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# Dealing with Carbon Risk and the Cost of Debt: Evidence from the European Market

**Fabio Pizzutilo [1,*], Massimo Mariani [2], Alessandra Caragnano [2] and Marianna Zito [2]**

1 Department of Economics, Management and Business Law, University of Bari Aldo Moro, 70124 Bari, Italy
2 Department of Management, LUM Jean Monnet University, 70010 Casamassima (BA), Italy; mariani@lum.it (M.M.); caragnano.phdstudent@lum.it (A.C.); zito.phdstudent@lum.it (M.Z.)
* Correspondence: fabio.pizzutilo@uniba.it; Tel.: +39-0805049285

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**Abstract:** The ever-increasing attention towards climate change has led to investigate the economic and financial impact of environmental risk. In this scenario, we aimed at investigating the relationship between a specific component of environmental risk, namely the so-called carbon risk, and the cost of debt. This research is motivated by the fact that few studies have focused on the aforementioned relationship. We fill this gap by using a sample of companies listed on the Eurostoxx 600 Index. Our results evidence a positive relationship between carbon risk and cost of debt, providing a relevant contribution to the scarce existing literature on this topic.

**Keywords:** environmental finance; carbon risk; cost of debt; European financial market

**JEL Classification:** G32; M14

## 1. Introduction

Concerns about the environment have become heavily debated. Several interventions on behalf of the States adhering to the United Nations Framework Convention on Climate Change (UNFCCC) took place in order to agree, evaluate and improve climate change mitigation actions. One of the elements that arouses great concern is represented by the so-called greenhouse gases (GHG) emissions, composed mainly by carbon dioxide ($CO_2$). In 2018, GHG emissions remarkably increased at a global level reaching a record of 55.3 gigatons and registering an increase of 2% compared to the previous year. As stressed in the Emissions Gap Report 2018, "nations must triple their current efforts, ( . . . ) to limit warming to 2 °C and multiply their current efforts by at least five times to align global climate action and emissions with limiting warming close to 1.5 °C" (United Nations Environment Programme 2019).

Within the academic framework, it has been noticed an ever-increasing attention towards topics regarding sustainability. In the corporate finance field of studies, the first contributions go back to the so-called "pays to be green" literature, subsequently evolved into the more critical question "When does it pay to be green?" (Hart and Ahuja 1996; Russo and Fouts 1997; Dowell et al. 2000; King and Lenox 2001; Konar and Cohen 2001). Such stream of studies was born with the purpose of investigating if the implementation of environmentally virtuous practices (in particular, pollution reduction deriving from GHG emissions) represents a cost for companies or, on the other hand, it brings economic benefits. Although there are some dissenting opinions, (for example, in 1984 Mahapatra discussed that pollution monitoring activities do not create profit but on the contrary they increase production costs and capital consumption (Mahapatra 1984)), the prevailing opinion in existing literature is that there is a positive relation between environmental performances—represented by strategies of pollution prevention and adoption of environmental management practices, reduction of $CO_2$ emissions and energy consumption, use of resources deriving from renewable sources—and economic performances, generally measured in terms of both operating and financial performances (Klassen and McLaughlin 1996; Pogutz and Russo 2009).

Recently, the attention of governments, communities and academic research has gone beyond the mere measurement of environmental performance and led to the genesis of a new and complementary line of research focused on the so-called "environmental risk". In the most recent literature, the expressions "environmental risk", "climatic risk" and "carbon risk" are often used as synonyms. To avoid misleading confusion in terms, in this paper we intend the expression carbon risk as a subset of environmental risks and in particular, following Hoffmann and Busch (2008) "any corporate risk related to climate change or the use of fossil fuels". This source of risk derives from the intense dependence that firms have from the use of fossil fuels within the company's production processes and the consequent impacts of GHG emissions on the environment.

