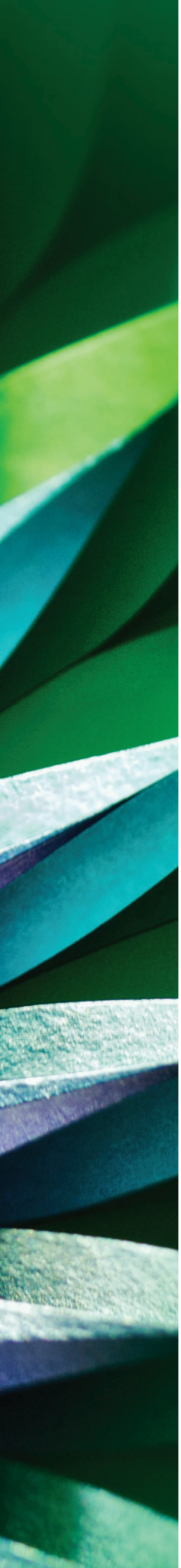


BACKGROUND PAPER

The Price of Carbon Risk: Evidence from the Kyoto Protocol Ratification

Bohui Zhang

THE PRICE OF CARBON RISK: EVIDENCE FROM THE KYOTO PROTOCOL RATIFICATION

Bohui Zhang
The Chinese University of Hong Kong, Shenzhen

Abstract

This paper examines the impact of carbon risk on financing costs of firms. We exploit the Kyoto Protocol ratification (KPR) committed by the Government of Australia in December 2007 as an exogenous increase in carbon risk. In the post-KPR period, we find that firms with high carbon emissions (carbon emitters) experience a substantial increase in the costs of debt and equity relative to those firms with a lower carbon footprint. We further identify higher cash flow risk and lower investor recognition as the two channels through which carbon risk affects the financing costs. Moreover, after the KPR, carbon emitters are less likely to be financed by major banks and more likely to borrow from new lenders. When conducting seasoned equity offerings, carbon emitters are more willing to use underwriting services rather than rights offerings. Our findings suggest that capital providers incorporate exposure of firms to carbon risk into their decisions and charge them a corresponding risk premium.

Keywords

carbon risk, cost of debt, cost of equity, cash flow risk, investor recognition

JEL Classification

G32, Q51, Q58

Our customers mining for coal, oil and gas, as well as those in coal-fired electricity generation, and related industries, are increasingly exposed and may experience transition risk as a result of decreasing demand for fossil fuels and increasing demand for clean energy. We encourage customers in these sectors to plan for, and start making the necessary changes for climate adaptation.

– The Australia and New Zealand Banking Group Limited
Corporate Sustainability Review, 2016.

I. INTRODUCTION

In the recent 2019–2020 Australian bushfires, 18.6 million hectares were burned, 5,900 buildings were destroyed, and an estimated one billion animals were killed. A consequence of this bushfire crisis is that public anger has intensified over the Government of Australia's inaction toward climate change.[1] As the world's largest exporter of coal, the Government of Australia is under pressure to rectify its past pro-coal policies by curbing the coal industry and reducing carbon emissions. Consequently, firms in carbon-intensive industries would be influenced by any new carbon-related policy that is introduced. The uncertainty associated with carbon-related policies that these firms face is called carbon risk.[2] Given that the cost of capital is central to corporate decisions, this paper investigates the effect of carbon risk on a firm's cost of capital. It is anticipated that such an investigation will deepen our understanding of the pricing implications of environmental risk.

We expect a positive relationship between carbon risk and the cost of capital for two reasons. First, concerns about global warming prompt regulators around the world to implement new carbon

[1] For the damage caused by the 2019–2020 Australian bushfires, refer to https://en.wikipedia.org/wiki/2019%E2%80%9320_Australian_bushfire_season; and https://www.abc.net.au/news/2020-02-02/battle-against-bushfires-war-against-climate-inaction/11909806.

[2] Carbon risk, a main subset of environmental risk, represents a firm's financial vulnerability to the transition away from a fossil fuel-based economy to a lower-carbon economy. That transition is in response to the global call for a reduction of carbon dioxide, a main component of greenhouse gas emissions that cause climate change (i.e., global warming) (Stern 2008 and IPCC 2014). Despite being important to firms' managers and shareholders as well as policy makers, the question of how carbon risk may affect firm value remains relatively under-researched up to this point (Diaz-Rainey, Robertson, and Wilson 2017).

control policies with the aim of reducing carbon emissions. To cope with the change towards more stringent carbon-related regulations and policies, firms need to internalize the various costs of carbon emissions such as disclosure cost, compliance and management costs, and extra capital expenditures for the shift to low carbon technologies (e.g., Barth and McNichols 1994; Clarkson, Li, and Richardson 2004; Acemoglu et al. 2012; Matsumura, Prakash, and Vera-Muñoz 2014; Acemoglu et al. 2016; and Aghion et al. 2016).[3] By holding firms' revenues unchanged, these changes caused by carbon risk would increase firms' operating leverage, which further translates into a higher uncertainty about firms' future cash flows.

Moreover, because of heightened public pressure on environmental sustainability and performance (Thompson 1998, Labatt and White 2007, and Subramaniam et al. 2015), carbon risk exposure increases firms' vulnerability to potential legal penalties and reputation losses, which hurts firm performance. For example, carbon-intensive firms are more likely to violate environmental regulations because of their underinvestment in pollutant abatement, thereby risking customer boycotts and lawsuits (Delmas and Toffel 2004, Habib and Bhuiyan 2017, and Brekke and Pekovic 2018). In addition, under tightened carbon-related policies, firms may be forced to forgo high carbon-emitting but profitable projects. Taken together, carbon risk can erode firms' future revenues and increase firms' operating leverage. Both possibilities result in higher cash flow risk, and thus lead to a higher cost of capital. We refer to this mechanism as *the cash flow risk channel*.

Second, carbon risk may correlate with the cost of capital through its negative effect on investor recognition. Over the past decade, socially responsible investments have become an important investment vehicle around the world. For example, according to the US SIF Foundation's 2018 report, US$11.6 trillion of all professionally managed assets is under environmental, social, and governance (ESG) investment strategies, which accounts for 25% of funds invested in the United States (US). Given that the level of carbon emissions is an important criterion for firms' ESG

---

[3] For example, the theoretical model in Acemoglu et al. (2012) suggests that policy interventions can effectively redirect innovation from dirty technologies to clean ones, especially when the two types of technologies are highly substitutable. Consistent with Acemoglu et al.'s (2012) theoretical predictions, Aghion et al. (2016) show that, when firms in the automobile industry face higher tax-inclusive fuel prices (a proxy for carbon taxes), they innovate more in clean and less in dirty technologies.

ratings, socially responsible investors may abstain from investing in carbon-intensive firms.[4] This means that firms with high carbon emissions would have a smaller investor base, and hence a lower level of investor recognition. As denoted in Merton's (1987) investor recognition theory, firms that are less recognized by investors would incur a larger cost of capital. We view this mechanism as *the investor recognition channel*.

To the extent that higher carbon risk leads to either higher cash flow risk or lower investor recognition, we expect firms in the transition away from a fossil fuel-based economy to incur a higher cost of capital. We also acknowledge that the predicted positive link between carbon risk and the cost of capital is not without tension. First, the impact of carbon risk on firms' future cash flows might be idiosyncratic in nature. Investors who hold a diversified portfolio may not require compensation for such a diversifiable risk. Second, firms in carbon-intensive industries may be able to switch to carbon-efficient technologies at a low cost. In such cases, carbon risk can be hedged internally by exercising firms' real options. Third, socially responsible investors that prefer firms with a low carbon footprint may not be the marginal investors who determine equity and bond prices in equilibrium. If these conjectures are plausible, we expect no relation between carbon risk and the cost of capital.

The hypothesized effects of carbon risk on the cost of capital should be tested empirically. However, there are several challenges to the empirical analysis. First, corporate decisions on the level of exposure to carbon risk and financing costs may be jointly determined by or correlated with unobservable firm characteristics (Roberts and Whited 2013). Second, because of the sparse data on firm-level carbon-related activities such as greenhouse gas (GHG) emissions or energy consumption (Konar and Cohen 2001), it is difficult to know the exact amount of carbon emissions to draw a valid inference on the relation between carbon risk and the cost of capital. Third, carbon risk tends to be forward-looking in nature. Thus, it is inaccurate to measure a firm's carbon risk simply based on its past or current carbon activities.

---

[4] A more general observation is that investors avoid stocks with poor ESG performance. For details: Hong and Kacperczyk (2009); Chava (2014); Riedl and Smeets (2017); Gibson and Krueger (2018); Ramelli, Ossola, and Rancan (2020); Hsu, Li, and Tsou (2020); and Seltzer, Starks, and Zhu (2020).

To tackle these empirical concerns, we focus on a quasi-experiment from the Australian setting. Specially, we exploit the Government of Australia's commitment to the Kyoto Protocol ratification (KPR) in December 2007 as a shock that heightens Australian firms' carbon risk, and then examine the KPR impact on these firms' cost of capital. The Kyoto Protocol is an international agreement whereby participating countries commit to reducing carbon emissions to satisfy national reduction targets (UNEP 2006). The Kyoto Protocol was adopted in Kyoto, Japan in December 1997 and entered into force in February 2005. At the beginning, Australia did not ratify the Kyoto treaty. However, on 3 December 2007, the then-Prime Minister Kevin Rudd signed the instrument of ratification of the Kyoto Protocol, his first act after being sworn into office. This event marks the starting point of an era of stricter environmental regulations for Australian businesses (Ramiah, Martin, and Moosa 2013; Balachandran and Nguyen 2018; Nguyen 2018; and Nguyen and Phan 2020).

According to the KPR, Australia is required to restrict its average annual GHG emissions over the 2008–2012 commitment period to 8% above its 1990 level.[5] Therefore, the KPR serves as an exogenous shock that significantly raises carbon risk faced by high carbon emitters (hereafter emitters) as opposed to low carbon emitters (hereafter non-emitters). This empirical design would allow us to investigate the difference in the cost of capital between emitters and non-emitters both before and after the KPR. To classify firms into emitters and non-emitters, we use the information provided by the Carbon Disclosure Project (CDP) and consider the carbon emission nature of a firm's industry; that is, the relative industry-based level of carbon emissions and energy consumption. For example, the energy sector is considered the most dominant source of Australia's GHG emissions, reflecting the nation's heavy reliance on fossil fuels, coal in particular, as a primary energy source. We then sort firms into either emitter or non-emitter subgroups based on their industry classifications.[6]

[5] https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook45p/InternationalApproach.

[6] Because a firm's industry classification does not change with the time-series variation in its firm characteristics, this helps alleviate the concern that the firm may make a decision on the level of carbon risk exposure conditional on its cost of capital. Further, to address the possibility that industry classifications may pick up the effects of industry characteristics such as business risk, other than carbon risk, we control for industry fixed effects and other time-varying determinants of the cost of capital in our empirical analysis.

Our sample includes firms listed on the Australian Stock Exchange over the 2002–2013 period. First, to validate the notion that the KPR heightens carbon risk for Australian firms, we examine the stock market response to the announcement of the KPR using various windows of cumulative abnormal returns around the announcement date. We document an overall significant negative stock return response, suggesting that the market perceives the announcement of the KPR as negative news (i.e., an increase in carbon risk). Further, our subsample analysis indicates that the negative market reaction is more pronounced for the subgroup of emitters than the subgroup of non-emitters. This evidence suggests that the KPR by Australia has a more significant impact on emitters' stock prices than those of non-emitters.

Next, we employ the difference-in-differences (DiD) analysis to study the change in emitters' cost of capital relative to that of non-emitters in the periods before and after the KPR. To gauge a firm's cost of capital, we measure the cost of debt by using the interest rate spread and estimate the implied cost of equity capital that equates the current stock price with discounted values of future earnings. Consistent with an increase in carbon risk for emitters following the KPR, we document that emitters exhibit a significant increase in the costs of both debt and equity after such a policy change. In terms of economic significance, relative to non-emitters, emitters experience an increase in the interest rate spread of 5.4% in the post-KPR period. At the same time, emitters show an increase in the implied cost of equity of 2.5% after the KPR. Our dynamic DiD test further indicates that the effect on the cost of capital prevails only after 2007 when the KPR was committed while being insignificant before the KPR, which validates the parallel trends assumption underlying our DiD analysis.

We conduct additional tests and demonstrate that our findings hold using two alternative *firm-level* proxies for carbon risk. First, we employ the National Greenhouse and Energy Reporting Act 2007 (NGER Act) to redefine emitters. This particular act mandates that firms with carbon emission levels above a certain threshold report their carbon emissions and energy consumption to the government in order to inform the KPR implementation as well as other environmental policies. Accordingly, these mandated firms are the largest emitters, and, hence, are most likely to be affected by the KPR. We revisit our main DiD analysis by designating these firms as treated ones, while using the non-mandated peers as control firms. Second, we rely on the stock market reaction

to the KPR announcement to identify treated and control firms. This classification is based on the assumption that a firm's value-relevance to the KPR may correlate with the firm's carbon risk. Specifically, treated (control) firms are defined as those whose stock prices react negatively (non-negatively) to the KPR announcement. In both tests, we also use the propensity score matching (PSM) procedure to better select control firms to ensure that treated and control firms come from the same industry and are similar along several observable dimensions immediately before entering the KPR shock. We obtain consistent evidence that carbon risk drives the cost of capital upwardly after the KPR.

Next, we study two plausible economic channels through which carbon risk increases the cost of capital; namely, the cash flow risk channel and the investor recognition channel. We perform the two sets of tests, including the level analysis where we examine the impacts of carbon risk on the proxies for cash flow risk and investor recognition, and also the sensitivity analysis to understand how firms with a higher ex-ante sensitivity to either cash flow risk or investor recognition experience the change in the cost of capital after the KPR. First, we construct several proxies for cash flow risk, such as financial distress risk measured by the probability of default and cash flow volatility, systematic risk measured by the market beta, and firm-specific risk measured by idiosyncratic volatility. We find that these cash flow risk proxies increase significantly more for emitters after the KPR. In the further sensitivity analysis, we use the average operating leverage before the KPR as a measure of firms' ex-ante sensitivity to cash flow risk, and find that emitters with greater pre-KPR operating leverage suffer a higher cost of capital in the post-KPR period.

Second, to capture investor recognition, we focus on institutional ownership and show that the level of institutional ownership significantly declines for emitters after the KPR. Moreover, we document that those emitters with a greater level of pre-KPR institutional ownership experience a stronger surge in the cost of capital in the post-KPR period. These results are consistent with the notion that institutional investors are able to perceive the threats of ESG issues to their portfolio values relatively well, and, hence, incorporate the changes in these risks, especially the emerging environmental regulatory risks, into their investment decisions (Chava 2014; Riedl and Smeets 2017; Dyck et al. 2019; and Krueger, Sautner, and Starks 2020). Institutional investors with greater holdings of emitter stocks before the KPR suffer more severe losses, which trigger their avoidance

from such environmentally risky investments after the KPR. Consequently, the reduction in investor recognition leads to an increase in the cost of capital for emitters.

In our final avenue of inquiry, we investigate the effect of carbon risk on the non-price aspects of debt and equity financing. Specifically, we hand-collect bank loan information for each firm from each loan provider. In the post-KPR period, we find that emitters are less likely to be financed by major banks. Also, emitters are more likely to seek debt financing from new lenders instead of existing lenders. Following the KPR, when conducting seasoned equity offerings in need of capital, emitters are more likely to rely on underwriting services instead of rights offerings. These findings suggest that access to capital is generally more difficult for emitters in the post-KPR period. We also examine the impact of carbon risk on corporate policies and find that emitters—especially financially constrained firms—increase their cash holdings and reduce dividend payouts significantly after the KPR.

This paper contributes to the literature in three important ways. Our first contribution lies in the identification of the effect of carbon risk on the cost of capital. Previous studies have shown that carbon risk is related to firm value and performance (Matsumura, Prakash, and Vera-Muñoz 2014; and Nguyen, 2018), productivity (Garvey, Iyer, and Nash 2018), financial and investment policies (Balachandran and Nguyen 2018; Bartram, Hou, and Kim 2019; and Nguyen and Phan 2020), tail risk (Ilhan, Sautner, and Vilkov 2020), systematic risk (Monasterolo and De Angelis 2020), and stock returns (Bolton and Kacperczyk 2020; and Choi, Gao, and Jiang 2020). Cross-sectional correlations between carbon risk and stock characteristics are subject to the possibility that the extent of carbon exposure and corporate risk-taking policies are determined jointly. Our KPR setting offers an exogenous shock in carbon risk to identify its impact on firms' costs of debt and equity.

Second, we add to an emerging literature that examines the pricing implications of environmental risks in capital markets. Seltzer, Starks, and Zhu (2020) document that bond credit ratings and yield spreads can be influenced by a firm's environmental performance and regulatory conditions, and Painter (2020) shows that municipal bond yields incorporate local climate risk. Studies by Hsu, Li, and Tsou (2020) and Görgen et al. (2019) report a pollution premium in the stock market

as polluting firms are exposed to policy regime shift risks, and, therefore, are expected to exhibit higher average returns.[7] Recent survey results in Krueger, Sautner, and Starks (2020) indicate that institutional investors believe environmental risks have financial implications for their portfolio firms, particularly regulatory risks. Our study shows that carbon risk, a main subset of environmental risk, is especially important for the cost of capital when a new regulation heightens the market's perception of this risk.

Third, our research provides a timely contribution to the policy debate on the necessity of carbon control measures.[8] If carbon emissions account for a large proportion of overall economic activities, it follows that the control on carbon-related activities should also place significant impacts on the cross-section of individual firms. Therefore, the more controversial issue for participants in the financial markets now is what exactly these costs are, how to measure them, and how to address them. We demonstrate that the more stringent carbon control measures matter to both the providers and users of capital.

The remainder of the paper is organized as follows. Section II describes institutional background, data, and methodology. Section III discusses main empirical results. Section IV presents additional tests. Section V concludes the paper.

II. INSTITUTIONAL BACKGROUND, DATA, AND VARIABLE CONSTRUCTION

A. Institutional Background

The Kyoto Protocol, named after the Japanese city of Kyoto in which it was first adopted in December 1997, is an international treaty that extends the 1992 United Nations Framework

---

[7] Sharfman and Fernando (2008) report that, when firms demonstrate improved environmental risk management, there is a lower cost of capital. This is because that environmental risk management improves on the market's risk perception of the firm. Studies such as Amiraslani et al. (2017); Jiraporn et al. (2014); and Ramelli, Ossola, and Rancan (2020) show that firms' management of environmental risk is value-adding, while other studies (Bansal and Ochoa 2011; Bansal, Kiku, and Ochoa 2016; Hong, Li, and Xu 2019; Chen, Kumar, and Zhang 2020; and Krueger, Sautner, and Starks 2020) document the pricing of environmental risk in the cross-section of stock returns. Ginglinger and Moreau (2019) shows that climate risk determines the level of firms' leverage.

[8] The debate has recently been fiercely ignited by US President Donald Trump's decision to withdraw from the Paris Climate Accord. This sole withdrawal has aggravated the leadership shortage in combating global climate issues and created a bad precedent for international climate cooperation (Zhang et al. 2017).

Convention on Climate Change (UNFCCC) in reducing the emission of gases that contribute to global warming. The Kyoto Protocol commits most of the countries of the UNFCCC to the mandatory targets of emission reduction, while the specific target depends on the unique situation of each country. The base year for setting targets, in most cases, is 1990. Collectively, the group of committed countries, which account for at least 55% of global carbon dioxide emissions in 1990, aim to reduce their emissions by 5.2% on average for the 2008–2012 period relative to the base year (Grubb and Depledge 2001). The Kyoto Protocol entered into force in February 2005, and is often considered the most significant international environmental treaty ever negotiated.[9]

Australia's ratification of the Kyoto Protocol came in December 2007, and this was a radical act of the Government of Australia. Specifically, Australia agreed to a target of limiting itself to less than 8% increase in GHG emissions over the 2008–2012 period relative to its 1990 baseline. While Australia was allowed an increase of emission levels on its 1990 level, this target still equates to a 30% reduction from "business as usual" projections. The Government of Australia acknowledged that Australia's Kyoto Protocol target would be a significant challenge, requiring the full implementation of existing and innovative emission mitigation measures. Therefore, the KPR in Australia marks 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.

The KPR came as a surprise in Australia partially because of a swift change in the political landscape of the country with the policy adoption being conditional on the outcome of the federal election in November 2007. While the Australian Labor Party candidate Kevin Rudd expressed a pro-climate spirit in his election campaign, this policy was not really welcomed by large businesses at the time because the KPR would lead to a strong restriction on carbon-intensive activities for those mining/energy companies.

During the four consecutive terms from 11 March 1996 to 3 December 2007 of former Prime Minister John Howard (leader of the Liberal Party of Australia), Australia's position was that the

---

[9] Also, the treaty has been subject to much scepticism and critique. Notably, the US signed the Kyoto Protocol in November 1998 but did not submit it to the US Senate for ratification. The Government of Canada also withdrew from the Kyoto Protocol in December 2011 after having ratified it in 2002. While Canada was originally committed to cutting emissions to 6% below its 1990 level, the country was not able to meet this target as emissions in 2009 alone were 17% higher than in 1990.

country intended to meet the Kyoto Protocol target but did not intend to ratify the treaty.[10] Had the Liberal Party of Australia of the then-Prime Minister John Howard won the election, the Kyoto Protocol might not have been ratified and the Emission Trading Scheme, which does not commit Australia to emission reduction, would have been adopted instead.[11] On the change of government following the victory of the Australian Labor Party, Prime Minister Kevin Rudd signed the ratification of the Kyoto Protocol immediately after taking office on 3 December 2007. The ratification took effect in March 2008. The new government, in contrast to the former one, announced it would meet its Kyoto Protocol target.

