Carbon Risk and Corporate Capital Structure

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Abstract

This research exploits Australia's ratification of the Kyoto Protocol, which mandates the country to reduce carbon emissions, as a quasi-natural experiment to examine the effect of carbon risk on the capital structure of Australian firms. We find that heavy carbon emitting firms reduce financial leverage significantly following the ratification, and the leverage decrease is more pronounced for financially constrained or distressed firms. Further analysis indicates that, among the borrowers, heavy carbon emitters are less likely to be financed by major banks and are more likely to obtain new loans following the ratification. Our evidence indicates that heightened carbon risk increases financial distress risk, leading firms to decrease financial leverage.

JEL classification: G32, Q51, Q58

Keywords: Carbon risk; Capital structure; Financial distress; Financial constraint

1. Introduction

How do the costs associated with environmental responsibility in general and carbon risk, which is a firm's financial vulnerability to the transition away from a fossil fuel-based to a lower-carbon economy, in particular affect corporate capital structure? Previous studies suggest that firms with poorer environmental records, such as higher carbon emissions, or greater exposure to environmental risks typically incur higher costs of capital (Chava 2014), and have inferior financial and investment performance (Chava 2014; Derwall *et al.* 2005; Konar & Cohen 2001; Sharfman & Fernando 2008). The recent introduction of more stringent environmental regulations increases carbon risk and the costs to control carbon emissions (hereafter referred to as carbon costs) for heavy carbon emitters, such as firms operating in the energy, materials, or utilities industries. While it is well-documented in the literature that carbon risk has a significant impact on corporate investment and performance, whether and how this type of risk affects firm capital structure is relatively under-researched.

The relation between carbon risk and capital structure is unclear *ex ante*. On the one hand, an increase in carbon risk may discourage firms from using carbon-intensive technologies while encouraging them to switch to more carbon-efficient ones. Reduced carbon emissions may lower firms' operating risk and facilitate their access to external capital markets, potentially leading to an increase in debt financing and higher financial leverage (Sharfman & Fernando 2008). On the other hand, it is noteworthy that carbon-intensive firms are more likely to violate environmental regulations by underinvesting in pollutants processing or sticking to obsolete polluting production processes that risk customer boycotts or lawsuits, potentially leading to adverse cash flow shocks or even bankruptcies (Karpoff *et al.* 2005). Moreover, it could be challenging for firms operating in industries with high carbon emissions to reduce carbon costs when they need to do so, such as during economic downturns. Thus, carbon costs can become fixed in nature that increase firms' operating leverage and financial distress risk. Firms typically consider the trade-off between the benefits and the risk and costs of financial distress of debt financing in making capital structure decision (Kraus & Litzenberger 1973). To the extent that carbon risk increases financial distress risk while adversely affecting corporate performance, thereby decreasing the tax shield benefits of debt, firms may choose to lower debt financing, hence financial leverage, to mitigate the consequences of carbon risk. Our research examines this proposition.

An investigation of the effect of carbon risk on firm capital structure is subject to at least two empirical challenges. The first challenge is endogeneity concerns since the decisions on the level of corporate exposure to carbon risk and financing choices may be jointly determined or both of them may be correlated with unobservable firm characteristics (Al-Tuwaijri *et al.* 2004; Flammer 2015), which render the parameter estimates biased and inconsistent. The second challenge arises from the small sample size due to the lack of firm-level carbon-related data, e.g., greenhouse gas (GHG) emissions or energy consumptions (Konar & Cohen 2001), which prevents researchers from drawing valid inferences or generalizing the findings. Even if the carbon emission data were available, they might measure current or past carbon performance, whereas carbon risk, which indicates a firm's financial vulnerability to the transition from fossil fuel-reliant to lower-carbon stages, is forward-looking and not directly observable.

In this study, we follow a two-pronged strategy to tackle these challenges. First, to alleviate the endogeneity concerns, we exploit the ratification of the Kyoto Protocol by Australia in December 2007 as a quasi-natural experiment. The Kyoto Protocol is an international agreement whereby participating countries commit to reduce carbon emissions to satisfy national reduction targets (UNEP 2006). In particular, under the Kyoto Protocol, Australia is required to restrict its average annual emissions over the period 2008–2012 to eight percent above its 1990 level.[1] Moreover, the ratification of the Kyoto Protocol was the first act of the former Prime Minister Kevin Rudd after being sworn in and widely regarded as the starting point of an era of stricter environmental regulations for Australia (Ramiah *et al.* 2013; Rootes 2008; Subramaniam *et al.* 2015). The Kyoto Protocol ratification (KPR) serves as an exogenous shock to the carbon risk faced by heavy carbon emitters (heavy emitters).

[1] Source:
http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Browse_by_Topic/ClimateChangeold/governance/international/theKyoto

Thus, using the shock for identification purpose allows us to establish a causal relation between carbon risk and firm capital structure.

Second, to address the small sample size concern, we rely on the carbon emission nature of a firm's industry, that is, the relative industry-based level of carbon emissions and energy consumption, to identify heavy emitters. In particular, we sort firms into heavy emitter or light emitter subgroups based on their industry classification. Since the use of industry classification is independent of firm characteristics, it alleviates a concern that a firm may make a decision on the level of carbon risk exposure conditional on its level of financial leverage or both financial leverage and the level of carbon risk exposure may be correlated with other firm characteristics (Krüger 2015). Furthermore, to address a possibility that the industry-based classification of heavy and light emitters picks up the effects of some unobserved industry characteristics, such as business risk, rather than carbon risk, we control for industry fixed effects and other time-varying determinants of financial leverage in our analysis.

To validate the argument about the exogeneity of the KPR by Australia and the relevance of using carbon emission by industry for classification purpose, we examine the market reaction to the announcement of KPR and find negative cumulative abnormal stock returns, using two-day CAR(-1, 0) and three-day CAR(-1, 1) centered on the ratification day, for the average firm. Further subsample analysis indicates that the negative market reaction is concentrated among firms in the subgroup of heavy emitters but the market reaction is insignificant for the subgroup of light emitters. This evidence indicates that the market, at least, did not fully anticipate the KPR by Australia and heavy emitters experience higher carbon risk following the ratification.

Next, we employ the difference-in-differences (DID) analysis framework to track the evolvement of financial leverage of heavy emitters relative to that of light emitters from before to after the ratification of the Kyoto Protocol. We find that increased carbon risk following the KPR is associated with a decrease in firm financial leverage. Our results are robust to controlling for firm fixed effects and two-dimensional firm-year clustering of the standard errors. Our estimation indicates that, relative to the light emitter control firms, heavy emitters reduce the book and market leverage by 0.054 and 0.037, respectively, following the KPR. Given the respective sample means of these two leverage measures of 0.165 and 0.116, the observed decreases are both substantial and economically meaningful.

To further address a concern that our industry-based definition of heavy and light emitters simply picks up industry effects rather than firms' exposure to carbon risk, we run additional tests to demonstrate that our findings hold using firm-level carbon risk exposure to identify treatment and control firms. First, we exploit the National Greenhouse and Energy Reporting (NGER) Act 2007, which mandates businesses that have carbon emission levels above a certain threshold (adjusted on yearly basis from 2008-2009 financial year onwards) to report their carbon emissions and energy consumption to the government that subsequently discloses them publicly. Intuitively, the NGER-mandated firms are the biggest emitters, therefore we designate these firms as the treated ones while using non-NGER-mandated peers as the control firms.

Second, we rely on the stock market reaction to the KPR announcement to identify the treated and control firms for additional analysis. In particular, treated (control) firms include those whose investors reacted negatively (positively or insignificantly) to the announcement of the KPR. The reason is that the ratification could be a bad news for heavy emitters, possibly due to an increase in operating and financing costs or a restriction of some carbon-intensive activities, whereas it is not necessarily a bad news for light emitters (e.g., these firms may even be better off due to reduced competition or better access to external funds). In this and preceding NGER-based tests, we use the propensity score matching (PSM) procedure to select control firms to ensure that the treated and control firms come from the same industry and are similar along several observable dimensions before the exogenous shock. It is worth noting that this approach is not susceptible to industry heterogeneity that may confound our results. The robustness checks based on firm-specific identifications of heavy and light emitters confirm our main findings that carbon risk negatively affects corporate financial leverage.

In additional robustness checks, we use alternative measures of financial leverage that include total liabilities, which account for both debt and non-debt liabilities such as trade credits and accruals, short-term debt, or long-term debt, all divided by either the book or market value of assets to better understand the carbon risk impact on debt components (Titman & Wessels 1988). We also employ a cash flow-based measure of leverage to better capture the real financing activities (Bradshaw *et al.* 2006; Butler *et al.* 2011; Lewis & Tan 2016). Moreover, we exclude financial firms from our analysis since these firms' capital structure has a different meaning (DeAngelo & Stulz 2015; Diamond & Rajan 2000). We further control for the possible effects of the Global Financial Crisis on firm leverage (Kahle & Stulz 2013). The test results confirm the robustness of our findings.

We then investigate the effects of carbon risk on capital structure of firms that vary on the levels of financial constraints. Intuitively, if the decrease in financial leverage is attributable to an increase in carbon risk, this effect should be stronger for financially constrained firms since these firms face more difficulties when accessing external capital markets (Agrawal & Matsa 2013). The lack of external financing may push these firms to reduce investment in carbon risk management and/or discourage them from switching to carbon-efficient technologies, which ultimately increase their carbon risk exposure. Consistent with this view, we find that the decrease in financial leverage post KPR is more pronounced for financially constrained heavy emitters characterized by small size, dividend omissions, or low operating cash flows.

Next, we examine whether financial distress risk is a channel through which carbon risk affects capital structure. We employ the modified Altman Z-score and earnings volatility as alternative measures of financial distress risk. The lower the Altman Z-score, the more likely a firm becomes insolvent and the less likely it can repay its debt (Agrawal & Matsa 2013; MacKie-Mason 1990). Higher earnings volatility implies higher fixed costs that make earnings more sensitive to economic downturns and weakens a firm's ability to meet its debt obligations (Serfling 2016). Our analysis indicates that heavy emitters experience a decrease in Altman Z-score and an increase in earnings volatility after the KPR, implying an increase in financial distress risk. Moreover, the decrease in financial leverage is more pronounced for heavy emitters with lower Altman Z-score or higher earnings volatility.