Labatt and White (2007) investigated the carbon risk and split it into three specific components, namely regulatory, physical and business risk. The first aspect refers to the possible implementation of carbon-related regulations and/or guidelines, which can lead to compliance costs or benefits in the case of virtuous behavior. Otherwise, the physical risk is strictly connected to natural events, such as drought, floods, tsunamis and earthquakes, which could occur both in the short and in the long term. Finally, the authors include the business risk that involves the 360° corporate context, as it includes additional risk sub-components, such as legal, reputational and competitive. In this perspective, Romilly (2007) highlights that the environmental risk, which embraces the carbon risk as a specific component, creates uncertainty on the economic-financial performance and economic benefits for all stakeholders. In this vein, some studies remarked the importance of the systematic side of carbon risk, that is the undiversifiable risk associated with macroeconomic concerns ((Wellington and Sauer 2005; Kelly et al. 2015; Donadelli et al. 2019), among others). Indeed, climate change, and policies to combat its impacts create systematic risk across the entire economy, affecting energy prices, national income, health, agriculture, production, consumption, etc. that can significantly affect companies' value and market prices.

Other scholars preferred analyzing the impact of carbon risk on corporate operations under 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 environmental regulation and legislation, shifts in supply and demand, changes in prices of products and services, costs related to environmental lawsuits, etc. (Chapple et al. 2013; Connors et al. 2013; Subramaniam et al. 2015). Information uncertainty reflects the degree to which the firm's value is influenced by uncertainties surrounding environmental issues that relate to the company and its business (Jiang et al. 2005; Jacobs et al. 2010). Jung et al. (2018) focus on the uncertainty of present and future cash flows due to exposure to carbon risk and argue that the latter may influence default risk. In addition, they highlight that due to this circumstance lenders take into account carbon risk during their overall risk assessment and can then recur to loan contract terms governing collateral, debt maturity and the price of debt in order to mitigate the impact of a borrower's carbon risk. More recently, Bolton and Kacperczyk (2020) found robust evidence that carbon emissions significantly and positively affect US stock returns. They portray the higher returns associated with higher emissions as carbon risk premium. Interestingly, they also found a significant carbon premium associated with the year-to-year growth in emissions, arguing that companies that succeed in reducing their emissions can afford to offer lower stock returns, but companies that keep on burning more and more fossil fuel must resign themselves to offering higher returns.

However, few studies really concentrated on the relation between carbon risk, or more generically company's environmental risk profile, and cost of equity (Sharfman and Fernando 2008; Chava 2014; Li et al. 2014; Kim et al. 2015; Park and Noh 2018) or cost of debt. Specifically, the limited available contributions on the latter relationship are very recent, and they refer to limited geographical areas. In the scarce existing literature, a positive relationship has been found between GHG emissions (generally used, through different operationalizations, as proxy of the carbon risk) and the cost of debt.

Among the most relevant contributions on the relationship between carbon emissions and cost of debt, Maaloul (2018) argued that carbon emissions significantly impact on cost of debt of large Canadian companies. On the same vein, Kumar and Firoz (2018) found a positive relationship, statistically significant, between Indian companies' cost of debt and their carbon emissions. Zhou et al. (2018) analyzed a sample of Chinese firms belonging to high-carbon industries in the years 2011–2015. They evidenced the existence of a U-shaped relationship between carbon risk and the cost of debt and concluded that positive media attention significantly contributes to mitigate the effect of carbon emission intensity over the cost of debt. Finally, Jung et al. (2018), concentrated on a sample of Australian firms postulating that the debt capital cost increases as a consequence of firm's negative carbon risk profile. They also argued that the strength of this relationship is mitigated in firms aware of their carbon risk exposure as lenders take into high consideration this circumstance.

We aimed at extending this line of research by verifying whether it exists a significant relationship between the carbon risk profile and the cost of the debt to which European companies are subject. Our study differs in two relevant aspects. First of all, we analyzed the European market, that is the second and the third in the world in terms of GDP and $CO_2$ equivalent emissions, respectively. Moreover, we cover a much larger dataset in terms of both number of firms inspected (more than 600) and years under inspection (eight), providing further and updated insights and food for thought.

The attention towards this specific topic and the purpose to contribute to this line of research are stimulated by several considerations. Firstly, by analyzing the issue through the agency theory lens, it has been argued that there is a not negligible misalignment of carbon-related objectives between lenders and borrowers (Armstrong et al. 2010). Furthermore, scholars argued that in the light of the legislative interventions aimed at reducing GHG emissions, highly polluting firms have to deal with further costs (and then with lower expected free cash flows) in terms of taxation, as well as of compliance with the foreseen standards. Therefore, lenders may incorporate carbon risk evaluations in their credit risk assessment process and ask higher interest rates to high carbon risk companies (Kim et al. 2015; Maaloul 2018; Delis et al. 2019). This aspect can be particularly relevant in the case of medium and large companies, which are generally subject to careful evaluation by banks and financial institutions.