The KPR by Australia, together with a clear lack of anticipation of this act, offers a strong quasi-experiment to study its effects on the corporate cost of capital. First, the overall Australian economy and firms are heavily exposed to carbon emissions for business operations. Based on GHG emissions per capita, Australia is the most polluting nation in the Organisation for Economic Co-operation and Development (OECD) group (Garnaut 2011). Second, the KPR by Australia was followed by several new and stringent carbon regulations with which firms need to strictly comply (Ramiah, Martin, and Moosa 2013). Correspondingly, emitters may have to change business operations for regulatory compliance in the post-KPR period. Third, Australia is among the countries with the highest awareness of carbon responsibilities by all types of market participants, such as banks, firm management, and investors (Balachandran and Nguyen 2018; and Nguyen and Phan 2020).[12] If carbon risk truly represents an important element of business risk, the Australian capital market would effectively incorporate such risk into asset valuations.

Panel A of Figure 1 plots the percentage of annual contribution to the gross domestic product (GDP) by industry in Australia over the sample period. Industries such as energy, materials, and

---

[10] Justifications for this stance by Howard's government include: (i) the treaty did not cover 70% of global emissions, (ii) developing countries are exempted from emission limits, and (iii) the US, the largest emitter, also refused to ratify the Kyoto Protocol.

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

[12] One noticeable piece of anecdotal evidence is the rejection by Australia's Big Four banks (Commonwealth Bank of Australia [CBA] and National Australia Bank [NAB] in 2015, Australia and New Zealand Banking Group [ANZ] in 2016, and Westpac in 2017) of the $12.8 billion loan application for the development of the Carmichael coal mine by the Indian conglomerate Adani. If developed, the coal mine would be one of the world's largest coal mines, producing a climate-destroying 60 million tons of coal annually, mostly for export to India (Banktrack 2018). The Big Four banks arrived at this uneasy decision after experiencing intense pressure from the Government of Australia, environmental activists, scholars, media, and other banks' important stakeholders such as depositors. This action also reveals the Big Four banks' determination in tightening credit for fossil fuels such as coal-fired power projects, which have long been their favourite customers.

utilities together account for the largest proportion of the GDP, ranging from 25.7% to 28.9% per year. Other key contributors to the GDP include industries such as public administration and safety, education and training, and health care and social assistance, which collectively contribute 16.7%. Contributions to the GDP are 11.1% for financial and real estate industries, 10.0% for wholesale and retail trade industries, and 8.0% for agriculture and transport industries.

Panel A of Figure 2 compares the time-series variation in carbon emissions (as measured by carbon dioxide (CO_2) emissions in metric tons per capita) between Australia and the world on average. The graph plots the percentage change in carbon emissions for each year over the sample period 2002–2013 relative to the beginning year 2002.[13] There is a noticeable trend. While the increase in carbon emissions in Australia starts to slow down in 2009 before officially entering a downtrend afterwards, the world on average witnesses an uptrend on carbon intensity throughout the whole sample period.

Figure 3 compares the stringency of environmental regulation between Australia and other energy-intensive and developed countries such as Canada, the US, or the OECD in general. For this purpose, we use the famous Environmental Policy Stringency (EPS) Index as constructed by the OECD statistics, with higher values indicating more stringent environmental policies.[14] We plot the data for the two critical points in our sample period, at the end of the pre-KPR period (2007) and the end of the post-KPR period (2013). It is clear that the environmental regulation in Australia almost doubles in the level of environmental police stringency (the EPS index increasing from 2.01 to 4.07), lifting this country from the lowest position in 2007 to the highest one in 2013.

---

[13] Data on carbon emissions per capita for both Australia and the world is sourced from the World Bank at https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?end=2013&locations=AU-1W&start=2002. Data on carbon emissions by the economic sector is published by the Department of Industry, Science, Energy and Resources of Australia at https://publications.industry.gov.au/publications/climate-change/climate-change/climate-science-data/greenhouse-gas-measurement/publications.html#economic. We aggregate direct emissions of the following sectors to derive emissions information for emitters: (1) coal mining; (2) oil and gas extraction; (3) metal ore and nonmetallic mineral mining and quarrying; (4) wood, pulp, paper, and printing; (5) petroleum and coal product manufacturing; (6) basic chemical, polymer, and rubber product manufacturing; (7) primary metal and metal product manufacturing; (8) fabricated metal product manufacturing; (9) electricity supply; (10) gas supply; (11) building construction; (12) heavy and civil engineering construction; and (13) construction services. We then subtract the emitters' emissions from the national total emissions to compute non-emitters' emissions. Finally, we divide the emissions amounts by the number of Australia's population each year, which is also sourced from the World Bank, to arrive at the carbon emissions per capita separately for emitters and non-emitters.

[14] Data on Environmental Policy Stringency Index as designed by the OECD can be found at: https://stats.oecd.org/Index.aspx?DataSetCode=EPS.

B. Sample Selection

We include in our sample firms that are publicly listed on the Australian Stock Exchange. We obtain the financial data and Global Industry Classification Standard (GICS) industry classifications for Australian public firms from Morningstar DatAnalysis, and stock return data from Datastream. The sample period of 2002–2013 is made up of the 6-year period of 2002–2007 before the KPR and the 6-year period of 2008–2013 after the KPR. The post-KPR period is selected to correspond to the official KPR commitment period.[15] To minimize the impacts of outliers, we winsorize all continuous variables at the top and bottom 1%. Our full sample includes 15,518 firm-year observations for 2,512 unique firms.

We also construct two separate samples for the analyses of the costs of debt and equity. For the cost of debt analysis, we start with 7,430 firm-year observations that have sufficient interest expense and debt balance to calculate the cost of debt. Further, we require available data for control variables in the baseline regression of the cost of debt, which yields a final sample of 6,578 observations for 1,165 unique Australian firms. The total market size of our sample firms correspond to 41% of the overall market capitalization for listed firms on Australian Stock Exchange.

For the cost of equity analysis, we start with 3,602 firm-year observations that have sufficient data to compute the implied cost of equity capital. The relatively small sample size of the cost of equity is mainly because of the low availability of data on earnings forecasts for Australian firms. However, this sample size is comparable with other studies that investigate the determinants of the implied cost of capital in Australia for different time spans. For example, using a similar method to estimate the implied cost of equity, Gray, Koh, and Tong (2009) adopt a sample of 1,362 firm-year observations over an 8-year period, 1998–2005, while Li (2015) employs a sample of 2,730 firm-years over a 15-year period, 1993–2007. We further require available data for control variables in the baseline regression of the cost of equity, which yields a final sample of 3,169 observations for 648 unique firms.

[15] 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 cost of capital is the results of 2012 financing policies. Nonetheless, in an untabulated analysis, we define the post-Kyoto Protocol period as 2008–2012 and obtain qualitatively similar results.

C. Emitters and Non-emitters

To test the effect of carbon risk on the cost of capital, for several reasons we rely on the industry-based classification to capture firm-level carbon risk exposure rather than actual firm-level carbon emissions. First, corporate decisions on the level of exposure to carbon risk may be correlated with unobservable firm characteristics. Second, given sparse data on firm-level carbon-related activities (Konar and Cohen 2001), it is difficult to know the exact amount of carbon emissions so as to draw a valid inference on the relation between carbon risk and the cost of capital. Third, it might be inaccurate to measure a firm's carbon risk based on its past carbon activities when carbon risk tends to be forward-looking in nature.

Specifically, we classify firms as either emitters or non-emitters based on the emitting nature of the industry in which they operate; that is, the relative industry-based level of carbon emissions and energy consumption (Balachandran and Nguyen 2018). First, we consider emitters as firms in the highest carbon-risk GICS industries, which reportedly emit the most GHGs and consume the most energy as described by the Greenhouse Gas Protocol (GHG Protocol).[16] Based on this classification, the three sectors of energy, utilities, and materials are the largest emitters of GHGs. For example, according to the report of AMP Capital (the leading Australian investment house), the energy, utility, and materials sectors were the largest contributors to ASX200 GHG emission intensity as of the end of August 2015, accounting for 85% of total carbon emissions (AMPCAPITAL 2016).[17]

Second, we address the possibility that some industries within the above three sectors may be less carbon-intensive than others. In particular, we follow the classification of the CDP and identify the following nine GICS industries as emitters: (1) oil, gas, and consumable fuels; (2) electric utilities; (3) gas utilities; (4) independent power producers and energy traders; (5) multi-utilities;

---

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

[17] AMP Capital is a leading Australian investment house with AU$178.9 billion in funds under management as of 30 June 2017. They were among 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. https://www.ampcapital.com/au/en/capabilities/responsible-investment.

(6) chemicals; (7) construction materials; (8) metals and mining; and (9) paper and forest products (CDP 2012).[18]

This GICS industry-based definition of emitters is also equivalent to a recent Moody's identification of high environmental risk industries. Specifically, the top nine industries with immediate or emerging elevated exposure to environmental risks as per Moody's (2015) classification include: (1) mining coal; (2) unregulated utilities and unregulated power; (3) power generation; (4) oil and gas: refining and marketing; (5) building materials; (6) chemicals; (7) steel; (8) mining-metals and other materials, excluding coal; and (9) oil and gas: independent (Nieto 2017). Also, our baseline results remain qualitatively the same when we adopt a number of alternative definitions of polluters, such as all industries within energy, utilities, and materials sectors.

We define non-emitters as the remaining firms coming from other GICS industries with relatively lower levels of carbon emissions. For example, financial, health care, information technology, and telecommucation services industries each contribute about 1%, while consumer discretionary and consumer staples industries each account for about 3% of total carbon emissions in Australia (AMPCAPITAL 2016).

In principal, we expect emitters to face adverse financial implications in the form of carbon-related management and accounting costs, clean-up costs, compliance and litigation costs, or reputation damage (Barth and McNichols 1994; and Clarkson, Li, and Richardson 2004). When carbon regulations become more stringent, carbon costs are expected to increase substantially for emitters.

Panel B of Figure 1 shows the early percentage of contribution to GDP by emitters and non-emitters over the period 2000–2013. While non-emitters show an overall larger contribution, emitters contribute up to more than 25% of GDP. Panel B of Figure 2 compares the time-series variation in carbon emissions between emitters and non-emitters. Non-emitters' emissions remain

[18] The 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. https://www.cdp.net/en/info/about-us. Some recent studies have used the environmental information provided by CDP (e.g., Matsumura, Prakash, and Vera-Muñoz 2014).

relatively stable after the KPR in 2008, while emitters' emissions keep decreasing following the event.[19] In general, firms in carbon-intensive industries seem to be affected by the KPR as evidenced in their reduction in carbon emissions after the policy change.

D. Cost of Debt

We measure the cost of debt using the interest rate spread, denoted as *COD*, which is calculated as the difference between the average interest rate on a firm's debt and the risk-free rate. We calculate the average interest rate as the aggregate interest expenses in a year scaled by the average of short-term and long-term debt at the beginning and the end of that year (Pittman and Fortin 2004; Francis, LaFond, Olsson, and Schipper 2005; and Francis, Khurana, and Pereira 2005). Data on debt interest rates are sourced from Morningstar DatAnalysis.

The method of interest rate calculation is most appropriate for the Australian debt capital market, where businesses are heavily reliant on private debt over public debt. The market-based measures such as bond yields are not particularly relevant in the Australian market (Jung, Herbohn, and Clarkson 2016). Further, databases such as Dealscan that provide the interest information on private debt predominantly cover large US bank loans (e.g., syndicated loans), which is not directly useful for drawing reliable inferences from research in the Australian market.

We use the Reserve Bank of Australia (RBA) cash rate as a proxy for the risk-free rate (Jung, Herbohn, and Clarkson 2016). This cash rate is publicly announced by the RBA on a monthly basis. We take the average of the 12 monthly RBA cash rates in a year to construct the annual risk-free rate. Table 1 reports *COD* of 10.7% on average. The standard deviation of *COD* is 5%. The 10 percentile value is -3.2% while the 90 percentile value is 18.9%.

[19] In the 2017 Review of Climate Change Policies report, the Government of Australia confirms that the target of limiting emissions to 108% of the 1990 levels over the 2008–2012 commitment period under the KPR was well met (Government of Australia 2017). Also, emissions per capita by March 2017 declined by 34.2%, while the emissions intensity of the whole economy decreased by 58.4% since 1990.

E. Cost of Equity

To measure the cost of equity, we estimate the implied cost of equity capital, which equates the current stock price with future earnings. Specifically, we use consensus earnings forecasts from the Institutional Brokers Estimate System database to estimate future earnings. We deduce the four individual firm-level estimates of the implied cost of equity measures from the models of Gebhardt, Lee, and Swaminathan (2001); Claus and Thomas (2001); Gode and Mohanram (2003); and Easton (2004), respectively.[20] We also follow Hou, Van Dijk, and Zhang (2012) in deriving expected earnings from the cross-sectional forecasting models as inputs for the implied cost of equity capital estimation.

Because there is a lack of consensus in the literature on which models best estimate a firm's cost of equity (Gode and Mohanram 2003; and Botosan and Plumlee 2005), we employ a consolidated measure of the implied cost of equity capital by averaging the four individual implied cost of equity estimates for each firm to mitigate the effect of measurement errors associated with one particular model (refer to, e.g., Hail and Leuz 2006; Lau, Ng, and Zhang 2010; Li 2010; and Dhaliwal et al. 2016). Appendix 2 provides a detailed description of the estimation procedure.

Finally, to derive our variable of interest, we subtract the risk-free rate from the average implied cost of equity, denoted as *COE*. Table 1 reports *COE* of 21.5% on average. The standard deviation of *COE* is 17.8%. The 10 percentile value is 3.5% while the 90 percentile value is 50.4%.

F. Control Variables

We employ the two groups of control variables for the tests on the costs of debt and equity. First, in the regressions of the cost of equity, we control for several standard firm-level factors including firm size (*SIZE*) computed as the natural logarithm of the market value of equity, the book-to-market ratio (*BM*) computed as the natural logarithm of the ratio of book value over the market value of equity, and firm risk as proxied by systematic risk (*BETA*) and idiosyncratic risk (*IVOL*).

[20] Pastor, Sinha, and Swaminathan (2008) discuss the difference between expected and realized returns and advocate the use of the implied cost of equity capital as a superior proxy for expected returns. They offer theoretical underpinnings for the value of the implied cost of equity capital in uncovering the intertemporal risk-return relation.

To computer *BETA* and *IVOL*, we regress daily stock returns on market returns on a yearly basis. *BETA* is the coefficient estimate from this market model and *IVOL* is the standard deviation of the residuals from the model.

According to the literature, larger firms are generally less risky, more transparent, and, hence, expected to be able to access cheaper capital (e.g., Dhaliwal et al. 2016). A higher book-to-market ratio generally indicates a firm with fewer growth opportunities and riskier cash flows with a high discount rate; hence, this kind of firm normally suffers a relatively higher cost of capital (e.g., Fama and French 1993). We also expect firms with either larger systematic risk or idiosyncratic risk to be associated with a higher cost of equity capital.

In the regressions of the cost of debt, we use the two measures of financial distress risk, including Altman's (1968) Z-score (*ZSCORE*) and cash flow volatility (*CFVOL*) as proxies for firm risk. In our Australian setting, we follow Jung, Herbohn, and Clarkson (2016) and estimate Australian Z-score using the following formula: Z-score = -0.38 + 2.05×*RETAIN/TA* + 3.06×*EBIT/TA* + 1.09×*SALES/TA* - 2.91×*TDEBT/TA* + 0.16×*WCAP/TA*. We then define a distressed firm as falling into the bottom tercile of estimated Z-score distribution. Note that, for robustness, we also use the bottom quintile and bottom quartile of Z-score values to define distressed firms. In an additional sensitivity check, we employ MacKie-Mason's (1990) modified Z-score model, which is normally used for US firms, for our Australian sample. All the alternative measures of financial distress risk based on Z-score yield similar findings, but, for brevity, these are not reported. Cash flow volatility is defined as the natural logarithm of standard deviation of annual *EBIT/TA* ratio over a 5-year rolling window ending in the current year (-4, 0).

Firms with lower Z-scores are more likely to go bankrupt, hence failing to repay their debt (Altman 1968). Meanwhile, a high level of earnings variability indicates a high degree of fixed costs leaving available funds to meet debt obligation unstable. Both Altman's (1968) Z-score and cash flow volatility are expected to be positively correlated with the cost of debt. The detailed definitions of these variables can be found in Appendix 1.

III. BASELINE ANALYSES

A. Market Reaction to Australia's Ratification of the Kyoto Protocol

We first examine the stock market reaction to the announcement of the KPR. This test would help validate our choice of the KPR as an exogenous shock to carbon risk. We estimate cumulative abnormal stock returns for all Australian firms around 4 December 2007, because the decision of the Kevin Rudd government on the KPR was announced late in the day of 3 December 2007.[21]

Specifically, we calculate the abnormal stock return as the difference between the actual return and the expected return. We estimate the expected return using the market model over the 200-day estimation window (-260, -61) relative to the announcement day. We construct the 2-day cumulative abnormal returns denoted as CAR(-1, 0) and the 3-day cumulative abnormal CAR(-1, 1) to account for the possibility of news leakage and delayed response. The short event windows should capture the immediate market response to the announcement of the KPR and minimize any potential confounding effects, especially when the announcement came out at the onset of the global financial crisis (GCF) 2008–2009.

The results reported in Panel A of Table 2 indicate that the stock market reacts negatively to the announcement of the KPR by Australia (the means of CAR(-1, 0) and CAR(-1, 1) = -0.396% and -0.360% with *t*-statistics = -2.80 and -2.16, respectively). The negative market reaction to the KPR is statistically significant for emitters (CAR(-1, 0) = -0.668% with *t*-statistics = -2.65, and CAR(-1, 1) = -0.534% with *t*-statistics = -1.79) but insignificant for non-emitters. These results suggest that, for emitters, the KPR is at least partially unanticipated. However, the announcement has little effect on shareholders' value for non-emitters. This evidence provides initial support for the conjecture that emitters are immediately prone to higher carbon risk when carbon regulations are tightened.

[21] The news was first released after 5:00 p.m. on 3 December 2007 by the most popular newspapers in Australia such as ABC News (http://www.abc.net.au/news/2007-12-03/rudd-signs-kyoto-ratification-document/976234), or The Age (http://www.theage.com.au/news/national/rudd-ratifies-kyoto/2007/12/03/1196530553722.html).

The results in Panel B and Panel C of Table 2 show similar findings. In Panel B, we extend the window to CAR(-3, 3) and CAR(-5,5) and also find that emitters exhibit much larger negative effects on shareholders' wealth. In Panel C, we regress cumulative returns on a dummy variable for emitters. The coefficients on *EMITTER* dummy are negative and statistically significant in three out of four model specifications.

B. Carbon Risk and the Cost of Capital

To examine a causal link between carbon risk and the cost of capital, we estimate the DiD models in the following forms:

$$COD_{it} = a_0 + a_1\, EMITTER_i \times POST_t + a_2\, EMITTER_i + a_3\, POST_t + a_4\, SIZE_{it} + a_5\, BM_{it} + a_6\, CFVOL_{it} + a_7\, ZSCORE_{it} + \text{Industry fixed effects} + \text{Year fixed effects} + e_{it}, \quad (1)$$

$$COE_{it} = b_0 + b_1\, EMITTER_i \times POST_t + b_2\, EMITTER_i + b_3\, POST_t + b_4\, SIZE_{it} + b_5\, BM_{it} + b_6\, BETA_{it} + b_7\, IVOL_{it} + \text{Industry fixed effects} + \text{Year fixed effects} + e_{it}, \quad (2)$$

where COD_{it} (COE_{it}) is the measure of the cost of debt (cost of equity) for firm i in year t. $EMITTER_i$ is a dummy variable that equals one if firm i is an emitter, and zero otherwise. $POST_t$ is a dummy variable that equals one if year t is in the post-KPR period, and zero otherwise. The models are estimated with heteroscedasticity-robust standard errors clustered at the firm level.[22] Appendix 1 provides the detailed definitions of all variables.

The coefficient of interest in Equation 1 (2) is a_1 (b_1), which captures the change in the cost of debt (cost of equity) for emitters relative to that for non-emitters from before to after the KPR. A negative (positive) a_1 or b_1 indicates that emitters exhibit a relative decrease (increase) in their cost of capital subsequent to the KPR. To account for a possibility that *EMITTER* inadvertently captures the effects of industry characteristics, we control for GICS industry fixed effects in some specifications. We also include year fixed effects to control for the time-varying macroeconomic

[22] In robustness checks, we also control for one-dimensional clustering effects by industry or two-dimensional clustering effects by firm and year, and obtain qualitatively consistent results.

conditions that may affect the cost of capital. In the models that control for industry and year fixed effects, we do not include the stand-alone dummies of *EMITTER* and *POST* because their explanatory powers are absorbed by these fixed effects, respectively.

We run regressions both with and without controlling for fixed effects and present the results in Table 3. The results consistently indicate that emitters exhibit an increase in the cost of capital subsequent to the KPR. For example, in column 1, the coefficient on the interaction term *EMITTER*×*POST* is both positive and statistically significant with a value of 0.062, indicating that the cost of debt increases for emitters relative to non-emitter counterparts in the period after the KPR. Likewise, the implied cost of equity capital is relatively higher for emitters after the KPR, as shown in column 3 where the coefficient estimate on the interaction term *EMITTER*×*POST* is 0.030 and also statistically significant. The increase in the cost of capital is not sensitive to controlling for industry and year fixed effects as reported in columns 2 and 4.