It is possible that heavy emitters reduce investment following the KPR, lowering the need for debt financing and hence a decrease in financial leverage. Therefore, in a complementary analysis, we examine but do not find a significant change in the heavy emitters' investment following the KPR. This result rules out decreased investment as an alternative explanation for the negative relation between carbon risk and financial leverage. Taken together, our evidence indicates that heavy emitters decrease financial leverage due to heightened financial distress risk in the post-KPR period.

In our final robustness check, we investigate the sources of debt financing for firms following the KPR. We use a hand-collected sample of bank loans in this analysis since bank loans are the main source of external financing for Australian firms. We find that heavy emitters are less likely financed by major banks, and are more likely to obtain new loans (as opposed to subsequent loans) following the KPR. These results imply that heavy emitters are likely to be screened out by big banks due to increased carbon risk exposure, therefore they have to rely on less reputable lenders for their financing needs.

Our research adds to the capital structure literature in two important ways. First, previous studies focus on the effects of macro-economic conditions, institutional features, and firm characteristics on corporate financial leverage, e.g., (Agrawal & Matsa 2013; Almazan *et al.* 2010; Bancel & Mittoo 2004; Frank & Goyal 2009; Lemmon *et al.* 2008; Rajan & Zingales 1995; Titman & Wessels 1988). To the best of our knowledge, our study is the first that establishes a causal relation between carbon risk and firm capital structure. We document that firms that are exposed to higher carbon risk due to tightened carbon controls decrease financial leverage, and the effect of carbon risk on capital structure works largely through the traditional trade-off mechanism (Kraus & Litzenberger 1973). Thus, our study suggests carbon risk in particular, and environmental responsibility in general, as an additional determinant of firm capital structure.

Second, our study provides new insights into the effects of carbon risk on debt contracting. Some research close to ours focus on the effects of corporate social responsibilities or environmental responsibilities on the costs of capital (Chava 2014; El Ghoul *et al.* 2011; Goss & Roberts 2011; Sharfman & Fernando 2008). However, the relation between environmental responsibilities and the costs of capital documented by these studies is prone to endogeneity concerns due to possible reverse causality or omitted variable bias. Our identification strategy that exploits the Australia's KPR as a quasi-natural experiment allows us to draw causal inference about the relation between carbon risk and corporate financial policy.

The remainder of the paper proceeds as follows. Section 2 reviews the literature and develops hypotheses. Section 3 discusses identification strategy. Section 4 describes data and empirical methodology. Section 5 presents the analysis results and discussions and Section 6 concludes the paper.

2. Related Literature and Hypothesis Development

The relation between carbon risk and capital structure is unclear ex ante. Heightened carbon risk may discourage firms from engaging in carbon-intensive activities while encouraging them to switch to cleaner technologies (Dionne & Spaeter 2003). Subsequently, a decrease in carbon emissions could facilitate a firm's access to external capital markets, leading to an increase in debt financing, hence financial leverage, to exploit the interest tax shields (Sharfman & Fernando 2008).

However, higher carbon costs may increase financial distress risk, lowering the optimal level of financial leverage. Carbon-intensive firms typically have large fixed costs, which make them less adaptable to changing environmental regulations. These firm are more likely to stick to obsolete polluting production processes while being slow in making investment in pollutants processing, exposing themselves to potential customer boycotts or lawsuits that may result in adverse cash flow shocks and even bankruptcies (Karpoff *et al.* 2005). Moreover, it is challenging for the firms operating in carbon-intensive industries, such as metals and mining, chemicals, and paper and forest products, to reduce carbon costs when they need to do so, particularly during economic downturns. This feature makes carbon costs more fixed in nature for firms in these industries, increasing their operating leverage and financial distress risk. Given the opposite arguments about the possible effects of the increase in carbon risk on financial leverage following the KPR, we state our alternative testable hypotheses as follows:

Hypothesis 1A: Increased carbon risk following the ratification of Kyoto Protocol leads to higher firm financial leverage.

Hypothesis 1B: Increased carbon risk following the ratification of Kyoto Protocol leads to lower firm financial leverage.

3. Identification Strategy

3.1. Definition of Heavy and Light Emitters

We classify firms as either heavy or light emitters based on the emitting nature of the industry in which a firm operates (Nguyen 2018). Heavy emitters include firms in the industries recognized as "carbon intensive" including biggest GHG emitters or energy consumers. Heavy emitters are more likely to face environmental challenges such as climate change, which may have negative financial effects in the form of carbon-related management and accounting costs, clean-up costs, compliance and litigation costs, or reputation damage (Barth & McNichols 1994; Clarkson *et al.* 2004; Karpoff *et al.* 2005). As carbon regulations become more stringent, carbon costs are expected to increase for heavy emitters. An important advantage of using industry-based classification for analysis is that it allows us to alleviate the small sample bias concern (Konar & Cohen 2001).

The highest carbon-risk GICS industries include those that reportedly emit the most GHG and consume the most energy as described by the Greenhouse Gas Protocol (GHG Protocol).[2, 3] Based on a broad classification, among the 10 GICS sectors, three sectors including Energy, Utilities, and Materials have been recognized as the biggest GHG emitters. For example, according to AMP Capital, energy, utility, and materials were the largest contributors to ASX200 GHG emission intensity as of the end of August 2015, accounting for

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[2] Global Industry Classification Standard (GICS) is a joint Standard and Poor's and Morgan Stanley Capital International product aimed at standardising industry definition worldwide (source: http://www.asx.com.au/products/gics.htm).

[3] Source: http://www.ghgprotocol.org/

85% of total emissions.[4] To address a possibility that some industries within these three sectors are less carbon-intensive than others, we further follow the classification of the Carbon Disclosure Project to identify the most emitting industries in the energy, utilities and materials sectors.[5] Specifically, firms in the following nine GICS industries are defined as heavy emitters: Oil, Gas & Consumable Fuels; Electric Utilities; Gas Utilities; Independent Power Producers & Energy Traders; Multi-Utilities; Chemicals; Construction Materials; Metals & Mining; and Paper & Forest Products (CDP 2012).

3.2. Australia's Ratification of Kyoto Protocol

Australia's ratification of Kyoto Protocol provides a useful setting to examine the relation between carbon risk and firm capital structure for the following reasons. First, according to Climate Change Review Update 2011, Australia is the most polluting nation in the Organisation for Economic Co-operation and Development (OECD) group based on GHG emissions per capita (Garnaut 2011). This fact gives rise to some features of Australian carbon regulatory framework that have important implications for Australian businesses. Second, Australian policy-makers have enacted several new and stringent carbon regulations with which firms have to comply following the ratification of Kyoto Protocol in 2007 (Moosa & Ramiah 2014). Third, Australia is among the countries with the highest awareness of carbon

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[4] AMP Capital is a leading Australian investment house with AU$178.9 billion in funds under management as of 30 June 2017. They were amongst the first to sign on to the Principles for Responsible Investment in 2007 and have broadly considered Environmental, Social and Corporate Governance issues in equity investment strategies and advice (source: https://www.ampcapital.com.au/about-us)

[5] Carbon Disclosure Project (CDP) runs the global disclosure system that enables corporations, cities, states, and regions to measure and manage their environmental impacts. Its network of investors and purchasers represents US$100 trillion in assets (source: https://www.cdp.net/en/info/about-us). Some recent studies have used the carbon emission data provided by CDP (e.g., (Matsumura *et al.* 2013).

responsibilities by all types of market participants, such as banks, savers, investors, and business managers (Nguyen 2018).[6]

The ratification of the Kyoto Protocol in December 2007 was the first act of the newly-elected Labor Prime Minister Kevin Rudd to fulfil his promises to protect the environment (Ramiah *et al.* 2013). The ratification also marked a shift in the stringency of the country's carbon policies and an end to decades of Australia being criticized as a resource-based economy. Indeed, Australia and United Stated were the only two major industrialized countries that refused to ratify the Kyoto Protocol when it was first introduced in 1997, and Australia had not taken any decisive actions on cutting the national level of emissions prior to the KPR (Rootes 2008; Subramaniam *et al.* 2015). By November 2007, it remained unclear if Australia would ratify the Kyoto Protocol and such important decision totally depended on the outcome of the 2007 federal election. Had the Liberal Party of the then Prime Minister John Howard won the election, the Kyoto Protocol might not have been ratified and the Emission Trading Scheme would have been adopted instead.[7] Furthermore, the Kyoto Protocol was aimed at reducing the Australia's GHG emission level to no more than eight percent above the 1990 levels for the period 2008-2012, reflecting the Rudd government's commitment to join global efforts in protecting the environment as a top priority. The KPR, therefore, came as an

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[6] One notable recent example is the extensive protest involving the petition of over 100,000 Australians asking the CEOs of Australia's Big 4 banks to rule out financing the Abbot Point coal port expansion on the Great Barrier Reef. Financing for this project was refused by some of the world's biggest banks, such as HSBC, Deutsche Bank, The Royal Bank of Scotland, Barclays and Citibank because it is estimated that the project will triple Australia's carbon emissions, locking the country into at least 30 more years of coal-fired power.

[7] See the Prime Minister's address on June 3, 2007 to the Liberal Party Federal Council (source: http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22media%2Fpressrel%2FIU9N6%22).

exogenous shock to firms in resource-intensive industries, which had long been the main drivers of the Australian economy.

[Insert Figure 1 about here]

Figure 1 plots the percentage of annual contribution to Gross Domestic Product (GDP) by industry in Australia over the sample period 2002-2013. It is worth noting that industries belonging to the energy, materials, and utilities sectors together account for the biggest proportion of the GDP, ranging from 25.7% to 28.9% per year over the sample period. Other key contributors to the GDP include public industries such as public administration and safety, education and training, and health care and social assistance, which collectively represent approximately 16.7% of the GDP. Financials and real estate industries contribute about 11.1%, wholesale and retail trade industries generate 10.0%, and agriculture and transportation industries contribute around 8.0% of the GDP.

[Insert Figure 2 about here]

Figure 2 illustrates the annual carbon dioxide (CO_2) emissions in metric tons per capita of Australia in comparison with other nine nations that are listed in the top 10 by market capitalization as well as the OECD group over the sample period 2002-2013. There are three noticeable trends. First, in the pre-KPR period, Australia increased the level of emissions per capita rapidly from below Canada and United States, the second and third biggest emitters, to above all of the studied nations in 2009. Second, the pace of increase in carbon emissions started to slow down after the Kyoto Protocol was ratified in late 2007 before the level of emissions officially decreased after 2009. Third, Australia has been always among the top carbon emitters as compared to other major developed and developing economies.