Moreover, Li et al. (2014) identified three key aspects on which to focus the attention in order to justify the relation between carbon risk and debt capital cost: first of all, rating agencies can lower the judgement on some companies due to concerns regarding GHG emissions and so the company default premium may increase. Secondly, carbon costs could have a negative impact on the market value of firm's assets and consequently the possibility of violating the covenants on the debt would increase. Finally, the increase of litigation and reorganization costs associated to higher GHG emissions can reduce the financial resources for debt repayment.

A further element to take into account concerns the reputational problem. In this perspective, as highlighted by Jung et al. (2018), reputational risks do not involve only borrowers but also lenders, as they could be considered by their own stakeholders supporting and financing negative environmental impact activities.

The results of our analysis are in line with these previous studies. We found a high significant positive relationship between carbon emission intensity, used as a proxy for carbon risk profile, and the cost of debt to which the company is subject.

The remainder of the paper is organized as follows. Section 2 describes the data and the methodology. Section 3 reports and discusses the empirical findings. The last section concludes.

## 2. Data and Methodology

We analyzed companies that have been included in EuroStoxx's 600 constituent list for at least one quarter during the years 2010 to 2017. After excluding companies belonging to the financial sector because of their business and financial peculiarities, and companies that did not disclose their carbon dioxide equivalent emissions during the years under inspection we had a final unbalanced panel of 3867 observations for 616 companies. A within regression model where the cost of debt (KD) is regressed on Total $CO_2$ equivalents emissions intensity (Carbon) along with control variables that are known to affect KD has been employed for the analysis (Equation (1)). KD was retrieved from Bloomberg Professional Database. Carbon intensity is measured as yearly total metric tons of $CO_2$ equivalents emission scaled by the firm's total asset.

Prior research argued that, all other things being equal, larger firms benefit on average of lower rate of interest on borrowed money compared to smaller ones, bringing it back to their longer history, to the existence of more assets to collateralize, to a more resilient cash flow and to a general lower risk of default (Fama and French 1992; Anderson et al. 2003; Lorca et al. 2011). The natural logarithm of the average end of month market value is here used to control for size. Similarly, high profitable companies are supposed to be more in the position to repay principal and interests in due time than not profitable ones, thus being able to borrow money at a lower cost (Ettredge et al. 2011).

As usual in financial literature, Return on Assets has been used as proxy for profitability. On the other hand, it is suggested that leverage is positively related to the cost of debt since a high indebtedness is likely to increase default risk (Mishra et al. 2009). Total book value of debt scaled by the book value of total assets has been employed to control for leverage.

Consistently with the results of Hausman test and Breusch–Pagan Lagrange multiplier test, we also controlled for fixed and time effects; that is unspecified differences between firms that are time-invariant (such as Country, Industry, etc.) and time-dependent firm-invariant effects (like the prevailing macroeconomic conditions and the general rates of interests in the money market) that actually influence each firm's cost of debt.

All data but KD were retrieved from Thomson Reuters Datastream. Descriptive statistics of model variables are reported in Table 1.