The increase in the cost of capital incurred by emitters is also economically meaningful. The coefficient estimates reported in columns 2 and 4 of Table 3 indicate that the relative increases in *COD* and *COE* of emitters are 5.4% and 2.5%. This is equivalent to 50.5% (=0.054/0.107) and 11.6% (=0.025/0.215) of their sample means, respectively. The relatively stronger impact of carbon risk on *COD* may be because of the fact that lenders lack diversification options when carbon-intensive firms (e.g., those in energy, materials, and utilities) have long been their traditional borrowers, while the secondary market for loans has not been developed in Australia.

In sum, the baseline regression results in Table 3 provide supporting evidence for our hypothesis. That is, higher carbon risk following the KPR leads to an increase in the cost of capital for emitters relative to non-emitters.

C. Dynamic Difference-in-Differences Regression

In this section, we employ a falsification test as suggested by Roberts and Whited (2013) to rule out the possibility that either the KPR is anticipated or the documented increase in the cost of capital merely follows a time trend. To do so, instead of using the static DiD models as per

Equation 1 and Equation 2, we run dynamic DiD models.

In particular, we create the five dummy variables, $BEFORE^{-2y}$, $BEFORE^{-1y}$, $CURRENT^{0}$, $AFTER^{+1y}$, and $AFTER^{2y+}$, where $BEFORE^{-2y}$ equals one if a firm is observed in 2006, and zero otherwise; $BEFORE^{-1y}$ equals one if a firm is observed in 2007, and zero otherwise; $CURRENT^{0}$ equals one if the firm is observed in 2008, and zero otherwise; $AFTER^{+1y}$ equals one if the firm is observed in 2009, and zero otherwise; and $AFTER^{2y+}$ equals one if the firm is observed in the period of 2010 onwards, and zero otherwise. If the change in emitters' cost of capital is because of a time trend rather than the KPR, we would expect a significant and positive coefficients on the interaction terms before the KPR ($EMITTER \times BEFORE^{-2y}$ and $EMITTER \times BEFORE^{-1y}$).

We report the results of the dynamic DiD regression in Table 4. For *COD*, the coefficients on $EMITTER \times BEFORE^{-2y}$, $EMITTER \times BEFORE^{-1y}$, and $EMITTER \times CURRENT^{0}$ are statistically insignificant, while the coefficients on $EMITTER \times AFTER^{+1y}$, and $EMITTER \times AFTER^{2y+}$ are significant and positive. This indicates that *COD* of emitters start to rise mainly from 1 year after the KPR. Similarly for *COE*, only the coefficient on $EMITTER \times AFTER^{2y+}$ is statistically significant while it is insignificant for the other three interaction terms. This means that *COE* of emitters start to surge mainly from 2 years after the KPR. Again, the evidence seems to suggest that lenders respond to such an exogenous increase in carbon risk after the KPR not only more aggressively but also more swiftly than shareholders do. More importantly, the dynamic DiD results indicate that the relative increase in the cost of capital for emitters is unlikely to occur before the KPR and that such effect only prevails after the KPR.

Overall, the falsification test results tend to rule out the possibility that our baseline findings are driven by time trend. These results also suggest that the assumption of parallel trends underlying the exogeneity of the KPR event is satisfied.

D. Alternative Definitions of Emitters and Non-emitters

The use of industry-based classification of emitters and non-emitters in the above analysis is potentially subject to the possibility that the dummy variable, *EMITTER*, simply picks up the

effects of industry characteristics rather than firm-level exposure to carbon risk. We have adopted two strategies to validate this industry-level definition of emitters. First, firms in heavy emitting industries experience more negative stock returns around the announcement of the KPR. Second, we have included controls for industry fixed effects in regression models. Nonetheless, firm-based classifications of emitters and non-emitters may still better account for the heterogeneity in firm-level carbon risk. Therefore, we construct two alternative definitions of emitters based on firm-level information.

1. National Greenhouse and Energy Act 2007

Our first firm-level measure of carbon risk is based on the enforcement of the National Greenhouse and Energy Act 2007 (NGER Act). The NGER Act provides a single national legislative framework for the reporting and dissemination of information related to GHG emissions of firms, and also their energy consumption and production. Enforcement of the NEGR Act enables the gathering of necessary carbon emission and energy information for the implementation of the KPR as well as other environmental policies in Australia. Under the NGER Act, Australian firms that emit CO_2, consume, or produce energy above certain thresholds are mandated to report their emissions and energy information to the Clean Energy Regulator by 31 October each year. As the thresholds have been reset to lower levels over time, more and more firms are required to provide their emissions and energy information to the government and the public. These disclosures are compulsory and businesses that fail to comply with the NGER Act are subject to civil and criminal penalties.[23]

The NGER reporting scheme provides a useful setting for our DiD analysis because NGER-mandated firms are clearly identified as the largest emitters. These firms can be used as treated firms (i.e., firms that are most likely affected by the KPR), whereas non-NGER-mandated peers serve as control firms. Following this logic, we redefine emitters as those required to disclose their emissions and energy information under the NGER Act (hence listed in the Clean Energy Regulator's website) in any reporting years over the post-KPR period of 2008–2013 ($EMITTER_{NGER}$=1). We definite non-emitters as firms not required to disclose ($EMITTER_{NGER}$=0).

[23] For more details on penalties for noncompliance with the NGER Act: http://www.cleanenergyregulator.gov.au/NGER/Reporting-cycle/Complying-with-NGER.

Next, we perform a propensity score matching (PSM) procedure to better identify non-emitters. Specifically, in the first stage, we run a probit model of the dummy variable, $EMITTER_{NGER}$, on all control variables used in the baseline models for the year 2007, and obtain the predicted probability, or p-score, of a firm being a treated one.[24] We then match each emitter with a non-emitter in the same GICS industry using the nearest neighbor matching within 0.01 caliper and with replacement criteria. In the second stage, we rerun both the static and dynamic DiD models using the new PSM-matched sample.

We present both static and dynamic DiD regression results using the PSM sample in Table 5. Here, $EMITTER_{NGER}$ is the dummy variable that equals one (zero) for NGER-mandated (PSM-matched non-NGER-mandated) firms. Because we match treated and control firms in the same GICS industry, in principal our analysis is not susceptible to industry effects that might confound the main findings. The regression results suggest that emitters incur both a higher cost of debt and a higher cost of equity compared to non-emitters subsequent to the KPR. The increases are particularly significant 2 years after the event.

In sum, relying on regulators to identify emitters and non-emitters, the reported results are consistent with the baseline analysis where identification is based on industry-level classification.

2. Market Reaction to the Announcement of the Kyoto Protocol Ratification

Our second strategy to identify emitters and non-emitters relies on the stock market reaction to the announcement of the KPR. This identification is based on the notion that investors respond in accordance to the extent of firm-level carbon risk. A firm is considered to be heavily (lightly) exposed to carbon risk if its investors reacted negatively (non-negatively) to the announcement of the KPR. The intuition is that the KPR could be bad news for carbon-intensive firms because of an increase in operating costs and restrictions on their carbon-intensive activities. The KPR is not necessarily bad news for firms with low carbon risk because the KPR is unlikely to have a

[24] The first NGER reporting year is 2008, the same year of the beginning of the KPR commitment period in Australia. Firm characteristics for PSM matching purposes are measured in 2007. Our t-tests confirm treatment and control firms are similar along all used dimensions post-match for both the cost of debt and the cost of equity.

significant impact or may even reduce competition and facilitate access to external funds for these firms.

Following the above proposition, we estimate the stock market reaction using the 2-day CAR(-1, 0) around the announcement day. We designate a firm as an emitter (non-emitter) if it experiences negative (non-negative) CAR(-1, 0).[25] We generate a new dummy variable, $EMITTER_{CAR}$, which equals one (zero) for the negative (non-negative) reacting firms. Following the previous firm-based test, we use the PSM procedure with replacements to identify a non-emitter in the same GICS industry with the emitter. Matching is based on the nearest neighbor within 0.01 caliper based on observable firm characteristics (i.e., control variables used in the baseline regressions) measured in 2007.

Table 6 presents the results of this analysis. Employing model specifications and variables similar to those in Table 5, we document that both the costs of debt and equity increase significantly for emitters compared to non-emitters after the KPR. More importantly, the effect is only present 2 years after the KPR, indicating that the parallel trends assumption underlying the validity of the DiD framework is again satisfied.

In summary, relying on investors' response to the KPR to identify emitters and non-emitters, we document the results consistent with our baseline analysis.

E. Pseudo Test: United States Emitters versus United States Non-emitters

In this section, we conduct a pseudo test where we investigate the change in the cost of capital for US emitters following the pseudo adoption of the KPR in Australia. The idea is that US emitters should not experience an increase in carbon risk because the US did not ratify the Kyoto Protocol. As such, there should be no significant increase in the cost of capital for US emitters. We also use industry-based classification to determine US emitters and non-emitters over the same sample period 2002–2013 as in the main analysis.

[25] In an untabulated test, we employ a 3-day CAR(-1, 1) instead of 2-day CAR(-1, 0) and obtain qualitatively similar results.

Table 7 reports the results from this analysis. The interaction coefficient estimate on *EMITTER×POST* is statistically insignificant in columns 1 and 2. This suggests that US emitters exhibit no change in the cost of debt following the pseudo adoption of the KPR in Australia. Interestingly, in columns 3 and 4, we find negative coefficient estimates on *EMITTER×POST* and these coefficients are statistically significant at the 1% level. Thus, US emitters not only show no increase in the cost of equity, but there is a remarkable decrease in their cost of equity after the pseudo adoption of the KPR in Australia. We interpret this finding as the KPR restrictions on Australian emitters makes US emitters more competitive in the global market, hence resulting in a lower of cost of equity capital.

Overall, this pseudo analysis confirms no increase in the cost of capital for US emitters following the pseudo adoption of the KPR in Australia. This is consistent with the notion that there was no legal restriction on emissions for US emitters, unlike what was observed for Australian firms.

F. Robustness Tests

We conduct a battery of robustness checks that are reported in the Internet Appendix.

1. Alternative Definitions of Emitters and Non-emitters

In Table IA1, we employ a list of alternative industry-based *EMITTER* dummies following recent evidence in both academic studies and practitioner reports on carbon risk. First, we follow Krueger et al. (2020) and redefine firms with top six stranded assets as emitters. Second, consistent with Andersson, Bolton, and Samama (2016), we deem firms in top three climate risk industries as emitters. Third, we rely on Moody's (2015) research to identify firms in top nine environmental risk industries as emitters. Fourth, we use the carbon beta as a measure of carbon risk as in Görgen et al. (2019) and consider firms in the four highest carbon beta industries as emitters. Finally, we employ the carbon emissions measure in the international study of Bolton and Kacperczyk (2020) and redefine firms in the 10 most carbon-intensive industries as emitters.

Consistent with the main analysis, for each alternative definition, we define non-emitters as those in the remaining industries. The robustness check results based on these alternative industry-based

identifications of treated and control firms yield similar results with the main ones; that is, from before to after the KPR in Australia, emitters experience a significant increase in the cost of capital in comparison to non-emitters.

2. Controlling for Possible Confounding Factors

In Table IA2, we control for possible confounding factors that may drive the cost of capital for emitters and non-emitters differently. For example, the price of commodity, especially iron ore and oil prices, declined sharply during the GFC 2008–2009, which could lower the performance of mining/energy firms and increase their cost of capital. Moreover, the changes in labor protection by Rudd's Labour government may have a disproportionally high effect on capital-intensive firms (versus service firms), which constitute the majority of firms in the treated group.

To account for these factors, we further include both the commodity price index (*CPI*) and the labor regulation index (*LRI*) in the baseline model. Here, the yearly *CPI* is an average of monthly index as constructed by the RBA to provide an indicator of the prices received by Australian commodity exporters;[26] the yearly *LRI* is an average of 40 individual scores on different aspects of Australian labor regulations as developed at the Centre for Business Research (CBR) in Cambridge.[27] We take the natural logarithms of these indexes before fitting into the regression model. Table IA2 report results consistent with the baseline findings as manifested in the significantly positive coefficients of $EMITTER \times POST$ across all eight columns.

3. Exclusion of the Transition Year

In Table IA3, we exclude the transition fiscal year 2008 when the KPR came into effect in Australia. The interaction coefficient estimates on $EMITTER \times POST$ are positive and significant in both the cost of debt and cost of equity regressions, suggesting a higher cost of capital for emitters in the period after the KPR even when the transition year is not included.

In Table IA4, we further adopt various alternative event windows spanning 2, 3, 4, or 5 years around the transition year. The choice of windows around the transition year does not qualitatively

[26] Data on commodity price index designed by RBA can be found at https://www.rba.gov.au/statistics/frequency/commodity-prices/2020/.
[27] Data on labor regulation index designed by CBR can be found at https://www.cbr.cam.ac.uk/datasets/.

change the main findings. We continue to find positive and significant coefficient estimates on *EMITTER×POST* for both the cost of debt and cost of equity regressions.

4. Inclusion of Firm Fixed Effects

In Table IA5, we include firm fixed effects to replace industry fixed effects. We continue to document robust findings, suggesting that constant firm characteristics do not explain the observed changes in the cost of capital in the post-KPR period. The coefficient estimates on *EMITTER×POST* are positive and statistically significant at the 10% level and lower.

5. Exclusion of Financial Industries

We exclude financial firms from our sample and repeat the main analysis in Table IA6. This exclusion reduces the sample to 6,357 observations for the cost of debt regression and 2,426 for the cost of equity regression. We find that the coefficient estimates on *EMITTER×POST* are positive and statistically significant at the 5% or 1% levels. Thus, the findings in our study are not driven by financial firms in the sample.

6. Controlling for Corporate and Stock Liquidity

It is plausible that emitters reserve more cash in anticipation of future negative cash flow shocks (i.e., financial constraints) after the KPR (Opler et al. 1999; and Bates, Kahle, and Stulz 2009), which may be positively related to the cost of debt. Moreover, emitters' stocks become less liquid in the post-KPR period and stock investors tend to incorporate the illiquidity premium into their asset pricing models (Brennan et al. 2012; and Yang, Zhang, and Zhang 2020). In this robustness check, we control for corporate and stock liquidity measures in our baseline regressions.

For the tests on the cost of debt, we include cash holdings, *CASH*, which captures the level of cash balance over total assets, as an additional independent variable in Equation 1. For the tests on the cost of equity, we add the Amihud (2002) illiquidity measure, *AMIHUD*, to the list of control variables in Equation 2. The robustness check results in Table IA7 confirm our main findings that emitters incur a relatively higher cost of capital after the KPR, and this effect is not subsumed even with controlling for these liquidity measures.

7. Controlling for the Global Financial Crisis

We address the possible confounding effect of the GFC 2008–2009. Because capital was more costly due to the deteriorated economic and financing conditions during this crisis time (Ivashina and Scharfstein 2010; De Haas and Van Horen 2012; Giannetti and Laeven 2012; and Kahle and Stulz 2013), tighter capital provisions possibly explain our main findings.

We adopt two alternative strategies for this robustness check. First, we include the interaction term with a dummy variable, *GFC*, to control for the differential effect on emitters and non-emitters caused by the crisis. Second, we exclude the crisis period from our sample. We define the GFC period as spanning 2 years from 2008 to 2009. The results for this robustness test are presented in Table IA8. We find insignificant coefficients on *EMITTER×GFC* in columns 1 and 2, and significantly negative coefficients on *EMITTER×GFC* in columns 5 and 6. These results indicate that, while *COD* is not significantly different between the GFC period and the non-GFC period, *COE* is in fact significantly lower for emitters relative to non-emitters during the GFC.

More importantly, the coefficients on the interaction term of interest, *EMITTER×POST,* remain positive and highly significant in all the estimated models. This evidence rules out the possibility that the adverse effects of the GFC that occurred in the post-KPR period confound our main findings.

8. Future Cost of Capital

In Table IA9, we employ the cost of capital in year t+1 as the main dependent variable. We continue to document a higher cost of capital for emitters in 1 year ahead following the adoption of the KPR. The coefficient estimates on *EMITTER×POST* are positive and statistically significant at the 5% or 1% levels in both the cost of debt and cost of equity regressions. The magnitude of these coefficient estimates is similar to that observed in Table 3. This finding is consistent with the notion that the increase in carbon risk is permanent and is not only factored into the current cost of capital but also the future cost of capital.

IV. ADDITIONAL TESTS

A. Channels Through Which Carbon Risk Affects the Cost of Capital

Having established a causal effect of carbon risk on the cost of capital, we next investigate two possible channels; namely, cash flow risk and investor recognition, which as predicted by theories underpin this effect. For each channel, we perform the two sets of tests including the level analysis where we examine the impacts of carbon risk on the proxies for cash flow risk and investor recognition, and also the sensitivity analysis where we study how firms with a higher sensitivity to carbon risk experience the change in the cost of capital as carbon risk increases after the KPR.

1. Cash Flow Risk Channel

First, we postulate that the higher costs of managing carbon risk (e.g., reporting, compliance, clean-up, or litigation costs) after the KPR increase the overall level of fixed costs for emitters. These increased fixed costs should make cash flows more susceptible to uncertain economic conditions. Higher cash flow risk, if observed, can explain why emitters incur the higher costs of debt and equity in the post-KPR period. We adopt the two accounting-based risk measures, cash flow volatility and default probability, which are of interest to debtholders, and the two market-based risk measures, systematic and idiosyncratic risks, which are relevant to shareholders.

With regard to the cost of debt, the two accounting-based proxies of cash flow risk include: (i) future cash flow volatility, denoted as *FCFVOL*, calculated as the standard deviation of annual operating margins over the next 5 years starting with the current year (refer to Appendix 1 for detailed definition). Firms with a high degree of fixed costs relative to total costs should have cash flows more sensitive to macroeconomic fluctuations, rendering higher cash flow uncertainty (Lemmon, Roberts, and Zender 2008; and Serfling 2016); and (ii) the default probability, *DEFAULT*, is a dummy variable indicating the bottom tercile of Z-score distribution of our sample firms. Our calculation of Z-score for Australian firms is consistent with the methodology in Jung, Herbohn, and Clarkson (2016), which relies on productivity, profitability, asset-turnover, leverage, and liquidity (refer to Appendix 1 for detailed definition). A lower Z-score value indicates the higher probability of default (Altman 1968; and MacKie-Mason 1990).

We run the DiD regressions of each of the two accounting-based measures on carbon risk controlling for firm size, the book-to-market ratio, and past cash flow volatility. Panel A of Table 8 reports the results of this analysis. The positive and statistically significant coefficients on the interaction of interest, *EMITTER×POST*, in columns 1 through 4 suggest that emitters are more likely to default and exhibit higher cash flow uncertainty subsequent to the KPR. Consistent with the pricing of debt capital (Fisher 1959; Merton 1974; and Jaffee 1975), the increase in default risk and cash flow volatility should translate to a higher cost of debt.

With regard to the cost of equity, we employ a market model to estimate systematic and idiosyncratic risks. Specifically, we regress daily stock returns on market returns to calculate the values of *BETA* and *IVOL* every year. Systematic risk is measured by the market beta, *BETA*, and firm-specific risk is measured by the annualized standard deviation of the residuals in regressing stock returns on market returns, *IVOL*. The increase in fixed costs in the post-KPR period may expose emitters to the more sources of non-diversifiable risk, which induce stock investors to require higher compensation, leading to more costly equity capital (Sharpe 1964; Lintner 1965; and Lambert, Leuz, and Verrecchia 2007). Meanwhile, the higher cash flow volatility may lead to a higher idiosyncratic risk, which is diversifiable in theory but can still be incorporated in the equity pricing given the market frictions such as incomplete information, transaction costs, or investor preference biases (Merton 1987; Fu 2009; and Yang, Zhang, and Zhang 2020).

We investigate the possible direct impact of carbon risk on systematic and idiosyncratic risks by estimating the DiD models for *BETA* and *IVOL*. The results presented in Panel B of Table 8 suggest that emitters indeed exhibit increases in both *BETA* and *IVOL* after the KPR, as shown in the positive and statistically significant coefficients on *EMITTER×POST* in columns 1 through 4. In other words, higher systematic and firm-specific risks faced by the shareholders of emitters following the KPR might help explain the increase in their required rate of returns.

In a supplementary analysis, we aim to pin down whether the increase in cash flow risk caused by the KPR indeed leads to the increase in the cost of capital. Specifically, we examine if emitters with higher ex-ante fixed costs, and hence operating leverage, are more heavily affected by the KPR. To perform this sensitivity analysis, we first gauge the pre-KPR operating leverage by

averaging the ratio of the change in EBIT over the change in sales (i.e., the annual degree of operating leverage or *OPLEV*) over a 5-year window between 2003 and 2007. We then classify firms into the two subgroups of above and below the median value of pre-KPR operating leverage and re-estimate the baseline regressions of *COD* and *COE* using these two subsamples.

Estimation results in Panel C of Table 8 show that the positive impact of carbon risk on the cost of capital holds true only among firms with a relatively higher level of ex-ante operating leverage, as manifested in the statistically significant and positive coefficient on *EMITTER×POST* in columns 1 and 3. In contrast, the results are insignificant for the subgroup of firms with a lower level of pre-KPR operating leverage. This evidence indicates that emitters with higher pre-KPR fixed costs are more sensitive to the impact of KPR and consequently experience a stronger surge in the cost of capital in the post-KPR period.

2. Investor Recognition Channel

Riedl and Smeets (2017) document that fund investors tend to prioritize social preferences and social signaling over financial motives when it comes to socially responsible investment decisions. For example, according to the US SIF Foundation's 2018 report, US$11.6 trillion of all professionally managed assets is under ESG investment strategies, which accounts for 25% of funds invested in the US. Given that the level of carbon emissions is an important criterion for firms' ESG ratings, socially responsible investors may abstain from investing in carbon-intensive firms. That is, heavy carbon emitters are expected to be associated with a smaller shareholder base and less recognized by investors. As predicted in Merton's (1987) investor recognition theory, these firms would suffer a higher cost of capital.