3.3. Market Reaction to Australia's Ratification of Kyoto Protocol

In this section, we validate our choice of the KPR as an exogenous shock for identification purpose by examining the stock market reaction upon the announcement of the ratification. We estimate the abnormal stock returns for firms listed on the Australia Stock Exchange (ASX) on December 4, 2007, by taking the difference between the actual and the expected stock returns, where the expected stock returns are calculated using the market model parameters estimated over the 200-day window (-260, -61) relative to the announcement day. In fact, the decision of the Rudd government on KPR was first announced at late night of December 3, 2007, when the market had already been closed.[8] We therefore use two event windows for our validation purpose, two-day CAR(-1, 0) and three-day CAR(-1, 1), to account for the possibility that the news was leaked and investor reaction was delayed. We choose to focus on the short event windows to capture the immediate market response to the news and minimize potential confounding effects, especially when the news came out at the onset of the Global Financial Crisis.

[Insert Table 1 about here]

The results reported in Table 1 indicate that the market reacted negatively to the announcement of KPR by Australia (mean CAR(-1, 0) and CAR(-1, 1) = -0.396% and -0.360% with *t*-statistics = -2.80 and -2.16, respectively). Moreover, the negative stock price reaction to the KPR is statistically significant for heavy emitters (CAR(-1, 0) = -0.668% with *t*-stat. = -2.65, and CAR(-1, 1) = -0.534% with *t*-stat. = 1.79) but insignificant for light emitters. Overall, these results suggest that the KPR was at least partially unanticipated and had negative (little)

[8] The news was first released after 5.00 pm on December 3, 2007 by the most popular newspapers in Australia such as ABC News (source: http://www.abc.net.au/news/2007-12-03/rudd-signs-kyoto-ratification-document/976234), or The Age (source: http://www.theage.com.au/news/national/rudd-ratifies-kyoto/2007/12/03/1196530553722.html)

effect on the stock value of heavy (light) emitters. This evidence supports our argument that heavy emitters are prone to higher carbon risk when carbon regulations are tightened.

4. Data and Empirical Models

4.1. Data

Our sample consists of 15,484 firm-year observations of 2,092 unique firms that were publicly listed in ASX from 2002 to 2013. We obtain financial data and GICS industry classifications from Morningstar DatAnalysis, and stock return data from Datastream. A firm-year needs to have non-missing data for the main variables to be included in the sample. The sample period covers the pre-Kyoto 2002-2007 and the post-Kyoto 2008-2013 sub-periods. The post-ratification subperiod is selected to correspond to the Australian government's commitment period as a part of the KPR.[9] The pre-Kyoto subperiod is chosen to be of the same length with the post-Kyoto subperiod. However, for the variables that require both historical and future data such as earnings volatility, we extend the sample period to begin in 2000 and end in 2015.

We use two main measures of financial leverage, book leverage and market leverage, in our analysis. Book leverage is the ratio of the sum of short-term and long-term debt to the book value of assets. Market leverage is the ratio of the sum of short-term and long-term debt to the market value of assets, where the market value of assets is calculated as the book value of assets minus the book value of equity plus the market value of equity. Control variables consist of firm characteristics that are documented to have power to explain firm capital

[9] The original Kyoto Protocol commitment period in Australia is 2008-2012. We add 2013 to account for the fact that for many firms, the 2013 financial leverages are the results of 2012 financing policies. In an unreported analysis, we define the post-Kyoto period as 2008-2012 and obtain qualitatively similar results.

structure, including size (*Log(BA)*), growth opportunities (*MB/BA*), profitability (*EBIT/BA*), and tangibility (*PP&E/BA*) (Graham *et al.* 2015; Leary & Roberts 2014; Rajan & Zingales 1995; Simintzi *et al.* 2014). To minimize the impacts of outliers, we winsorize all continuous variables at the top and bottom 1%. Appendix A1 provides a detailed description of the variables.

[Insert Table 2 about here]

Table 2 provides the summary statistics of the main variables. The statistics reported in Panel A indicate that, on average, firms' book and market leverages are 0.165 and 0.116, respectively, and a large number of firms do not use any debt financing as indicated by the 25th percentile value of zero. When we replace total debt with total liabilities to calculate financial leverage, the means of these measures are 0.403 and 0.276, respectively, suggesting that Australian firms also use other sources of financing such as trade credits or accruals extensively. The ratios of short-term and long-term debt to book value of assets (market value of assets) are 0.067 and 0.087 (0.047 and 0.068), respectively. In addition, the average cash flow-based borrow ratio (i.e., net borrowing-to-external financing cash flows) is 0.408.

4.2. Difference-in-Differences Model Specification

Our baseline DID model has the following form:

$$Y_{it} = b_0 + b_1 Emitter_{it} + b_2 Post + b_3 Emitter_{it} {*} Post + b_4 Log(BA)_{it} + b_5 EBIT/BA_{it} + b_6 PP\&E/BA_{it} + b_7 MA/BA_{it} + \text{(Industry \& Year) FEs} + e_{it} \quad (1)$$

where Y_{it} is the measure of financial leverage of firm i in year t. $Emitter_{it}$ is an indicator that takes a value of one if firm i in year t is a heavy emitter, and 0 otherwise. *Post* is an indicator that takes a value of one for years following the KPR, and 0 otherwise. The list of control variables includes size (*Log(BA)),* profitability (*EBIT/BA*)*,* tangibility (*PP&E/BA*)*,* growth opportunities (*MA/BA*) (Graham *et al.* 2015; Leary & Roberts 2014; Rajan & Zingales 1995; Simintzi *et al.* 2014). The models are estimated with heteroscedasticity-robust standard errors clustered by firm.[10] Appendix A1 provides the definitions of the variables.

The coefficient of interest in Equation 1 is b_3, which captures the change in financial leverage of heavy emitters relative to that of light emitters from before to after the ratification of Kyoto Protocol. A positive (negative) b_3 in the financial leverage regressions indicates that heavy emitters increase (decrease) their leverage relative to that of the light emitters subsequent to the KPR, which is consistent with Hypothesis 1A (1B).

To address a possibility that the *Emitter* dummy variable may capture the effects of industry characteristics or other time-invariant firm fixed effects rather than carbon risk, we control for GICS industry or firm fixed effects in some specifications. We further include year fixed effects to control for time-varying macro-economic conditions that may affect financial leverage. However, in the models that control for industry (or firm) and year fixed effects, we do not include the stand-alone $Emitter_{it}$ and *Post* dummies because their explanatory powers are absorbed by these fixed effects.

5. Empirical Results and Discussions

5.1. Univariate Analysis Results

We perform two-sample *t*-tests of the differences in the means of the measures of financial leverage between heavy emitters and light emitters in the pre- and post-KPR periods. We also examine the *changes* in leverage for heavy emitters and light emitters subsequent to Australia's KPR in December 2007.

[10] In robustness checks, we also control for two-dimensional clustering effects by firm and year. Main results are qualitatively unchanged.

[Insert Table 3 about here]

Table 3 reports the univariate analysis results for the book leverage *TDebt/BA* (Panel A) and market leverage *TDebt/MA* (Panel B). We observe opposite trends in financial leverage of heavy emitters and light emitters following the KPR. Specifically, the results in Panel A indicate that heavy emitters decrease their book leverage by 0.027, which is equivalent to 19.6% of its sample mean. In contrast, light emitters increase their book leverage by 0.027, which is equivalent to 14.2% of its sample mean. As a result, the gap in book leverage of these two groups widens by 0.053, an increase of 103.9% from the pre-ratification gap. We observe a similar pattern for market leverage, which decreases by 11.8% from its sample mean for the heavy emitters but increases by 17.5% for the light emitters post KPR. In short, the univariate analysis results provide initial evidence of the negative association between increased carbon risk and firm financial leverage following the KPR.

5.2. Multivariate Analysis Results

In this section, we examine the effect of the KPR on firm financial leverage in a multivariate setting that controls for other factors that have been documented to affect financial leverage. We estimate Equation 1 with the dependent variable being either the book leverage (*TDebt/BA*) or market leverage (*TDebt/MA*). Since the relation between carbon risk and market leverage could be driven by the fluctuation in stock prices rather than the change in financing policies (Welch 2004) and managers typically rely on book leverage to make capital structure decisions (Graham 2003; Serfling 2016), we use book leverage analysis results for discussion in this section.

[Insert Table 4 about here]

Table 4 reports the regression results of the book leverage (Columns 1-4) and market leverage (Columns 5-8). Columns 1 and 5 include *Emitter* dummy and other control variables but without fixed effects. Columns 2 and 6 further include the *Post* dummy and its interaction with the *Emitter* dummy. Columns 3 and 7 further control for industry and year fixed effects. Columns 4 and 8 control for firm rather than industry fixed effects and year fixed effects. The estimation results consistently indicate that heavy emitters decrease financial leverage subsequent to the KPR. For illustration, in Column 1, the coefficient of *Emitter* is -0.085 and statistically significant at the 1% level, suggesting that an average heavy emitter's book leverage is 0.085 lower than that of an average light emitter. In Column 2, the coefficient of *Emitter* is negative (-0.056) and statistically significant, indicating that, absent the ratification of the Kyoto Protocol, the book leverage of an average heavy emitter is 0.056 lower than that of an average light emitter. On average, the control light emitters increase their book leverage following the KPR as evidenced by the positive coefficient of *Post* (0.031). However, the negative (-0.054) and highly significant coefficient of the interaction term *Emitter*Post* indicates that heavy emitters experience a significant decrease in book leverage from before to after the KPR relative to their light emitter counterparts over the same period. Furthermore, this finding is not sensitive to controlling for industry or firm fixed effects. The impact of KPR on the capital structure of heavy emitters is also economically meaningful. For illustration, the coefficient estimates reported in Columns 2 and 6 of Table 4 indicate that the relative decreases in book and market leverage of heavy emitters are 0.054 and 0.037, which are equivalent to 32.7% and 31.9% of their respective sample means.