**Table 1.** Descriptive statistics.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Panel (a) Cost of debt, %** | | | | | | | | | |
| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **'10–'17** |
| Mean | 2.96 | 3.03 | 2.15 | 1.97 | 1.83 | 1.21 | 0.91 | 0.99 | 1.86 |
| Median | 2.83 | 2.78 | 1.83 | 1.78 | 1.61 | 0.92 | 0.61 | 0.69 | 1.58 |
| SD | 1.34 | 1.67 | 1.67 | 1.21 | 1.17 | 1.14 | 1.42 | 1.21 | 1.57 |
| Min | 0.33 | 0.42 | 0.07 | 0.07 | 0.03 | 0.00 | −0.61 | −0.17 | −0.61 |
| Max | 13.69 | 14.04 | 17.88 | 10.63 | 12.05 | 12.05 | 19.24 | 14.57 | 19.24 |
| **Panel (b) Total $CO_2$ equivalents emissions, Ktons** | | | | | | | | | |
| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **'10–'17** |
| Mean | 6517.72 | 6471.56 | 5993.38 | 5279.72 | 4871.83 | 4516.04 | 4538.82 | 4622.07 | 5289.83 |
| Median | 329.68 | 379.19 | 346.57 | 289.00 | 248.90 | 238.87 | 244.63 | 245.62 | 273.41 |
| SD | 20,352.99 | 20,454.98 | 20,085.01 | 17,811.79 | 17,557.67 | 16,668.57 | 17,024.06 | 16,540.67 | 18,279.38 |
| Min | 0.34 | 0.28 | 0.32 | 0.39 | 0.11 | 0.24 | 0.09 | 0.05 | 0.05 |
| Max | 184,825 | 179,930 | 183,600 | 190,000 | 191,000 | 192,000 | 190,000 | 194,000 | 194,000 |
| **Panel (c) Market value monthly average, M€** | | | | | | | | | |
| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **'10–'17** |
| Mean | 8957.72 | 9521.52 | 9544.43 | 10,663.66 | 11,645.45 | 13,003.66 | 12,248.02 | 13,554.54 | 11,203.37 |
| Median | 3135.03 | 3535.72 | 3535.07 | 4139.85 | 4512.50 | 5128.70 | 5149.30 | 5840.21 | 4384.37 |
| SD | 16,019.04 | 16,647.67 | 17,455.45 | 19,173.39 | 20,873.50 | 23,719.71 | 21,941.59 | 23,381.00 | 20,270.20 |
| Min | 28.11 | 27.12 | 15.22 | 4.45 | 1.04 | 0.21 | 0.21 | 0.05 | 0.05 |
| Max | 134,802.26 | 145,983.03 | 154,920.71 | 167,632.26 | 181,991.60 | 234,662.53 | 213,075.74 | 222,870.27 | 234,662.53 |
| **Panel (d) Return on Asset (ROA), %** | | | | | | | | | |
| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **'10–'17** |
| Mean | 8.01 | 7.75 | 6.93 | 6.53 | 6.78 | 5.72 | 6.14 | 6.73 | 6.82 |
| Median | 6.26 | 6.43 | 6.04 | 5.63 | 5.41 | 5.14 | 5.40 | 5.99 | 5.79 |
| SD | 8.20 | 9.44 | 11.94 | 13.46 | 14.12 | 14.37 | 14.10 | 22.89 | 14.13 |
| Min | −12.37 | −47.21 | −32.80 | −70.42 | −53.22 | −90.85 | −57.36 | −417.73 | −417.73 |
| Max | 122.08 | 109.51 | 175.04 | 234.42 | 269.11 | 266.67 | 267.24 | 241.29 | 269.11 |

**Table 1.** *Cont.*

| Panel (e) Total Debt on Total Asset, % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **'10–'17** |
| Mean | 25.18 | 25.12 | 26.13 | 26.25 | 26.43 | 26.66 | 26.31 | 25.69 | 25.97 |
| Median | 23.05 | 23.48 | 24.23 | 24.79 | 24.44 | 25.10 | 24.31 | 23.76 | 24.23 |
| SD | 18.74 | 18.61 | 20.67 | 20.60 | 21.16 | 18.93 | 18.45 | 17.19 | 19.36 |
| Min | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Max | 239.50 | 230.61 | 249.85 | 225.50 | 269.79 | 172.69 | 166.61 | 156.10 | 269.79 |
| **Panel (f) Sample composition by size** | | | | | | | | | |
| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | |
| Less than 1000 M€ | 13.92% | 10.85% | 10.92% | 6.74% | 5.06% | 5.94% | 7.83% | 6.98% | |
| 1000 to 5000 M€ | 47.20% | 48.75% | 50.70% | 49.57% | 48.74% | 43.40% | 40.62% | 37.34% | |
| 5001 to 10,000 M€ | 18.63% | 17.79% | 16.20% | 19.69% | 20.24% | 20.46% | 23.65% | 23.86% | |
| More than 10,000 M€ | 20.25% | 22.60% | 22.18% | 24.01% | 25.97% | 30.20% | 27.90% | 31.82% | |
| Total | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | |
| **Panel (g) Sample composition by Total $CO_2$ equivalents emissions** | | | | | | | | | |
| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | |
| <than 100 Ktons | 25.66% | 26.13% | 28.82% | 30.61% | 33.99% | 33.53% | 34.09% | 34.05% | |
| 101 to 1000 Ktons | 38.37% | 37.84% | 37.12% | 36.69% | 36.15% | 37.96% | 37.50% | 35.99% | |
| 1001 to 10,000 Ktons | 23.02% | 23.20% | 22.27% | 22.64% | 19.84% | 19.08% | 19.32% | 20.62% | |
| >than 10,000 Ktons | 12.95% | 12.84% | 11.79% | 10.27% | 10.22% | 9.44% | 9.09% | 9.34% | |
| Total | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | |

Concerning the dependent variable (KD), the mean cost of debt for the whole period under analysis is 1.86% and ranges from a maximum average value of 3.03% in 2011 to a minimum average of 0.91% in 2016. As for the Total $CO_2$ equivalent emissions, the mean for the whole period is 5289.83 Ktons, ranging from a minimum value of 0.05 Ktons to a maximum value of 194,000.00 Ktons. Regarding the control variables, Table 1 shows that the mean of Market value monthly average is 11,203.37 M€, as our sample refers to large firms. Continuing on the variable Return on Assets (ROA), it posts a mean value of 6.82% in the whole period; finally, the mean value of the ratio between Total Debt and Total Assets is 25.97% considering the whole period of analysis. The panel is mainly composed by firms with a capitalization between 1000 and 5000 €Millions that disclose yearly $CO_2$ equivalent emissions lower than 1000 Ktons.

The panel regression model employed is as follows:

$$KD_{it} = \beta_1\ Carbon_{it} + \beta_2 Size_{it} + \beta_3\ Profitability_{it} + \beta_4\ Leverage_{it} + \Sigma\ \alpha_i\ F_i + \Sigma\ \gamma_t\ Y_t + \varepsilon_{it} \quad (1)$$

where $F_i$ and $Y_t$ denote fixed and time effect, respectively, all the rest are as above. Within estimators have been employed to estimate the model.

## 3. Results and Discussion

We found a positive strong relationship between European large firms' cost of debt and their carbon intensity over the period 2010–2017. On average, European firms benefit from a 16 basis point (b.p.) reduction in the cost of debt for a 100 b.p. reduction in their carbon intensity. Carbon intensity seems to significantly contribute to the overall firm risk assessed by lenders and to affect lending prices. The relationship is statistically significant at 1% confidence level (F-stat 74.281) after controlling for size, profitability and leverage. The coefficients of the control variables are also significant and in line with the sign predicted by classical financial theory (Modigliani and Miller 1958; Fama and French 1993; Berk and DeMarzo 2017; Brealey et al. 2020).

Table 2 provides the main regression figures.

**Table 2.** Panel regression results.

| | Dependent Variable KD | | | | |
|---|---|---|---|---|---|
| | **Coeff.** | **Std. Error** | **T-Value** | ***p*-Value** | |
| Carbon | 0.1559 | 0.0299 | 5.2182 | $1.91 \times 10^{-7}$ | |
| Size | −0.1044 | 0.0159 | −6.5883 | $5.09 \times 10^{-11}$ | |
| Profitability | −0.0119 | 0.0002 | −4.8614 | $1.22 \times 10^{-6}$ | |
| Leverage | 0.0133 | 0.0011 | 12.2722 | $<2.20 \times 10^{-16}$ | |
| Residuals: | Min | 1st Quarter | Median | 3rd Quarter | Max |
| | −2.871 | −0.573 | −0.152 | 0.375 | 12.89 |
| F-Stat | 74.281 | *p*-Value | $<2.20 \times 10^{-16}$ | | |
| Adj. R-Sq. | 0.0729 | | | | |
| R-Squared | 0.0757 | | | | |
| Tot. Sum of Squares | 5174.7 | | | | |
| Res. Sum of Squares | 4783.1 | | | | |

Supplementary tests have been conducted in order to check for the robustness of our results. In particular, different specification of KD and carbon intensity and different measures for market value, profitability and leverage have been employed. We also tested for direct $CO_2$ equivalents emissions as proxy for carbon emissions and for country and industry effect. No relevant differences have been measured in the results. Finally, we tested for the inclusion in the model of other control variables, namely natural logarithm of capital expenditures, market to book value and current ratio, not obtaining relevant improvements to the significance of model outcomes (see Appendix A).