To test this investor recognition channel, we examine the investment behavior of one important group of investors, institutional investors, who actively drive the corporate social responsibility on the one hand, and increasingly incorporate climate risks into their portfolio selection on the other hand (Chava 2014; Dyck et al. 2019; and Krueger, Sautner, and Starks 2020). If an exogenous increase in carbon risk following the KPR triggers an exit of institutional investors from emitter stocks, this may help explain why the cost of capital is significantly heightened fo such environmentally risky firms.

Specifically, we perform the two alternative tests of the investor recognition channel based on the fraction of institutional ownership measured at year-end, *IO*, where the level analysis examines the change in *IO* for emitters relative to non-emitters in the post-KPR period, and the sensitivity analysis evaluates the relative change in emitters' cost of capital conditional on emitters' pre-KPR *IO*.[28] All institutional ownership information is sourced from the Securities Industry Research Centre of Asia-Pacific database.

Results of the two tests are presented in Panel A and Panel B of Table 9. Consistent with our prediction, the evidence in Panel A suggests that institutional ownership declines significantly more for emitters subsequent to the KPR, as manifested in the negative and statistically significant coefficients on *EMITTER×POST* in both columns. The effect is also economically meaningful. Specially, the estimated coefficient of -0.132 indicates that institutional ownership drops by 13.2% for emitters compared to non-emitters subsequent to the KPR, which represents a 35.2% decline (=0.132/0.375) from the *IO* sample mean.

Likewise, the results in Panel B indicate that the increase in the costs of debt and equity is higher for emitters whose institutional ownership is above the median level measured at the end of 2007. This evidence is supportive of the conjecture that firms with greater pre-KPR institutional ownership are more susceptible to the impact of KPR, and hence suffer a stronger increase in the cost of capital in the post-KPR period. In sum, the findings in Table 9 are in line with our argument that lower investor recognition caused by the heightened carbon risk induces a higher cost of capital.

B. External Financing Decisions

In this section, we examine the effect of carbon risk on the various non-price characteristics of external financing activities. Because capital providers use both price and non-price terms to deal with firms' risk, the changes in non-price features can also reflect how debt and equity capital

[28] In an untabulated analysis, we construct an institutional ownership count variable that equals the log of one plus the number of institutional investors at year-end, and find qualitatively consistent results with those based on the fraction of institutional ownership. This means that emitters experience a drop not only in the level of institutional ownership but also in the number of institutional owners after the KPR.

providers view emitters' risk profile in the period after the KPR. Specifically, we examine how the KPR affects the choice of bank loans and the methods of issuing seasoned equity offerings.

1. Bank Loan Choices

First, we examine whether emitters face a change in their sources of bank loans besides incurring higher interest spreads. To comply with the KPR, emitters may need to invest in new and cleaner technologies. These investments are not only costly, but their outcomes are likely uncertain. This then requires longer payback periods and implies higher credit risk. Because reputable banks have more stringent capital regulation in risk control and stronger commitments to environmental protection, it would be more difficult for emitters to obtain loans from reputable banks.[29] We conjecture that emitters are more likely to borrow from smaller, more risk-tolerant, and less environmentally conscious banks in the period after the KPR. Emitters are also more likely to obtain new loans as opposed to subsequent loans.

To conduct this analysis, we collect the bank loan data from newswires. We read each original announcement of loan approval to identify borrowers, loan providers, and loan characteristics. Specifically, we use key words to search for loan announcement articles in the Securities Industry Research Centre Asia-Pacific database. These keywords include "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 information from the DatAnalysis database. While bank loan data can be sourced from DealScan, these data mainly consist of syndicated loans for US firms. Given a more comprehensive approach using newswires, our collection of loan announcements contains all types of loans.

[29] Banks have an inherent interest in carefully evaluating borrowers' carbon risk exposure in their screening of the loan applications and subsequent monitoring because they are potentially liable for environmental damages caused by the borrowers and exposed to litigation and reputation risks as a result of lending to environmentally harmful projects (Pitchford 1995 and Chava 2014). Thus, the banks' close monitoring of the borrowers' carbon risk exposure can help ensure the borrowers' timely repayment of the loans, which is central to the banks' credit risk management. Moreover, banks possess superior screening and monitoring capability relative to other capital market participants because of their access to private information of the prospective borrowers (Fama 1985 and Diamond 1991).

We re-estimate Equation 1 with the dependent variable being either *BIG4* or *NEWLOAN*. Here, *BIG4* is a dummy variable that equals one if a loan is financed by one of four of Australia's major banks—Australia and New Zealand Banking Group (ANZ), Commonwealth Bank of Australia (CBA), National Australia Bank (NAB), and Westpac Banking Corporation (Westpac)–and zero otherwise. These Big Four banks account for more than 80% of the lending market share in Australia and are highly committed to environmental responsibilities in their lending activities. For example, they are the only Australian banks which participate in global initiatives on environmental protection such as United Nations Environmental Programme Statement by Financial Institutions and the Equator Principles (UNEP 1997 and IFC 2013).

NEWLOAN is a dummy variable taking the value of one if a loan is granted for the first time to the borrower, and zero otherwise. Banks are more likely to grant subsequent loans to high-quality clients whose private information banks have accumulated over their long-term relations (Lummer and McConnell 1989). Therefore, lower-quality and riskier clients may have to initiate new loans. This process often takes a longer time and entails higher costs.

We re-estimate Equation 1 with the dependent variable as either *BIG4* or *NEWLOAN*. Table 10 presents the results. The negative and statistically significant coefficients on *EMITTER*×*POST* in columns 1 and 2 indicate that emitters are less likely to be financed by the four major banks following the KPR. As indicated by the positive and significant coefficients on *EMITTER*×*POST* in columns 3 and 4, emitters are more likely to obtain new loans. Since we estimate linear regressions, the coefficients of the interaction term capture the marginal treatment effects. For example, the coefficient of -0.272 in column 2 suggests that the probability of securing a loan with one of the Big Four banks declines by 27.2% for emitters in the post-KPR period. In addition, the coefficient of 0.191 in column 4 indicates that emitters are 19.1% more likely to resort to new lenders for loans after the KPR.

These results suggest that major lenders reduce their lending to emitters in the post-KPR period and emitters seek new financing from smaller and more risk-tolerant banks. These changes in non-price features of bank loans is consistent with the notion that emitters pay a higher cost of debt after the KPR.

2. Seasoned Equity Offerings

Next, we examine the impact of the KPR on how emitters raise additional equity capital. Specifically, we examine the choice of methods in issuing seasoned equity offerings (SEOs). We hypothesize that emitters are less likely to issue equity via rights offerings in the post-KPR period, given their higher cash flow risk and smaller investor recognition. This is because such a high risk and investor exit may make equity issuance to the existing investor base more difficult (e.g., a more time-consuming process and insufficient buyers), motivating the issuing emitters to sell their equity to the public instead.

In addition, we also hypothesize that emitters issuing new equity are more likely to rely on underwriting services to enhance the chance of successful SEOs. This is expected because of the fact that the large investor base and high reputation of underwriters (mostly investment banks) can minimize adverse selection costs incurred by outside investors, and hence help the issuing emitters to access more potential investors and raise their desired capital (Eckbo and Masulis 1992; Slovin, Sushka, and Lai 2000; and Cooney, Kato, and Schallheim 2003).

To conduct this analysis, we obtain SEO data from Bloomberg. We then construct a dummy variable, *RIGHTS*, which takes the value of one if the equity issue is classified as "RIGHTS, Primary Share Offering" in the offer type, and zero otherwise (other types include primary share offerings with accelerated bookbuild, best efforts, block, bought deal, distribution requirements planning shortfall; private placement; and secondary share offerings). Over the sample period 2002–2013, rights account for about 32%, primary share, offerings account for about 52%, and others account for the remaining 16% of all SEOs. We next use the underwriter information to construct a dummy variable, *UNDERWRITING*, which equals one if the SEO is underwritten by at least one investment bank (i.e., non-missing book-runners), and zero otherwise. Data indicate that about 59% of primary share offerings are underwritten, while roughly 2% of rights offerings use this underwriting service over the sample period.[30]

[30] In an untabulated test, we construct a dummy variable indicating the top 10 underwriters by SEO market share. The descending order includes (i) UBS, (ii) Macquarie, (iii) Goldman Sachs, (iv) JP Morgan, (v) Bank of America Merrill Lynch, (vi) Deutsche Bank, (vii) Credit Suisse, (viii) Citi, (xi) RBS, and (x) Morgan Stanley. We find that SEOs of emitters are more likely to be underwritten by one of these reputable investment banks in the post-KPR period.

We re-run the baseline DiD model with the dependent variable being either *RIGHTS* or *UNDERWRITING*. Table 11 presents the results of this analysis, which are supportive of our conjecture. In particular, the negative and significant coefficients on *EMITTER×POST* in columns 1 and 2 indicate that emitters are less likely to issue rights offerings for their SEOs following the KPR. In columns 3 and 4, there is also evidence that emitters are more likely to use underwriting services for their SEOs in the period after the KPR. With regard to economic meaning, the estimated coefficients of -0.084 and 0.073 in columns 2 and 4 reveal that emitters are 8.4% less likely to use rights offerings, while 7.3% more likely to hire underwriters when raising seasoned equity capital.

These results are consistent with the notion that emitters face a higher cost of raising additional equity after the KPR. Therefore, they are less likely to raise equity capital in the form of rights offerings. In cases where additional equity is issued, emitters are also more likely to rely on underwriting services to mitigate the impact of carbon risk.

C. Corporate Financial Policies

In this section, we examine the impact of carbon risk on firms' corporate policies such as cash holdings and dividend payouts, especially under the increased cost of capital. The precautionary motive is one of the key explanations of why firms hold large amounts of cash (e.g., Opler et al. 1999). Most importantly, Bates, Kahle, and Stulz (2009) show that the significant increase in the cash holdings of US firms over time is consistent with the notion that the demand for cash is to mitigate many risks that firms cannot effectively hedge. We, therefore, investigate if firms increase cash holdings after the KPR as a way to mitigate higher risk. At the same time, we conjecture that firms reduce dividend payouts in anticipation of higher unexpected shocks to future cash flows.

Our variable *CASH* is defined as cash and cash equivalents scaled by total assets (Opler et al. 1999 and Bates et al. 2009). Variable *PAYOUT* is defined as cash dividend payment scaled by net income (Floyd, Li, and Skinner 2015; and Balachandran and Nguyen 2018). Data to construct these variables are sourced from Morningstar DatAnalysis. As indicated in Panel A of Table 1, an

average firm holds 23.2% of assets in the form of cash or cash equivalents, and pays out 15.8% of net income to shareholders in the form of cash dividend.

Table 12 presents the results of this analysis. In Panel A, the negative and statistically significant coefficients on *EMITTER×POST* in columns 1 and 2 indicate that emitters are more likely to adopt a higher level of cash holdings following the KPR. In columns 3 and 4, there is also evidence that emitters reduce payout in the period after the KPR. In terms of economic magnitude of the treatment effect, the estimated coefficients of 0.022 and -0.036 in columns 2 and 4 suggest that emitters increase their cash holdings by 2.2% and decrease the dividend payout ratio by 3.6% in the post-KPR period. Both findings suggest that emitters adjust corporate policies in response to the higher carbon risk in the period after the KPR.

In Panel B, we further split the sample based on the level of financial constraints to show that the observed changes in financial policies of emitters are really driven by their increased difficulties in accessing external capital. We measure financial constraints using the well-known Whited and Wu's (2006) index, and define financially constrained (unconstrained) firms as those with the above (below) median value of the WW index. We then rerun the regressions of *CASH* and *PAYOUT* on *EMITTER×POST* separately for constrained (FC) and unconstrained (UC) subsamples.

The regression results suggest that the surging in cash reserves and shrinking in dividend payments are indeed mainly the case among FC firms, as manifested in the significantly positive coefficient in column 1 and significantly negative coefficient of *EMITTER×POST* in column 3, respectively, while they are insignificant in other columns. These findings lends support to our prediction.

V. CONCLUSION

This paper examines whether carbon risk affects a firm's cost of capital. We exploit the Kyoto Protocol by the Government of Australia in December 2007 as an exogenous regulatory shock, which increases carbon risk faced by firms in high carbon-emitting industries (emitters) as opposed to those in lower carbon-emitting industries (non-emitters).

Adopting a difference-in-differences specification, we show that the costs of both debt and equity significantly increase for emitters relative to non-emitters from before to after the KPR. The effect is economically significant with the relative increase in the cost of debt (the cost of equity) being 5.4% (2.5%) on a yearly basis. This finding is robust to the dynamic DiD regression, the two alternative firm-level definitions of emitters and non-emitters based on both the NGER Act and market reactions to the KPR announcement, and a battery of additional robustness checks.

We document two economic channels through which carbon risk drives the cost of capital upward, including cash flow risk and investor recognition. First, we show that, after the KPR, emitters experience increases in financial distress risk (i.e., higher default probability and cash flow uncertainty), as well as in systematic and firm-specific risks (i.e., higher market beta and idiosyncratic volatility), and those emitters with greater pre-KPR operating leverage incur a significantly higher cost of capital in the post-KPR period. Second, we find that, after the KPR, institutional ownership significantly declines for emitters, and those emitters with a higher fraction of institutional ownership before the KPR suffer a stronger increase in the cost of capital after the KPR.

By looking at the details of capital providers, we further find that emitters are less likely to be financed by reputable major banks and more likely to borrow new loans as opposed to subsequent loans in debt financing, and are more willing to use underwriting services rather than rights offerings in seasoned equity offerings. Overall, the findings in our study point towards the conclusion that environmental risks related to regulations have already started to materialize in firms' financing costs.

There are at least three important implications. First, given rising investor engagement of environmental and climate risks in their investment decisions and the strong public belief of a significant rise in global temperature by the end of the last century, carbon risk is expected to be more heavily priced in asset valuations in the years to come. Second, capital market awareness, together with tighter regulations on carbon risk, would cause firms in carbon-intensive industries to be stranded. It is imperative that firms and the overall economy seek new and greener technologies. Third, when environmentally harmful and obsolete technologies are not easily substitutable and the transition to a low-carbon economy is slow, both regulations and subsidies are necessary to encourage firms' investment and innovation in clean technologies.

REFERENCES

Acemoglu, D., P. Aghion, L. Bursztyn, and D. Hemous. 2012. The environment and directed technical change. *American Economic Review*, 102(1), pp. 131–66.

Acemoglu, D., U. Akcigit, D. Hanley, and W. Kerr. 2016. Transition to clean technology. *Journal of Political Economy*, 124(1), pp. 52–104.

Aghion, P., A. Dechezleprêtre, D. Hemous, R. Martin, and J. Van Reenen. 2016. Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy*, 124(1), pp. 1–51.

Altman, E. I. 1968. Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *Journal of Finance*, 23(4), pp. 589–609.

Amihud, Y. 2002. Illiquidity and stock returns: cross-section and time-series effects. *Journal of Financial Markets*, 5(1), pp. 31–56.

Amiraslani, H., K. V. Lins, H. Servaes, and A. Tamayo. 2017. A matter of trust? The bond market benefits of corporate social capital during the financial crisis. *CEPR Discussion Paper* No. DP12321. https://ssrn.com/abstract=3042634.

Ampcapital. 2016. Greenhouse Gas Emissions: Risks And Challenges For Portfolios. *Insight Paper*. https://www.ampcapital.com/content/dam/capital/02-global-files-only/02-esg-resources/201602-insight-paper-esg-climate-change.pdf.

Andersson, M., P. Bolton, and F. Samama. 2016. Hedging climate risk. *Financial Analysts Journal*, 72(3), pp. 13–32.

Balachandran, B. and J. H. Nguyen. 2018. Does Carbon Risk Matter in Firm Dividend Policy? Evidence from a Quasi-natural Experiment in an Imputation Environment. *Journal of Banking and Finance*, 96, pp. 249–267.

Banktrack. 2018. *Banking on Climate Change 2018. Fossil Fuel Finance Report Card*. https://www.banktrack.org/download/banking_on_climate_change_2018_fossil_fuel_finance_report_card/banking_on_climate_change_2018_web_final_1.pdf.

Bansal, R. and M Ochoa. 2011. Temperature, aggregate risk, and expected returns. *NBER Working Paper* 17575. http://www.nber.org/papers/w17575.

Bansal, R., D. Kiku, and M. Ochoa. 2016. Price of long-run temperature shifts in capital markets. *NBER Working Paper* 22529. http://www.nber.org/papers/w22529.

Barth, M. E. and M. F. McNichols. 1994. Estimation and market valuation of environmental liabilities relating to superfund sites. *Journal of Accounting Research*, pp. 177–209.

Bartram, S., K. Hou, and S. Kim. 2019. *Real Effects of Climate Policy: Financial Constraints and Spillovers*. Working paper. https://ssrn.com/abstract=3262211.

Bates, T. W., K. M. Kahle, and R. M. Stulz. 2009. Why do US firms hold so much more cash than they used to? *Journal of Finance*, 64(5), 1985–2021.

Bolton, P. and M. T. Kacperczyk. 2020. Carbon premium around the *world*. Working paper. https://ssrn.com/abstract=3594188.

Botosan, C. A. and M. A. Plumlee. 2005. Assessing alternative proxies for the expected risk premium. *The Accounting Review*, 80(1), pp. 21–53.

Brekke, K. A. and S. Pekovic. 2018. Why are firms environmentally responsible? A review and assessment of the main mechanisms. *International Review of Environmental and Resource Economics*, 12(4), pp. 355–398.

Brennan, M. J., T. Chordia, A. Subrahmanyam, and Q. Tong. 2012. Sell-order liquidity and the cross-section of expected stock returns. *Journal of Financial Economics*, 105(3), pp. 523–541.

CDP. 2012. *Carbon reductions generate positive ROI. Carbon Action Report 2012. Carbon Action Plan*. https://www.cdp.net/documents/carbon-action-report-2013.pdf.

Chava, S. 2014. Environmental externalities and cost of capital. *Management Science*, 60(9), pp. 2223-2247.

Chen, Y., A. Kumar, and C. Zhang. 2020. *Dynamic ESG Preferences and Asset Prices*. Working paper. https://ssrn.com/abstract=3331866.

Chen, Z., O. Z. Li, and H. Zou. 2016. Directors′ and officers′ liability insurance and the cost of equity. Journal of Accounting and Economics, 61(1), pp. 100–120.

Choi, D., Z. Gao, and W. Jiang. 2020. Attention to global warming. *Review of Financial Studies*, 33(3), pp. 1112-1145.

Clarkson, P. M., Y. Li, and G. D. Richardson. 2004. The market valuation of environmental capital expenditures by pulp and paper companies. *The Accounting Review*, 79(2), pp. 329–353.

Claus, J. and J. Thomas. 2001. Equity premia as low as three percent? Evidence from analysts' earnings forecasts for domestic and international stock markets. *Journal of Finance*, 56(5), pp. 1629–1666.

Cooney Jr, J. W., H. K. Kato, and J. S. Schallheim. 2003. Underwriter certification and Japanese seasoned equity issues. *Review of Financial Studies*, 16(3), pp. 949–982.

De Haas, R. and N. Van Horen. 2012. Running for the exit? International bank lending during a financial crisis. *Review of Financial Studies*, 26(1), pp. 244–285.

Delmas, M. and M. W. Toffel. 2004. Stakeholders and environmental management practices: an institutional framework. *Business Strategy and the Environment*, 13(4), pp. 209–222.

Dhaliwal, D., J. S. Judd, M. Serfling, and S. Shaikh. 2016. Customer concentration risk and the cost of equity capital. *Journal of Accounting and Economics*, 61(1), pp. 23–48.

Diamond, D. W. 1991. Monitoring and reputation: The choice between bank loans and directly placed debt. *Journal of Political Economy*, pp. 689–721.

Diaz-Rainey, I., B. Robertson, and C. Wilson. 2017. Stranded research? Leading finance journals are silent on climate change. Climatic Change, 143, pp. 243–260.

Dyck, A., K. V. Lins, L. Roth, and H. F. Wagner. 2019. Do institutional investors drive corporate social responsibility? International evidence. *Journal of Financial Economics*, 131(3), pp. 693–714.

Easton, P. D. 2004. PE ratios, PEG ratios, and estimating the implied expected rate of return on equity capital. *The Accounting Review*, 79(1), pp. 73–95.

Eckbo, B. E. and R. W. Masulis. 1992. Adverse selection and the rights offer paradox. *Journal of Financial Economics*, 32(3), pp. 293–332.

Fama, E. F. 1985. What's different about banks? *Journal of Monetary Economics*, 15(1), pp. 29–39.

Fama, E. F. and K. R. French. 1993. Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33(1), pp. 3–56.

Fisher, L. 1959. Determinants of risk premiums on corporate bonds. *Journal of Political Economy*, 67(3), pp. 217–237.

Floyd, E., N. Li, and D. Skinner. 2015. Payout policy through the financial crisis: The growth of repurchases and the resilience of dividends. Journal of Financial Economics, 118(2), pp. 299–316.

Francis, J. R., I. K. Khurana, and R. Pereira. 2005. Disclosure incentives and effects on cost of capital around the world. *The Accounting Review*, 80(4), pp. 1125–1162.

Francis, J., R. LaFond, P. Olsson, and K. Schipper. 2005. The market pricing of accruals quality. *Journal of Accounting and Economics*, 39(2), pp. 295-327.