In short, both the univariate and multivariate results consistently indicate that an increase in carbon risk due to the KPR leads to a decrease in financial leverage of heavy emitters.

5.3. Robustness Checks

5.3.1. Firm-Based Definitions of Heavy and Light Emitters

The use of industry-based classification of heavy and light emitters in the above analysis may raise a concern that the *Emitter* dummy variable simply picks up the effects of industry characteristics rather than firms' level of exposure to carbon risk on their capital structure. Thus far, we have adopted two strategies to validate this industry-level definition of heavy emitters including showing that heavy emitters experience a negative stock market reaction to the announcement of KPR and controlling for industry or firm fixed effects in the regression models. Nonetheless, firm-based classifications of heavy and light emitters may better account for the heterogeneity of carbon risk faced by firms. Therefore, we construct two additional firm-level emitter dummy variables that measure carbon risk from the regulators' perspectives and the stock market's perspective in the next analysis.

5.3.1.1. National Greenhouse and Energy Reporting Act 2007

Our first firm-level measure of carbon risk is constructed based on the enforcement of the National Greenhouse and Energy Act (NGER) 2007. The NGER Act provides a single national legislative framework for the reporting and dissemination of information related to GHG emissions, energy consumption, and production of corporations. Under the NGER Act, by 31 October each year, Australian corporations that emit carbon dioxide and/or consume or produce energy above certain thresholds are mandated to report their emissions and energy information to the Clean Energy Regulator, the Government body responsible for administering the Act compliance, which subsequently discloses the information to the public. In other words, more businesses have been required to provide their emissions and energy information to the government and the public since 2008-09 period. Note that these disclosures are compulsory and businesses that fail to comply with the NGER Act are subject to civil and criminal penalties.[11]

The NGER reporting scheme provides a useful setting for our DID analysis since NGER-mandated firms are clearly identified as the biggest emitters that can be considered as treated firms (i.e., firms that are most likely affected by the KPR), whereas non-NGER-mandated peers are considered lighter emitters, hence serving as control firms. Thus, we define treated firms as those that are required to disclose their emissions and energy information under the NGER Act (hence appearing in the Clean Energy Regulator's website) in any reporting years over the period 2008-2013, and possible control firms include the remaining ones. We then use the PSM without replacement to identify control firms in the same GICS industry, which are the nearest neighbors within the 1% caliper based on observable firm characteristics (i.e., control variables used in the baseline regressions) in the year preceding the first NGER reporting period.

[Insert Table 5 about here]

Panel A of Table 5 reports the post-match diagnostic test results, where we conduct *t*-tests of the difference in the means of the variables used in the first-stage probit regression of the *Treated* dummy. The test statistics indicate that the PSM procedure produces 27 pairs of treated and control firms that are similar along the observable dimensions before the NGER Act adoption. Since we match treated and control firms in the same GICS industry, our analysis is not susceptible to industry effects that might confound the findings. Panel B of Table 5 reports the estimation results of the DID models using the PSM-matched sample. $Before^{-1}$, $Current^{0}$, $After^{+1}$, and $After^{2+}$ are dummy variables indicating one year before, the same year,

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[11] Readers can refer to information at this link http://www.cleanenergyregulator.gov.au/NGER/Reporting-cycle/Complying-with-NGER for more details on penalties for non-compliance with the NGER Act.

one year after, and two or more years after the event year 2007, respectively. The regression results suggest that treated firms decrease their financial leverage significantly compared to control firms from before to after the NGER Act, and the effect is significant from two years after the event. We note that the weaker results of the regressions that include firm rather than industry fixed effects (in Columns 3, 4 and 8) may be due to the small degrees of freedom associated with the small PSM sample. In sum, our firm-level identification of heavy and light emitters from the regulators' perspective provides results consistent with the baseline analysis based on the industry-level classification.

5.3.1.2. Market Reaction to the Announcement of KPR

Our second strategy to identify treated and control firms relies on the stock market reaction to the announcement of the KPR to gauge the carbon risk exposure of each firm from the stock market's perspectives. Specifically, a firm is considered to be heavily (lightly) exposed to carbon risk if its investors reacted negatively (positively or insignificantly) to the announcement of KPR. The intuition is that the KPR could be a bad news for carbon-intensive firms since it may increase their operating and financing costs or restrict their polluting activities. On the other hand, the ratification is not necessarily a bad news for low emitting firms since, to a certain extent, it may reduce competition or facilitates access to external funds for these firms.

Following the above argument, we estimate the stock market reaction using the three-day CAR(-1, 1) centered on the KPR day. We designate a firm as a treated (control) firm if it experiences negative (insignificant or positive) CAR(-1, 1).[12] Next, we perform a PSM procedure to identify control firms. Specifically, in the first stage, we run a probit model of

[12] In an untabulated test, we employ a two-day CAR(-1, 0) instead of three-day CAR(-1, 1) and obtain qualitatively similar results.

Treated dummy on all control variables used in the baseline models for year 2007, and obtain the predicted probability, or *p*-score, of a firm being a treated one. We then match each treated firm with a control firm in the same GICS industry using nearest neighbor matching within 1% caliper and without replacement. In the second stage, we rerun the DID analysis using the new PSM sample.

[Insert Table 6 about here]

The test results presented in Table 6 support our main findings. In particular, the statistics reported in Panel A of Table 6 indicate that there are 305 pairs of treated and control firms and they are not significantly different along the observable dimensions, validating the matching procedure. In Panel B of Table 6, we employ the model specifications and variables similar to those in Table 5 and find consistent evidence that treated firms reduce their financial leverage relative to the control firms after the ratification of the Kyoto Protocol. More importantly, the effect is only present in or after the event year of 2007, implying that the pre-trend parallel assumption underlying the validity of the DID framework is valid.

In summary, our alternative firm-based classification of heavy and light emitters from the market's perspective corroborate the argument that an increase in carbon risk due to the KPR has a negative effect on firm financial leverage.

5.3.2. Alternative Measures of Financial Leverage

In this section, we consider alternative measures of financial leverage, which include total liabilities, and short- and long-term debt ratios (Titman & Wessels 1988). This consideration is important since Rauh and Sufi (2010) point out that "fallen angels" may change the composition of firm debt rather than the total debt levels. We construct six additional proxies for financial leverage for which the relevant data are available, including *TLiability/BA, TLiability/MA, STDebt/BA, STDebt/MA, LTDebt/BA,* and *LTDebt/MA*. The summary statistics reported in Table 2 indicate that these measures vary greatly. For example, the mean of *TLiability/BA* (0.403) is more than 2.4 times that of *TDebt/BA* (0.165), which suggests that a large portion of assets is financed with trade credits and/or accruals in addition to bank borrowings or debt issues.

We further consider another measure of leverage, *Borrow/NF*, which is the cash flow-based borrow ratio (Bradshaw *et al.* 2006; Butler *et al.* 2011; Lewis & Tan 2016). While the two main measures of financial leverage used in the baseline regressions (*TDebt/BA* and *TDebt/MA*) are subject to mean reversion over time, the cash flow-based borrow ratio can better capture the real financing activities, that is, how much a firm's net financing is raised through debt versus equity issuance. Therefore, this measure is more dynamic and less likely to be affected by time trends (Lemmon *et al.* 2008). However, one caveat of the cash flow-based borrow ratio is that it could be a noisy measure, especially when firms issue extremely small or large amounts of debt relative to equity (Lewis & Tan 2016).

[Insert Table 7 about here]

The results reported in Table 7 indicate that the coefficients of *Emitter*Post* are all negative, ranging from -0.113 to -0.013, and statistically significant across models using seven alternative measures of financial leverage. In short, our evidence indicates that heavy emitters reduce not only the aggregate but also the components of total debts and other forms of liabilities in their capital structure.

5.4. Carbon Risk and Financial Constraints

Due to their insufficient internal cash flow and lack of access to external capital markets, financially constrained heavy emitters may find it harder to make investment in new technology that reduces carbon emission to meet the more stringent environmental regulations, thus, carbon risk could be more detrimental to these firms. Following this proposition, we predict that the negative effect of carbon risk on financial leverage is more pronounced for financially constrained firms. To test this prediction, we sort firms into the financially constrained (FC) and unconstrained (UC) subgroups using firm size, dividend payouts, or operating cash flows (Agrawal & Matsa 2013) for analysis.[13] FC firms include those that have either book assets below the sample median, zero dividends, or operating cash flows-to-total assets ratio below the sample median. The remaining firms are considered financially unconstrained. Consistent with our prediction, the results reported in Table 8 indicate that the coefficients of *Emitter*Post* interaction term are negative and larger in magnitude for FC than for UC firms across all three financial constraint measures.

[Insert Table 8 about here]

5.5. Channel of Effects

Our results thus far suggest that an increase in carbon risk leads to a decrease in financial leverage. In this section, we perform two tests to examine whether financial distress risk is a possible channel through which carbon risk affects capital structure. In the first test, we examine the direct relation between carbon risk and financial distress. In the second test, we re-examine the relation between carbon risk and financial leverage using subsamples of firms sorted on the level of financial distress risk. To the extent that carbon risk heightens firms' financial distress risk, leading to their reduced leverage, we expect a positive relation between carbon risk and financial distress and a stronger negative relation between carbon risk and financial leverage for firms faced with higher financially distressed risk.

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[13] We choose to use firm characteristics against composite indices such as KZ (Kaplan & Zingales 1997), or WW (Whited & Wu 2006) to measure the degree of financial constraints because all these composite indices contain financial leverage in their calculations while financial leverage is our dependent variable.

[Insert Table 9 about here]

We employ two measures of financial distress risk. The first measure is modified Altman Z-score, *Z-score*, developed by MacKie-Mason (1990), which indicates the likelihood of bankruptcy of a firm in a given year. It is calculated as: Z-score = 3.3**EBIT/BA* + 1.0**Sales/BA* + 1.4**Retained/BA* + 1.2**WCap/BA*, where *EBIT* is earnings before interest and taxes, *Sales* is total revenue, *Retained* is retained earnings, *WCAP* is working capital. A lower Z-score implies a higher likelihood of bankruptcy. The second proxy for financial distress risk is *RoaVol*, which measures a firm's earnings variability. This measure is calculated as the standard deviation of annual *EBIT/BA* over five-year rolling windows (see Appendix A1 for a detailed description). Firms with higher degrees of fixed costs relative to total costs have their earnings more susceptible to changing economic conditions, resulting in higher earnings volatility, hence higher financial distress risk (Lemmon *et al.* 2008; Serfling 2016).

