Growth* (7) | 0.202$^{***}$ | -0.058 | 0.053 | 0.321$^{***}$ | 0.001 | 0.072 | 1 | | |
| *Newness* (8) | -0.143$^{*}$ | -0.264$^{***}$ | 0.200$^{***}$ | 0.039 | 0.057 | -0.145$^{*}$ | 0.096 | 1 | |
| *Capital Intensity* (9) | 0.026 | 0.125$^{*}$ | -0.131 | 0.002 | -0.086 | 0.016 | 0.179$^{**}$ | 0.202$^{***}$ | 1 |

Panel B – The Cost of Debt Sample

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| *YTM_Spread* (1) | 1 | | | | | | | | |
| *Emissions Rate* (2) | 0.212$^{**}$ | 1 | | | | | | | |
| *Size* (3) | -0.085 | -0.507$^{***}$ | 1 | | | | | | |
| *M/B* (4) | -0.206$^{**}$ | -0.003 | -0.065 | 1 | | | | | |
| *Leverage* (5) | 0.122 | 0.306$^{***}$ | -0.009 | 0.233$^{**}$ | 1 | | | | |
| *σ(Cash Flows)* (6) | 0.259$^{***}$ | 0.236$^{**}$ | -0.201$^{**}$ | 0.081 | -0.037 | 1 | | | |
| *Growth* (7) | 0.022 | -0.164$^{*}$ | 0.205$^{**}$ | 0.011 | 0.004 | -0.136 | 1 | | |
| *Newness* (8) | 0.157$^{*}$ | -0.203$^{**}$ | 0.179$^{*}$ | -0.013 | -0.009 | -0.134 | 0.283$^{***}$ | 1 | |
| *Capital Intensity* (9) | -0.244$^{***}$ | 0.099 | -0.054 | 0.155$^{*}$ | 0.036 | -0.077 | 0.073 | 0.143 | 1 |

The significance levels are given by: *** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.10$.

**Table 3 - Regressions of the Implied Cost of Equity on Carbon Emissions Rate**

| | Predicted Sign | Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| *Intercept* | | 4.311 | 2.231 | 3.534 |
| | | *22.916*$^{***}$ | *2.207*$^{**}$ | *2.810*$^{***}$ |
| *Emissions Rate* | (+) | 0.279 | 0.700 | 0.561 |
| | | *0.999* | *2.214*$^{**}$ | *1.733*$^{*}$ |
| *Size* | (-) | | 0.213 | 0.213 |
| | | | *2.220*$^{**}$ | *2.195*$^{**}$ |
| *M/B* | (-) | | -0.916 | -0.899 |
| | | | *-4.122*$^{***}$ | *-4.051*$^{***}$ |
| *Leverage* | (+) | | -1.601 | -1.409 |
| | | | *-1.510* | *-1.329* |
| *σ(Cash Flows)* | (+) | | 13.316 | 12.092 |
| | | | *2.146*$^{**}$ | *1.945*$^{*}$ |
| *Growth* | (+) | | 0.112 | 0.110 |
| | | | *4.236*$^{***}$ | *4.210*$^{***}$ |
| *Newness* | (?) | | | -2.103 |
| | | | | *-1.851*$^{*}$ |
| *Capital Intensity* | (?) | | | 0.647 |
| | | | | *0.198* |
| *Adj.* $R^2$ | | 0.161 | 0.316 | 0.329 |
| *F*-statistics | | 8.517 | 8.810 | 7.581 |
| *Number of Obs* | | 182 | 182 | 182 |

All models are estimated using pooled cross-sectional regressions with robust standard errors clustered at the firm level. t-statistics are reported below each coefficient in italic. The significance levels for the independent variables are given by: *** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.10$.

**Table 4 - Regressions of the Bond Yield to Maturity Spread on Carbon Emissions Rate**

| | Predicted Sign | Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| *Intercept* | | 2.522 | 1.359 | -4.271 |
| | | *4.884*$^{***}$ | *0.492* | *-1.301* |
| *Emissions Rate* | (+) | 1.497 | 1.634 | 2.424 |
| | | *1.903*$^{*}$ | *1.639* | *2.506*$^{***}$ |
| *Size* | (-) | | -0.020 | 0.021 |
| | | | *-0.074* | *0.084* |
| *M/B* | (-) | | -2.554 | -2.223 |
| | | | *-2.546*$^{**}$ | *-2.289*$^{**}$ |
| *Leverage* | (+) | | 6.585 | 5.547 |
| | | | *2.387*$^{**}$ | *2.109*$^{**}$ |
| *σ(Cash Flows)* | (+) | | 28.301 | 34.690 |
| | | | *1.657*$^{*}$ | *2.136*$^{**}$ |
| *Growth* | (?) | | 0.088 | 0.032 |
| | | | 1.127 | 0.432 |
| *Newness* | (?) | | | 9.679 |
| | | | | *3.219*$^{***}$ |
| *Capital Intensity* | (?) | | | -18.978 |
| | | | | *-1.982*$^{**}$ |
| *Adj.* $R^2$ | | 0.177 | 0.279 | 0.370 |
| *F*-statistics | | 6.015 | 3.998 | 4.852 |
| *Number of Obs* | | 117 | 117 | 117 |

All models are estimated using pooled cross-sectional regressions with robust standard errors clustered at the firm level. t-statistics are reported below each coefficient in italic. The significance levels for the independent variables are given by: *** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.10$.

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