Fu, F. 2009. Idiosyncratic risk and the cross-section of expected stock returns. *Journal of Financial Economics*, 91(1), pp. 24–37.

Garnaut, R. 2011. *Garnaut Review 2011: Australia in the Global Response to Climate Change. Garnaut Climate Change Review. Commonwealth of Australia*. http://www.garnautreview.org.au/update-2011/garnaut-review-2011.html.

Garvey, G. T., M. Iyer, and J. Nash. 2018. Carbon Footprint and Productivity: Does the "E" in ESG Capture Efficiency as well as Enviroment? *Journal of Investment Management*, 16(1), pp. 59–69.

Gebhardt, W. R., C. M. Lee, and B. Swaminathan. 2001. Toward an implied cost of capital. *Journal of Accounting Research*, 39(1), pp. 135–176.

Giannetti, M. and L. Laeven. 2012. The flight home effect: Evidence from the syndicated loan market during financial crises. *Journal of Financial Economics*, 104(1), pp. 23–43.

Gibson, R. and P. Krueger. 2018. The sustainability footprint of institutional investors. *Swiss Finance Institute Research Paper* No. 17-05. Working paper. https://ssrn.com/abstract=2918926.

Ginglinger, E. and Q. Moreau. 2019. Climate risk and capital structure. *Université Paris-Dauphine Research Paper* No. 3327185. https://ssrn.com/abstract=3327185.

Gode, D. and P. Mohanram. 2003. Inferring the cost of capital using the Ohlson–Juettner model. *Review of Accounting Studies*, 8(4), pp. 399–431.

Görgen, M., A. Jacob, M. Nerlinger, R. Riordan, M. Rohleder, and M.Wilkens. 2019. *Carbon risk*. Working paper. https://ssrn.com/abstract=2930897.

Government of Australia. 2017. *2017 Review of Climate Change Policies. Commonwealth of Australia*. https://www.environment.gov.au/system/files/resources/18690271-59ac-43c8-aee1-92d930141f54/files/2017-review-of-climate-change-policies.pdf.

Gray, P., P. S. Koh, and Y. H. Tong. 2009. Accruals quality, information risk and cost of capital: Evidence from Australia. *Journal of Business Finance & Accounting*, 36(1-2), pp. 51-72.

Grubb, M. and J. Depledge. 2001. Seven myths of the Kyoto Protocol. *Climate Policy*, 1, pp. 269–272.

Habib, A. and M. B. U. Bhuiyan. 2017. Determinants of monetary penalties for environmental violations. *Business Strategy and the Environment*, 26(6), pp. 754–775.

Hail, L. and C. Leuz. 2006. International differences in the cost of equity capital: Do legal institutions and securities regulation matter? *Journal of Accounting Research*, 44(3), pp. 485–531.

Hong, H. and M. Kacperczyk. 2009. The price of sin: The effects of social norms on markets. *Journal of Financial Economics*, 93, pp. 15–26.

Hong, H., F. Li, and J. Xu. 2019. Climate risks and market efficiency. *Journal of Econometrics*, 208 (1), pp. 265–281.

Hou, K., M. A. Van Dijk, and Y. Zhang. 2012. The implied cost of capital: A new approach. *Journal of Accounting and Economics*, 53(3), pp. 504–526.

Hsu, P.H., K. Li, and C. Tsou. 2020. *The pollution premium*. Working paper. https://ssrn.com/abstract=3578215.

IFC. 2013. A financial industry benchmark for determining, assessing and managing environmental and social risk in projects. *The Equator Principles*. International Finance Corporation. http://www.equatorprinciples.com/resources/equator_principles_III.pdf.

Ilhan, E., Z. Sautner, and G. Vilkov. 2020. Carbon tail risk. *Review of Financial Studies*. Forthcoming.

IPCC. 2014. *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, R.K. Pachauri, and L.A. Meyer (eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change, 151 pages.

https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf.

Ivashina, V. and D. Scharfstein. 2010. Bank lending during the financial crisis of 2008. *Journal of Financial Economics*, 97(3), 319-338.

Jaffee, D. M. 1975. Cyclical variations in the risk structure of interest rates. *Journal of Monetary Economics*, 1(3), pp. 309–325.

Jiraporn, P., N. Jiraporn, A. Boeprasert, and K. Chang. 2014. Does corporate social responsibility (CSR) improve credit ratings? Evidence from geographic identification. *Financial Management*, 43(3), pp. 505–531.

Jung, J., K. Herbohn, and P. Clarkson. 2016. Carbon risk, carbon risk awareness and the cost of debt financing. *Journal of Business Ethics*, pp. 1–21.

Kahle, K. M. and R. M. Stulz. 2013. Access to capital, investment, and the financial crisis. *Journal of Financial Economics*, 110(2), pp. 280–299.

Konar, S. and M. A. Cohen. 2001. Does the market value environmental performance? *Review of Economics and Statistics*, 83(2), pp. 281–289.

Krueger, P., Z. Sautner, and L. T. Starks. 2020. The importance of climate risks for institutional investors. *Review of Financial Studies*, 33(3), pp. 1067–1111.

Labatt, S. and R. R. White. 2007. *Carbon Finance: the Financial Implication of Climate Change*. Hoboken: John Wiley & Sons, 1-2.

Lambert, R., C. Leuz, and R. E. Verrecchia. 2007. Accounting information, disclosure, and the cost of capital. *Journal of Accounting Research*, 45(2), pp. 385–420.

Lau, S. T., L. Ng, and B. Zhang. 2010. The world price of home bias. *Journal of Financial Economics*, 97(2), pp. 191–217.

Lemmon, M. L., M. R. Roberts, and J. F. Zender. 2008. Back to the beginning: persistence and the cross-section of corporate capital structure. *Journal of Finance*, 63(4), pp. 1575–1608.

Li, S. 2010. Does mandatory adoption of International Financial Reporting Standards in the European Union reduce the cost of equity capital? *The Accounting Review*, 85(2), pp. 607–636.

Li, X. 2015. Accounting conservatism and the cost of capital: An international analysis. *Journal of Business Finance & Accounting*, 42(5-6), pp. 555–582.

Lintner, J. 1965. The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets. *Review of Economics and Statistics*, 65, pp. 13–37.

Lummer, S. L. and J. J. McConnell. 1989. Further evidence on the bank lending process and the capital-market response to bank loan agreements. *Journal of Financial Economics*, 25(1), pp. 99–122.

MacKie-Mason, J. K. 1990. Do taxes affect corporate financing decisions? *Journal of Finance*, 45(5), pp. 1471–1493.

Matsumura, E. M., R. Prakash, and S. C. Vera-Muñoz. 2014. Firm-value effects of carbon emissions and carbon disclosures. *The Accounting Review*, 89(2), pp. 695–724.

Merton, R. C. 1974. On the pricing of corporate debt: The risk structure of interest rates. *Journal of Finance*, 29(2), pp. 449–470.

Merton, R. C. 1987. A simple model of capital market equilibrium with incomplete information. *Journal of Finance*, 42(3), pp. 483–510.

Monasterolo, I. and L. De Angelis. 2020. Blind to carbon risk? An analysis of stock market reaction to the Paris Agreement. *Ecological Economics*, 170, 106571.

Moody's. 2015. *Cross Sector - Global: Moody's approach to assessing the credit impacts of environmental risks*. New York.

Nguyen, J. H. 2018. Carbon risk and firm performance: Evidence from a quasi-natural experiment. *Australian Journal of Management*, 43(1), pp. 65–90.

Nguyen, J. H. and H. V. Phan. 2020. Carbon risk and corporate capital structure. *Journal of Corporate Finance*. Forthcoming.

Nieto, M. 2017. *Banks and environmental sustainability: Some financial stability reflections. International Research Centre on Cooperative Finance*. Working paper. https://ssrn.com/abstract=3082107

Ohlson, J. A. and B. E. Juettner-Nauroth. 2005. Expected EPS and EPS growth as determinants of value. *Review of Accounting Studies*, 10(2-3), pp. 349–365.

Opler, T., L. Pinkowitz, R. Stulz, and R. Williamson. 1999. The determinants and implications of corporate cash holdings. *Journal of Financial Economics*, 52(1), pp. 3–46.

Painter, M. 2020. An inconvenient cost: The effects of climate change on municipal bond. *Journal of Financial Economics*, 135(2), pp. 468–482.

Pástor, Ľ., M. Sinha, and B. Swaminathan. 2008. Estimating the intertemporal risk–return tradeoff using the implied cost of capital. *Journal of Finance*, 63(6), pp. 2859–2897.

Pitchford, R. 1995. How liable should a lender be? The case of judgment-proof firms and environmental risk. *American Economic Review*, pp. 1171–1186.

Pittman, J. A. and S. Fortin. 2004. Auditor choice and the cost of debt capital for newly public firms. *Journal of Accounting and Economics*, 37(1), pp. 113–136.

Ramelli, S., E. Ossola, and M. Rancan. 2020. *Climate Sin Stocks: Stock Price Reactions to Global Climate Strikes*. https://ssrn.com/abstract=3544669.

Ramiah, V., B. Martin, and I. Moosa. 2013. How does the stock market react to the announcement of green policies? *Journal of Banking and Finance*, 37(5), pp. 1747–1758.

Riedl, A. and P. Smeets. 2017. Why do investors hold socially responsible mutual funds? *Journal of Finance*, 72(6), pp. 2505–2550.

Roberts, M. R. and T. M. Whited. 2013. Endogeneity in empirical corporate finance. *Handbook of the Economics of Finance*. Elsevier. 2, pp. 493–572.

Seltzer, L., L. T. Starks, and Q. Zhu. 2020. *Climate Regulatory Risks and Corporate Bonds*. Working paper. https://ssrn.com/abstract=3563271.

Serfling, M. 2016. Firing costs and capital structure decisions. *Journal of Finance*, 71(5), pp. 2239–2286.

Sharfman, M. P. and C. C. Fernando. 2008. Environmental risk management and the cost of capital. *Strategic Management Journal*, 29(6), pp. 569–592.

Sharpe, W. F. 1964. Capital asset prices: A theory of market equilibrium under conditions of risk. *Journal of Finance*, 19(3), pp. 425–442.

Slovin, M. B., M. E. Sushka, and K. W. Lai. 2000. Alternative flotation methods, adverse selection, and ownership structure: evidence from seasoned equity issuance in the UK. *Journal of Financial Economics*, 57(2), pp. 157-190.

Stern, N. 2008. The economics of climate change. *American Economic Review*, 98(2), pp. 1-37.

Subramaniam, N., D. Wahyuni, B. J. Cooper, P. Leung, and G. Wines. 2015. Integration of carbon risks and opportunities in enterprise risk management systems: evidence from Australian firms. *Journal of Cleaner Production*, 96, pp. 407–417.

Thompson, P. 1998. Bank lending and the environment: policies and opportunities. *International Journal of Bank Marketing*, 16(6), pp. 243–252.

UNEP. 1997. *UNEP Statement by Financial Institutions on the Environment & Sustainable Development*. Geneva: United Nations Environment Programme Finance Initiative.

UNEP. 2006. *Global climate change: Risk to bank loans. United Nations Environment Programme Finance Initiative*. New York.
http://www.unepfi.org/fileadmin/documents/global_climate_change_risk.pdf.

US SIF Foundation. 2018. Report on US Sustainable, Responsible and Impact Investing Trends. https://www.ussif.org/files/Trends/Trends%202018%20executive%20summary%20FINAL.pdf.

Whited, T. M. and G. Wu. 2006. Financial constraints risk. *Review of Financial Studies*, 19(2), pp. 531–559.

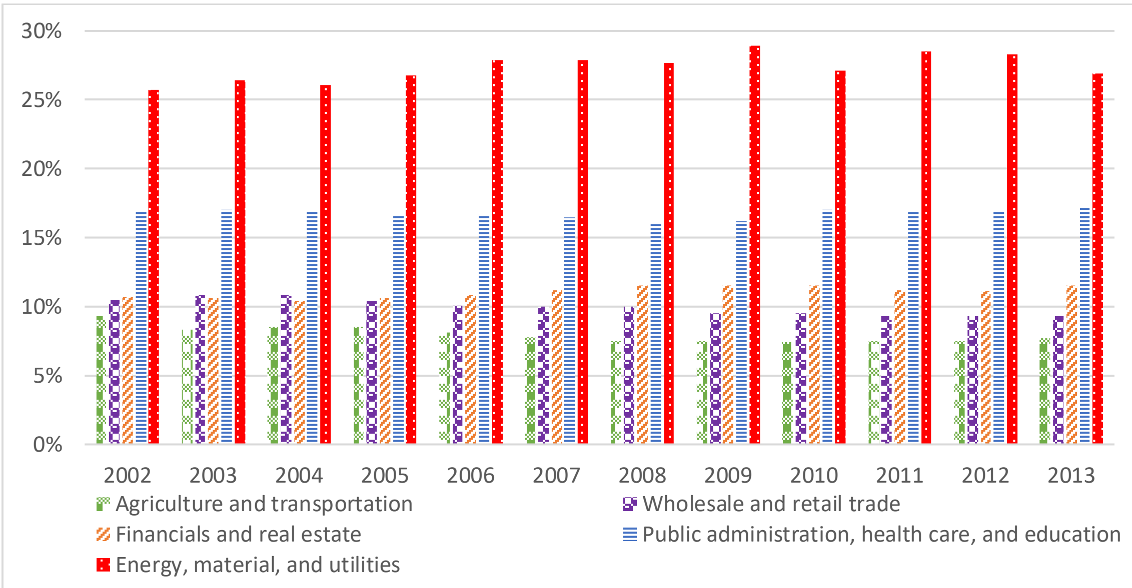
Yang, Y. C., B. Zhang, and C. Zhang. 2020. Is information risk priced? Evidence from abnormal idiosyncratic volatility. *Journal of Financial Economics*, 135(2), pp. 528–554.

Zhang, H.-B., H.–C. Dai, H.-X., Lai, and W.-T. Wang. 2017. US withdrawal from the Paris Agreement: Reasons, impacts, and China's response. *Advances in Climate Change Research*, 8(4), pp. 220–225.

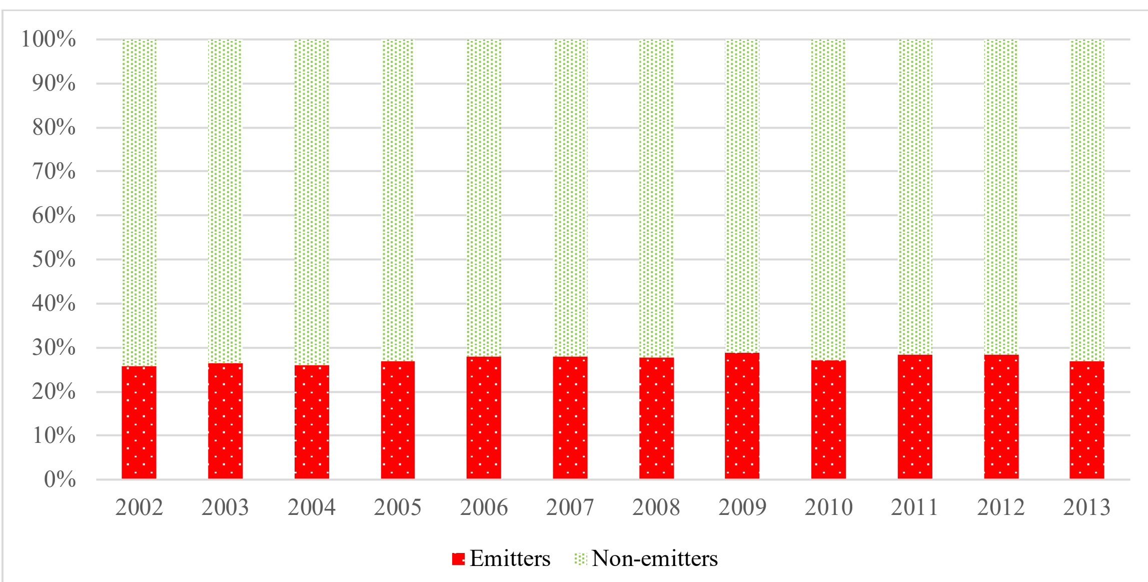
Figure 1 plots the annual percentage of contribution to gross domestic product by major industries (Panel A) and emitters versus non-emitters (Panel B) over the 2002–2013 period.

Figure 1: Percentage of Gross Domestic Product by Industry in Australia

Panel A: By Industry



Panel B: By Emitters and Non-emitters

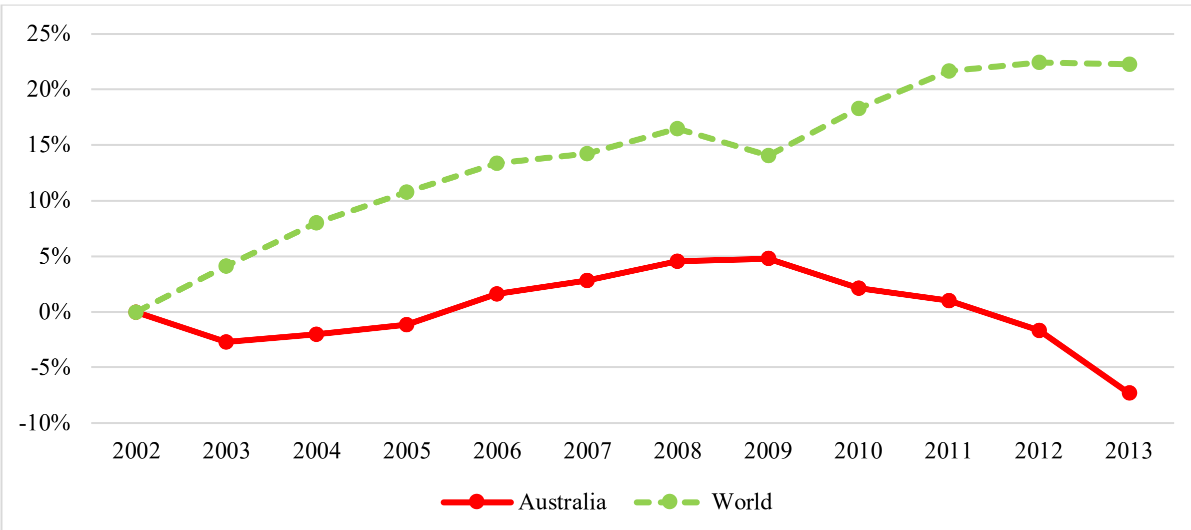


Source: The data are synthesized by the authors and sourced from Australia Bureau of Statistics category no. 5204.0, table 5.

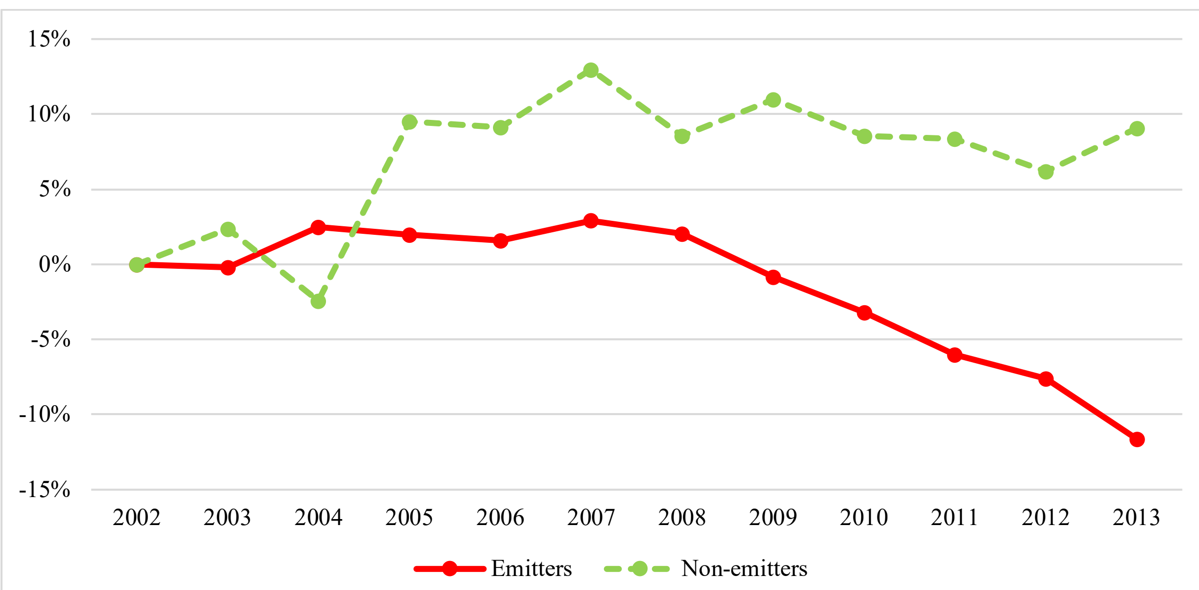
Figure 2 plots the percentage change in carbon emissions (as measured by metric tons of carbon dioxide emissions per capita) for each year over the 2002–2013 period relative to the base year 2002.