Table 9 reports the test results. We re-estimate Equation 1 with the dependent variable being either *Z-score* (Column 1) or *Log(RoaVol)* (Column 4) for the direct tests. For the indirect tests, we re-estimate Equation 1 with the dependent variable being book leverage, *TDebt/BA*, for subsamples of financially distressed (FD) or undistressed (UD) firms sorted on either *Z-score* (Columns 2 and 3) or *Log(RoaVol)* (Columns 5 and 6). Since financial distress is an extreme case when firms are very close to bankruptcies, we define FD firms as those belonging to the first quartile of the sample *Z-score* (or fourth quartile of sample *RoaVol*) and define UD firms as those belonging to the fourth quartile of sample *Z-score* (or first quartile of sample *RoaVol*).[14] The estimation results indicate that heavy emitters experience a decrease in Z-score and an increase in earnings volatility in the post-KPR period, suggesting that heavy emitters face more financial distress risk than light emitters do. In addition, the decrease in book

[14] We obtain qualitatively similar results if we use median partitions.

leverage of heavy emitters is more pronounced for FD firms compared to UD firms. For example, the results in Columns 2 and 3 reveal that FD heavy emitters decrease their book leverage by 0.11 from before to after the KPR while UD heavy emitters experience little change in leverage relative to the light emitter controls. Overall, our tests are consistent with the view that higher carbon risk heightens financial distress risk, motivating firms to lower financial leverage.

5.6. Carbon Risk and Bank Loans

In this section, we examine the impact of carbon risk on corporate debt contracting to gain further insight into the heavy emitters' decreased financial leverage subsequent to the ratification of the Kyoto Protocol. We first use a sample of bank loans for analysis since they are the main source of debt financing for Australian businesses. We hand-collect the bank loan data by reading each original announcement of loan approval to identify the borrowers, lending banks, and loan characteristics.[15] We follow the literature that studies bank loans in applying the following key words to search for the loan announcement articles in Sirca database: "bank loan", "bank credit", "bank debt", "bank borrowing", "bank lending", "bank financing", "bank funding", "syndicated loan", "credit line, "revolving loan", "loan extension, "loan expansion", "loan renewal", and "loan approval". We then merge bank loan data with the borrowing firms and obtain the GICS industry classification from DatAnalysis.

Banks have an inherent interest in carefully evaluating borrowers' carbon risk in the screening and monitoring process because they are potentially liable for environmental damages caused by borrowers and exposed to reputation risks as a result of lending to environmentally harmful projects (Chava 2014; Pitchford 1995). Thus, a banks' better

[15] Bank loan data can be downloaded from other databases, such as the famous LoanConnector DealScan. While DealScan consists of only syndicated loans, our manually collected loan announcements contain all types of loans.

management of the borrowers' carbon risk ensures the borrowers' timely repayment of the loan, which is central to the banks' credit risk management. Moreover, banks possess superior screening and monitoring capability relative to other market participants due to their access to private information of prospective borrowers (Diamond 1991; Fama 1985). These arguments suggest that faced with higher carbon risk, heavy emitters will have more difficulties in obtaining bank loans from reputable banks that have information advantages and strong commitments to environmental protection when they access external debt markets. Furthermore, the investment in new and cleaner technologies required by stricter environmental regulations would be costly, its outcome would be uncertain, and the payback period could be longer. As a result, heavy emitters might be forced to borrow from smaller, more risk-tolerant, but less environmentally responsible banks. We, therefore, predict that heavy emitters are more likely to obtain new loans as opposed to subsequent loans.

To examine the above predictions, we re-estimate Equation 1 with the dependent variable being either *Big4* or *NewLoan*. *Big4* is a dummy variable that takes the value of one if a loan is financed by one of four Australia's major banks – ANZ, CBA, NAB, and Westpac, and zero otherwise. These four big banks account for more than 80% of the lending market share in Australia and are highly committed to environmental responsibilities in their lending activities. They are also the only Australia's banks that participate in global initiatives on environmental protection such as United Nations Environmental Programme (UNEP) Statement by Financial Institutions and the Equator Principles (EP) (IFC 2013; UNEP 1997). *NewLoan* is a dummy variable that equals one if a loan is granted for the first time to a particular borrower by a certain bank(s), and zero otherwise. Banks are more likely to grant subsequent loans to their quality clients since banks can benefit from private information accumulated over their long-term lending relations (Aintablian & Roberts 2000; Lummer & McConnell 1989).

Lower quality and riskier clients, therefore, may need to initiate new loans, which may take longer to process and have cost disadvantages.

[Insert Table 10 about here]

Table 10 reports the results of the linear probability regressions of *Big4* and *NewLoan* on *Emitter*, *Post*, and the interaction term *Emitter*Post*.[16] In addition to the four main control variables (*Log(BA), EBIT/BA, PP&E/BA, MA/BA*), we further control for lagged book leverage (*TDebt/BA*) in all regressions since financial leverage may influence a bank's decision on loan approval. The negative and significant coefficients of *Emitter*Post* in Columns 2 and 3 indicate that heavy emitters are less likely to be financed by one of the four major banks following the KPR. Moreover, heavy emitters are more likely to obtain new loans as suggested by the positive and significant coefficients of *Emitter*Post* in Columns 5 and 6. These results are consistent with the view that major lenders reduce their lending to heavy emitters in the post-KPR period, which is consistent with the negative relation between carbon risk and firm financial leverage that we document above. Moreover, if heavy emitters are forced to seek new financing from smaller and more risk-tolerant banks, they will need to pay higher cost of debt as documented in Nguyen et al. (2018).

5.7. Additional Robustness Checks

In this section, we conduct other robustness checks. First, we exclude firms in financial industries from the sample since these firms may adopt fundamentally different capital structure choices in comparison with others (DeAngelo & Stulz 2015; Diamond & Rajan 2000).

[16] Angrist and Pischke (2010) note that the asymptotic properties and flexibility of linear models often generate more robust results than nonlinear models. Moreover, linear models can include big numbers of industry and year fixed effects, and coefficients on interaction terms in these models capture the marginal effects. Nevertheless, our results based on probit models are qualitatively similar.

In particular, we exclude banks, capital markets, consumer finance, diversified financial services, insurance, real estate investment trusts, real estate management and development, and thrifts and mortgage finance. This filter drops 587 firm-year observations from the sample. We then rerun the book and market leverage regression models. The estimation results reported in Appendix A2 suggest that our findings are not sensitive to the exclusion of firms in the financial industry.

Second, we control for the Global Financial Crisis since a large number of firms adjust their financial leverage downward due to deteriorated economic and financing conditions (Kahle & Stulz 2013). Specifically, we re-estimate Equation 1 augmented with an indicator variable for the period 2008-2009, *GFC*, and an interaction, *Emitter*GFC*. We report the results of these tests in Appendix A3. The results in Columns 1 and 4 indicate that the coefficient on the *GFC* dummy is statistically insignificant in the book leverage regression but positive and significant in the market leverage regression. The latter result could be due to the substantial decline in firm market values during the crisis. The results in all columns indicate that the interaction *Emitter*GFC* does not relate significantly to financial leverage. In other words, heavy emitters do not change their capital structure significantly relative to light emitters during the Global Financial Crisis. More importantly, the coefficients on the interaction *Emitter*Post* remain negative and highly significant in all models that control for the impact of the GFC. This evidence rules out the possibility that the adverse effects of the Global Financial Crisis that occurred in the post-KPR period confound our findings.

Third, we examine whether or not a decrease in investment, rather than the increase in financial distress risk, of the heavy emitters post KPR explains the decrease in debt financing. In particular, we run a DID regression of investment on *Emitter*, *Post*, their interaction *Emitter*Post*, and control variables. The investment-q model specification is similar to (Fazzari *et al.* 1988; Peters & Taylor 2017), in which investment is measured as capital expenditure in year *t* scaled by the book value of assets at the beginning of year *t*, *Capex/LagBA*. We control for firm growth opportunities, proxied by Tobin's Q, at the beginning of the year, and contemporaneous cash flows scaled by the book value of assets at the beginning of the year. Appendix A4 reports the investment regression results. The coefficients on the interaction term *Emitter*Post* in Columns 1 and 2 are statistically insignificant, suggesting that heavy emitters do not change their investment significantly relative to the light emitters subsequent to the KPR. Taken together, these results rule out the possibility that lower investment explains the decrease in financial leverage observed for heavy emitters post KPR.

6. Conclusions

This research examines the effects of carbon risk on firm capital structure. We exploit the ratification of Kyoto Protocol by Australia in December 2007 that exogenously increases carbon risk and costs of firms in carbon-intensive industries for identification purpose. Our analyses yield four main findings. First, we document that relative to the control light emitters, heavy emitters decrease financial leverage subsequent to the KPR. Second, we find that carbon risk increases heavy emitters' financial distress risk, which leads to their decrease in financial leverage. Third, we demonstrate that financially constrained heavy emitters decrease financial leverage more than the financially unconstrained ones do. Finally, heavy emitters are more likely to borrow from small and more risk-tolerant banks, and are more likely to obtain new loans following the KPR. Overall, our evidence suggests that carbon risk exacerbates financial distress risk, leading firms to decrease financial leverage.