## 4. Conclusions

We provide empirical evidence that companies with high carbon intensity bear a higher cost of debt. We used a within estimator model with time effects to inspect the relationship between EuroStoxx 600 companies' carbon emissions and cost of debt in the years 2010 to 2017. We argued that the cost of debt financing is significantly related to company's carbon emission intensity and that on average a reduction of 100 basis points in the carbon intensity leads to a reduction of 16 b.p. in the overall cost of debt of European large firms.

Several theoretical and practical implications derive from the study. First of all, our results suggest that nowadays European financial markets take into consideration firms' exposition to carbon risk. Moreover, it highlights that companies have to reconsider their future borrowing abilities in the light of their actual and expected environmental policy. Our study also claims that companies should take greater care on environmental risk management since there are not negligible financial implications.

Finally, our study opens space for further analyses. Indeed, if on the one hand we can conclude that exposure to carbon risk impacts a European large firm's creditworthiness, further analyses are needed in order to assess whether the actual carbon exposure/policy of European firms is adequately priced by financial markets.

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## Appendix A. Robustness Checks

**Table A1.** Robustness checks regression results.

| | Dependent Variable KD | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| Carbon | 0.1559 *** | 0.1684 *** | 0.1303 *** | 0.1532 *** | 0.0588 *** | 0.0990 *** | 0.1100 *** | 0.1697 *** | 0.1492 *** | 0.1587 *** |
| | (0.0299) | (0.0323) | (0.0300) | (0.0313) | (0.0122) | (0.0327) | (0.0330) | (0.0299) | (0.0299) | (0.0305) |
| Size | −0.1044 *** | −0.0747 *** | −0.0916 *** | −0.0504 *** | −0.1058 *** | −0.1036 *** | −0.458 *** | −0.0858 *** | −0.0988 *** | 0.1142 *** |
| | (0.0159) | (0.0169) | (0.0159) | (0.0163) | (0.0159) | (0.0164) | (0.0139) | (0.0141) | (0.0159) | (0.0163) |
| Profitability | −0.0119 *** | −0.0082 *** | −0.0073 *** | −0.0055 *** | −0.0119 *** | −0.0110 *** | −0.0143 *** | −0.0155 *** | −1.4623 *** | 0.014 *** |
| | (0.0002) | (0.0017) | (0.0022) | (0.0016) | (0.0025) | (0.0026) | (0.0025) | (0.0024) | (0.2123) | (0.0024) |
| Leverage | 0.0133 *** | 0.0167 *** | 0.0123 *** | 0.0139 *** | 0.0132 *** | 0.0161 *** | 0.0170 *** | 0.0135 *** | 0.0134 *** | 0.0001 |
| | (0.0011) | (0.0012) | (0.0011) | (0.0011) | (0.0011) | (0.0012) | (0.0012) | (0.0010) | (0.0011) | (0.0000) |
| within estimators | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| pooling estimators | N | N | N | N | N | N | N | N | N | N |
| fixed effect | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| time effect | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| country effect | N | N | N | N | N | N | N | N | N | N |
| industry effect | N | N | N | N | N | N | N | N | N | N |
| F-Stat | 74.281 *** | 80.645 *** | 56.324 *** | 57.104 *** | 72.464 *** | 72.993 *** | 66.436 *** | 73.159 *** | 80.486 *** | 35.264 *** |
| Adj. R-Sq. | 0.0729 | 0.076 | 0.055 | 0.054 | 0.0741 | 0.0759 | 0.0717 | 0.0714 | 0.0784 | 0.0374 |
| | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) |
| Carbon | 0.1632 *** | 0.1661 *** | 0.1383 *** | 0.1538 *** | 0.1520 *** | 0.1289 *** | 0.1337 *** | 0.2213 *** | 0.2004 *** | 0.1151 *** |
| | (0.0308) | (0.0306) | (0.0303) | (0.0299) | (0.0298) | (0.0303) | (0.0303) | (0.0331) | (0.0377) | (0.0267) |
| Size | −0.0311 * | 0.0947 *** | −0.1527 *** | −0.0985 *** | −0.1061 *** | −0.1562 *** | −0.1516 *** | −0.0968 *** | −0.1506 *** | −0.0284 *** |
| | (0.0146) | (0.0143) | (0.0237) | (0.0160) | (0.0159) | (0.0239) | (0.0237) | (0.0177) | (0.0198) | (0.0141) |
| Profitability | −1.9290 *** | 2.0410 *** | −0.0098 *** | −0.0128 *** | −0.0119 *** | −0.0103 *** | −0.0106 *** | −0.0052 * | −0.0019 *** | −0.0151 *** |
| | (0.2173) | (0.2170) | (0.0026) | (0.0025) | (0.0025) | (0.0026) | (0.0026) | (0.0027) | (0.0030) | (0.0021) |
| Leverage | 0.0001 | 0.0001 | 0.0126 *** | 0.0141 *** | 0.0133 *** | 0.0132 *** | 0.0133 *** | 0.0093 *** | 0.0125 *** | 0.0107 *** |
| | (0.0000) | (0.0000) | (0.0011) | (0.0040) | (0.0011) | (0.0011) | (0.0011) | (0.0012) | (0.0013 | (0.0009) |
| Ln_CAPEX | | | 0.0456 *** | | | 0.0531 *** | 0.0509 *** | | | |
| | | | (0.0170) | | | (0.0172) | (0.0171) | | | |
| Current ratio | | | | 0.0520 *** | | 0.0564 *** | 0.0577 *** | | | |
| | | | | (0.0193) | | (0.0192) | (0.0191) | | | |