Figure 2: Time-Series Variation in Carbon Dioxide Emissions in Australia

Panel A: Australia versus the World



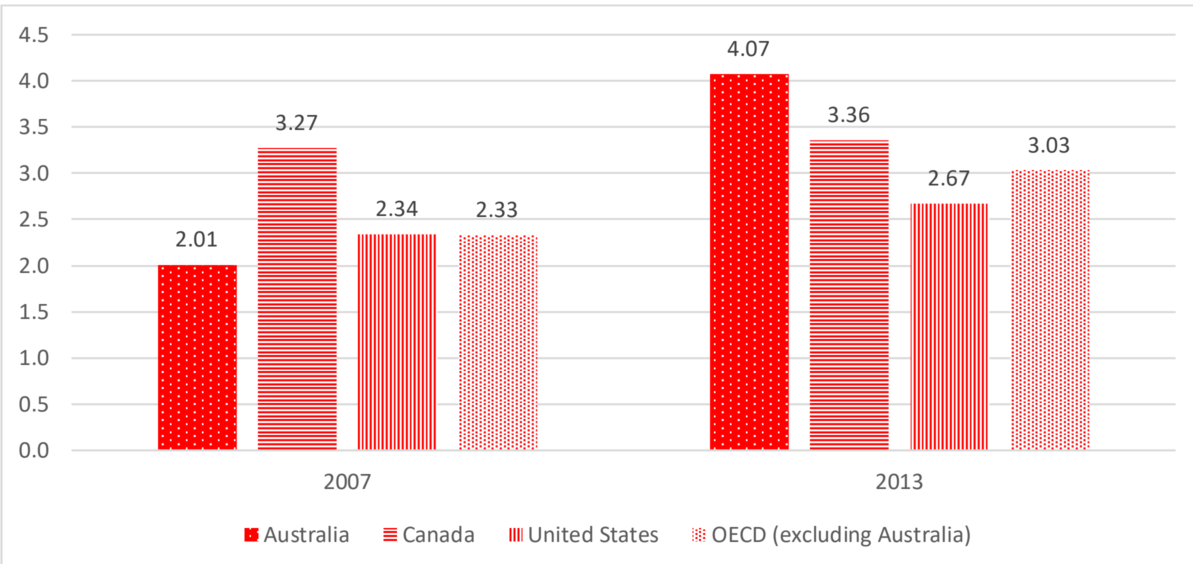
Panel B: Emitters versus Non-emitters in Australia



Sources: The data are synthesized by the authors and sourced from World Bank development indicators; and Department of Industry, Science, Energy and Resources of Australia.

Figure 3 plots the Environmental Policy Stringency Index for Australia, Canada, the United States, and average of all OECD countries (excluding Australia) by the end of pre-KPR (2007) and the end of post-KPR (2013) periods.

Figure 3: Environmental Policy Stringency in Australia versus the Organisation for Economic Co-operation and Development



KPR = Kyoto Protocol ratification, OECD = Organisation for Economic Co-operation and Development.

Source: The data are synthesized by the authors and sourced from OECD.Stats.

Appendix 1: Definitions of Variables

Abbreviation	Name	Definition
Panel A: Cost of Capital Variables		
COD	Cost of debt	Difference between interest rate and a benchmark rate. Interest rate is calculated as interest expense divided by average total debt (short-term and long-term debt) between the beginning and the ending of a particular year. Benchmark rate is average monthly cash rate of the Reserve Bank of Australia over 12 months in the same year.
COE	Cost of equity	Difference between average implied cost of equity and a benchmark rate. Average implied cost of equity is calculated as the average of Ohlson and Juettner-Nauroth (2005), Easton (2004), Claus and Thomas (2001), and Gebhardt et al. (2001) measures of cost of equity capital. Benchmark rate is average monthly cash rate of the Reserve Bank of Australia over 12 months in the same year.
Panel B: Carbon Risk Variables		
EMITTER	Emitter dummy	A dummy that takes the value of one if a firm belongs to one of following nine GICS industries: (1) oil, gas, and consumable fuels; (2) electric utilities; (3) gas utilities; (4) independent power producers and energy traders; (5) multi-utilities; (6) chemicals; (7) construction materials; (8) metals and mining; and (9) paper and forest products, and zero otherwise (CDP 2012).
POST	Post-Kyoto dummy	A dummy that takes the value of one for the post-Kyoto period 2008–2013, and zero for the pre-Kyoto period 2002–2007.
EMITTER×POST	Interaction term	An interaction term between EMITTER and POST dummies.
Panel C: Other Firm Characteristics		
SIZE	Firm size	Log of market value of equity.
BM	Book to market	Log of ratio of book value of equity over market value of equity.
CFVOL	Cash flow risk	Log of standard deviation of annual EBIT/TA ratio over 5-year rolling window ending in current year (-4,0).
FCFVOL	Future cash-flow risk	Log of standard deviation of annual EBIT/TA ratio over 5-year rolling window beginning in current year (0,4).

Abbreviation	Name	Definition
Panel C: Other Firm Characteristics		
ZSCORE	Z-score	Z-score is computed as: -0.38 + 2.05×RETAIN/TA + 3.06×EBIT/TA + 1.09×SALES/TA - 2.91×TDEBT/TA+ 0.16×WCAP/TA, where EBIT is earnings before interest and taxes, SALES is total revenue, RETAIN is retained earnings, WCAP is working capital, and TA is total assets in a particular year.
DEFAULT	Default probability	A dummy that takes the value of one for the bottom tercile, and zero for higher terciles of the distribution of Z-score values.
BETA	Systematic risk	Market beta that is estimated by regressing daily individual stock returns over the fiscal year on the contemporaneous market returns.
IVOL	Idiosyncratic risk	Annualized standard deviation of the residuals from regressing daily individual stock returns over the fiscal year on the contemporaneous market returns.
OPLEV	Operating leverage	Ratio of annual change in EBIT over annual change in SALES. Pre-KPR values are calculated by average of annual OPLEV over 5-year window 2003–2007.
IO	Institutional ownership	Percentage of institutional ownership by year end. Missing are replaced with zero. Pre-KPR values are measured at the end of calendar year 2007.
CASH	Cash holdings	Ratio of cash and cash equivalents over total assets
PAYOUT	Dividend payout ratio	Ratio of cash dividend payment over after-tax profit
Panel D: Bank Loan Variables		
BIG4	Big 4 bank dummy	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), and The National Australia Bank (NAB).
NEWLOAN	New loan dummy	A dummy variable that takes the value of one if a borrower is granted a loan for the first time by a particular bank, and zero if the loan is renewed by the same bank.

Abbreviation	Name	Definition
Panel E: Equity Issue Variables		
RIGHTS	Rights issue dummy	A dummy variable that takes the value of one if an additional equity issue is in the form of rights, and zero if it is seasoned equity offering
UNDERWRITING	Underwriting service dummy	A dummy variable that indicates if an additional equity issue uses underwriting services or not.

Source: Author's elaboration.

Appendix 2: The Implied Cost of Capital Models

ICC	Model	Source
r_{GLS}	$MV_t = BV_t + \sum_{k=1}^{11} \frac{E_t[(ROE_{t+k} - R) \times BV_{t+k-1}]}{(1+R)^k} + \frac{E_t[(ROE_{t+12} - R) \times BV_{t+11}]}{R \times (1+R)^{11}}$, where MV_t denotes the market value of equity in year *t*; R is the implied cost of equity capital (ICC); BV_t is the book value of equity; $E_t[.]$ denotes market expectations based on information available in year *t*; and $(ROE_{t+k} - R) \times BV_{t+k-1}$ is the residual income in year *t+k*. Following Hou *et al.* (2012), we estimate the expected ROE_{t+k} in years *t*+1 to *t*+3 using model-based earnings forecasts in year *t+k*. Book value of equity is computed using clean surplus accounting: $BV_{t+k} = BV_{t+k-1} + E_{t+k} - D_{t+k}$, where E_{t+k} is the earnings in year *t+k*, D_{t+k} is the dividend in year *t+k*, computed using the current dividend payout ratio for firms with positive earnings, or using current dividends divided by 0.06 × total assets as an estimate of the payout ratio for firms with negative earnings. After year *t*+3, the expected ROE is assumed to mean-revert to the historical industry median value until year *t*+11, after which point the residual income becomes a perpetuity. Loss firms are excluded from the calculation of industry median ROE (Gebhardt et al., 2001).	Gebhardt, Lee, and Swaminathan (2001)
r_{CT}	$MV_t = BV_t + \sum_{k=1}^{5} \frac{E_t[(ROE_{t+k} - R) \times BV_{t+k-1}]}{(1+R)^k} + \frac{E_t[(ROE_{t+5} - R) \times BV_{t+4}](1+g)}{(R-g) \times (1+R)^5}$, where MV_t denotes the market value of equity in year *t*; R is the implied cost of equity capital (ICC); BV_t is the book value of equity; $E_t[.]$ denotes market expectations based on information available in year *t*; and $(ROE_{t+k} - R) \times BV_{t+k-1}$ is the residual income in year *t+k*. Following Hou *et al.* (2012), we estimate the expected ROE_{t+k} in years *t*+1 to *t*+5 using model-based earnings forecasts in year *t+k*. Book value of equity is computed using clean surplus accounting: $BV_{t+k} = BV_{t+k-1} + E_{t+k} - D_{t+k}$, where E_{t+k} is the earnings in year *t+k*, D_{t+k} is the dividend in year *t+k*, computed using the current dividend payout ratio for firms with positive earnings, or using current dividends divided by 0.06 × total assets as an estimate of the payout ratio for firms with negative earnings.	Claus and Thomas (2001)
r_{GM}	$R = A + \sqrt{A^2 + \frac{E_t[E_{t+1}]}{MV_t} \times (g - (\gamma - 1))}$, where $A = 0.5\left((\gamma - 1) + \frac{E_t[D_{t+1}]}{M_t}\right), g = 0.5\left(\frac{E_t[E_{t+3}] - E_t[E_{t+2}]}{E_t[E_{t+2}]} + \frac{E_t[E_{t+5}] - E_t[E_{t+4}]}{E_t[E_{t+4}]}\right)$,	Gode and Mohanram (2003), Ohlson and Juettner-Nauroth (2005)

	MV_t denotes the market value of equity in year *t*; R is the implied cost of equity capital (ICC); BV_t is the book value of equity; $E_t[.]$ denotes market expectations based on information available in year *t*; E_t is the earnings in year *t*; D_{t+1} is the dividend in year *t*+1, computed using the current dividend payout ratio for firms with positive earnings, or using current dividends divided by 0.06 × total assets as an estimate of the payout ratio for firms with negative earnings; g is the short-term growth rate. We follow Gode and Mohanram (2003) and use the average of forecasted near-term growth and five-year growth as an estimate of g. γ is the perpetual growth rate in abnormal earnings beyond the forecast horizon.	
r_{Easton}	$MV_t = \frac{E_t[E_{t+2}]+R\times E_t[D_{t+1}]-E_t[E_{t+1}]}{R^2}$, where MV_t denotes the market value of equity in year *t*; R is the implied cost of equity capital (ICC); $E_t[.]$ denotes market expectations based on information available in year *t*; E_{t+1} and E_{t+2} are the earnings in year *t*+1 and year *t*+2, respectively; D_{t+1} is the dividend in year *t*+1, computed using the current dividend payout ratio for firms with positive earnings, or using current dividends divided by 0.06 × total assets as an estimate of the payout ratio for firms with negative earnings.	Easton (2004)
COE	$COE = \frac{r_{GLS} + r_{CT} + r_{GM} + r_{Easton}}{4} - rf$	Hail and Leuz (2006)

Source: Author’s elaboration.

Appendix 3: Number of Firms by Industry and Year

This table summarizes the number of our sample firms for each industry over the 2002–2012 sample period. The first column reports the name of the industry. The column "Emitters" reports "Yes" for emitters and "No" for non-emitters. The column "N" reports the total number of observations across all sample periods for each industry. The rest of the columns report the number of firms in each year.

GICS Industry	Emitters	N	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Chemicals	Yes	113	5	7	8	8	10	9	8	8	12	12	13	13
Construction materials	Yes	107	10	12	10	10	10	10	7	7	8	7	8	8
Electric utilities	Yes	54	4	4	4	2	2	4	6	6	6	7	4	5
Gas utilities	Yes	34	3	3	3	3	3	2	2	3	3	3	3	3
Independent power producers and energy traders	Yes	131	4	5	7	8	8	10	13	15	16	15	15	15
Metals and mining	Yes	4,873	176	191	237	269	300	391	454	476	519	592	632	636
Multi-utilities	Yes	34	2	2	2	4	4	4	4	4	3	2	2	1
Oil, gas, and consumable fuels	Yes	1,800	69	73	84	106	134	155	174	174	186	205	213	227
Paper and forest products	Yes	75	8	8	10	10	8	8	7	5	3	3	3	2
Aerospace and defense	No	40	2	2	2	2	4	4	4	4	4	4	4	4
Air freight and logistics	No	57	5	5	5	5	5	5	5	5	5	4	4	4
Airlines	No	41	2	2	2	3	3	3	3	3	4	5	6	5
Auto components	No	81	6	6	6	7	8	8	8	6	6	7	7	6
Automobiles	No	7	0	0	0	0	0	1	1	1	1	1	1	1
Banks	No	110	12	11	11	11	11	11	8	7	7	7	7	7
Beverages	No	106	11	7	8	7	8	10	11	9	8	9	10	8
Biotechnology	No	372	22	23	29	35	39	36	39	35	29	29	29	27
Building products	No	77	4	5	6	5	7	7	8	7	8	7	6	7
Capital markets	No	437	14	14	18	28	32	39	44	45	49	49	53	52
Commercial services and supplies	No	464	39	40	38	38	41	39	43	43	40	37	35	31
Communications equipment	No	59	5	5	7	8	7	5	4	4	3	3	4	4
Construction and engineering	No	366	17	17	19	20	24	32	37	38	38	40	41	43
Consumer finance	No	82	2	3	3	3	5	9	10	9	9	9	10	10
Containers and packaging	No	46	3	3	3	4	4	4	4	5	5	5	3	3
Distributors	No	90	6	6	9	9	7	6	8	8	8	8	7	8
Diversified consumer services	No	94	5	5	7	8	7	7	6	7	10	10	9	13
Diversified financial services	No	706	47	56	65	69	64	62	60	54	59	59	56	55
Diversified telecommunication services	No	167	12	11	10	13	15	15	15	16	16	16	15	13
Electrical equipment	No	72	5	4	4	5	7	7	6	6	6	8	8	6
Electronic equipment, instruments, and components	No	162	11	13	13	16	15	12	13	13	12	14	16	14
Energy equipment and services	No	54	0	1	3	6	6	6	6	5	6	6	5	4
Food and staples retailing	No	62	7	7	6	7	6	6	5	4	4	3	3	4
Food products	No	264	18	20	22	18	20	23	24	25	25	23	23	23
Health care equipment and supplies	No	333	17	17	21	23	27	29	33	30	32	35	36	33
Health care providers and services	No	224	16	18	20	18	19	21	19	21	21	18	16	17
Health care technology	No	33	1	1	2	2	3	3	3	4	3	4	3	4

Appendix 3 - continuation

GICS Industry	Emitters	N	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Hotels, restaurants, and leisure	No	308	30	31	30	30	28	24	23	25	21	21	21	24
Household durables	No	123	10	10	10	10	10	10	9	9	11	12	12	10
Household products	No	2	0	0	0	0	0	0	0	0	0	0	1	1
Information technology services	No	205	12	15	16	17	18	19	19	17	19	18	18	17
Industrial conglomerates	No	36	4	4	3	3	3	4	4	3	3	2	2	1
Insurance	No	115	7	8	8	9	10	9	11	11	12	10	10	10
Internet and catalog retail	No	39	2	1	1	3	4	4	4	4	3	4	4	5
Internet software and services	No	125	12	11	11	9	12	13	9	11	11	9	9	8
Leisure products	No	16	1	1	1	1	1	1	1	2	2	1	2	2
Life sciences tools and services	No	67	2	2	2	4	4	5	8	7	8	8	8	9
Machinery	No	211	14	13	14	19	20	22	22	21	20	17	15	14
Marine	No	23	2	2	2	1	2	2	2	2	2	2	2	2
Media	No	298	25	26	24	27	26	26	25	23	24	23	25	24
Multiline retail	No	48	3	3	4	4	4	4	4	4	5	5	4	4
Personal products	No	18	2	1	1	1	1	1	1	2	2	2	2	2
Pharmaceuticals	No	181	6	5	11	14	14	16	18	18	20	19	21	19
Professional services	No	121	6	5	7	8	8	8	10	10	11	13	16	19
Real estate investment trusts	No	386	30	32	30	27	29	33	35	33	37	34	31	35
Real estate management and development	No	430	35	33	34	34	38	40	39	41	39	34	31	32
Road and rail	No	28	1	1	1	1	2	2	3	3	3	3	4	4
Semiconductors and semiconductor equipment	No	27	1	1	1	1	2	3	3	3	3	3	3	3
Software	No	260	21	18	17	21	20	21	21	23	25	26	25	22
Specialty retail	No	219	17	15	17	20	22	19	18	18	19	19	18	17
Technology hardware, storage, and peripherals	No	13	2	2	1	0	1	1	1	1	1	1	1	1
Textiles, apparel, and luxury goods	No	85	5	5	5	5	6	9	9	9	9	8	8	7
Thrifts and mortgage finance	No	34	1	1	1	2	3	3	4	3	4	4	4	4
Trading companies and distributors	No	154	8	8	9	11	13	14	14	13	17	17	16	14
Transportation infrastructure	No	77	7	7	6	7	7	6	5	6	7	7	6	6
Wireless telecommunication services	No	42	3	3	2	2	4	6	5	5	5	3	2	2
Total		**15,518**	**839**	**871**	**973**	**1,081**	**1,185**	**1,328**	**1,429**	**1,439**	**1,517**	**1,591**	**1,631**	**1,634**

Source: Author’s summary.

Table 1: Summary Statistics

	N	Mean	STD	10%	25%	Median	75%	90%
Panel A: Full Sample								
SIZE	15,518	17.754	2.113	15.263	16.188	17.451	19.081	20.806
BM	15,518	-0.450	0.956	-1.681	-1.028	-0.385	0.175	0.671
CFVOL	15,518	-2.275	1.404	-4.033	-3.257	-2.319	-1.378	-0.485
FCFVOL	15,518	-2.358	1.565	-4.289	-3.469	-2.406	-1.346	-0.390
ZSCORE	15,518	-0.788	3.078	-3.066	-1.446	-0.468	0.607	1.718
DEFAULT	15,518	0.279	0.449	0.000	0.000	0.000	1.000	1.000
BETA	15,518	0.792	1.149	-0.002	0.211	0.641	1.226	1.900
IVOL	15,518	0.068	0.063	0.017	0.029	0.053	0.084	0.126
IO	15,518	0.375	0.484	0.000	0.000	0.000	1.000	1.000
CASH	15,518	0.232	0.256	0.011	0.039	0.127	0.343	0.648
PAYOUT	15,518	0.158	0.369	0.000	0.000	0.000	0.266	0.568
Panel B: COD Regression Sample								
COD	6,578	0.107	0.350	-0.032	0.005	0.032	0.073	0.189
SIZE	6,578	18.002	2.202	15.338	16.354	17.693	19.490	21.188
BM	6,578	-0.475	0.961	-1.685	-1.037	-0.445	0.142	0.679
CFVOL	6,578	-2.494	1.391	-4.202	-3.482	-2.558	-1.619	-0.744
ZSCORE	6,578	-0.547	2.844	-2.670	-1.277	-0.256	0.776	1.818
Panel C: COE Regression Sample								
COE	3,169	0.215	0.178	0.035	0.076	0.159	0.307	0.504
SIZE	3,169	19.706	1.867	17.365	18.368	19.482	21.058	22.478
BM	3,169	-0.549	0.786	-1.589	-1.017	-0.505	-0.007	0.370
BETA	3,169	0.456	0.508	0.014	0.171	0.411	0.676	0.985
IVOL	3,169	0.029	0.024	0.013	0.017	0.023	0.034	0.048

Note: Table 1 presents the number of observations (N), mean, median, standard deviation (STD), quartiles (25% and 75%), and the percentiles (10% and 90%) for the two main measures of the cost of capital (*COD* and *COE*) and the key control variables. The sample period is between 2002 and 2013. The detailed definitions of all variables are provided in Appendix 1.
Source: Author's calculations.

Table 2: Stock Market Reaction to Australia's Ratification of the Kyoto Protocol

Panel A: One Day Around the Event Day

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

Panel B: One Week Around the Event Day

	NStocks	CAR(-3, 3)		CAR(-5, 5)	
		Mean (%)	***t*-stat.**	**Mean** (%)	***t*-stat.**
Overall	1,404	-2.040	-8.68***	-2.235	-8.02***
Emitters	599	-3.513	-8.74***	-3.851	-8.10***
Non-emitters	805	-0.945	-3.45***	-1.033	-3.16***

Panel C: CAR Regressions

	CAR(-1, 0)	**CAR(-1, 1)**	**CAR(-3, 3)**	**CAR(-5, 5)**
Variable	(1)	(2)	(3)	(4)
EMITTER	**-0.002**	**-0.001**	**-0.016****	**-0.017****
	[-0.62]	**[-0.27]**	**[-2.56]**	**[-2.25]**
SIZE	0.000	-0.000	0.002	0.001
	[0.37]	[-0.33]	[1.14]	[0.30]
BM	0.001	0.004*	0.012***	0.012***
	[0.68]	[1.66]	[3.54]	[3.11]
BETA	-0.002	-0.001	-0.013***	-0.013**
	[-0.71]	[-0.34]	[-2.82]	[-2.44]
IVOL	-0.049	-0.097	-0.093	-0.087
	[-0.80]	[-1.34]	[-0.92]	[-0.72]
Observations	977	977	977	977
Adjusted R-squared	0.002	0.003	0.062	0.044

Note: Table 2 reports cumulative abnormal returns for emitters and non-emitters around the day when the news that Australia would officially ratify the Kyoto Protocol was released to the public (Day zero = 4 December 2007). NStocks denotes the number of stocks. In Panel A, CAR(-1, 0) and CAR(-1, 1) denote a firm's cumulative abnormal returns from 1 day before Day zero to Day zero, and from 1 day before to 1 day after Day zero, respectively. In Panel B, CAR(-3, 3) and CAR(-5, 5) denote a firm's cumulative abnormal returns from 3 days before to 3 days after Day zero, and from 5 days before to 5 days after Day zero, respectively. In Panel C, we run regressions of CARs on the *EMITTER* dummy. The firm's abnormal stock return is calculated as the difference between the actual return and the expected return using the 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 (two-tailed *t*-tests), respectively.
Source: Author's estimate.