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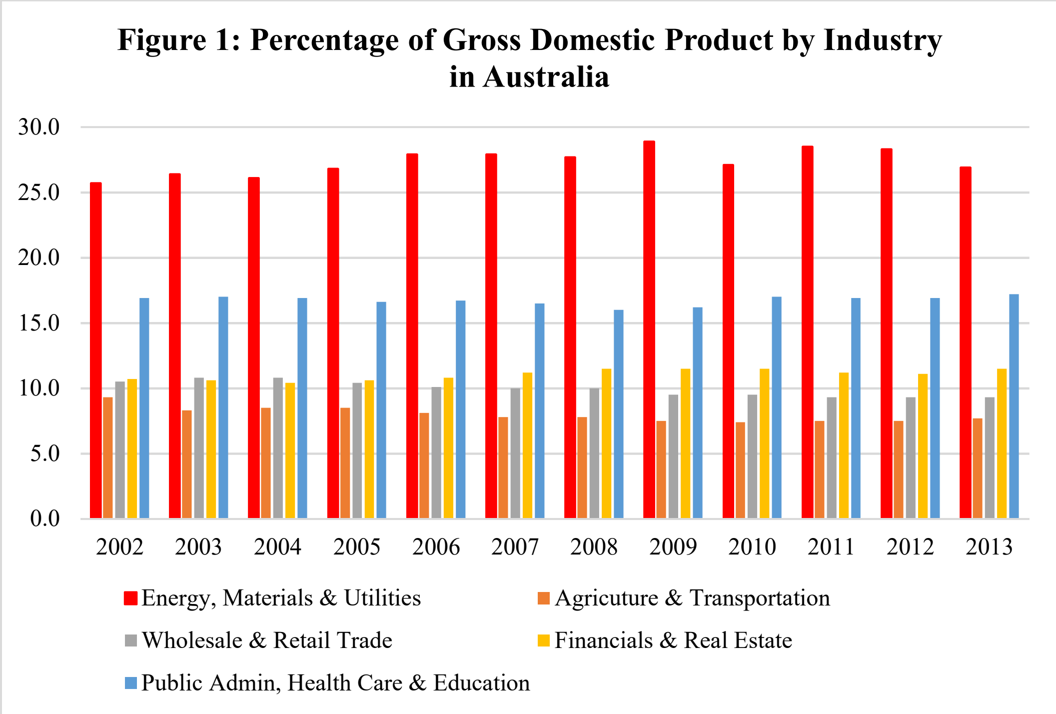
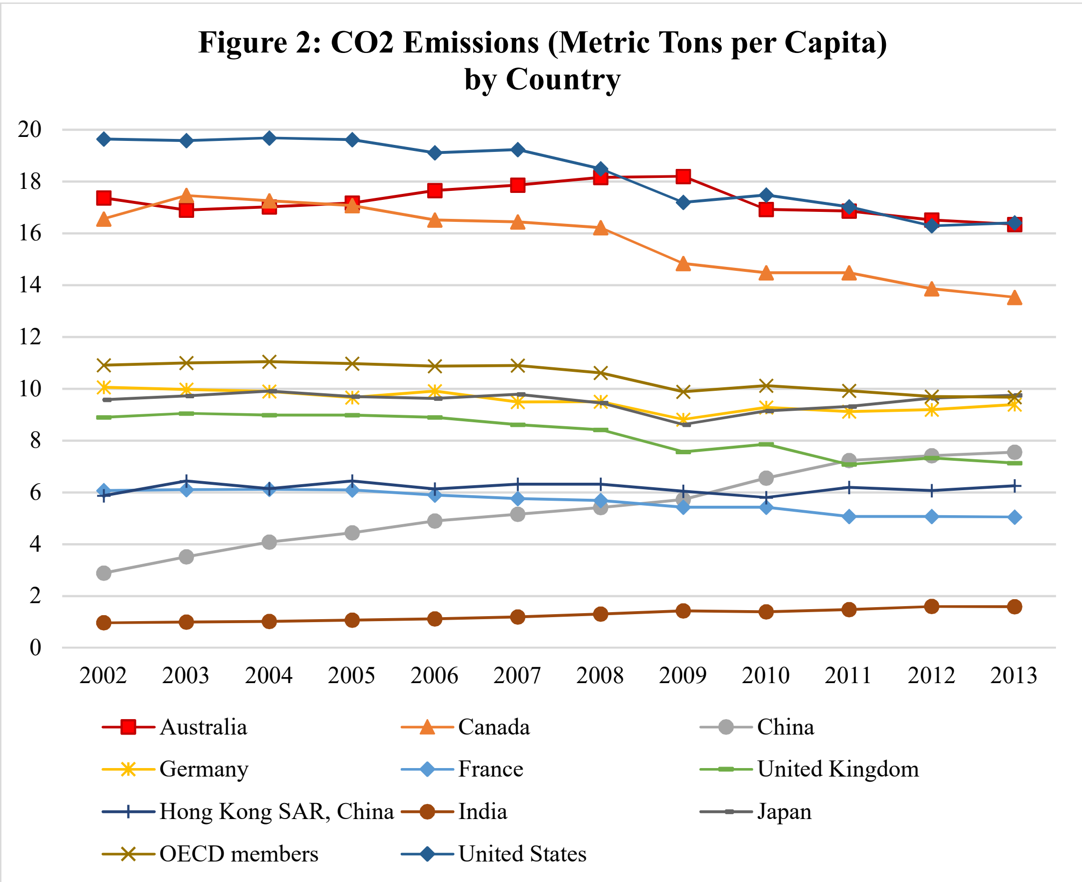


Source: Australia Bureau of Statistics category no. 5204.0, table 5



Source: World Bank development indicators

Table 1
Market Reaction to Australia's Ratification of Kyoto Protocol

This table displays cumulative abnormal stock returns by heavy and light emitters around the first day (day 0) when the news that Australia was going to officially ratify Kyoto Protocol was publicly released to the market (December 4, 2007). A firm's abnormal stock return is calculated as the difference between the actual return and the expected return using market model parameters estimated over the window (-260, -61) relative to the announcement date. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	N	CAR(-1,0)		CAR(-1,1)	
		Mean (%)	t-stat.	Mean (%)	t-stat.
Overall	1,404	-0.396	-2.80***	-0.360	-2.16**
Heavy Emitters	599	-0.668	-2.65***	-0.534	-1.79*
Light Emitters	805	-0.194	-1.20	-0.231	-1.22

Table 2
Summary Statistics

The sample consists of 15,484 firm-year observations over the period 2002- 2013. *TDebt* is total debts, *TLiability* is total liabilities, *STDebt* and *LTDebt* are short and long-term debts, respectively. *BA* and *MA* are book and market values of total assets, respectively. *Borrow* is net borrowing cash flow that equals the proceeds from net of repayments of borrowings. *NF* is net external financing cash flow that is the sum of net borrowings and issues using data from cash-flow statements. *EBIT* is earnings before interest and taxes. *PP&E* is net book value of property, plant and equipment. A detailed description of the variable construction is provided in Appendix A1. All continuous variables are winsorized at the 1st and 99th percentiles.

	N	Mean	25^{th} p.	Median	75^{th} p.	S.D.
TDebt/BA	15,484	0.165	0.000	0.042	0.240	0.308
TDebt/MA	15,484	0.116	0.000	0.025	0.181	0.168
TLiability/BA	15,484	0.403	0.099	0.311	0.537	0.542
TLiability/MA	15,484	0.276	0.055	0.200	0.433	0.257
STDebt/BA	15,484	0.067	0.000	0.003	0.054	0.177
STDebt/MA	15,484	0.047	0.000	0.002	0.040	0.103
LTDebt/BA	15,484	0.087	0.000	0.001	0.129	0.151
LTDebt/MA	15,484	0.068	0.000	0.001	0.091	0.123
Borrow/NF	13,585	0.408	0.000	0.151	1.000	0.756
BA (in mil. AUD)	15,484	654.932	8.007	27.930	146.205	2792.801
EBIT/BA	15,484	-0.245	-0.268	-0.046	0.081	0.770
PP&E/BA	15,484	0.189	0.015	0.078	0.313	0.228
MA/BA	15,484	2.279	0.930	1.383	2.363	3.211

Table 3
Univariate Analysis

This table presents mean, standard deviation values, and results of the *t*-tests of the difference in means between heavy emitters and light emitters in the pre- and post-Kyoto periods for the two main dependent variables (*TDebt/BA*, and *TDebt/MA*). The detailed description of the variable construction is provided in Appendix A1. *** denotes statistical significance at the 1% level (2-tailed t-tests).

	Heavy Emitter (HE)		Light Emitter (LE)		*t*-test (HE-LE)	
	Mean	S.D.	Mean	S.D.	Mean diff.	*t*-stat.
Panel A: *TDebt/BA*						
Pre-Kyoto	0.138	0.309	0.190	0.257	-0.051	-7.64***
Post-Kyoto	0.112	0.304	0.216	0.345	-0.105	-14.77***
Mean diff. (Post-Pre)	-0.027		0.027		-0.053	
t-stat.	-3.65***		3.96***			
Panel B: *TDebt/MA*						
Pre-Kyoto	0.085	0.153	0.137	0.165	-0.051	-13.39***
Post-Kyoto	0.075	0.151	0.160	0.183	-0.085	-23.30***
Mean Diff. (Post-Pre)	-0.010		0.024		-0.034	
t-stat.	-2.73***		6.22***			

Table 4
Carbon Risk and Firm Financial Leverage

This table reports the results of the OLS regressions of book and market leverages (*TDebt/BA* and *TDebt/MA*) on *Emitter*, *Post* dummies, and an interaction term *Emitter*Post*. All regressions control for size (*Log(BA)*), profitability (*EBIT/BA*), tangibility (*PP&E/BA*), and growth opportunities *(MA/BA*). Some regression models also control for year and either industry or firm fixed effects, but their estimates are suppressed for brevity. The *t*-statistics based on robust standard errors clustered by firms are provided in brackets. A detailed description of the variable construction is provided in Appendix A1. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	1	2	3	4	5	6	7	8
Dep =	*TDebt/BA*				*TDebt/MA*			
Emitter	-0.085***	-0.056***			-0.064***	-0.044***		
	[-9.21]	[-5.31]			[-12.04]	[-7.13]		
Post		0.031***				0.022***		
		[3.34]				[4.20]		
*Emitter*Post*		-0.054***	-0.057***	-0.045***		-0.037***	-0.037***	-0.042***
		[-4.14]	[-4.34]	[-2.85]		[-5.27]	[-5.21]	[-5.64]
Log(BA)	0.019***	0.019***	0.014***	-0.004	0.018***	0.018***	0.013***	0.018***
	[7.96]	[7.83]	[5.67]	[-0.64]	[11.02]	[10.90]	[8.54]	[6.73]
EBIT/BA	-0.081***	-0.082***	-0.080***	-0.073***	-0.024***	-0.024***	-0.021***	-0.017***
	[-8.18]	[-8.17]	[-7.99]	[-7.02]	[-8.39]	[-8.33]	[-7.79]	[-7.06]
PP&E/BA	0.271***	0.272***	0.254***	0.210***	0.166***	0.167***	0.142***	0.113***
	[11.68]	[11.62]	[10.28]	[6.36]	[12.37]	[12.37]	[11.26]	[8.23]
MA/BA	0.021***	0.021***	0.022***	0.022***	-0.005***	-0.005***	-0.004***	-0.002**
	[6.55]	[6.49]	[7.04]	[7.33]	[-5.70]	[-5.78]	[-4.64]	[-2.25]
Industry FE	No	No	Yes	No	No	No	Yes	No
Firm FE	No	No	No	Yes	No	No	No	Yes
Year FE	No	No	Yes	Yes	No	No	Yes	Yes
N	15,484	15,484	15,484	15,484	15,484	15,484	15,484	15,484
Adj. R^2	0.166	0.168	0.199	0.467	0.189	0.193	0.263	0.592