**Table A1.** *Cont.*

| | Dependent Variable KD | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| MTBV | | | | | 0.0001<br>(0.0008) | 0.0030<br>(0.0008) | | | | |
| within estimators | Y | Y | Y | Y | Y | Y | Y | N | N | N |
| pooling estimators | N | N | N | N | N | N | N | Y | Y | Y |
| fixed effect | Y | Y | Y | Y | Y | Y | Y | N | N | N |
| time effect | Y | Y | Y | Y | Y | Y | Y | N | N | Y |
| country effect | N | N | N | N | N | N | N | Y | N | Y |
| industry effect | N | N | N | N | N | N | N | N | Y | Y |
| F-Stat | 30.072 *** | 41.089 *** | 62.963 *** | 60.9717 *** | 59.208 *** | 46.249 *** | 54.098 *** | 45.099 *** | 22.383 *** | 108.381 *** |
| Adj. R-Sq. | 0.2904 | 0.0432 | 0.0769 | 0.0744 | 0.0756 | 0.0790 | 0.0789 | 0.2667 | 0.0711 | 0.5701 |

Standard errors are in brackets *, **, *** denotes significant at 10%, 5% and 1% respectively. (1) is the baseline model (Equation (1), Table 2); (2) Yearly KD measured by Bloomberg Professional service is the dependant variable; (3) and (4) previous year average monthly KD and previous year KD are the dependant variables, respectively; (5) the ratio between Total emissions and Net Sales is employed as proxy for carbon intensity; (6) the ratio between Direct emissions and Total Asset is employed as proxy for carbon intensity; (7) size is proxied by the natural logarithm of Total Assets; (8) size is proxied by the natural logarithm of Net Sales; (9) Profitability is proxied by the ratio between EBIT and Total Assets; (10) Leverage is proxied by the ratio between Long-term debt and Market Value; (11) size is proxied by the natural logarithm of Total Assets, Profitability is proxied by the ratio between EBIT and Total Assets and Leverage is proxied by the ratio between Long-term debt and Market Value; (12) size is proxied by the natural logarithm of Net Sales, Profitability is proxied by the ratio between EBIT and Total Assets and Leverage is proxied by the ratio between Long-term debt and Market Value; ln_CAPEX is the natural logarithm of Capital expenditures, Current ratio is the ratio between current assets and current liabilities; MTBV is the market to book value; all the rest mirrors (1).

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