Table 3: Carbon Risk and Cost of Capital

	COD		*COE*	
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.062*** **	**0.054** **	**0.030** **	**0.025** **
	[2.95]	**[2.50]**	**[2.40]**	**[2.02]**
EMITTER	-0.018		-0.028***	
	[-1.28]		[-2.74]	
POST	0.018		-0.035***	
	[1.34]		[-5.93]	
SIZE	-0.005*	-0.004	-0.069***	-0.073***
	[-1.71]	[-1.32]	[-22.79]	[-24.50]
BM	-0.007	-0.005	0.024***	0.023***
	[-0.98]	[-0.64]	[5.69]	[4.88]
CFVOL	0.017***	0.012**		
	[3.33]	[2.29]		
ZSCORE	0.002	0.002		
	[0.78]	[0.99]		
BETA			0.003	-0.003
			[0.45]	[-0.51]
IVOL			0.486***	0.300**
			[3.02]	[2.16]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	6,578	6,578	3,169	3,169
Adjusted R-squared	0.013	0.030	0.610	0.648

Note: Table 3 reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table 4: The Dynamic Difference-in-Differences Regression

Variable	*COD* (1)	*COD* (2)	*COE* (3)	*COE* (4)
EMITTER×BEFORE^{-2y}	**0.003**	**0.000**	**-0.045*****	**-0.042*****
	[0.08]	**[0.00]**	**[-3.46]**	**[-3.18]**
EMITTER×BEFORE^{-1y}	**0.007**	**0.001**	**-0.009**	**-0.006**
	[0.24]	**[0.04]**	**[-0.61]**	**[-0.38]**
EMITTER×CURRENT^{0}	**0.008**	**0.008**	**-0.022**	**-0.022**
	[0.21]	**[0.02]**	**[-1.29]**	**[-1.29]**
EMITTER×AFTER^{+1y}	**0.087****	**0.079****	**-0.004**	**-0.002**
	[2.26]	**[2.04]**	**[-0.18]**	**[-0.11]**
EMITTER×AFTER^{2y+}	**0.073*****	**0.061****	**0.035****	**0.037****
	[2.86]	**[2.35]**	**[2.25]**	**[2.31]**
EMITTER	-0.019		-0.015	
	[-1.17]		[-1.38]	
BEFORE^{-2y}	0.017		0.033***	
	[0.70]		[4.38]	
BEFORE^{-1y}	0.001		-0.003	
	[0.04]		[-0.37]	
CURRENT^{0}	0.027		0.019**	
	[1.01]		[2.17]	
AFTER^{+1y}	0.026		0.015	
	[1.19]		[1.60]	
AFTER^{2y+}	0.019		-0.048***	
	[1.13]		[-7.26]	
SIZE	-0.005*	-0.004	-0.069***	-0.073***
	[-1.73]	[-1.32]	[-23.03]	[-24.67]
BM	-0.008	-0.005	0.023***	0.022***
	[-1.07]	[-0.69]	[5.75]	[4.77]
CFVOL	0.016***	0.012**		
	[3.24]	[2.29]		
ZSCORE	0.002	0.002		
	[0.81]	[1.02]		
BETA			0.001	-0.003
			[0.25]	[-0.53]
IVOL			0.298**	0.293**
			[2.11]	[2.11]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	6,578	6,578	3,169	3,169
Adjusted R-squared	0.013	0.030	0.624	0.649

Note: Table 4 reports the falsification test results that counterfactually assume that the Kyoto Protocol ratification took place a few years before and after the actual event. Specifically, we estimate the dynamic difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *BEFORE^{-2y}*, *BEFORE^{-1y}*, *CURRENT^{0}*, *AFTER^{+1y}*, and *AFTER^{2y+}* dummies as well as their interactions with *EMITTER* dummy. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table 5: Emitters defined based on the NGER Act

Variable	*COD* (1)	*COD* (2)	*COE* (3)	*COE* (4)
$\boldsymbol{EMITTER_{NGER} \times POST}$	**0.039*** **		**0.020** **	
	[2.74]		**[2.11]**	
$\boldsymbol{EMITTER_{NGER} \times BEFORE^{-2y}}$		**0.005**		**-0.035**
		[0.30]		**[-1.09]**
$\boldsymbol{EMITTER_{NGER} \times BEFORE^{-1y}}$		**0.003**		**0.017**
		[0.10]		**[1.51]**
$\boldsymbol{EMITTER_{NGER} \times CURRENT^{0}}$		**0.024**		**-0.019**
		[1.47]		**[-0.93]**
$\boldsymbol{EMITTER_{NGER} \times AFTER^{+1y}}$		**0.048**		**0.032**
		[1.43]		**[1.20]**
$\boldsymbol{EMITTER_{NGER} \times AFTER^{2y+}}$		**0.042** **		**0.033*** **
		[2.37]		**[3.41]**
SIZE	-0.015***	-0.015***	-0.037***	-0.037***
	[-3.73]	[-3.73]	[-9.35]	[-9.47]
BM	0.002	0.002	0.032***	0.032***
	[0.28]	[0.26]	[4.26]	[4.31]
CFVOL	0.012*	0.012*		
	[1.89]	[1.89]		
ZSCORE	0.018***	0.018***		
	[3.92]	[3.85]		
BETA			0.009	0.009
			[0.76]	[0.79]
IVOL			0.219	0.228
			[0.76]	[0.80]
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	945	945	841	841
Adjusted R-squared	0.083	0.080	0.514	0.516

Note: Table 5 reports the second-stage results of the impact of carbon risk on the cost of capital using a firm-specific definition of emitters, which is based on data from the National Greenhouse and Energy Reporting Act 2007 (NGER Act). In the first stage, we estimate a probit model of $EMITTER_{NGER}$ dummy on all firm characteristics (separately for *COD* and *COE*) used in the baseline models observed in 2007. The $EMITTER_{NGER}$ dummy takes a value of one for firms that are mandated to disclose their emissions according to the NGER Act (emit more than thresholds set out in the NGER Act on yearly basis), and zero otherwise. We then propensity-score-match treated with control firms on the criteria of same Global Industry Classification Standard industry, and nearest neighbor with replacement. In the second stage, we estimate the difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* (or $BEFORE^{-2y}$, $BEFORE^{-1y}$, $CURRENT^{0}$, $AFTER^{+1y}$, and $AFTER^{2y+}$ dummies) as well as its (their) interactions with *EMITTER* dummy. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table 6: Emitters Defined Based on Market Reaction to the Kyoto Protocol Ratification Announcement

	COD		*COE*	
Variable	(1)	(2)	(3)	(4)
$\boldsymbol{EMITTER_{CAR} \times POST}$	**0.032****		**0.019****	
	[2.26]		**[2.25]**	
$\boldsymbol{EMITTER_{CAR} \times BEFORE^{-2y}}$		**0.004**		**0.008**
		[0.18]		**[0.39]**
$\boldsymbol{EMITTER_{CAR} \times BEFORE^{-1y}}$		**-0.024**		**-0.000**
		[-0.93]		**[-0.01]**
$\boldsymbol{EMITTER_{CAR} \times CURRENT^{0}}$		**0.005**		**-0.001**
		[0.17]		**[-0.04]**
$\boldsymbol{EMITTER_{CAR} \times AFTER^{+1y}}$		**0.042**		**0.018**
		[1.27]		**[0.85]**
$\boldsymbol{EMITTER_{CAR} \times AFTER^{2y+}}$		**0.038****		**0.025****
		[2.10]		**[2.57]**
SIZE	-0.003	-0.003	-0.077***	-0.077***
	[-1.24]	[-1.21]	[-27.50]	[-27.45]
BM	0.001	0.001	0.030***	0.030***
	[0.18]	[0.20]	[6.01]	[5.97]
CFVOL	0.009*	0.009*		
	[1.85]	[1.89]		
ZSCORE	0.000	0.000		
	[0.00]	[0.03]		
BETA			-0.009	-0.009
			[-1.06]	[-1.06]
IVOL			0.091	0.091
			[0.54]	[0.55]
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	2,457	2,457	1,454	1,454
Adjusted R-squared	0.036	0.035	0.664	0.663

Note: Table 6 reports the second-stage results of the impact of carbon risk on the cost of capital using a firm-specific definition of emitters, which is based on the stock market reaction to the announcement of the Kyoto Protocol ratification in Australia. In the first stage, we estimate a probit model of $EMITTER_{CAR}$ dummy on all firm characteristics (separately for *COD* and *COE*) used in the baseline models observed in 2007. The $EMITTER_{CAR}$ dummy takes a value of one for firms whose shareholders reacted negatively to the news, and zero otherwise. We then propensity-score-match treated with control firms on the criteria of same GICS industry, and nearest neighbour within 0.01 caliper and with replacement. In the second stage, we estimate the difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* (or $BEFORE^{-2y}$, $BEFORE^{-1y}$, $CURRENT^{0}$, $AFTER^{+1y}$, and $AFTER^{2y+}$ dummies) as well as its (their) interactions with *EMITTER* dummy. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table 7: Pseudo Test: United States Emitters versus United States Non-emitters

	COD		COE	
Variable	**(1)**	**(2)**	**(3)**	**(4)**
EMITTER×POST	**0.007**	**0.006**	**-0.017*****	**-0.017*****
	[1.30]	**[1.08]**	**[-7.11]**	**[-7.38]**
EMITTER	-0.016***		0.020***	
	[-4.07]		[9.46]	
POST	-0.000		0.023***	
	[-0.00]		[22.38]	
SIZE	-0.007***	-0.007***	-0.017***	-0.016***
	[-9.44]	[-8.81]	[-33.54]	[-31.51]
BM	-0.015***	-0.013***	0.046***	0.044***
	[-8.27]	[-6.84]	[17.72]	[17.02]
CFVOL	0.030***	0.030***		
	[18.57]	[16.23]		
ZSCORE	-0.001***	-0.001***		
	[-3.07]	[-2.90]		
BETA			-0.021***	-0.020***
			[-20.68]	[-19.40]
IVOL			0.601***	1.049***
			[10.33]	[15.73]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	50,914	50,914	22,425	22,425
Adjusted R-squared	0.058	0.064	0.483	0.513

Note: Table 7 reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST* using United States data. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table 8: Channel Analysis – Cash Flow Risk

Panel A: Level Analysis of Financial Distress Risk

	DEFAULT		*FCFVOL*	
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.075***** **[4.55]**	**0.077***** **[4.74]**	**0.192***** **[3.00]**	**0.204***** **[3.23]**
EMITTER	0.062*** [4.05]		0.322*** [6.59]	
POST	0.015 [1.31]		-0.169*** [-4.02]	
SIZE	-0.061*** [-18.07]	-0.065*** [-19.97]	-0.299*** [-28.49]	-0.288*** [-26.89]
BM	-0.120*** [-20.34]	-0.118*** [-20.25]	-0.333*** [-16.89]	-0.285*** [-14.38]
CFVOL	0.068*** [13.72]	0.065*** [14.20]	0.322*** [19.01]	0.295*** [17.28]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	15,518	15,518	15,518	15,518
Adjusted R-squared	0.261	0.315	0.403	0.432

Panel B: Level Analysis of Market and Idiosyncratic Risk

	BETA		*IVOL*	
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.087**** **[2.31]**	**0.076**** **[2.03]**	**0.007***** **[3.16]**	**0.008***** **[3.48]**
EMITTER	0.428*** [14.19]		0.006*** [3.11]	
POST	-0.049* [-1.78]		0.015*** [8.94]	
SIZE	-0.060*** [-10.17]	-0.048*** [-7.58]	-0.015*** [-33.58]	-0.016*** [-30.93]
BM	-0.016 [-1.27]	0.006 [0.44]	-0.002** [-2.12]	-0.002** [-2.57]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	15,518	15,518	15,518	15,518
Adjusted R-squared	0.063	0.109	0.306	0.332

Panel C: Sensitivity Analysis of Ex-Ante Operating Leverage

	COD		*COE*	
	High *OPLEV* Pre-KPR	**Low *OPLEV* Pre-KPR**	**High *OPLEV* Pre-KPR**	**Low *OPLEV* Pre-KPR**
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.073****	**0.066**	**0.038****	**0.033**
	[2.11]	**[1.62]**	**[2.37]**	**[1.20]**
SIZE	-0.004	-0.008*	-0.083***	-0.077***
	[-0.70]	[-1.73]	[-15.47]	[-14.51]
BM	-0.003	-0.005	0.012*	0.025***
	[-0.20]	[-0.45]	[1.85]	[2.92]
CFVOL	0.016*	0.003		
	[1.72]	[0.39]		
ZSCORE	0.006**	-0.004		
	[2.07]	[-0.92]		
BETA			-0.024**	0.013
			[-2.42]	[1.43]
IVOL			0.350*	0.597***
			[1.66]	[2.73]
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	2,962	2,597	1,213	1,112
Adjusted R-squared	0.046	0.022	0.717	0.620

KPR = Kyoto Protocol ratification.

Note: Panel A reports the results of difference-in-differences regressions of default probability (*DEFAULT*) and future cash-flow volatility (*FCFVOL*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*. Panel B reports the results of difference-in-differences regressions of market beta (*BETA*) and idiosyncratic volatility (*IVOL*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*. Panel C reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER×POST* conditional on the pre-Kyoto Protocol ratification degree of operating leverage (*OPLEV*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: Author's estimate.

Table 9: Channel Analysis – Investor Recognition

Panel A: Level Analysis of Institutional Ownership		
	IO	
Variable	(1)	(2)
EMITTER×POST	**-0.132*****	**-0.132*****
	[-7.09]	**[-7.08]**
EMITTER	0.038	
	[1.46]	
POST	0.051***	
	[4.13]	
SIZE	0.090***	0.097***
	[20.17]	[20.45]
BM	0.019**	0.031***
	[2.36]	[3.79]
BETA	0.006**	0.006**
	[2.07]	[2.06]
IVOL	-0.303***	-0.285***
	[-3.44]	[-3.25]
Industry fixed effects	No	Yes
Year fixed effects	No	Yes
Observations	15,518	15,518
Adjusted R-squared	0.178	0.213

Panel B: Sensitivity Analysis of Ex-Ante Institutional Ownership				
	COD		***COE***	
	High *IO* Pre-KPR	**Low *IO* Pre-KPR**	**High *IO* Pre-KPR**	**Low *IO* Pre-KPR**
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.081*****	**0.039**	**0.040****	**0.012**
	[2.96]	**[1.35]**	**[2.11]**	**[1.06]**
SIZE	-0.012***	0.000	-0.065***	-0.098***
	[-2.82]	[0.01]	[-28.06]	[-32.67]
BM	-0.005	-0.006	0.031***	0.015***
	[-0.46]	[-0.61]	[8.11]	[2.71]
CFVOL	0.012*	0.009		
	[1.67]	[1.39]		
ZSCORE	0.004	0.001		
	[0.86]	[0.61]		
BETA			-0.003	-0.001
			[-0.32]	[-0.15]
IVOL			0.331*	-0.118
			[1.93]	[-0.55]
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	2,817	3,761	2,057	1,104
Adjusted R-squared	0.054	0.016	0.616	0.707

KPR = Kyoto Protocol ratification.

Note: Panel A reports the results of difference-in-differences regressions of level of institutional ownership (*IO*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*. Panel B reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER×POST* conditional on the pre-Kyoto Protocol ratification level of institutional ownership. *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: Author’s estimate.

Table 10: Carbon Risk and Bank Loans

	BIG4		*NEWLOAN*	
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**-0.292****	**-0.272*****	**0.168***	**0.191****
	[-2.49]	**[-2.76]**	**[1.73]**	**[2.08]**
EMITTER	-0.184*		0.120	
	[-1.71]		[1.39]	
POST	0.061		-0.272***	
	[0.63]		[-3.37]	
SIZE	0.052***	0.043***	-0.031***	-0.032***
	[3.70]	[2.87]	[-2.76]	[-2.64]
BM	0.051*	0.017	-0.058**	-0.060**
	[1.75]	[0.52]	[-2.31]	[-2.26]
CFVOL	-0.023	-0.022	-0.031*	-0.037*
	[-1.05]	[-1.00]	[-1.73]	[-1.91]
ZSCORE	-0.003	-0.002	-0.005	-0.005
	[-0.26]	[-0.12]	[-0.39]	[-0.41]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	460	460	561	561
Adjusted R-squared	0.270	0.340	0.129	0.128

Note: Table 10 reports the results of difference-in-differences regressions of the big four bank dummy (*BIG4*) and the new loan dummy (*NEWLOAN*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*. All regressions control for market capitalization (*SIZE*), book-to-market ratio (*BM*), past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table 11: Carbon Risk and Equity Issues

Variable	*RIGHTS* (1)	*RIGHTS* (2)	*UNDERWRITING* (3)	*UNDERWRITING* (4)
EMITTER×POST	**-0.142*** **	**-0.084*** **	**0.130*** **	**0.073** **
	[-4.73]	**[-2.83]**	**[3.55]**	**[2.02]**
EMITTER	0.036		-0.083***	
	[1.48]		[-2.66]	
POST	0.153***		-0.195***	
	[6.50]		[-7.09]	
SIZE	-0.041***	-0.052***	0.093***	0.094***
	[-8.87]	[-10.30]	[19.04]	[17.48]
BM	0.048***	0.054***	-0.019**	-0.022**
	[5.44]	[5.82]	[-2.08]	[-2.19]
BETA	-0.012	-0.011	-0.008	0.004
	[-1.39]	[-1.30]	[-0.92]	[0.48]
IVOL	0.782***	0.501***	-0.451**	-0.393**
	[3.90]	[2.71]	[-2.44]	[-2.27]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	3,670	3,670	3,670	3,670
Adjusted R-squared	0.095	0.137	0.208	0.232

Note: Table 11 reports the results of difference-in-differences regressions of the rights offering dummy (*RIGHTS*) and the underwriting dummy (*UNDERWRITING*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*. All regressions control for market capitalization (*SIZE*), the book-to-market ratio (*BM*), market beta (*BETA*), and idiosyncratic volatility (*IVOL*). Some regressions also control for year and industry fixed effects, but their estimates are suppressed for brevity. *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table 12: Carbon Risk and Financial Constraints

Panel A: Analysis of Cash Holdings and Payout Policies

	CASH		*PAYOUT*	
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.017***	**0.022****	**-0.037*****	**-0.036*****
	[1.70]	**[2.22]**	**[-3.37]**	**[-3.37]**
EMITTER	0.042***		-0.094***	
	[4.56]		[-9.81]	
POST	0.022***		0.023**	
	[3.19]		[2.55]	
SIZE	-0.032***	-0.030***	0.041***	0.038***
	[-17.48]	[-15.99]	[18.88]	[18.16]
BM	-0.092***	-0.083***	0.003	-0.001
	[-25.10]	[-22.73]	[1.00]	[-0.43]
CFVOL	0.030***	0.024***	-0.033***	-0.025***
	[11.07]	[9.03]	[-11.74]	[-10.49]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	15,518	15,518	15,518	15,518
Adjusted R-squared	0.247	0.286	0.193	0.236

Panel B: Analysis of Cash Holdings and Payout Policies Conditional on Financial Constraints

	CASH		*PAYOUT*	
	FC	**UC**	**FC**	**UC**
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.034****	**-0.005**	**-0.037*****	**-0.034**
	[2.10]	[-0.40]	[-2.88]	[-1.10]
SIZE	-0.018***	-0.014***	0.036***	0.031***
	[-6.26]	[-6.29]	[11.03]	[6.90]
BM	-0.061***	-0.050***	0.006	-0.034***
	[-11.37]	[-10.44]	[1.56]	[-3.80]
CFVOL	0.042***	0.022***	-0.018***	-0.054***
	[9.89]	[7.10]	[-5.72]	[-8.63]
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	5,493	5,523	5,493	5,523
Adjusted R-squared	0.215	0.288	0.151	0.163

Note: Panel A reports the results of difference-in-differences regressions of cash holdings (*CASH*) and dividend payout ratio (*PAYOUT*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*. All regressions control for market capitalization (*SIZE*), book-to-market ratio (*BM*), and past cash-flow volatility (*CFVOL*). Some regressions also control for year and industry fixed effects, but their estimates are suppressed for brevity. Panel B re-does the regressions on subsamples of financially constrained (FC) and unconstrained (UC) firms, where financial constraints are measured using Whited and Wu's (2006) index. *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Internet Appendix: The Price of Carbon Risk: Evidence from the Kyoto Protocol Ratification