Table 5
Firm-based Definitions of Emitters: National Greenhouse and Energy Reporting Act 2007

This table reports the results on the impact of carbon risk on bank loan certification value using a PSM-matched sample. In the first stage, we estimate a probit model of Treated dummy on all firm characterisitcs used in the baseline models observed in year 2007. The Treated dummy takes a value of one for firms that are mandated to disclose their emissions by the NGER Act 2007 (emit more than thresholds set out in NGER Act on yearly basis), and zero otherwise. We then match each treated with one control firm on same GICS industry, nearest neighbor within 1% caliper and without replacement. Panel A presents the post-match diagnostic test results with t-tests of mean differences between treated and control firms. Panel B documents our re-estimation of DID model using the PSM-matched sample. The *t*-statistics based on robust standard errors are reported in square brackets. We report detailed definitions of all variables in Appendix A1. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Panel A: Post-match Diagnostic Test

	Treated N=27	Control N=27	Mean Diff.	t-stat.
Log(BA)	20.161	20.158	0.003	0.01
EBIT/BA	0.091	0.088	0.003	0.07
PP&E/BA	0.353	0.363	-0.010	-0.14
MA/BA	2.516	2.154	0.362	1.08

Panel B: DiD Regression Using PSM-matched Sample

	1	2	3	4	5	6	7	8
Dep =	*TDebt/BA*				*TDebt/MA*			
*Treated*Post*	-0.055**		-0.023		-0.056***		-0.046**	
	[-2.53]		[-0.75]		[-3.32]		[-2.41]	
*Treated*Before*$^{-1}$		-0.008		0.011		-0.006		-0.003
		[-0.22]		[0.28]		[-0.25]		[-0.14]
*Treated*Current*^{0}		0.022		0.047		0.005		0.006
		[0.46]		[1.05]		[0.22]		[0.22]
*Treated*After*$^{+1}$		-0.059		-0.020		-0.060		-0.053*
		[-1.20]		[-0.49]		[-1.65]		[-1.70]
*Treated*After*$^{2+}$		-0.054**		-0.009		-0.055***		-0.044*
		[-2.47]		[-0.22]		[-2.94]		[-1.80]
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	No	No	Yes	Yes	No	No
Firm FE	No	No	Yes	Yes	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

N	525	525	525	525	525	525	525	525
Adj. R^2	0.239	0.235	0.403	0.401	0.245	0.241	0.478	0.475

Table 6
Firm-based Definitions of Emitters: Reaction to KPR

This table reports the results on the impact of carbon risk on bank loan certification value using a PSM-matched sample. In the first stage, we estimate a probit model of Treated dummy on all firm characteristics used in the baseline models observed in year 2007. The Treated dummy takes a value of one for firms whose shareholders reacted negatively to the announcement of KPR in Australia, and zero otherwise. We then match each treated with one control firm on same GICS industry, nearest neighbor within 1% caliper and without replacement. Panel A presents the post-match diagnostic test results with t-tests of mean differences between treated and control firms. Panel B documents our re-estimation of DID model using the PSM-matched sample. The t-statistics based on robust standard errors are reported in square brackets. We report detailed definitions of all variables in Appendix A1. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Panel A: Post-match Diagnostic Test

	Treated N=305	Control N=305	Mean Diff.	t-stat.
Log(BA)	17.475	17.816	-0.340	-1.69
EBIT/BA	-0.147	-0.123	-0.024	-0.66
PP&E/BA	0.170	0.196	-0.026	-1.46
MA/BA	2.586	2.557	0.028	0.14

Panel B: DiD Regression Using PSM-matched Sample

	1	2	3	4	5	6	7	8
Dep =	*TDebt/BA*				*TDebt/MA*			
*Treated*Post*	-0.047***		-0.037***		-0.020***		-0.016***	
	[-4.05]		[-3.08]		[-3.49]		[-2.74]	
*Treated*Before*$^{-1}$		-0.012		-0.006		0.001		0.009
		[-0.64]		[-0.30]		[0.12]		[0.87]
*Treated*Current*^{0}		-0.031*		-0.026		-0.009		-0.003
		[-1.88]		[-1.44]		[-1.02]		[-0.30]
*Treated*After*$^{+1}$		-0.048**		-0.049**		-0.030**		-0.022**
		[-2.32]		[-2.49]		[-2.46]		[-2.10]
*Treated*After*$^{2+}$		-0.046***		-0.043***		-0.017***		-0.013*
		[-3.47]		[-2.71]		[-2.73]		[-1.75]
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	No	No	Yes	Yes	No	No
Firm FE	No	No	Yes	Yes	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	5,819	5,819	5,819	5,819	5,819	5,819	5,819	5,819

Adj. R^2	0.179	0.179	0.477	0.476	0.260	0.260	0.573	0.573

Table 7
Alternative measures of financial leverage

This table shows the regression results of seven alternative measures of financial leverage including *TLiability/BA*, *TLiability/MA*, *STDebt/BA*, *STDebt/MA*, *LTDebt/BA*, *LTDebt/MA*, and *Borrow/NF* on the interaction term *Emitter*Post*. All regressions control for size (*Log(BA)*), profitability (*EBIT/BA*), tangibility (*PP&E/BA*), and growth opportunities (*MA/BA*). The models control for industry and year fixed effects but their estimates are suppressed for brevity. The *t*-statistics based on robust standard errors clustered by firms are provided in brackets. A detailed description of the variable construction is provided in Appendix A1. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	1	2	3	4	5	6	7
Dep =	*TLiability/BA*	*TLiability/MA*	*STDebt/BA*	*STDebt/MA*	*LTDebt/BA*	*LTDebt/MA*	*Borrow/NF*
*Emitter*Post*	-0.113***	-0.078***	-0.021***	-0.013***	-0.025***	-0.013***	-0.103***
	[-5.30]	[-7.80]	[-3.05]	[-2.98]	[-4.06]	[-2.98]	[-3.89]
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	15,484	15,484	15,484	15,484	15,484	15,484	13,585
Adj. R^2	0.323	0.319	0.110	0.074	0.276	0.074	0.121

Table 8
The Role of Financial Constraints

This table reports the results of the regression of book leverage (*TDebt/BA*) on the interaction term *Emitter*Post*, for subsamples of firms sorted on the degree of financial constraints. A firm is defined to be financially constrained (FC) if its (i) size (*log(BA)*) is smaller than the sample median, (ii) dividends (*Div*) are omitted, or (iii) ratio of operating cash flows to assets (*OCF/BA*) is smaller than the sample median. The remaining firms are defined to be financially unconstrained (UC). All regressions control for size (*Log(BA)*), profitability (*EBIT/BA*), tangibility (*PP&E/BA*), and growth opportunities (*MA/BA*), and industry and year fixed effects, but their estimates are suppressed for brevity. The *t*-statistics based on robust standard errors clustered by firms are provided in brackets. A detailed description of the variable construction is provided in Appendix A1. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	1	2	3	4	5	6
Dep =	*TDebt/BA*					
FC criteria	Size		Dividend		Operating Cash-flow	
	FC (<Median)	UC (>Median)	FC (Zero)	UC (Postive)	FC (<Median)	UC (>Median)
*Emitter*Post*	-0.074***	-0.042***	-0.075***	-0.048***	-0.087***	-0.047***
	[-3.23]	[-3.49]	[-4.12]	[-3.00]	[-3.91]	[-3.77]
P-value (Chi-squared test)	0.08*		0.09*		0.04**	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	7,741	7,740	10,705	4,776	7,547	7,552
Adj. R^2	0.199	0.284	0.197	0.323	0.211	0.226

Table 9
Channel Analysis: Financial Distress Risk

The table reports the regression results of financial distress risk (Z-score and Log(RoaVol)), and book leverage (TDebt/BA) on the interaction term Emitter*Post. Firms with Z-score (RoaVol) below (above) 25th (75th) percentile value are assumed to be financially distressed (FD). Firms with Z-score (RoaVol) above (below) 75th (25th) percentile values are assumed to be financially undistressed (UD). All regressions control for size (Log(BA)), profitability (EBIT/BA), tangibility (PP&E/BA), and growth opportunities (MA/BA), and industry and year fixed effects, but their estimates are suppressed for brevity. The *t*-statistics based on robust standard errors clustered by firms are provided in brackets. A detailed description of the variable construction is provided in Appendix A1. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	1	2	3	4	5	6
Dep =	*Z-score*	*TDebt/BA*		*Log(RoaVol)*	*TDebt/BA*	
Sample	Full	FD (1st *Z-score*)	UD (4th *Z-score*)	Full	FD (4th *RoaVol*)	UD (1st *RoaVol*)
*Emitter*Post*	-0.098**	-0.110***	-0.042	0.156***	-0.131***	-0.028**
	[-2.23]	[-2.79]	[-1.35]	[3.05]	[-3.09]	[-2.13]
P-value (Chi-squared test)		0.08*			0.00***	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	15,484	3,866	3,867	15,484	3,869	3,871
Adj. R^2	0.898	0.225	0.139	0.484	0.229	0.414

Table 10
Carbon Risk and Bank Loans

This table reports results of the regressions of two characteristics of bank loans, including *Big4* and *New_Loan* over *Emitter*, *Post* dummies, and an interaction term *Emitter*Post*. *Big4* indicates whether a loan is granted by one of the Australia's four major banks; and *New_Loan* indicates whether a loan is granted for the first time to a particular borrower by a particular bank. All regressions control for size (*Log(BA)*), profitability (*EBIT/BA*), tangibility (*PP&E/BA*), and growth opportunities (*MA/BA*). Some regression models also control for year and either industry or firm fixed effects, but their estimates are suppressed for brevity. The *t*-statistics based on robust standard errors clustered by firms are provided in brackets. A detailed description of the variable construction is provided in Appendix A1. *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	1	2	3	4	5	6
Dep =		*Big4*			*New_Loan*	
Emitter	-0.377***	-0.211***		0.227***	0.073	
	[-8.27]	[-2.65]		[4.99]	[0.87]	
Post		0.051			-0.304***	
		[0.68]			[-3.97]	
*Emitter*Post*		-0.249***	-0.144*		0.185**	0.198**
		[-2.73]	[-1.69]		[1.97]	[2.20]
Log(BA)	0.051***	0.061***	0.059***	-0.017*	-0.009	-0.010
	[5.10]	[5.94]	[5.63]	[-1.72]	[-0.89]	[-0.92]
EBIT/BA	0.017	-0.006	-0.016	-0.117*	-0.137**	-0.150**
	[0.27]	[-0.09]	[-0.25]	[-1.75]	[-2.07]	[-2.07]
PP&E/BA	-0.121*	-0.110	-0.070	0.030	0.014	-0.018
	[-1.66]	[-1.52]	[-0.91]	[0.39]	[0.18]	[-0.22]
MA/BA	-0.016	-0.019	-0.006	0.033**	0.030*	0.036**
	[-1.04]	[-1.27]	[-0.41]	[2.09]	[1.90]	[2.18]
TDebt/BA	0.149	0.096	0.019	-0.232**	-0.256**	-0.383***
	[1.39]	[0.90]	[0.16]	[-2.27]	[-2.53]	[-3.21]
Industry FE	No	No	Yes	No	No	Yes
Year FE	No	No	Yes	No	No	Yes
N	493	493	488	589	589	584
Adj. R^2	0.268	0.287	0.309	0.115	0.142	0.142

Appendix A1
Definitions of Variables

This table provide detailed definitions and constructions of variables used in the article.

Variable	Definition
Panel A: Carbon risk variables	
Emitter	A dummy variable that indicates if a firm is classified into one the following nine GICS industries: (1) Oil, Gas & Consumable Fuels; (2) Electric Utilities; (3) Gas Utilities; (4) Independent Power Producers & Energy Traders; (5) Multi-Utilities; (6) Chemicals; (7) Construction Materials; (8) Metals & Mining; and (9) Paper & Forest Products
Post	A dummy variable that indicates the post-Kyoto period 2008-2013
Panel B: Scaling variables	
BA	Book value of total assets
MA	Market value of total assets that is equal BA - BE + ME, where BE and ME are book and market value of equity, respectively
NF	Net external financing cash-flows, that are equal Borrow + Issue, where Borrow and Issue are net proceeds from borrowing and securities issuing activities
Panel C: Leverage variables	
TDebt/BA	Ratio of total debts to book value of total assets
TDebt/MA	Ratio of total debts to market value of total assets
TLiability/BA	Ratio of total liabilities to book value of total assets
TLiability/MA	Ratio of total liabilities to market value of total assets
STDebt/BA	Ratio of short-term debts to book value of total assets
STDebt/MA	Ratio of short-term debts to market value of total assets
LTDebt/BA	Ratio of long-term debts to book value of total assets
LTDebt/MA	Ratio of long-term debts to market value of total assets
Borrow/NF	Ratio of net proceeds from borrowings to net external financing cash-flows
Panel D: Financial constraint variables	
Div	Dividend paying dummy that indicates if a firm-year pays cash dividend
OCF/BA	Ratio of operationg cash-flows to book value of total assets, where OCF is equal after-tax earnings + depreciations
Panel E: Financial distress variables	
Z-score	Modified Altman Z-score, that is equal 3.3*EBIT/BA + 1.0*Sales/BA + 1.4*Retained/BA + 1.2*WCap/BA, where EBIT is earnings before interest and taxes, Sales is total revenue, Retained is retained earnings, WCAP is working capital
RoaVol	Earnings volatility, that is equal standard deviation of annual Net Income/BA over 5-year rolling window. We require a minimum of 3 consecutive non-missing observations.
Panel F: Bank loan variables	
Big4	A dummy variable that indicates if a borrower is financed by one of four major banks in Australia, these being The Australia and New Zealand Banking Group Limited (ANZ), The Commonwealth Bank of Australia (CBA), The Westpac Banking Corporation (Westpac), The National Australia Bank (NAB)
New_Loan	A dummy variable that indicates if a borrower is granted a loan for the first time by a particular bank
Panel G: Firm control variables	
Log(BA)	Logarithm transformation of book value of total assets
EBIT/BA	Ratio of earnings before interest and taxes to book value of total assets

PP&E/BA	Ratio of net property, plant and equipment to book value of total assets
MA/BA	Ratio of market to book values of total assets

Appendix A2
Leverage Regressions - Exclude Financial Firms

This table reports the results of the OLS regressions of book and market leverages (*TDebt/BA* and *TDebt/MA*) on *Emitter*, *Post* dummies, and an interaction term *Emitter*Post*, where all financial firms are excluded. All regressions control for size (*Log(BA)*), profitability (*EBIT/BA*), tangibility (*PP&E/BA*), and growth opportunities (*MA/BA*). Some regression models also control for year and either industry or firm fixed effects, but their estimates are suppressed for brevity. The *t*-statistics based on robust standard errors clustered by firms are provided in brackets. A detailed description of the variable construction is provided in Appendix A1. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	1	2	3	4	5	6
Dep =		*TDebt/BA*			*TDebt/MA*	
Emitter	-0.055***			-0.044***		
	[-5.17]			[-7.01]		
Post	0.030***			0.023***		
	[3.20]			[4.17]		
*Emitter*Post*	-0.053***	-0.056***	-0.042***	-0.037***	-0.037***	-0.040***
	[-4.02]	[-4.26]	[-2.62]	[-5.17]	[-5.19]	[-5.49]
Log(BA)	0.018***	0.013***	-0.005	0.017***	0.012***	0.016***
	[7.55]	[5.36]	[-0.82]	[10.91]	[8.56]	[6.39]
EBIT/BA	-0.079***	-0.078***	-0.074***	-0.021***	-0.019***	-0.017***
	[-7.71]	[-7.58]	[-6.87]	[-7.79]	[-7.32]	[-7.14]
PP&E/BA	0.276***	0.257***	0.210***	0.171***	0.146***	0.114***
	[11.69]	[10.28]	[6.31]	[13.04]	[11.68]	[8.31]
MA/BA	0.021***	0.023***	0.022***	-0.005***	-0.004***	-0.002**
	[6.27]	[6.88]	[7.09]	[-5.48]	[-4.29]	[-2.25]
Industry FE	No	Yes	No	No	Yes	No
Firm FE	No	No	Yes	No	No	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
N	14,897	14,897	14,897	14,897	14,897	14,897
Adj. R^2	0.168	0.198	0.468	0.197	0.268	0.596

Appendix A3
Control for the Global Financial Crisis

This table reports the results of the OLS regressions of book and market leverages (*TDebt/BA* and *TDebt/MA*) on *Emitter*, *Post* dummies, and an interaction term *Emitter*Post*, controlling for the Global Financial Crisis (period 2008-2009). All regressions control for size (*Log(BA)*), profitability (*EBIT/BA*), tangibility (*PP&E/BA*), and growth opportunities (*MA/BA*). Some regression models also control for year and either industry or firm fixed effects, but their estimates are suppressed for brevity. The *t*-statistics based on robust standard errors clustered by firms are provided in brackets. A detailed description of the variable construction is provided in Appendix A1. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	1	2	3	4	5	6
Dep =		*TDebt/BA*			*TDebt/MA*	
Emitter	-0.056***			-0.044***		
	[-5.31]			[-7.13]		
Post	0.027**			0.016***		
	[2.48]			[2.73]		
*Emitter*Post*	-0.050***	-0.052***	-0.040**	-0.033***	-0.033***	-0.038***
	[-3.39]	[-3.60]	[-2.29]	[-4.23]	[-4.21]	[-4.61]
GFC	0.011			0.017***		
	[1.15]			[3.51]		
*Emitter*GFC*	-0.013	-0.013	-0.013	-0.011*	-0.012*	-0.009
	[-1.00]	[-1.03]	[-1.07]	[-1.65]	[-1.90]	[-1.52]
Log(BA)	0.019***	0.014***	-0.004	0.018***	0.013***	0.018***
	[7.84]	[5.67]	[-0.65]	[10.92]	[8.54]	[6.69]
EBIT/BA	-0.081***	-0.080***	-0.073***	-0.024***	-0.021***	-0.017***
	[-8.16]	[-7.99]	[-7.02]	[-8.26]	[-7.78]	[-7.05]
PP&E/BA	0.272***	0.254***	0.210***	0.166***	0.142***	0.112***
	[11.61]	[10.28]	[6.34]	[12.36]	[11.26]	[8.21]
MA/BA	0.021***	0.022***	0.022***	-0.005***	-0.004***	-0.002**
	[6.49]	[7.05]	[7.34]	[-5.74]	[-4.61]	[-2.23]
Industry FE	No	Yes	No	No	Yes	No
Firm FE	No	No	Yes	No	No	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
N	15,484	15,484	15,484	15,484	15,484	15,484
Adj. R^2	0.168	0.199	0.467	0.193	0.263	0.592

Appendix A4
Carbon Risk and Firms' Capital Investment

This table reports the results of the OLS regressions of investment (*Capex/LagBA*) on an interaction term Emitter*Post. All regressions control for growth opportunities (*LagMA/LagBA*), and cash flow (*CF/LagBA*). Regression models also control for year and either industry or firm fixed effects, but their estimates are suppressed for brevity. The *t*-statistics based on robust standard errors clustered by firms are provided in brackets. A detailed description of the variable construction is provided in Appendix A1. The *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	1	2
Dep =	*Capex/LagBA*	
*Emitter*Post*	-0.003	0.011
	[-0.31]	[1.13]
LagMA/LagBA	0.004***	0.009***
	[3.26]	[5.33]
CF/LagBA	0.080***	0.067***
	[9.34]	[7.87]
Industry FE	Yes	No
Firm FE	No	Yes
Year FE	Yes	Yes
N	14,641	14,606
Adj. R^2	0.052	0.116