Table IA1: Alternative Industry-Based Definitions of Emitters and Non-emitters

Ref. =	**Krueger et al. (2020)**				**Andersson, Bolton, and Samama (2016)**				**Moody's (2015)**			
Emitters =	**Top 6 Stranded Assets**				**Top 3 Climate Risk**				**Top 9 Environmental Risk**			
Variable	***COD***		***COE***		***COD***		***COE***		***COD***		***COE***	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
EMITTER×POST	**0.063*****	**0.056*****	**0.022****	**0.022****	**0.060*****	**0.052****	**0.028*****	**0.023****	**0.064*****	**0.055****	**0.023****	**0.022****
	[2.95]	[2.58]	[2.20]	[2.08]	[2.86]	[2.45]	[3.00]	[2.31]	[3.01]	[2.58]	[2.26]	[2.15]
EMITTER	-0.017		-0.022***		-0.018		-0.025***		-0.019		-0.023***	
	[-1.21]		[-3.41]		[-1.33]		[-4.01]		[-1.37]		[-3.61]	
POST	0.019		-0.033***		0.019		-0.035***		0.018		-0.033***	
	[1.38]		[-7.46]		[1.35]		[-7.72]		[1.32]		[-7.52]	
SIZE	-0.005*	-0.004	-0.068***	-0.073***	-0.005*	-0.004	-0.068***	-0.073***	-0.005*	-0.004	-0.068***	-0.073***
	[-1.74]	[-1.35]	[-43.09]	[-41.91]	[-1.69]	[-1.32]	[-43.07]	[-41.97]	[-1.69]	[-1.32]	[-43.43]	[-41.96]
BM	-0.007	-0.005	0.023***	0.023***	-0.007	-0.005	0.023***	0.023***	-0.007	-0.005	0.023***	0.023***
	[-0.99]	[-0.65]	[8.47]	[7.25]	[-0.98]	[-0.64]	[8.51]	[7.26]	[-0.96]	[-0.64]	[8.51]	[7.26]
PCFVOL	0.016***	0.012**			0.017***	0.012**			0.016***	0.012**		
	[3.25]	[2.28]			[3.34]	[2.29]			[3.32]	[2.28]		
ZSCORE	0.002	0.002			0.002	0.002			0.002	0.002		
	[0.78]	[0.99]			[0.75]	[0.98]			[0.74]	[0.98]		
BETA			0.002	-0.003			0.002	-0.003			0.002	-0.003
			[0.41]	[-0.54]			[0.39]	[-0.54]			[0.42]	[-0.54]
IVOL			0.483***	0.298**			0.478***	0.297**			0.482***	0.299**
			[3.14]	[2.26]			[3.12]	[2.26]			[3.14]	[2.27]
Industry fixed effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	6,578	6,578	3,169	3,169	6,578	6,578	3,169	3,169	6,578	6,578	3,169	3,169
Adjusted R-squared	0.013	0.030	0.613	0.652	0.013	0.030	0.614	0.652	0.013	0.030	0.613	0.652

Table IA1 continuation

Ref. =	Gorgen et al. (2019)				Bolton and Kacperczyk (2020)			
Emitters =	Top 4 Carbon Beta				Top 10 Carbon Risk			
Variable	*COD*		*COE*		*COD*		*COE*	
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
EMITTER×POST	**0.060*****	**0.052****	**0.036*****	**0.031*****	**0.066*****	**0.057*****	**0.022****	**0.021****
	[2.86]	[2.45]	[4.12]	[3.49]	[3.09]	[2.65]	[2.22]	[2.00]
EMITTER	-0.018		-0.031***		-0.018		-0.023***	
	[-1.33]		[-5.46]		[-1.34]		[-3.69]	
POST	0.019		-0.038***		0.017		-0.033***	
	[1.35]		[-8.13]		[1.29]		[-7.52]	
SIZE	-0.005*	-0.004	-0.068***	-0.073***	-0.005*	-0.004	-0.068***	-0.073***
	[-1.69]	[-1.32]	[-42.05]	[-41.94]	[-1.72]	[-1.32]	[-43.46]	[-41.97]
BM	-0.007	-0.005	0.024***	0.023***	-0.007	-0.005	0.023***	0.023***
	[-0.98]	[-0.64]	[8.55]	[7.25]	[-0.99]	[-0.64]	[8.56]	[7.26]
PCFVOL	0.017***	0.012**			0.016***	0.012**		
	[3.34]	[2.29]			[3.32]	[2.30]		
ZSCORE	0.002	0.002			0.002	0.002		
	[0.75]	[0.98]			[0.81]	[1.01]		
BETA			0.002	-0.003			0.002	-0.003
			[0.40]	[-0.58]			[0.45]	[-0.53]
IVOL			0.478***	0.291**			0.483***	0.299**
			[3.13]	[2.21]			[3.15]	[2.27]
Industry fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	6,578	6,578	3,169	3,169	6,578	6,578	3,169	3,169
Adjusted R-squared	0.013	0.030	0.615	0.653	0.013	0.030	0.613	0.652

Note: Table IA1 reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*, using alternative industry-based definitions of emitters and non-emitters. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimat

Table IA2: Controlling for Possible Confounding Factors

	COD				*COE*			
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EMITTER×POST	**0.062*** **	**0.062*** **	**0.062*** **	**0.054** **	**0.029** **	**0.027** **	**0.027** **	**0.025** **
	[2.95]	[2.94]	[2.94]	[2.53]	[2.40]	[2.27]	[2.27]	[2.05]
EMITTER	-0.018	-0.018	-0.018		-0.027***	-0.025**	-0.025**	
	[-1.28]	[-1.28]	[-1.28]		[-2.65]	[-2.49]	[-2.54]	
POST	0.017	0.013	-0.006	-0.002	-0.044***	-0.015**	0.009	0.008
	[0.87]	[0.80]	[-0.21]	[-0.07]	[-4.87]	[-2.40]	[0.72]	[0.73]
SIZE	-0.005*	-0.005*	-0.005*	-0.004	-0.068***	-0.069***	-0.069***	-0.073***
	[-1.71]	[-1.67]	[-1.71]	[-1.39]	[-22.87]	[-22.85]	[-22.93]	[-24.60]
BM	-0.007	-0.008	-0.007	-0.004	0.024***	0.025***	0.025***	0.024***
	[-0.99]	[-1.03]	[-1.01]	[-0.54]	[5.83]	[6.17]	[6.07]	[5.10]
CFVOL	0.016***	0.017***	0.016***	0.012**				
	[3.29]	[3.33]	[3.28]	[2.22]				
ZSCORE	0.002	0.002	0.002	0.002				
	[0.78]	[0.78]	[0.77]	[0.87]				
BETA					0.002	-0.001	-0.001	-0.000
					[0.35]	[-0.09]	[-0.09]	[-0.01]
IVOL					0.480***	0.431***	0.419***	0.399***
					[3.00]	[2.76]	[2.71]	[2.61]
CPI	0.003		0.029	0.034	0.019		-0.037**	-0.032**
	[0.10]		[0.77]	[0.90]	[1.36]		[-2.30]	[-1.99]
LRI		0.066	0.113	0.111		-0.202***	-0.260***	-0.263***
		[0.74]	[1.05]	[1.03]		[-5.31]	[-5.83]	[-5.87]
Industry fixed effects	No	No	No	Yes	No	No	No	Yes
Year fixed effects	No	No	No	No	No	No	No	No
Observations	6,578	6,578	6,578	6,578	3,169	3,169	3,169	3,169
Adjusted R-squared	0.013	0.013	0.013	0.030	0.614	0.617	0.618	0.635

Note: Table IA2 reports the results of difference-in-differences regressions of cost of debt (*COD*) and cost of equity (*COE*) on *EMITTER*, *POST* dummies, and an interaction term *EMITTER*POST*. All regressions control for market capitalization (*SIZE*), book-to-market ratio (*BM*), and the commodity price index (*CPI*) and/or the labor regulation index (*LRI*). *COD* regressions further control for past cash-flow volatility (*CFVOL*), and z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*), and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table IA3: Excluding Transition Year 2008

	COD		*COE*	
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.074*****	**0.066*****	**0.037*****	**0.035****
	[3.34]	**[2.90]**	**[2.71]**	**[2.46]**
EMITTER	-0.017		-0.027***	
	[-1.22]		[-2.75]	
POST	0.018		-0.043***	
	[1.29]		[-6.95]	
SIZE	-0.006*	-0.005	-0.068***	-0.072***
	[-1.90]	[-1.51]	[-22.50]	[-24.59]
BM	-0.010	-0.008	0.025***	0.023***
	[-1.45]	[-1.12]	[6.18]	[4.96]
CFVOL	0.015***	0.011**		
	[3.11]	[2.05]		
ZSCORE	0.002	0.002		
	[1.04]	[1.13]		
BETA			0.003	-0.001
			[0.50]	[-0.14]
IVOL			0.433***	0.299**
			[2.78]	[2.14]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	6,009	6,009	2,893	2,893
Adjusted R-squared	0.015	0.034	0.618	0.653

Note: Table IA3 reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*, with the transition year 2008 being excluded. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author’s estimate.

Table IA4: Alternative Event Windows (Excluding 2008)

Event Window	**(-2, 2)**				**(-3, 3)**			
	COD		***COE***		***COD***		***COE***	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EMITTER×POST	**0.086*****	**0.082****	**0.043****	**0.035****	**0.078*****	**0.071*****	**0.028***	**0.026***
	[2.74]	**[2.56]**	**[2.26]**	**[1.98]**	**[2.86]**	**[2.59]**	**[1.82]**	**[1.72]**
EMITTER	-0.013		-0.047***		-0.005		-0.030***	
	[-0.56]		[-3.64]		[-0.29]		[-2.70]	
POST	0.006		-0.040***		0.014		-0.033***	
	[0.33]		[-4.59]		[0.94]		[-4.69]	
SIZE	-0.008	-0.005	-0.067***	-0.069***	-0.009**	-0.007	-0.071***	-0.074***
	[-1.40]	[-0.93]	[-18.39]	[-18.90]	[-1.98]	[-1.62]	[-20.90]	[-21.36]
BM	-0.021*	-0.017	0.024***	0.021***	-0.018**	-0.014	0.024***	0.021***
	[-1.82]	[-1.42]	[4.31]	[3.36]	[-2.08]	[-1.61]	[4.69]	[3.68]
CFVOL	0.005	-0.002			0.007	0.002		
	[0.62]	[-0.20]			[1.04]	[0.31]		
ZSCORE	0.001	0.001			0.002	0.003		
	[0.23]	[0.30]			[0.77]	[0.92]		
BETA			0.000	-0.007			-0.003	-0.008
			[0.04]	[-0.63]			[-0.45]	[-0.91]
IVOL			0.725***	0.516**			0.486**	0.334*
			[3.47]	[2.42]			[2.52]	[1.82]
Industry fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2,261	2,260	1,150	1,149	3,343	3,343	1,727	1,727
Adjusted R-squared	0.011	0.033	0.613	0.649	0.013	0.029	0.640	0.673

Table IA4 continuation

Event Window	**(-4, 4)**				**(-5, 5)**			
	COD		***COE***		***COD***		***COE***	
Variable	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
EMITTER×POST	**0.069*****	**0.061****	**0.028****	**0.027***	**0.072*****	**0.064*****	**0.038*****	**0.034****
	[2.88]	**[2.51]**	**[2.00]**	**[1.88]**	**[3.16]**	**[2.72]**	**[2.76]**	**[2.41]**
EMITTER	-0.005		-0.027**		-0.013		-0.030***	
	[-0.30]		[-2.47]		[-0.86]		[-2.84]	
POST	0.025*		-0.030***		0.021		-0.042***	
	[1.76]		[-4.85]		[1.43]		[-6.70]	
SIZE	-0.007**	-0.006*	-0.070***	-0.074***	-0.006*	-0.005*	-0.067***	-0.071***
	[-2.00]	[-1.67]	[-21.49]	[-22.94]	[-1.95]	[-1.69]	[-21.73]	[-24.06]
BM	-0.012	-0.008	0.025***	0.022***	-0.012*	-0.009	0.025***	0.023***
	[-1.53]	[-1.07]	[5.31]	[4.25]	[-1.66]	[-1.33]	[5.86]	[4.81]
CFVOL	0.011*	0.006			0.014***	0.009*		
	[1.88]	[1.05]			[2.66]	[1.65]		
ZSCORE	0.001	0.002			0.003	0.003		
	[0.55]	[0.63]			[1.19]	[1.41]		
BETA			-0.002	-0.008			0.003	-0.001
			[-0.28]	[-1.11]			[0.53]	[-0.12]
IVOL			0.506***	0.409***			0.446***	0.302**
			[3.33]	[2.85]			[2.67]	[2.05]
Industry fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	4,416	4,416	2,253	2,253	5,465	5,464	2,739	2,739
Adjusted R-squared	0.014	0.028	0.644	0.676	0.014	0.034	0.618	0.656

Note: Table IA4 reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*, using alternative event windows with the transition year 2008 being excluded. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table IA5: Controlling for Firm Fixed Effects (Excluding 2008)

Event Window	(-2, 2)		(-3, 3)		(-4, 4)		(-5, 5)	
	COD	***COE***	***COD***	***COE***	***COD***	***COE***	***COD***	***COE***
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EMITTER×POST	**0.049***	**0.050*****	**0.053****	**0.045*****	**0.049****	**0.050*****	**0.048****	**0.060*****
	[1.74]	**[2.91]**	**[2.08]**	**[3.24]**	**[2.09]**	**[3.76]**	**[2.21]**	**[4.45]**
SIZE	0.005	-0.064***	0.016	-0.080***	0.001	-0.079***	-0.010	-0.072***
	[0.34]	[-3.63]	[1.56]	[-7.06]	[0.10]	[-8.54]	[-1.39]	[-8.33]
BM	-0.013	0.059***	-0.009	0.045***	-0.010	0.041***	-0.019**	0.044***
	[-0.88]	[3.16]	[-0.77]	[3.74]	[-1.04]	[4.09]	[-2.22]	[4.86]
CFVOL	-0.010		-0.001		0.003		0.004	
	[-0.85]		[-0.14]		[0.41]		[0.67]	
ZSCORE	0.004		0.008**		0.004		0.004*	
	[0.84]		[2.17]		[1.57]		[1.65]	
BETA		0.009		-0.001		-0.006		0.001
		[0.86]		[-0.06]		[-0.82]		[0.09]
IVOL		0.157		-0.337		0.034		-0.031
		[0.42]		[-1.44]		[0.20]		[-0.22]
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,102	1,017	3,187	1,589	4,248	2,126	5,312	2,622
Adjusted R-squared	0.315	0.765	0.239	0.801	0.184	0.801	0.196	0.769

Note: Table IA5 reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on an interaction term *EMITTER×POST*, controlling for firm and year fixed effects and using alternative event windows with the transition year 2008 being excluded. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table IA6: Excluding Financial Industries

Variable	COD		COE	
	(1)	(2)	(3)	(4)
EMITTER×POST	**0.062*****	**0.056*****	**0.031*****	**0.025****
	[2.91]	**[2.58]**	**[2.97]**	**[2.34]**
EMITTER	-0.013		-0.019***	
	[-0.97]		[-2.83]	
POST	0.019		-0.036***	
	[1.34]		[-6.76]	
SIZE	-0.006**	-0.005*	-0.073***	-0.076***
	[-2.28]	[-1.69]	[-35.54]	[-35.46]
BM	-0.007	-0.004	0.017***	0.017***
	[-0.94]	[-0.49]	[5.04]	[4.87]
CFVOL	0.017***	0.013**		
	[3.47]	[2.50]		
ZSCORE	0.002	0.002		
	[0.90]	[1.05]		
BETA			0.002	-0.003
			[0.32]	[-0.41]
IVOL			0.691***	0.439***
			[3.96]	[2.74]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	6,357	6,357	2,426	2,426
Adjusted R-squared	0.015	0.030	0.615	0.644

Note: Table IA6 reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*, with financial firms being excluded. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table IA7: Controlling for Liquidity

	COD		*COE*	
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.061*****	**0.053****	**0.032****	**0.028***
	[2.89]	**[2.46]**	**[2.29]**	**[1.94]**
EMITTER	-0.020		-0.021*	
	[-1.41]		[-1.88]	
POST	0.018		-0.036***	
	[1.29]		[-5.60]	
SIZE	-0.004	-0.003	-0.069***	-0.078***
	[-1.27]	[-1.01]	[-14.00]	[-16.48]
BM	-0.000	0.000	0.021***	0.019***
	[-0.03]	[0.04]	[4.44]	[3.93]
CFVOL	0.013**	0.010*		
	[2.53]	[1.81]		
ZSCORE	0.002	0.002		
	[0.96]	[1.07]		
CASH	0.123***	0.097**		
	[3.09]	[2.43]		
BETA			-0.004	-0.006
			[-0.63]	[-0.83]
IVOL			0.843***	0.519**
			[3.76]	[2.38]
AMIHUD			-0.001	-0.002
			[-0.44]	[-1.27]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	6,578	6,578	2,565	2,565
Adjusted R-squared	0.013	0.030	0.600	0.639

Note: Table IA7 reports the results of difference-in-differences regressions of cost of debt (*COD*) and cost of equity (*COE*) on *EMITTER*, *POST* dummies, and an interaction term *EMITTER*POST*. All regressions control for market capitalization (*SIZE*), and book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*), z-score (*ZSCORE*), and cash holdings (*CASH*). *COE* regressions further control for market beta (*BETA*), idiosyncratic volatility (*IVOL*), and Amihud illiquidity (*AMIHUD*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table IA8: Controlling for the Global Financial Crisis

	COD		***COD***		***COE***		***COE***	
	Including GFC dummy (08-09)		**Excluding GFC period (08-09)**		**Including GFC dummy (08-09)**		**Excluding GFC period (08-09)**	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EMITTER×POST	**0.070*****	**0.060****	**0.071*****	**0.063*****	**0.051*****	**0.050*****	**0.051*****	**0.051*****
	[3.01]	[2.55]	[3.06]	[2.65]	[3.10]	[2.87]	[3.08]	[2.90]
EMITTER	-0.020		-0.019		-0.019*		-0.020*	
	[-1.41]		[-1.38]		[-1.74]		[-1.77]	
POST	0.015		0.016		-0.055***		-0.055***	
	[1.03]		[1.10]		[-7.84]		[-7.83]	
EMITTER×GFC	**-0.026**	**-0.023**			**-0.051*****	**-0.051*****		
	[-0.86]	[-0.74]			[-2.83]	[-2.72]		
GFC	0.007				0.060***			
	[0.41]				[7.73]			
SIZE	-0.004	-0.003	-0.005*	-0.004	-0.072***	-0.078***	-0.071***	-0.080***
	[-1.27]	[-1.01]	[-1.76]	[-1.53]	[-14.39]	[-16.66]	[-14.54]	[-17.03]
BM	-0.001	0.000	-0.004	-0.003	0.021***	0.019***	0.020***	0.018***
	[-0.07]	[0.01]	[-0.54]	[-0.48]	[4.39]	[3.84]	[4.41]	[3.63]
CFVOL	0.013**	0.010*	0.011**	0.008				
	[2.51]	[1.80]	[2.14]	[1.46]				
ZSCORE	0.002	0.002	0.002	0.002				
	[0.97]	[1.07]	[0.75]	[0.74]				
CASH	0.124***	0.097**	0.114***	0.090**				
	[3.10]	[2.44]	[2.87]	[2.34]				
BETA					-0.005	-0.006	-0.007	-0.011
					[-0.73]	[-0.86]	[-1.01]	[-1.53]
IVOL					0.570***	0.521**	0.753***	0.706***
					[2.62]	[2.39]	[3.38]	[3.07]
AMIHUD					-0.002	-0.002	-0.002	-0.003*
					[-1.06]	[-1.33]	[-0.89]	[-1.74]
Industry fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	6,578	6,578	5,442	5,442	2,565	2,565	2,082	2,082
Adjusted R-squared	0.016	0.032	0.017	0.038	0.611	0.640	0.616	0.645

Note: Table IA8 reports the results of difference-in-differences regressions of cost of debt (*COD*) and cost of equity (*COE*) on *EMITTER*, *POST* dummies, and an interaction term *EMITTER*POST*. All regressions control for market capitalization (*SIZE*), and book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*), Z-score (*ZSCORE*), and cash holdings (*CASH*). *COE* regressions further control for market beta (*BETA*), idiosyncratic volatility (*IVOL*), and Amihud illiquidity (*AMIHUD*). The global financial crisis time is defined to be 2008–2009 period. *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.

Table IA9: Cost of Capital in Year (t+1)

	COD(t+1)		*COE(t+1)*	
Variable	(1)	(2)	(3)	(4)
EMITTER×POST	**0.059*****	**0.051****	**0.053*****	**0.052*****
	[2.81]	**[2.36]**	**[3.36]**	**[3.12]**
EMITTER	-0.006		-0.033***	
	[-0.39]		[-2.72]	
POST	0.024*		-0.047***	
	[1.84]		[-6.81]	
SIZE	-0.003	-0.002	-0.061***	-0.069***
	[-0.88]	[-0.73]	[-12.34]	[-15.06]
BM	-0.002	0.001	0.013***	0.015***
	[-0.23]	[0.17]	[2.78]	[3.19]
CFVOL	0.015***	0.011**		
	[3.00]	[1.97]		
ZSCORE	0.006***	0.006***		
	[2.90]	[3.10]		
CASH	0.132***	0.108***		
	[3.33]	[2.77]		
BETA			0.006	-0.000
			[0.95]	[-0.06]
IVOL			0.573**	0.279
			[2.48]	[1.63]
AMIHUD			0.001	-0.001
			[0.32]	[-0.66]
Industry fixed effects	No	Yes	No	Yes
Year fixed effects	No	Yes	No	Yes
Observations	6,276	6,248	2,650	2,648
Adjusted R-squared	0.018	0.035	0.501	0.568

Note: Table IA9 reports the results of difference-in-differences regressions of the cost of debt (*COD*) and the cost of equity (*COE*) on *EMITTER* and *POST* dummies, and an interaction term *EMITTER×POST*, with *COE* being measured in year *t+1*. All regressions control for market capitalization (*SIZE*), and the book-to-market ratio (*BM*). *COD* regressions further control for past cash-flow volatility (*CFVOL*) and Z-score (*ZSCORE*). *COE* regressions further control for market beta (*BETA*) and idiosyncratic volatility (*IVOL*). *t*-statistics based on robust standard errors clustered by firms are provided in brackets. Detailed definitions of all variables are provided in appendixes. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimate.