CORPORATE CARBON PERFORMANCE AND ACCESS TO FINANCE: EMPIRICAL EVIDENCE FROM ASIA-PACIFIC COUNTRIES

This thesis is submitted by

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ABSTRACT

This thesis presents a series of investigations on the effect of corporate carbon performance (CCP) on a firm's access to finance. In particular, these studies examine the relationships between CCP and cost of debt (COD), cost of equity (COE) and firm risk. The research uses a sample from 14 countries in the Asia-Pacific region over the period 2002–2018. This thesis comprises three empirical studies. The first paper reports on the study that examined the CCP–COD relationship. The second paper reports on the investigation of the relationship between carbon risk (CRISK) and COE, while the third paper reports on the examination of the question of how and why CCP affects a firm's total, idiosyncratic and systematic risk. All three papers also report on the examination of whether country-level governance quality moderates or strengthens these relationships. The research particularly examines whether, and to what extent, these relationships are affected by country-level governance mechanisms.

In the first paper, COD is found to be lower when a firm has higher carbon performance (CCP). We also find that CCP produces greater reductions in COD for firms in countries with poor government effectiveness, weak regulatory quality and weak rule of law. Thus, a country-level governance mechanism and debt markets are substitutes in addressing corporate carbon performance (CCP). This means that debt markets are more sensitive to the climate change issue in a weak governance setting. Next, in the second paper, we find that firms with higher CRISK have higher implied COE, with this relationship stronger in countries with strong country-level governance. Finally, in the third paper, we find that CCP is negatively associated with a firm's total, idiosyncratic and systematic risk. We also find that CCP yields greater reductions in a firm's total and idiosyncratic (systematic) risk in countries with strong (weak) country-level governance. This study documents that debt and equity market participants are becoming more aware of firms' environmental performance and are paying close attention to corporate carbon performance (CCP).

This research employed unbalanced panel data and used the ordinary least squares (OLS) regression model to test the hypotheses after controlling for a set of firm-level and country-level variables, in addition to the year and industry dummies. To confirm our main finding, we run a series of robustness checks to control for sample selection bias, endogeneity, heterogeneity and simultaneous causality problems using alternative model specifications. We also control for the effect of the Global Financial Crisis (GFC) and the sensitivity to using sub-sample analysis and alternative measures.

This research contributes theoretically and empirically to the management and finance literature by studying the relationship between CCP and corporate financial performance (CFP) and by examining whether the findings of previous studies are robust or whether they can be generalised to another geographical scope or another time period. As previous studies have revealed mixed findings on the CCP–CFP relationship, this research aims to either support or refute the existing theoretical arguments on this relationship in a multi-country context. Although these topics are highly researched in the contexts of developed markets, we know little about whether the findings are transferrable to the Asia-Pacific context. A multi-country sample provides an additional dimension to this research; it helps us to compare countries based on the level of governance quality. Indeed, this research pioneers the study of the role of country-level governance in the CCP–CFP relationship.

Companies today are under pressure from internal and external stakeholders to take serious action regarding environmental issues and to adopt environmentally friendly strategies and activities. This research shows that managers can reduce firm risk, COD and COE by improving their carbon performance. This research has shed light on one of the indirect costs and/or benefits of green projects/carbon-intensive projects of which a manager should be aware when making an investment decision. Understanding the nature of the implications of sustainable performance is also important for diverse stakeholders. It helps a firm's creditors and investors to conduct a better evaluation of its real market value and to realise whether carbon risk economically affects its intrinsic value and, furthermore, whether carbon risk affects its credit standing. In addition, this research helps policy makers to determine the extent to which they can rely on the market mechanism to address climate change concerns and to discover the country-level governance context in which the market mechanism could have the greatest impact.

Keywords: Carbon risk, climate change, environmental performance, financial performance, financial distress, greenhouse gas (GHG), sustainability, corporate social responsibility.

DEDICATION

"In the name of **Allah**, the most gracious, the most merciful"

I dedicate this humble effort to the most precious things I have in life:

my loving **Father** and **Mother**

who give me the determination and strength

to overcome all difficulties.

Thank you for your support and encouragement.

To my lovely wife:

Reem

who is always beside me.

Thank you very much for your steadfast support and love.

You have served as my inspiration during my study.

Thank you to my darling children

Ameer and **Mohammad**

who are the beats of my heart.

CERTIFICATION OF THESIS

I ***Eltayyeb Ali Mustafa Al-Fakir Al Rabab'a*** declare that the PhD Thesis entitled "corporate carbon performance and access to finance: Empirical evidence from Asia-Pacific countries" is not more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes.

This Thesis is the work of ***Eltayyeb Ali Mustafa Al-Fakir Al Rabab'a*** except where otherwise acknowledged, with the majority of the contribution to the papers presented as a Thesis by Publication undertaken by the Student. The work is original and has not previously been submitted for any other award, except where acknowledged.

Signed: Date:

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Dr Afzalur Rashid

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Student and supervisors' signatures of endorsement are held at the University.

STATEMENT OF CONTRIBUTIONS

Three papers produced from this thesis are joint works by the authors identified below. The details of the co-authors' contributions are as follows:

- Paper 1: Al-Fakir al Rabab'a, E., Rashid, A., & Shams, S. 'Corporate carbon performance and cost of debt: Evidence from Asia-Pacific countries'. (The paper has been submitted to a suitable journal) (This paper was also presented at the 2021 Financial Markets and Corporate Governance (FMCG) Conference, 07–09 April 2021.)

  The percentages of the contributions of Eltayyeb Al-Fakir Al Rabab'a, Afzalur Rashid and Syed Shams in this paper were 65%, 20% and 15%, respectively. Eltayyeb's contributions were related to the concept development, critical review of related literature, data collection; curation and analysis, and drafting of the final manuscript. Afzalur Rashid contributed to the paper's structure and layout, methodology, data interpretation and theoretical framework development. Syed Shams contributed to the hypotheses development, empirical models and data analysis.

- Paper 2: Al-Fakir al Rabab'a, E., Shams, S., & Rashid, A. 'Carbon risk and cost of equity: The role of country-level governance' (The paper has been submitted to a suitable journal).

  The percentages of the contributions of Eltayyeb Al-Fakir Al Rabab'a, Syed Shams and Afzalur Rashid in this paper were 70%, 20% and 10%, respectively. Eltayyeb's contributions were related to the concept development, critical review of related literature, data collection; curation and analysis, hypotheses development and drafting of the final manuscript. Syed Shams contributed to the methodology, hypotheses development, empirical models and data analysis. Afzalur Rashid contributed to the paper's structure and theoretical framework development.

- Paper 3: Al-Fakir al Rabab'a, E., Rashid, A., & Shams, S. 'Corporate carbon performance and firm risk: Evidence from Asia-Pacific countries'. (The paper has been paper submitted to a suitable journal).

  The percentages of the contributions of Eltayyeb Al-Fakir Al Rabab'a, Afzalur Rashid and Syed Shams in this paper were 75%, 15% and 10%, respectively. Eltayyeb's contributions were related to the concept development, critical review of related literature, developing the theoretical framework and hypotheses, data collection, curation and analysis, and drafting of the final manuscript. Afzalur Rashid contributed to the paper's structure and layout, methodology and data interpretation. Syed Shams contributed to the empirical models and data analysis.

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ABBREVIATIONS

2SLS	two-stage least squares
ADR	Anti-Director Rights (Index)
AF	(debt) adjustment factor
ASX	Australian Securities Exchange
BSE	Bombay Stock Exchange
CAPM	capital asset pricing model
CCP	corporate carbon performance
CDP	Carbon Disclosure Project
CEO	Chief Executive Officer
CEP	corporate environmental performance
CER	corporate environmental responsibility
CFP	corporate financial performance
CMS	carbon mitigation score
CO_2	carbon dioxide
COC	cost of capital
COD	cost of debt
COE	cost of equity
CR	credit rating
CRISK	carbon risk
CSE	Colombo Stock Exchange
CSR	corporate social responsibility
CT	capital turnover
CVs	control variables
DiD	difference-in-differences (model)
DV	dependent variable
EMP	environmental management performance
EOP	environmental operational performance
EPS	earnings per share
ERM	enterprise risk management (system)

ESG	environmental, social and governance
FDI	foreign direct investment
FE	fixed effects
FMC	fair market curve
FMCG	financial markets and corporate governance
GDP	gross domestic product
GE	government effectiveness
GFC	Global Financial Crisis
GHG	greenhouse gase
GMM	generalised method of moments (model)
H1	Hypothesis 1
H1a	Hypothesis 1a
H1b	Hypothesis 1b
H1c	Hypothesis 1c
H2a	Hypothesis 2a
H2b	Hypothesis 2b
H2c	Hypothesis 2c
ICB	Industrial Classification Benchmark
IDX	Indonesia Stock Exchange
IMF	International Monetary Fund
IND-V	independent variable
IPCC	Intergovernmental Panel on Climate Change
IV	instrumental variable
JASDAQ	Japan Association of Securities Dealers Automated Quotation
KRX	South Korea Stock Exchange
LCC	low-carbon city
LTG	long-term growth
M&As	mergers and acquisitions
MV	market value
MVA	market value added

MYX	Malaysia Stock Exchange
NGER	National Greenhouse and Energy Reporting System
NGOs	non-governmental organisations
NOx	nitrogen oxides
NSE	Nagoya Stock Exchange
NSE	National Stock Exchange of India
NZX	New Zealand Stock Market
OLS	ordinary least squares
PPE	property, plant and equipment
PSE	Philippines Stock Market
PSM	propensity score matching
R&D	research and development
RFC	reason for concern (IPCC)
RL	rule of law
ROA	return on assets
ROE	return on equity
ROI	return on investment
ROS	return on sales
RQ	regulatory quality
S&P	Standard & Poor
SD	standard deviation
SE	standard error
SEHK	Hong Kong Stock Exchange
SET	Thailand Stock Market
SGX	Singapore Stock Exchange
SOx	sulphur oxides
SSE	Shanghai Stock Exchange
SZSE	Shenzhen Stock Exchange
TRI	Toxics Release Inventory Program
TSE	Tokyo Stock Exchange

TSR	total shareholder return
TWSE	Taiwan Stock Exchange
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US/USA	United States/United States of America
VIF	variance inflation factor
WACC	weighted average cost of capital

CHAPTER 1: INTRODUCTION

1.1 Chapter overview

This chapter introduces the thesis by presenting an overview of the topic. The chapter is organised as follows: Section 1.1 provides the overview of this chapter. Section 1.2 provides background on the climate change problem, the international efforts to mitigate this problem and the role of financial markets in this matter. Section 1.3 highlights the research aims, objectives and questions, followed by Section 1.4 which outlines the research motivations and significance. Section 1.5 provides a summary of the related literature, while Section 1.6 presents the contributions of this research and identifies the knowledge gap and Section 1.7 provides the conceptual framework and underlying hypotheses. Section 1.8 provides the research philosophy, while Section 1.9 describes the thesis organisation. Figure 1.1 below presents the graphical layout of this chapter.

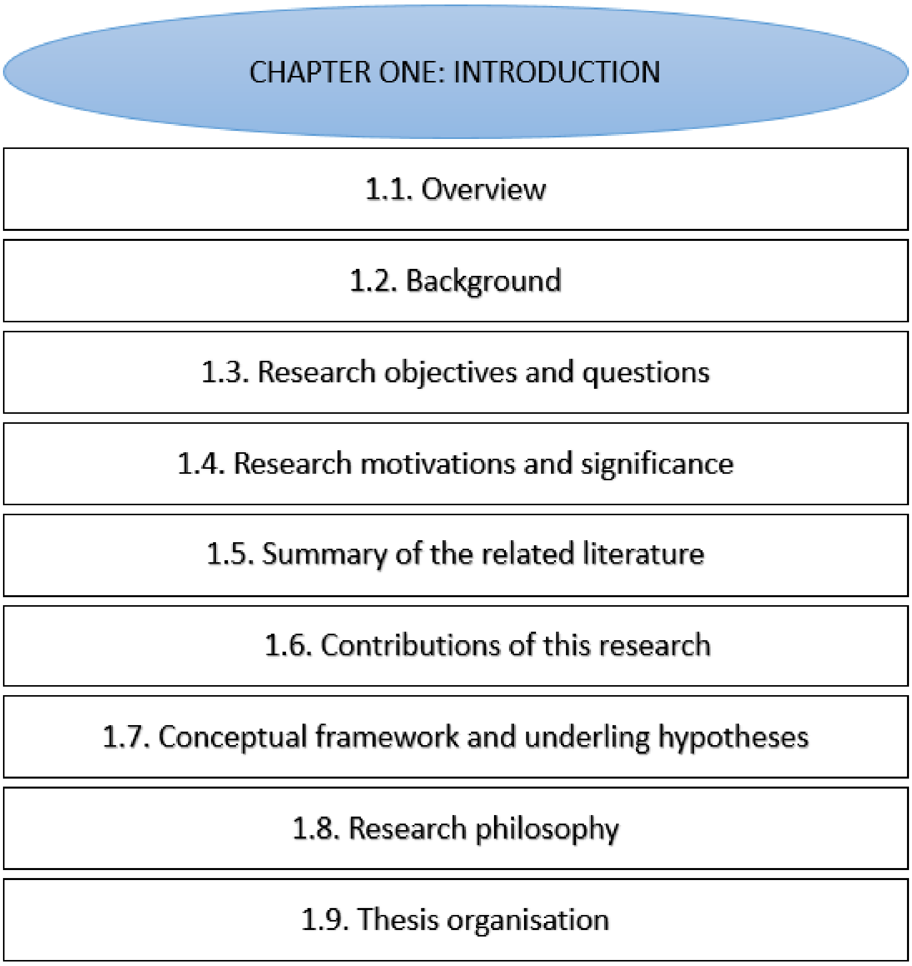

Figure 1.1. Flow chart for Chapter 1

Source: developed by the author

1.2 Background

> Mischief has appeared on land and sea because of (the evil) which people's hands have done, that (Allah) may make them taste a part of their deeds, in order that they may return (from the evil). Al-Quran: Surah Ar-Rum – Verse number 41

Anthropogenic effects on the environment have occurred since time immemorial. However, since the last century, the world has witnessed an accelerating increase in human activity at a level which mankind has never seen before to the extent that it is affecting the ecosystem on our planet. These concerns were summarised by a group of scholars, including 99 of the 196 living Nobel laureates, who penned the "World Scientists' Warning to Humanity" in 1992 (Ripple et al., 2017), putting forward a stark message about climate change. They expressed their grave concern about current and potential destruction on our planet, including ozone depletion, freshwater availability, ocean dead zones, soil productivity loss, forest loss, the irreversible loss of species and climate change. The production of greenhouse gas (GHG), the main cause of the climate change problem, receives a large part of the attention and is the core of the recent environmental debate. Therefore, this study particularly focuses on this issue.

The climate change problem has recently attracted widespread attention as one of the major concerns in this era. It has been acknowledged that overdependence on unsustainable energy sources is a real threat to ecological systems and human lives (Busch & Lewandowski, 2018; Stern, 2007). As part of global efforts to mitigate this problem, in 1992, many countries established an international treaty to reduce global warming. They formed the United Nations Framework Convention on Climate Change (UNFCCC). This treaty resulted in the adoption of the Kyoto Protocol in 1997 which aimed to mitigate climate change and global warming problems. In late 2015, 196 nations adopted a legally binding international agreement on climate change (the Paris Agreement) to limit global warming to a maximum of two degrees Celsius (2°C) compared to pre-industrial levels.[1]

In response to these initiatives, many countries have enacted legislation and adopted policies to reduce greenhouse gas (GHG) emissions, one of the elements that causes great concern (Lee et al., 2015). However, in recent years, countries have experienced a continuing increase in GHG emissions. Based on data from World Bank databases, Figure 1.2 shows the volume of global annual CO_2 emissions that stem from burning fossil fuels (solid, liquid and gas fuels) and cement manufacturing processes. As indicated in the figure, in the early 1960s, CO_2 emissions were below the 10-gigaton level. They then gradually grew to above the 35-

[1] See https://unfccc.int

gigaton mark in 2018. Thus, the numbers have more than tripled over that period, suggesting a recent exacerbation of the climate change problem.

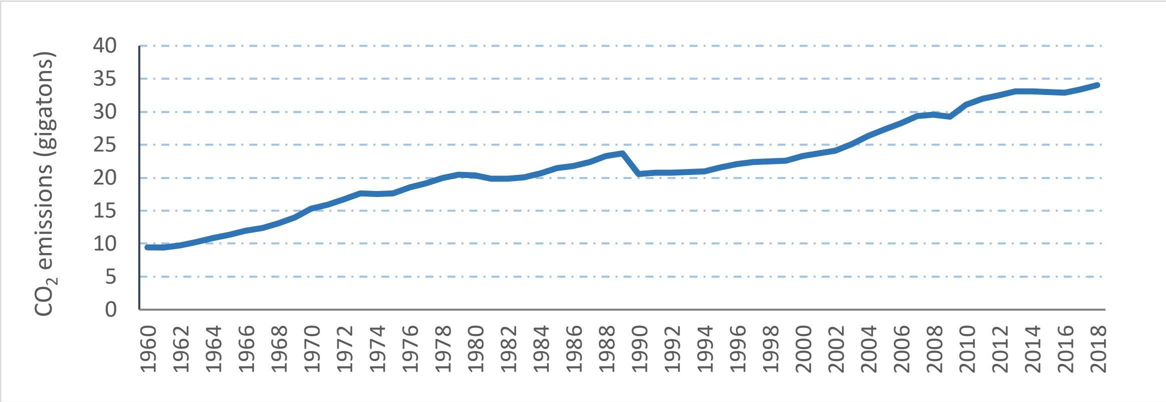

Figure 1.2. World carbon dioxide (CO_2) emissions in million kilotons (gigatons) between 1960 and 2018

Source: developed by the researchers based on data from World Bank databases

According to the Intergovernmental Panel on Climate Change (IPCC)[2], global warming has reached 1.0°C above pre-industrial levels and, if human activities continue to cause this phenomenon to increase at the current rate, it will undoubtedly reach 1.5°C by 2030. Although these numbers may seem small, and even modest to some people, in reality, they have a large impact on people, economies and ecosystems. For example, as found in its assessment in the recent literature, the IPCC (2018) provides a framework for the key impacts and risks of global warming in five “reasons for concern” (RFC1–RFC5). Figure 1.3 illustrates these five categories at different levels of global warming. As can be seen, climate change-related impacts on different categories have already been observed. The impacts on people’s health, economic growth and ecosystems are expected to increase when global warming reaches a 1.5°C level above pre-industrial levels, with further impacts with an increase to the 2°C level.

[2] The United Nations Intergovernmental Panel on Climate Change (IPCC) is the United Nations (UN) body established to provide and assess scientific information related to climate change.

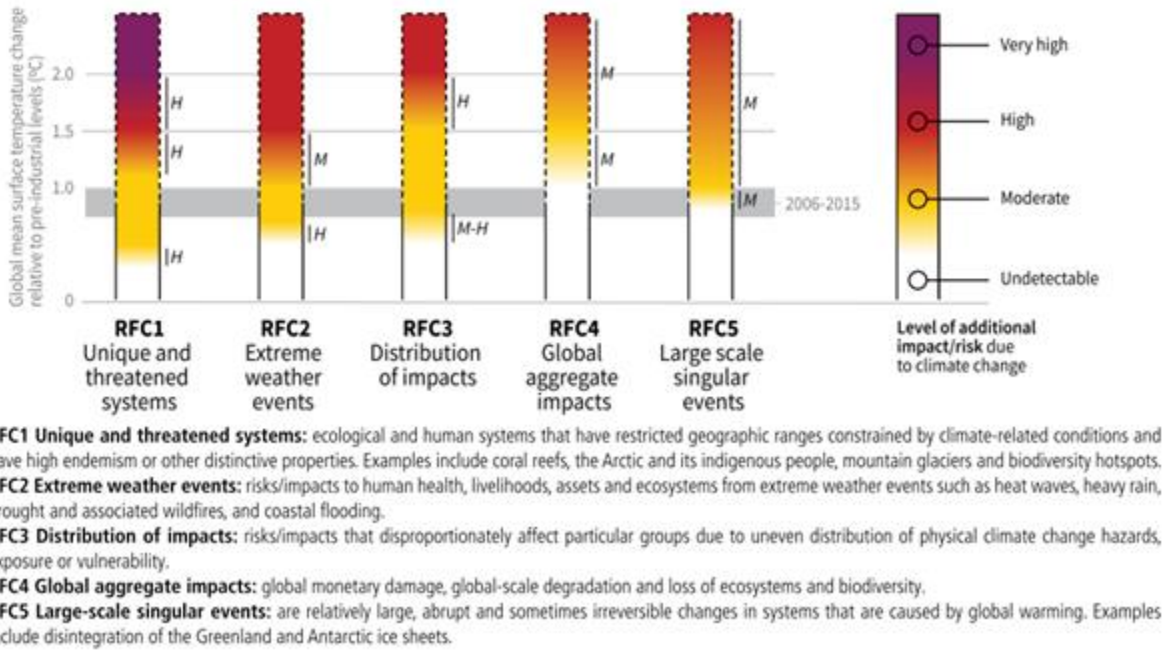

Figure 1.3. Risk level of different levels of global warming for ecosystems

Source: IPCC (2018)

The increase in human activities has coincided with developments in the concept of the company. Companies are now seen as the backbone of economic life. At the same time, they are also responsible for most global carbon emissions. For example, 100 of the world's companies produce nearly 1 trillion tonnes of GHG emissions, contributing more than 70% of global industrial carbon emissions (Griffin, 2017). Therefore, they can play a fundamental role in paving the way for a low carbon economy. In this regard, a huge amount of academic interest has been stimulated to explore the implications and determinants of firms' exposure to climate change-related risk. However, to build a better understanding about the motivations or constraints of adopting green strategies, more empirical and theoretical studies are needed to enable firms, their stakeholders (e.g., investors, creditors and customers) and policy makers to determine whether they are heading in the right direction.

As companies are key components of international efforts to reduce carbon emissions, they need to carry out their responsibilities in this regard. Activities that aim to mitigate the climate change problem and improve carbon performance are important parts of corporate social responsibility (CSR). Under the CSR concept, firms must consider not only the economic profits but also the social and environmental impacts of their operations. As the CSR concept has received increasing attention in recent years, a noticeable increase has occurred in the number of a firm's stakeholders who consider the social and environmental ratings (e.g., the environmental, social and governance [ESG] ratings) in their decisions (Cheung et al., 2018; Lagasio & Cucari, 2019). This attention to a firm's social and environmental issues shapes its strategic plans and influences its daily procedures. For example, Holder-Webb et al. (2009) indicate that the increase in investors' funds directed to socially and environmentally responsible firms undoubtedly will lead firms to pay more attention to this aspect. Firms attach significant importance to CSR-related disclosure and dedicate an important part of their annual reports to documenting this kind of information (Chan et al., 2014). For example, in our sample, a progressive increase was found in the number of observations over the sample period, reflecting the increase in carbon-related disclosures over time. As shown in Figure 1.4, our sample contained 14 and 16 firms in 2002 and 2003, respectively. The numbers then gradually increased to reach 823 firms in 2018.

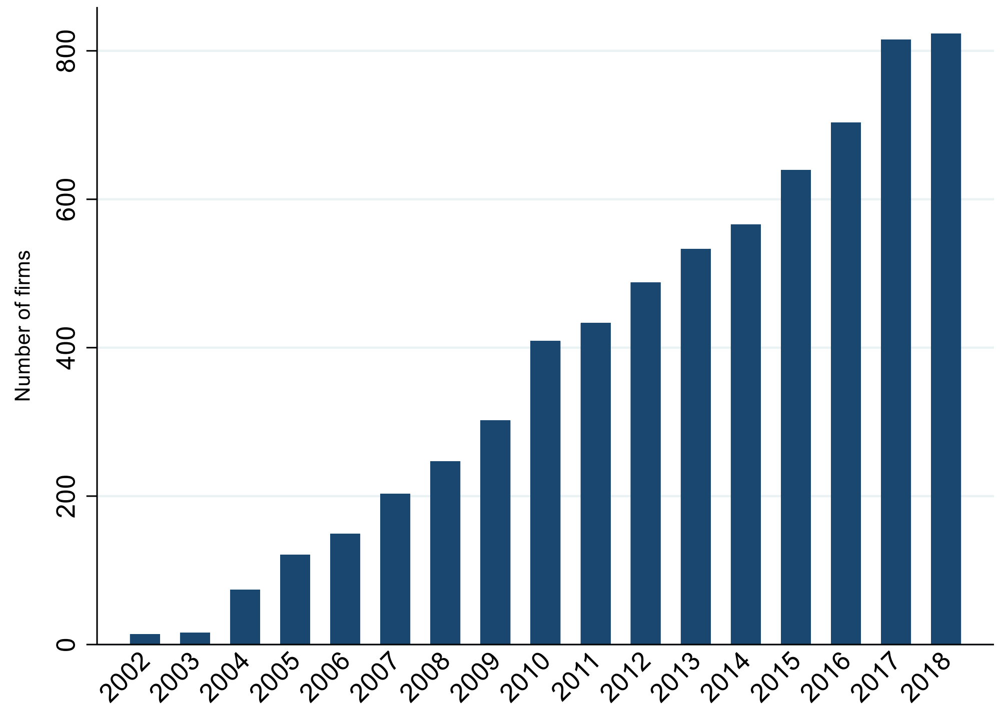

Figure 1.4. Number of firms reporting carbon data in initial sample

Source: developed by the author

Moving toward a low carbon economy necessitates collaborative efforts by different market players. Financial markets can play an essential role in providing the required finance to low carbon investments (Campiglio, 2016). Many financial institutions have already adopted risk management frameworks to assess and manage environmental and social risks (e.g., the Equator Principles).[3] Governments also need to adopt more restrictive carbon-related policies to pave the way towards a low carbon economy. With many GHG emissions stemming from industrial and energy production, firms also play a central role in accelerating the transition to

[3] http://www.equator -principles.com/

a low carbon economy. At present, they bear a large share of the climate change-related responsibility. This study sheds light on the climate change issue, one of the largest threats to human life in the current era. Having this issue receive more attention from firms' stakeholders, academics and policy makers will help to shape firms' future business activities.

Mounting pressure has raised awareness of this problem among firms' many stakeholders (e.g., creditors, consumers, investors and governments). Stakeholders are increasingly interested in the impacts of carbon risk on a firm's performance, with this having been shown to affect a firm's strategic decisions (Xue et al., 2020). The heightened attention to climate change issues from firms' stakeholders runs parallel to academic interest in this area of study. This scholarly attention has grown in different areas of study, including the management and finance literature. A new field of research, known as carbon accounting, has emerged (Busch & Lewandowski, 2018), aiming to study corporate carbon performance (CCP) and its determinants and implications. At the same time, the literature on CCP remains highly fragmented. Indirect benefits and costs of firms' adoption of low carbon emissions practices have been heavily debated during the past two decades.

As in any other project, direct costs and benefits of green projects (e.g., initial investment, ongoing operating costs, reductions in resource use and enhancement of production efficiency) are relatively easy to measure. However, indirect benefits and costs might not be easily observable (e.g., reputational losses/gains and increases/decreases in firm risk). Therefore, to provide a clearer view of the implications of adopting low carbon practices, this research has shed light on the impact of CCP and firms' exposure to carbon risk (CRISK) on firms' financial performance, using a comprehensive multi-country sample. The research empirically focuses on three aspects of financial performance: cost of debt (COD), cost of equity (COE) and firm risk. In addition, it examines the role of country-level governance in addressing CCP or carbon risk (CRISK). Specifically, it examines whether the effect of CCP on financial performance differs with different country-level governance characteristics.

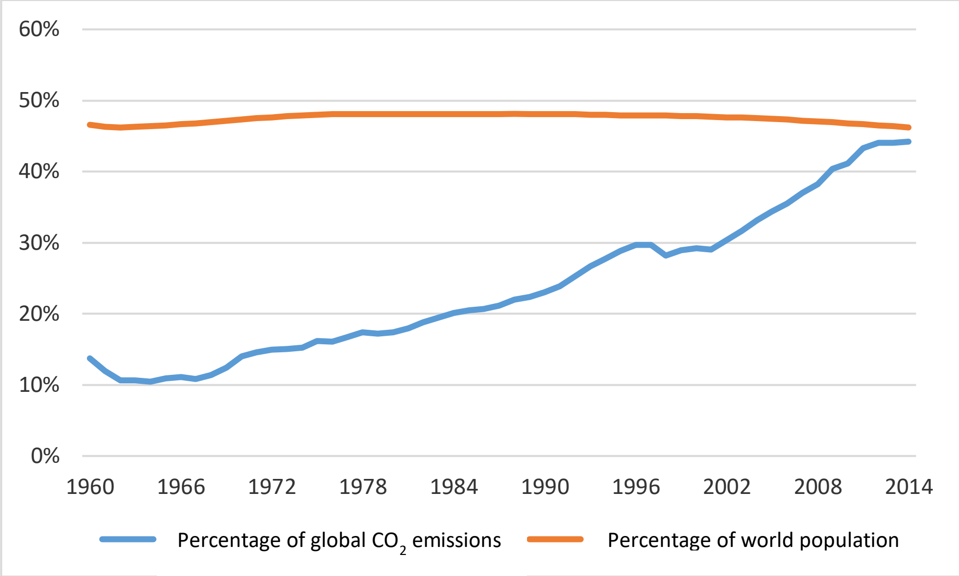

Figure 1.5. Percentage of global CO_2 emissions from countries included in sample and percentage of these countries' populations to world population (1960–2014)

Source: Developed by the researchers based on data from World Bank databases

The sample covers the period 2002–2018 and comprises data from 14 countries in the Asia-Pacific region, namely, Australia, New Zealand, China, Japan, South Korea, Hong Kong, India, Indonesia, Malaysia, Philippines, Sri Lanka, Singapore, Taiwan and Thailand. The Asia-Pacific markets provide a worthwhile setting in which to examine the research questions. These markets are experiencing increasing pressure from the international community to mitigate the climate change problem. As many of the countries in the sample are among the largest industrial countries in the world, they significantly contribute to global GHG emissions and exacerbate the climate change problem.

Figure 1.5 presents the percentage of global CO_2 emissions from countries in the sample and the percentage of these countries' populations to the world population from 1960–2014. These countries emitted approximately 44% of the world's CO_2 in 2014, compared with 14% in 1960. Over the same period, their percentage of the world population slightly decreased. As most of these countries ratified the Kyoto Protocol and other similar international treaties, they have already adopted stringent carbon-related legislation and policies with which firms must comply (Shyu, 2014), thus increasing firms' exposure to carbon risk. Therefore, firms and financial institutions are more vulnerable to carbon risk in this setting. In addition, these countries have recently experienced rapid economic growth. For example, in 2001, they contributed 24.7% of the world's gross domestic product (GDP) while, by 2018, they were contributing approximately 33% of the world's GDP (IMF, 2019).

1.3 Research objectives and questions

This research aims to empirically and theoretically examine the relationship between CCP and corporate financial performance (CFP) in a multi-country context. It aims to examine whether and how debt and equity markets price CCP or carbon risk. In particular, this research investigates whether corporate environmental responsibility (CER), in the case of carbon emissions, is correlated with COD, COE and firms' overall, systematic and idiosyncratic risk. It also aims to examine whether the impacts of CCP are different in countries with different country-level governance mechanisms.

Building on earlier work[4] on the relationship between corporate environmental performance (CEP) and CFP, this research develops and examines the following research questions. They are formed into testable hypotheses in each paper:

- Does corporate carbon performance (CCP) affect the cost of debt (COD)? (First paper)
- Does the CCP–COD relationship perform differently with different country-level governance mechanisms? (First paper)
- Does a firm's exposure to carbon risk (CRISK) affect the cost of equity (COE)? (Second paper)
- Does the CRISK–COE relationship work differently with different country-level governance mechanisms? (Second paper)
- Does corporate carbon performance (CCP) affect firm risk? (Third paper)
- Does the CCP–firm risk relationship perform differently with different country-level governance mechanisms? (Third paper)

1.4 Research motivations and significance

Companies today are under pressure from internal and external stakeholders to take serious action regarding environmental issues and to adopt environmentally friendly strategies and activities. Many governments have, for instance, implemented strategies and adopted policies to either encourage or penalise companies based on their carbon performance (Ganda, 2018). Financial markets also increasingly consider carbon risk in their investment and lending decisions, with more pressure on companies to disclose their carbon emissions information (Busch & Hoffmann, 2011). In addition, non-governmental organisations (NGOs), the media

[4] See Section 1.5

and consumers are exerting mounting pressure on companies to move toward a low carbon economy (Dixon-Fowler, Slater, Johnson, Ellstrand, & Romi, 2013).

We have several motivations for conducting this research. Firstly, as previous studies revealed mixed findings on the CCP–CFP relationship, this research aims to close this gap and contribute theoretically and empirically to support or refute the existing theoretical arguments on this relationship using a comprehensive sample from 14 countries from the Asia-Pacific region. The research aims to contribute to the literature by studying the CCP–CFP relationship and examining whether the results of previous studies are robust and can be generalised to another geographical scope or another time period.

Secondly, studies investigating the CCP–CFP relationship in a multi-country setting are rare (Caragnano, Mariani, Pizzutilo, & Zito, 2020). As mentioned earlier, scholars have made various contributions to this field of research in the past few decades. They have empirically and theoretically studied CEP, in general, and CCP, in particular. However, few studies have examined whether and how debt and equity markets price CCP in a multi-country setting. According to Dixon-Fowler et al. (2013), "[w]hile establishing a link between CEP and CFP provides an important contribution, the specific boundary conditions surrounding the relationship remain unclear" (p. 353). Therefore, many more empirical studies are required to draw a conclusion about this relationship in different contexts (Busch & Lewandowski, 2018; Lee et al., 2015; Wang, Li, & Gao, 2014).

Thirdly, a better understanding of the CCP–CFP relationship helps a firm and its creditors and investors to conduct a better evaluation of its real market value, understanding whether carbon risk economically affects the firm's intrinsic value and whether carbon risk affects its credit standing.

Finally, this research inaugurates the study of the role of country-level governance. It specifically studies whether the financial markets' evaluation of CCP is different with different country-level governance characteristics. A multi-country sample provides an additional dimension to this research; it helps us to compare countries based on the level of governance quality. Although some studies have investigated the CCP–CFP relationship (see Section 1.5), few studies have specifically examined how CCP interacts with country-level governance to influence firm risk, cost of equity (COE) and cost of debt (COD). Understanding the role of institutional and legal environments in the CCP–CFP relationship is important for firms, stakeholders and policy makers. For example, investors can understand how stock markets deal with CCP in a country with low/high governance quality. Policy makers in a weak/strong governance setting can know the extent to which they can rely on the market mechanism to deal with the carbon emissions issue.

As previous studies have yielded mixed findings (Busch & Lewandowski, 2018), examining the role of country-level governance in the CCP–CFP relationship helps to interpret some of these differences. Our study shows that the financial markets' sensitivity to CCP depends on country-level government quality, regulatory quality and rule of law.

This research and its findings are likely to have significant implications for policy makers. The findings will assist them in handling and mitigating the carbon emissions issue at the country level. Policy makers have two choices for dealing with companies' carbon emissions: direct interventions or relying on the market mechanism. They can incentivise green firms (e.g., provide a fiscal stimulus) and/or undertake direct lobbying of those with bad performance (e.g., fines and carbon tax). Although these approaches can produce quicker results, they have some disadvantages. For example, if monitoring and measuring firms' climate change-related activities are applicable, this would be costly. In addition, one of the main obstacles to enacting stricter environmental regulations is the fear of a slowdown in economic growth or of local companies' loss of their international competitive advantage. Therefore, for a quick and safe transition to a low carbon economy, policy makers need to balance between a company's environmental performance and its financial return.

In addition to the above approaches, policy makers can also rely on the market mechanism to deal with the carbon emissions issue. Markets can motivate or penalise firms based on their environmental performance through participants' interactions in the market. For example, a firm's reluctance to respond to increasing environmental pressure from diverse stakeholders (e.g., the media, the general public and environmental activists) will lead to a loss in its reputation, and clients may boycott its products or services. Creditors may consider this an indicator of the presence of potential business risk, while investors may refrain from buying its shares. This will force a firm to adopt green strategies that are aligned with stakeholders' expectations.

This research and its findings help policy makers to determine the extent to which they can rely on the market mechanism to deal with these concerns and in which governance context the market mechanism will have the greatest impact. For example, our study shows that stock markets are less sensitive to CCP in a weak governance setting. Therefore, in developing or less-developed countries, policy makers cannot rely on the market mechanism to alleviate this problem as effectively as would be the case in developed countries. For a greater reliance on the market mechanism, rather than direct government interventions, policy makers need to raise awareness on the climate change issue, target and influence public opinion and improve firms' carbon awareness and carbon-related disclosure.

Understanding the essence of the CCP–CFP relationship is also important for managers. With CCP being valued by stock and debt markets, managers can increase their investor base and reduce firm risks, COD and COE by improving firms' carbon performance. Our findings show that firms can access capital at a lower cost if they positively deal with carbon emissions. In addition, this research helps firms to conduct more accurate feasibility studies for investments. When firms intend to undertake a new investment, they must consider the above-mentioned benefits of green investments in their decision-making process or, conversely, the opportunity cost of choosing non-green investments. This research will also raise firms' awareness of the need for carbon risk to become part of their risk management activities.

1.5 Summary of the related literature

This section summarises the previous studies related to our research. In each of the three papers, we also review the related literature that helped in the development of our hypotheses. This research belongs to the group of numerous studies that focus on firms' performance on the climate change issue as part of their overall corporate environmental and social responsibility. For several decades, the impact of CEP on CFP has been a widely discussed issue and a worthwhile topic and subject for theoretical and empirical research. Some studies have examined the association between CEP and profitability (e.g., Busch & Hoffmann, 2011; Clarkson et al., 2008; Fujii et al., 2013; Iwata & Okada, 2011; Lannelongue et al., 2015; Misani & Pogutz, 2015); firm risk (e.g., Cai et al., 2016; Muhammad et al., 2015a); dividend policies (e.g., Balachandran & Nguyen, 2018; Cheung et al., 2018); and cost of capital (e.g., El Ghoul et al., 2018; Fonseka et al., 2019; Sharfman & Fernando, 2008).

Two research streams exist in the CCP literature. The first stream examines the determinants of CCP that could help a firm to reduce its carbon-related risk. For example, some studies examine board gender diversity, board nationality diversity, board independence and the existence of a sustainability committee (Atif et al., 2020; Atif et al., 2021; Ben-Amar et al., 2017; de Villiers et al., 2011; Haque, 2017; Kılıç & Kuzey, 2019; Liao et al., 2015); a firm's life cycle (Tascón et al., 2021); resource availability (Luo, 2013; Subramaniam et al., 2015); the presence of an emissions trading scheme, competitor pressure and the legal system (Luo & Tang, 2016); corporate governance quality (Giannarakis et al., 2019; Luo & Tang, 2021; Subramaniam et al., 2015); and ownership structure (Haque, 2017; Luo & Tang, 2016).

The second research stream, which is more related to the current research, studies the implications of CCP/carbon risk and carbon disclosure on firm financial performance and management performance. For example, some studies investigate the impact on a firm's profitability (e.g., Busch et al., 2020; Busch & Hoffmann, 2011; Siddique et al., 2021; Trumpp

& Guenther, 2017); sales effectiveness and product leadership (Chakrabarty & Wang, 2013); firm risk (Alsaifi et al., 2021; Lee & Faff, 2009; Trinks et al., 2020); business strategy (Bui & de Villiers, 2017); firm value (Clarkson et al., 2015; Ganda, 2018; Matsumura et al., 2013; Saka, 2014); dividends policy and capital structure (Balachandran & Nguyen, 2018; Nguyen & Phan, 2020; Tascón et al., 2021); credit ratings (Safiullah et al., 2021); and cost of capital (Albarrak et al., 2019; Bui et al., 2020; Caragnano et al., 2020; Fonseka et al., 2019; Jung et al., 2018; Kim et al., 2015; Lee & Choi, 2019; Li et al., 2014; Maaloul, 2018; Pizzutilo et al., 2020; Zhou et al., 2018).

Table 1.1 summarises a list of previous studies that examined the CCP–CFP relationship. In line with Busch and Lewandowski (2018), the table shows that existing literature has yielded mixed findings on this relationship. For example, some studies find that CCP increases a firm's long-term financial performance (Tobin's Q). However, it causes a negative effect (or no effect) on the short-term financial performance (return on assets [ROA]), suggesting that investors see the potential benefits of CEP in the long run but not in the short run (Busch & Hoffmann, 2011; Delmas et al., 2015; Siddique et al., 2021). In contrast, while some studies documented a positive relationship between CCP and a firm's profitability (Gallego-Álvarez et al., 2014; Iwata & Okada, 2011; Lannelongue et al., 2015; Lee et al., 2015; Nguyen, 2018; Nishitani & Kokubu, 2012; Saka, 2014; Trinks et al., 2020), others indicated the existence of a negative relationship (Busch et al., 2020; Hart & Ahuja, 1996; Hatakeda et al., 2012; Wang et al., 2014). While Trumpp and Guenther (2017) found a U-shaped relationship between CCP and ROA and total shareholder return (TSR), Misani and Pogutz (2015) found an inverse U-shaped relationship between CCP and Tobin's Q. The contradictions in previous studies probably come from different dimensions, such as market structure and mechanism, prevailing regulations, industry-specific characteristics, the data and measurements used, and the study period, its timing and duration (Endrikat et al., 2014).

Some studies have shown different results when researchers have re-conducted a previous study using a different time frame or a different sample construction. For example, Busch et al. (2020) re-conducted the study by Delmas et al. (2015) by extending the sample and using another time frame. They found that CCP was negatively associated with ROA and Tobin's Q, whereas the first study showed that CCP was negatively (positively) associated with ROA (Tobin's Q). In a similar study, Fujii et al. (2013) found that CCP was positively related to ROA and return on sales (ROS), with no significant relationship with capital turnover (CT). Lewandowski (2017) found that CCP was significantly and positively related to ROS but negatively related to Tobin's Q, while Damert et al. (2017) found no significant relationship between CCP and either ROA or return on equity (ROE).

Previous studies also examined the impact of CCP, carbon risk or carbon disclosure on a firm's cost of capital (COC), with this including cost of debt (COD) and cost of equity (COE). Most studies revealed the existence of a negative (positive) relationship between CCP or carbon disclosure (carbon risk) and cost of capital (Albarrak et al., 2019; Bui et al., 2020; Caragnano et al., 2020; Fonseka et al., 2019; Jung et al., 2018; Kim et al., 2015; Lee & Choi, 2019; Maaloul, 2018; Pizzutilo et al., 2020; Safiullah et al., 2021). However, other studies produced varying results. For example, Li et al. (2014) found a positive (neutral) relationship between carbon risk and COD (COE), while Zhou et al. (2018) found a U-shaped relationship between carbon risk and COD, with the relationship able to be mitigated by positive media attention (to become a flatter relationship).

This research contributes to the literature by examining the CCP–COC relationship in a multi-country context. Indeed, very few studies have examined this relationship using a cross country sample (Caragnano et al., 2020) and a previous study that has examined this relationship in a single country setting cannot be generalised to other countries owing to legal, social and/or economic factors. Jung et al. (2018) and Li et al. (2014), for example, examined the CCP–COC relationship in a single country setting (Australia). However, their findings cannot be generalised to other countries in the Asia-Pacific region. In our study, for instance, we find a positive relationship between CCP and COD using a sub-sample from Taiwan, suggesting that this relationship is conditional to the country context.

Using a multi- country sample helps us to examine whether the assessment by financial markets of carbon risk differs between developed and developing countries in terms of governance mechanisms, with this comprising one of the important contributions of this research. In addition, this research is different from previous studies as it applies additional proxies for CCP and addresses many empirical challenges, such as sample selection bias; sensitivity to the use of alternative model specifications and alternative measurements for key variables; and heterogeneity and endogeneity problems.

Table 1.1. Summary of previous studies that examined the determinants and/or implications of corporate carbon performance (CCP)

Author (year)	Sample	Independent variable/s	Dependent variable/s	Main findings
Albarrak et al. (2019)	US from 2009–2015	Carbon disclosure on Twitter's social media network	COE	A negative relationship
Alsaifi et al. (2021)	UK from 2007–2015	Voluntary carbon disclosure	Firm risk	Carbon disclosure reduces a firm's total, systematic and idiosyncratic risk
Atif et al. (2020)	US from 2004–2016	Board gender diversity	Sustainable investment	A positive relationship
Atif et al. (2021)	US from 2008–2016	Board gender diversity	Renewable energy consumption	A positive relationship
Balachandran and Nguyen (2018)	Australia from 2002–2013	Carbon risk	Dividend payout ratio and propensity to pay dividends	The dividend payout ratio and the probability of paying dividends are lower for firms with higher carbon risk
Ben-Amar et al. (2017)	Canada from 2008–2014	Board gender diversity	Voluntary climate change disclosure	A positive relationship
Bui and de Villiers (2017)	Interviews and data from five New Zealand electricity generators	Climate change risk	Organisations' strategies	Climate change risk changed a firm's strategies by moving from a stable strategy to a combination of anticipatory, proactive and creative strategies and then reverting to a reactive strategy. The carbon management accounting changed accordingly
Bui et al. (2020)	34 countries from 2010–2015	Carbon disclosure and carbon intensity	COE estimated by using the Easton (2004) model	Carbon intensity is positively associated with COE, with the relationship moderated by carbon disclosure
Busch et al. (2020)	US. and Europe from 2005–2014	The absolute measure of carbon emissions and carbon intensity	ROA, Tobin's Q	The relationship between the absolute measure of carbon emissions and ROA (Tobin's Q) is positive (neutral). The relationship between carbon intensity and ROA and Tobin's Q is positive

Table 1.1 *Continued*

Author (year)	Sample	Independent variable/s	Dependent variable/s	Main findings
Busch and Hoffmann (2011)	Global in 2006	CCP based on carbon intensity	ROA, ROE and Tobin's Q	CCP has a positive (neutral) effect on Tobin's Q (ROA and ROE)
Busch and Lewandowski (2018)	A meta-analysis. 68 estimations from 32 empirical studies	CCP	CFP	Carbon emissions (carbon performance) negatively (positively) affect CFP. Studies that use a relative measure of carbon emissions (carbon intensity) produce more pronounced results for the CCP–CFP relationship than studies that use an absolute measure (total emissions). Studies that use market-based measures of CFP (e.g., Tobin's Q and COD) produce a more positive relationship with CCP than studies that use accounting-based measures (e.g., ROA and ROE)
Caragnano et al. (2020)	Europe from 2010–2017	Carbon intensity	COD	Firms with higher carbon intensity have a higher COD
Chakrabarty and Wang (2013)	43 multinational US corporations from 2001–2009	CCP based on carbon intensity	Sales effectiveness, product leadership and ROE	CCP has a positive (neutral) effect on sales effectiveness and product leadership (ROE)
Clarkson et al. (2015)	Europe from 2006–2009	The absolute measure of carbon emissions and sector competitiveness	Market value (MV)	A firm's carbon emissions shortfall (under a cap-and-trade system) is negatively associated with market value (MV). This negative relationship is mitigated if firms have better CCP compared to their industry peers and if they are from a lower-competitiveness sector
Damert et al. (2017)	45 leading worldwide enterprises in 2008 and 2013	Carbon reduction activities and carbon performance based on carbon intensity	ROA and ROE	Carbon reduction activities increase CFP. However, no significant relationship exists between carbon performance and CFP
Delmas et al. (2015)	US from 2004–2008	The absolute measure of carbon emissions	ROA & Tobin's Q	CCP is positively (negatively) related to Tobin's Q (ROA)

Table 1.1 *Continued*

Author (year)	Sample	Independent variable/s	Dependent variable/s	Main findings

Table 1.1 *Continued*

Author (year)	Sample	Independent variable/s	Dependent variable/s	Main findings
Fonseka et al. (2019)	Chinese energy firms from 2008–2014	Environmental disclosure	COD	A negative relationship
Fujii et al. (2013)	Japanese manufacturing firms from 2006–2008	CCP based on carbon intensity	ROA, return on sales (ROS) and capital turnover (CT)	CCP is positively related to ROA. CCP has a monotonically positive effect on ROS. No significant results are obtained for CT.
Gallego-Álvarez et al. (2014)	855 international firms from 2006–2009	CCP based on carbon intensity	ROA	A positive relationship
Gallego-Álvarez et al. (2015)	89 international firms from 2006–2009	The absolute measure of carbon emissions	ROA and ROE	Reduction in emissions generates a positive impact on CFP
Ganda (2018)	South Africa from 2014–2015	CCP	ROE, ROS, ROI and market value added (MVA)	A positive (negative) relationship between CCP and ROE and ROS (ROI and MVA)
Giannarakis et al. (2019)	278 firms from US	Corporate governance factors	Sustainability reporting	The age of the youngest director (board independence) has a negative (positive) effect on sustainability reporting. The presence of a sustainability committee and the frequency of audit committee meetings do not affect sustainability reporting
Haque (2017)	UK from 2002–2014	Board characteristics	Carbon reduction initiatives and absolute measure of carbon emissions	Board independence and board gender diversity are positively related to carbon emissions reduction initiatives, with a neutral relationship between board characteristics and the absolute measure of carbon emissions
Hart and Ahuja (1996)	US from 1989–1992	Emissions reduction	ROS, ROA and ROE	Emissions reduction reduces CFP and firms with a higher level of emissions have higher profitability

Table 1.1 *Continued*

Author (year)	Sample	Independent variable/s	Dependent variable/s	Main findings
Hatakeda et al. (2012)	Japan in 2006	The absolute measure of carbon emissions, financial flexibility, firm-specific uncertainty and ownership structure	ROA and Tobin's Q	A positive relationship between carbon emissions and CFP. This relationship can be mitigated when a firm has higher financial flexibility, lower firm-specific uncertainty and a higher proportion of large shareholders
Huang et al. (2021)	China from 2006–2016	Carbon emissions reduction regulation	Firm risk	A positive relationship between the low-carbon city (LCC) regulation and a firm's total, systematic and idiosyncratic risks
Iwata and Okada (2011)	Japan from 2004–2008	CCP based on carbon intensity	ROA, ROE and Tobin's Q	A positive relationship
Jung et al. (2021)	South Korea from 2012–2019	Carbon emissions regulation	Corporate environmental responsibility	Firms respond to carbon emissions-related regulations by increasing the number of directors with environment-related backgrounds which, in turn, increases their environmental performance
Jung et al. (2018)	Australia from 2009–2013	Carbon risk and carbon risk awareness	COD	A positive relationship between carbon risk and COD, with a moderating effect of carbon risk awareness
Kim et al. (2015)	South Korea from 2007–2011	CCP based on carbon intensity and voluntary carbon disclosure	COE	A negative relationship between CCP and COE, with no moderating effect of voluntary carbon disclosure
Kılıç and Kuzey (2019)	Turkey 2011–2015	Corporate governance characteristics	Voluntary carbon disclosure	Board independence, board nationality diversity and existence of a sustainability committee are positively related to voluntary carbon disclosure
Lannelongue et al. (2015)	Spain in 2009	CCP based on carbon intensity	ROA, ROE and profits before tax	A positive relationship between CCP and ROA and profits before tax. Neutral relationship with ROE

Table 1.1 *Continued*

Author (year)	Sample	Independent variable/s	Dependent variable/s	Main findings
Lee and Faff (2009)	Global sample from 1998–2002	Corporate sustainability performance	Idiosyncratic risk	Firms with higher (lower) sustainability performance have a lower (higher) idiosyncratic risk. Firms with better sustainability performance do not underperform the market portfolio, while their counterparts, those with lower performance, outperform the market portfolio
Lee et al. (2015)	Japanese manufacturing firms from 2003–2010	The absolute measure of carbon emissions and environmental research and development (R&D) investment	ROA & Tobin's Q	Environmental research and development (R&D) investment (carbon emissions) increases (decrease) CFP
Lee and Choi (2019)	South Korea from 2010–2015	Carbon risk management	COD	Carbon risk management decreases COD
Lewandowski (2017)	Global sample from 2003–2015	CCP based on carbon intensity	ROS and Tobin's Q	CCP is positively (negatively) related to ROS (Tobin's Q)
Li et al. (2014)	Australia from 2006–2010	CCP based on carbon intensity	COD and COE	A positive (neutral) relationship between carbon risk and COD (COE)
Liao et al. (2015)	UK in 2011	Board gender diversity, board independence and environmental committee	Voluntary carbon disclosure	A positive association between board gender diversity, board independence and the presence of an environmental committee and the propensity for voluntary disclosure
Luo (2013)	Global sample in 2009	Resource availability (i.e., profitability, financial leverage and revenue growth)	Voluntary carbon disclosure	Resource restriction negatively affects voluntary carbon disclosure
Luo and Tang (2014)	US, UK and Australia in 2010	CCP based on carbon intensity, industry-adjusted carbon intensity, historical carbon emissions and other benchmarks	Level of carbon disclosure	A positive relationship between the level of carbon disclosure and actual carbon performance. This suggests that firms with better CCP are more likely to disclose more information about their carbon performance

Luo and Tang (2016)	Global sample in 2011 and 2012	Presence of an emissions trading scheme, competitor pressure, the legal system, carbon exposure and the percentage of shares held by institutional investors	The quality of carbon management systems	Firms have a higher-quality carbon management system if they operate in countries with emissions trading schemes, in sectors with higher competitiveness and in code law countries, and if they have higher carbon exposure
Luo and Tang (2021)	UK from 2004–2018	Corporate governance factors, carbon strategy and awareness of climate change risk	CCP based on carbon intensity	A positive relationship between corporate governance quality and CCP, with the relationship moderated by carbon strategy and carbon risk awareness
Maaloul (2018)	Canada from 2012–2015	The absolute and relative measure of CCP	COD	Carbon risk increases COD
Matsumura et al. (2013)	S&P 500 firms from 2006–2008	The absolute measure of carbon emissions	Firm value	A negative relationship
Misani and Pogutz (2015)	Global sample from 2007–2013	CCP based on carbon intensity	Tobin's Q	Inverse U-shaped relationship between CCP and Tobin's Q. The highest profitability can be achieved when CCP is neither low nor high
Nguyen (2018)	Australia from 2000–2014	Carbon risk	Tobin's Q, probability of loss and ROE	Firms with a high carbon risk have lower CFP, with the relationship more pronounced for financially constrained firms
Nguyen and Phan (2020)	Australia from 2002–2013	Carbon risk	Capital structure	Firms with a high carbon risk have lower financial leverage, with the relationship being more pronounced for financially constrained firms.
Nishitani and Kokubu (2012)	Japan from 2006–2008	CCP based on carbon intensity	Tobin's Q	Carbon emissions reduction (CCP) increases CFP

Table 1.1 *Continued*

Author (year)	Sample	Independent variable/s	Dependent variable/s	Main findings
Pizzutilo et al. (2020)	Europe from 2010–2017	Carbon risk	COD	A positive relationship
Safiullah et al. (2021)	US from 2004–2018	The absolute measure of carbon emissions	Credit ratings	Firms with high carbon emissions face lower credit ratings
Saka (2014)	Japan from 2006–2008	CCP based on carbon intensity and carbon disclosure	MV	Carbon emissions (carbon disclosure) have (has) a negative (positive) effect on MV. The positive relationship between carbon disclosure and MV is stronger for firms with higher total carbon emissions
Shyu (2014)	Taiwan	International climate change-related policies	Taiwanese government's climate change-related policies	Although Taiwan is not a signatory to either the UNFCCC or the Kyoto Protocol, international climate change-related policies and agreements affect the development of Taiwan's climate change-related policies
Siddique et al. (2021)	Global sample from 2011–2015	CCP and carbon disclosure	ROA and Tobin's Q	CCP positively affects carbon disclosure, and carbon disclosure negatively (positively) affects ROA (Tobin's Q)
Subramaniam et al. (2015)	Australia in 2011	Firm-level characteristics	The integration of carbon-related risks and opportunities into the enterprise risk management (ERM) system	A positive relationship exists between the inclusion of carbon risk into the enterprise risk management (ERM) system and the existence of a formal carbon strategy, internal audit involvement in carbon management, senior management involvement, availability of personnel and financial resources, and energy sector membership.
Tascón et al. (2021)	16 European countries from 2005–2018	Carbon performance and a firm's life cycle	Capital structure	Firms with better carbon performance have greater access to external financing during their growth stages, less access during maturity, with no effect during the shake-out stage

Table 1.1 *Continued*

Author (year)	Sample	Independent variable/s	Dependent variable/s	Main findings
Trinks et al. (2020)	Global sample from 2009–2017	Carbon efficiency (carbon intensity compared to sector–year peers)	ROA, Tobin's Q, systematic risk and total risk	Carbon efficiency is positively related to ROA and negatively related to systematic risk. No significant associations with Tobin's Q or total risk
Trumpp and Guenther (2017)	Global sample from 2008–2012	CCP based on carbon intensity	ROA and total shareholder return (TSR)	A U-shaped relationship
Wang et al. (2014)	Australia in 2010	The absolute measure of carbon emissions	Tobin's Q	A positive relationship
Zhou et al. (2018)	China from 2011–2015	Carbon risk and positive media attention	COD	A U-shaped relationship between carbon risk and COD, with the relationship able to be mitigated by positive media attention (to become a flatter relationship)

Notes: This table summarises the previous studies that examine the determinants and/or implications of CCP or carbon risk.

US = United States of America; COE = cost of equity; UK = United Kingdom; ROA = return on assets; Tobin's Q = (market value of equity + total liabilities + preferred stock + minority interest) divided by total assets; ROE = return on equity; CFP = corporate financial performance; COD = cost of debt; MV = market value; ROS = return on sales; CT = capital turnover; ROI = return on investment; MVA= market value added; UNFCCC = United Nations Framework Convention on Climate Change; ERM = enterprise risk management; TSR = total shareholder return.

The carbon scope is divided into three scopes based on the sources of emissions. Scope 1 refers to direct emissions of GHG caused by the company, such as fuel combustion or emissions from operational processes owned or controlled by the company. Scope 2 refers to emissions caused by purchasing electricity. Scope 3 refers to emissions from sources not owned or controlled by the company (see Busch & Lewandowski, 2018). The relative measure for CCP means that carbon emissions are deflated by a business metric (e.g., sales, revenues). The absolute measure means the amount of emitted CO_2 and CO_2-equivalent per year.

1.6 Contributions of this research

This research contributes to the literature in several ways. Firstly, it is a response to recent calls for further explanation of the CCP–CFP relationship (Safiullah et al., 2021; Siddique et al., 2021; Xue et al., 2020). This study is motivated by the need for cross-country empirical studies to draw conclusions about this relationship. Given the complex nature of CCP (does it bring benefits to the company or does it incur additional costs?) and the lack of empirical evidence on the CCP–CFP relationship in a cross-country setting, no agreed position about these relationships is found in the literature. Therefore, this study contributes to the literature by applying and discussing a multi-theoretical framework combining social theories with economic theories and presenting detailed empirical evidence.

Secondly, due to the lack of carbon information and the contemporary nature of the carbon issue at the firm level, most previous studies focus on a single country or single industry setting (e.g., Fonseka et al., 2019; Ganda, 2018; Jung et al., 2018; Maaloul, 2018; Safiullah et al., 2021; Zhou et al., 2018), or examine the CCP–CFP relationship over the short term (e.g., Bui et al., 2020; Fujii et al., 2013; Gallego-Álvarez et al., 2015; Lee & Choi, 2019; Li et al., 2014; Wang et al., 2014; Zhou et al., 2018). However, the current study not only uses a multi-country sample from 14 countries but also covers a relatively long-term horizon (2002–2018). As the results of previous studies are context-specific or time-specific, they cannot be generalised. The importance of using a long-term period lies in the fact that superior CEP is considered a strategic investment, with its benefits able to be harvested in the long run (Damert et al., 2017; Harjoto & Jo, 2015; Sharfman & Fernando, 2008).

Thirdly, the link between a firm's green practices and its economic success is a core topic in the CEP debate. While some researchers affirm that CEP generally pays off for stakeholders and shareholders alike (see, e.g., Fujii et al., 2013; Trinks et al., 2020), others assume that CEP incurs additional costs for firms at the expense of shareholders (see, e.g., Damert et al., 2017; Hart & Ahuja, 1996). The current study endeavours to explore one of the factors causing these different views by examining whether the impact of CCP on CFP varies with different country-level governance characteristics. To the best of our knowledge, this study is the first to provide empirical evidence on the effect of a country-level governance mechanism on the CCP–CFP relationship. Therefore, the current study attempts to fill this gap in the body of knowledge by examining whether and how country-level governance quality moderates or strengthens the CCP–CFP relationship.

Fourthly, this study also contributes to estimating CCP variables. While previous studies have mainly used carbon intensity and industry-adjusted carbon intensity as proxies for corporate carbon performance (CCP), the current research, in addition to using these proxies, applies additional proxies for corporate carbon performance (CCP).[5] In addition, in contrast to previous studies on the CCP–COE relationship, the current study uses four models to estimate COE to provide a more accurate estimate and to moderate any estimation errors that may occur through using a particular model. Finally, this research addresses the most common empirical challenges that potentially affect the robustness of the results, by dealing with widespread research method-related concerns such as endogeneity, sample selection bias, heterogeneity, sensitivity to using alternative model specifications, simultaneous causality between dependent and independent variables, and the confounding effect of the Global Financial Crisis (GFC).

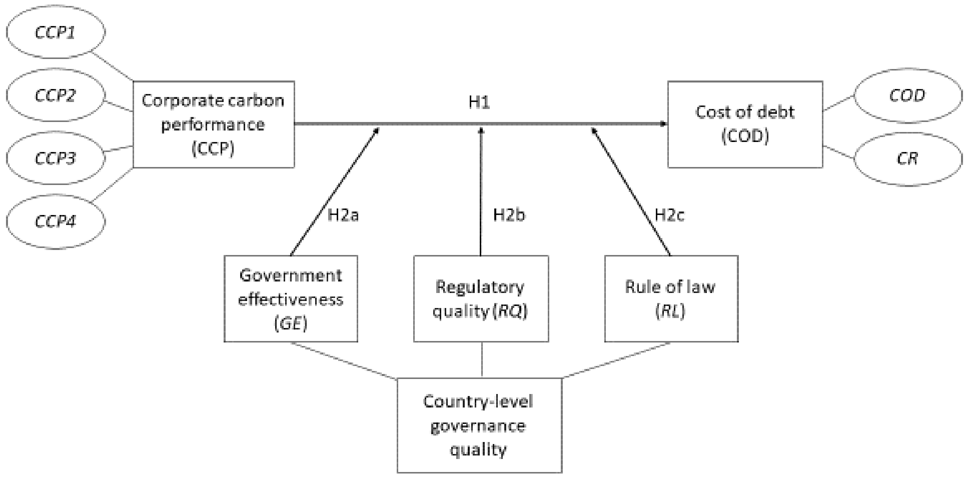

Figure 1.6. Conceptual framework and underlying hypotheses for first paper

Source: developed by the author

Note: CR = credit rating

1.7 Conceptual framework and underlying hypotheses

This section presents the conceptual framework and the underlying hypotheses for our three papers. Based on relevant literature, we posit a conceptual framework for each paper linking CCP and country-level governance characteristics with the cost of debt (COD), cost of equity (COE) and firm risk. Figure 1.6 presents the first paper's conceptual framework and hypotheses. In this paper, the independent variable is corporate carbon performance (CCP) measured using four proxies (*CCP1–CCP4*).[6] In our main analysis, we use *COD* as a dependent variable while using credit rating (*CR*) as an alternative measurement for COD in robustness checks. Country-level governance variables are used as moderating variables. Hypothesis 1

[5] Denoted as *CCP3* and *CCP4* in Paper 1, *CMS1* and *CMS2* in Paper 2 and *CMS* in Paper 3
[6] All variables are described in Appendix A.

(H1) examines the relationship between CCP and COD, while Hypothesis 2a (H2a), Hypothesis 2b (H2b) and Hypothesis 2c (H2c) investigate the effect of country-level governance quality on the CCP–COD relationship.

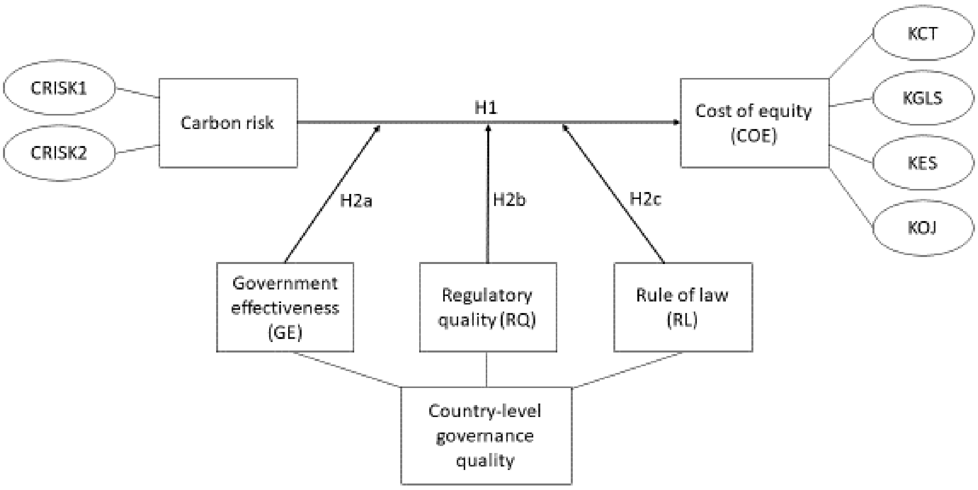

Figure 1.7. Conceptual framework and underlying hypotheses for second paper

Source: Developed by the author

Figure 1.7 presents the second paper's conceptual framework and hypotheses. This paper uses carbon risk (CRISK) as an independent variable measured using two proxies, *CRISK1* and *CRISK2*, with *COE* as a dependent variable. Following previous studies (Chen et al., 2009; El Ghoul et al., 2018; El Ghoul et al., 2011; Gupta, 2018; Hail & Leuz, 2006), we use the implied cost of equity (COE) capital. We specifically use four different models, *KCT*, *KGLS*, *KES* and *KOJ*, as proposed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005), respectively.[7] In our main analysis, we use the *COE* variable as the main estimate of implied cost of equity (COE) which is obtained from the average of at least two of the above-mentioned models. This helps to reduce estimation errors from using a particular model and simplifies the presentation of our results. As a robustness check, we investigate the association between CRISK and individual estimates of COE. We use country-level governance variables as moderating variables. Hypothesis 1 (H1) examines the relationship between CCP and COE, while H2a, H2b and H2c investigate the effect of country-level governance quality on the CCP–COE relationship.

Finally, Figure 1.8 presents the third paper's conceptual framework and hypotheses. The independent variable is corporate carbon performance (CCP) measured using three proxies

[7] Appendix B in the second paper (Chapter 3) provides more details about the implied cost of equity (COE) capital models.

(*CCP1*, *CMS1* and *CMS2*).[8] The dependent variables cover three categories of firm risk: total risk (*DEVRET*), idiosyncratic risk (*IDIO_RISK*) and systematic risk (*BETA*). Country-level governance variables are used as moderating variables. Hypothesis 1a (H1a), Hypothesis 1b (H1b) and Hypothesis 1c (H1c) examine the relationships between CCP and the three types of firm risk, while H2a, H2b and H2c investigate the effects of country-level governance quality on the CCP–COD relationship.

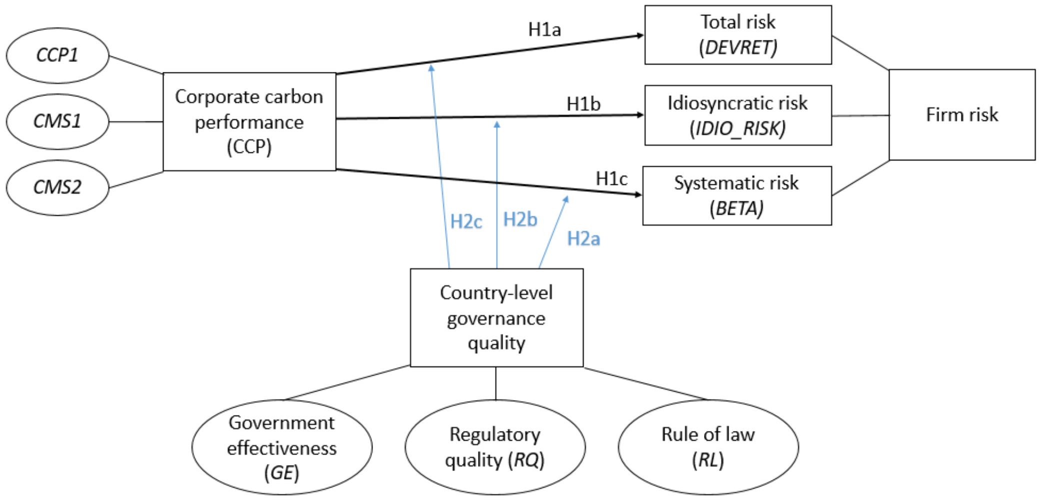

Figure 1.8. Conceptual framework and underlying hypotheses for third paper

Source: developed by the author

1.8 Research philosophy

The research philosophy is a researcher's "personal view of what constitutes acceptable knowledge and the process by which this is developed" (Saunders & Tosey, 2013, p. 58). The research philosophy contains assumptions about the way in which the researcher views the world. These philosophical assumptions and research paradigms provide directions for researchers and play an important role in realising the reality, achieving and interpreting results and measuring the overall research quality (Fossey et al., 2002; Wilson, 2014). Philosophical paradigms contain differences in essence that influence the way in which the researcher adopts the research process. Different studies reflect different philosophical assumptions. For example, researchers who study the cultural, ethical and social dimensions of human life drawn on their own personal understanding have a different view to how they approach the research

[8] All variables are described in Appendix A.

than those who conduct laboratory-based research or study a physical science (e.g., an engineer studying the resources needed to build a bridge).

1.8.1 Philosophical assumptions

All researchers in the social and behavioural sciences adopt explicit or implicit assumptions (philosophical positions) related to the nature of the social sciences and the method that can be used to reach the truth (Burrell & Morgan, 1979). The philosophical assumptions (paradigms) of the social sciences are linked to ontology, epistemology, axiology and methodology. The following subsections discuss these elements.

1.8.1.1 Ontology

Ontological assumptions relate to the researcher's view of the nature of reality and to the core of the phenomenon under investigation (Wilson, 2014). They attempt to answer the questions: what is the reality to be investigated and is it present and constant or does it change according to the actions of social actors (Burrell & Morgan, 1979)? Two extreme positions exist related to the ontological standpoints. The first position is realism which assumes that "the social world exists independently of an individual's appreciation of it" (Burrell & Morgan, 1979, p. 4). Realists postulate that the social world has "law-like regularities" which are as constant and coherent as the natural sciences (Keat & Urry, 2011; Radcliffe-Brown, 1952). From the other position, nominalism assumes that "the social world external to individual cognition is made up of nothing more than names, concepts and labels which are used to structure reality" (Burrell & Morgan, 1979, p. 4). This position emphasises the subjective nature of the social world. Nominalists postulate that the ultimate reality lies in the mind and that no universals exist outside the individual's consciousness (Armstrong, 1980). Reality "is only known through the form the mind gives it" (Heron, 1996, p. 11)

1.8.1.2 Epistemology

While ontology is related to reality, epistemology relates to knowledge (Wilson, 2014). It relates to the association between researchers and reality (Sobh & Perry, 2006). Specifically, it answers the questions of how we know what we know (Burrell & Morgan, 1979; Sobh & Perry, 2006), how is knowledge generated (Girod-Séville & Perret, 2001) and is the reality separate from the researcher, or is it the product of his/her knowledge or perception (Wilson, 2014)? The epistemological presuppositions are integral to identifying the research questions, methodologies and methods and formulating the researcher's decision about what constitutes an acceptable fact (Guba & Lincoln, 1994; Wilson, 2014). This subsection summarises two primary epistemological positions in the social sciences: positivism and anti-positivism (e.g., interpretivism and constructivism).

For positivists, what a researcher knows about reality is based on what he/she observes. In other words, a researcher is objective in observing reality (Sobh & Perry, 2006): reality is what a researcher's senses feel and is detached from his/her values, beliefs, desires, politics and ideology (Girod-Séville & Perret, 2001). A researcher does not play a crucial role in realising the truth and obtaining knowledge. Rather, a researcher's role is to explain, predict and search for regularities and causal relationships in the social world by using scientific and value-free procedures (Burrell & Morgan, 1979). For positivists, if the research results do not prove a theory, the theory must be reviewed (Saunders & Tosey, 2013).

On the other hand, anti-positivists postulate the existence of the relativistic nature of the social world, where reality changes according to the actions of social actors (Burrell & Morgan, 1979). Anti-positivists negate the standpoint that human activities can only be understood through observing the phenomenon and using the scientific method. From this point of view, the social world is a subjectively constructed entity, with a researcher subjective in realising the reality.

1.8.1.3 Axiology

Axiology is "concerned with the nature of value" (Wilson, 2014, p. 11). It is related to the researcher's view of the role of his/her values, perceptions or beliefs in conducting research (Saunders et al., 2009). Positivists postulate that the research is conducted in a value-free framework (Wilson, 2014) and that values do not play a role in interpreting results. In contrast, interpretivists consider that researchers' values are a foundation from which to issue judgements about the phenomenon under investigation (Heron, 1996). Thus, choosing the topic and methodology, gathering and interpreting data, and presenting findings are most likely to be affected by a researcher's values. These researchers stress the value-bound nature of the research, which places a burden on the researcher to ensure the provision of credible research results.

1.8.1.4 Methodology

Methodology refers to the research approaches (the way in which the research is conducted) that are used to acquire new knowledge. This philosophical assumption is related to a greater extent to the practical part of the research. The two main approaches used to conduct research are the inductive and deductive approaches. On one hand, the inductive approach aims to develop a new theory, in which the research starts with data collection, seeking to form a generalisation about the phenomenon under consideration and, accordingly, contributing to building a new theory (Hyde, 2000; Saunders et al., 2009). On the other hand, the deductive approach "is a theory testing process which commences with an established theory or generalisation, and seeks to see if the theory applies to specific instances" (Hyde, 2000, p. 83) by using rigorous tests. The current research adopts the deductive approach, where a research hypothesis is developed based on existing theory. Quantitative data are then collected and analysed. Finally, hypotheses are tested.

1.8.2 Research paradigm

A research paradigm is "a way of examining social phenomena from which particular understandings of these phenomena can be gained and explanations attempted" (Saunders et al., 2009, p. 597). It is "the basic belief system or worldview that guides the investigator, not only in choices of method but in ontologically and epistemologically fundamental ways" (Guba & Lincoln, 1994, p. 105). According to Burrell and Morgan (1979), the four sets of basic assumptions (paradigms) that define different perspectives for investigating social phenomena are radical humanist, interpretive, radical structuralist and functionalist. Each paradigm provides reasonable explanations of social phenomena within the terms of its own logical constructions. Therefore, as there is no optimal choice of paradigms, a researcher can work within the paradigm that is most compatible with his/her own perspectives (Sobh & Perry, 2006).

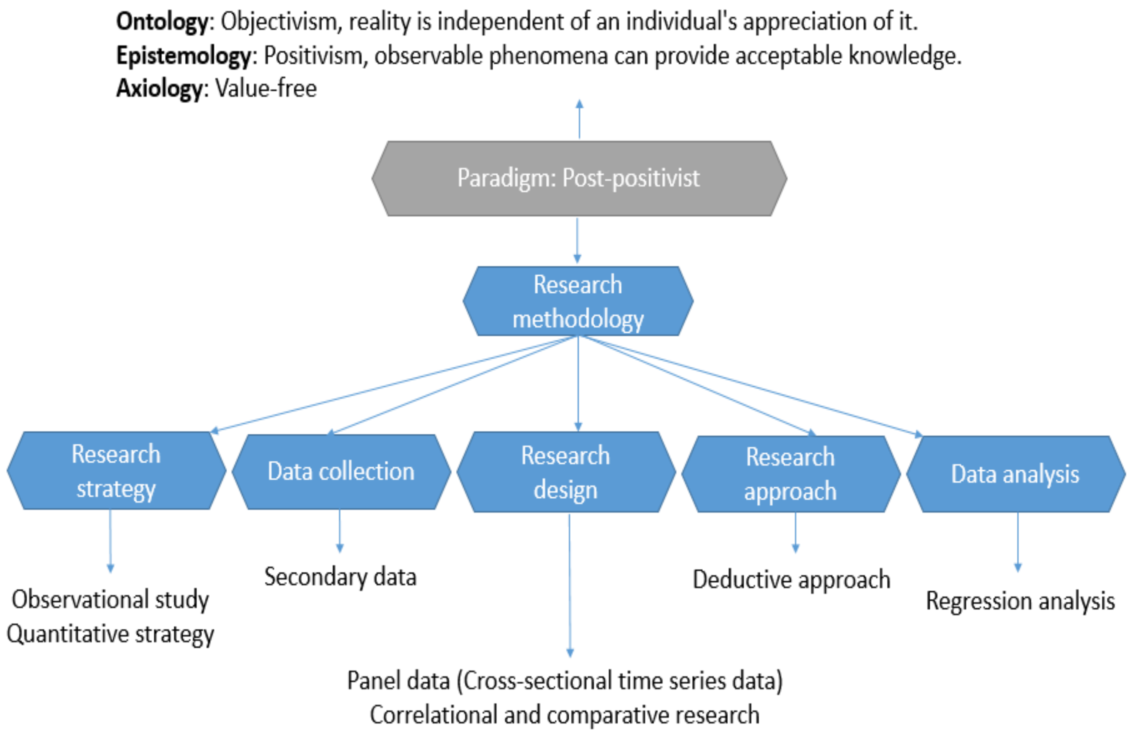

Figure 1.9. Research paradigm and methodology

The current study adopts the post-positivist view as a research paradigm. This study postulates objectivism as an ontological assumption in which reality is independent of an individual's appreciation of it, even though it is interpreted through social conditioning. We recognise the complexity of life in which society consists of an intricate web of multiple relationships. Reality is “real” but only to some people or a group of people and for a period of time. In addition, this study assumes positivism as its epistemological assumption. The knowledge is built based on testable observed evidence and can be interpreted by the human senses. Next, regarding the axiological position, this research adopts an objective point of view in which the research is separated as much as possible from the researcher’s values. Although choosing the study topic, the sample and methods depends on the researcher’s personal decision, the research is conducted with an objective approach by using value-free procedures. Figure 1.9 illustrates the research paradigm and methodology.

1.9 Thesis organisation

This section describes the structure of the thesis. The research work is presented as a thesis by publication. The thesis flow chart is provided in Figure 1.10. This thesis consists of five chapters arranged as follows:

- **Chapter 1:** Introduction

This chapter provides an introduction of the topic, outlines the research objectives and questions, and delineates the research motivations and significance. It also summarises the related literature and shows the contributions to the body of knowledge. In addition, it outlines the conceptual framework of the research, together with the hypotheses and thesis structure.

- **Chapter 2:** First paper

This chapter presents our first paper entitled "Corporate carbon performance and cost of debt: Evidence from Asia-Pacific countries". This study empirically examines the debt markets' response to corporate carbon performance (CCP). Specifically, it examines the impact of CCP on COD using a sample of 3,666 firm-year observations from 14 countries in the Asia-Pacific region over the 2003–2018 period. It also examines whether the CCP–COD relationship is different with different country-level governance settings (government effectiveness, regulatory quality and the rule of law). The cost of debt (COD) is found to be relatively lower when a firm has higher carbon performance (CCP). A country-level governance mechanism and debt markets are also found to be substitutes in addressing CCP; better CCP produces greater reductions in COD for firms from countries with poor government effectiveness, poor regulatory quality and weak rule of law.

- **Chapter 3:** Second paper

This chapter presents the second paper entitled "Carbon risk and cost of equity: The role of country-level governance". This study empirically examines the equity markets' response to carbon risk (CRISK). Specifically, it examines the impact of CRISK on COE using a sample of 5,021 firm-year observations from 13 countries in the Asia-Pacific region from 2002–2018. It also examines whether this relationship is affected by country-level governance settings. The cost of equity (COE) is found to be relatively higher when a firm has a higher carbon risk (CRISK). A country-level governance mechanism and equity markets are complementary in addressing CRISK: the impact of CRISK on COE is stronger in countries with strong government effectiveness, strong regulatory quality and strong rule of law.

- **Chapter 4:** Third paper

This chapter reports on the third paper entitled: "Corporate carbon performance and firm risk: Evidence from Asia-Pacific countries". This paper examines the question of how and why corporate carbon performance (CCP) affects a firm's total, idiosyncratic and systematic risks and whether this effect varies by country-level governance quality. Using a sample of 5,753 firm-year observations from 13 countries in the Asia-Pacific region over the period 2002–2018, we find that CCP produces an adverse effect on a firm's total, idiosyncratic and systematic risks. We also find that CCP yields greater reductions in a firm's total and idiosyncratic (systematic) risks in countries with strong (weak) country-level governance. Our primary results are robust after using alternative model specifications to control for sample selection bias, and endogeneity and heterogeneity problems. They are also robust after using sub-samples by country, controlling for the Global Financial Crisis (GFC) and controlling for simultaneous causality. We document that investors and stock markets are generally becoming more aware of firms' environmental performance and are paying close attention to corporate carbon performance (CCP).

- **Chapter 5:** Conclusion

This chapter presents a summary of the overall study findings. It highlights the implications of the study's findings for firms and managers, policy makers and regulators, and equity and debt market participants (e.g., investors, creditors and analysts). In addition, it presents the study limitations of all three papers and provides insights for future research.

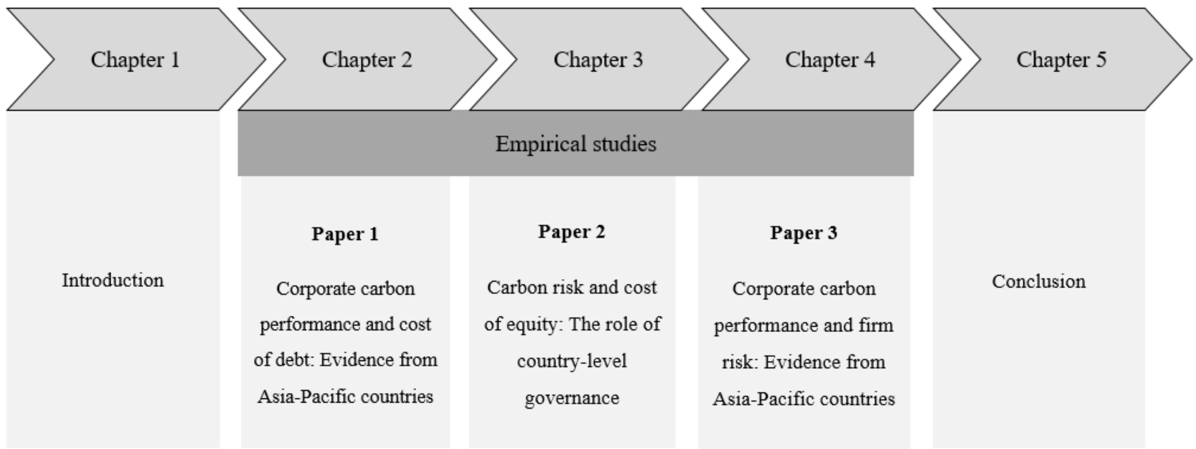

Figure 1.10. Thesis flow chart

Source: developed by the author

CHAPTER 2: FIRST PAPER

Corporate Carbon Performance and Cost of Debt: Evidence from Asia-Pacific Countries

Eltayyeb Al-Fakir Al Rabab'a, Afzalur Rashid, Syed Shams

Abstract

This study examines the relationship between corporate carbon performance (CCP) and corporate cost of debt (COD) in Asia-Pacific countries. Using a sample of 3,666 firm-year observations from 14 countries over the period 2003–2018, COD is found to be lower when a firm has higher carbon performance (CCP). We also find that CCP produces greater reductions in COD for firms in countries with poor government effectiveness, weak regulatory quality and weak rule of law. Thus, a country-level governance mechanism and debt markets are substitutes in addressing corporate carbon performance (CCP). Our main results are robust when controlling for potential sample selection bias and endogeneity problems using alternative model specifications. The results are robust in our additional analyses after controlling for heterogeneity problems using sub-samples, accounting for the Global Financial Crisis (GFC), using an alternative COD measure, and controlling for potential simultaneous causality and for corporate governance variables.

Keywords: Carbon risk, climate change, environmental performance, financial performance, financial distress, greenhouse gas(GHG).

2.1 Introduction

Climate change, resulting from greenhouse gas (GHG) emissions, has attracted widespread global attention in the past few decades. Extreme weather events, such as floods and droughts, resulting from climate change are causing adverse impacts on ecological systems as well as unprecedented damage to people's health and a serious threat to economic activities (Busch & Lewandowski, 2018; Stern, 2007). As part of worldwide efforts to reduce global warming, in 1992, countries joined an international treaty to form the United Nations Framework Convention on Climate Change (UNFCCC). In 1997, participating countries adopted the Kyoto Protocol to reduce GHG emissions and mitigate climate change and global warming problems. In response to the Kyoto Protocol, legislation has been enacted and policies have been adopted by many countries to not only reduce and monitor the environmental effects of firms' operations, but also to form a target for reduced GHG emissions (Lee et al., 2015). For example, the National Greenhouse and Energy Reporting (NGER) system obliges Australian firms that emit and use a particular level of carbon emissions to report their GHG emissions and their energy consumption and production (Borghei et al., 2016).

The complexity of the process of moving to a low carbon economy necessitates collaborative efforts by different market players. With increasing calls for companies to assume their environmental responsibilities, financial markets are becoming more aware of the potential financial implications resulting from carbon-related concerns (Jung et al., 2018; Lee & Choi, 2019). This study argues that financial markets can play an essential role in encouraging or penalising companies based on their carbon performance. As global awareness of the climate change problem has substantially increased, academic attention on this matter is growing in different areas of study including the literature in the fields of management and finance. In this study, we add to the existing literature by examining whether, and in what ways, corporate carbon performance (CCP) or carbon risk could affect corporate financial performance (CFP) and whether this relationship is different with different country-level governance characteristics.

The relationship between CCP and cost of debt (COD) is unclear. To date, no agreed position about this relationship is found in the literature (Trinks et al., 2020). In line with neoclassical economics (Friedman, 1970), the unnecessary increase in costs from green projects would be viewed as placing the firm at a competitive disadvantage (Aupperle et al., 1985), with these projects possibly perceived as a costly diversion of the firm's resources. To the extent that carbon-related costs negatively affect CFP, thereby increasing the financial distress risk, CCP will increase the cost of debt (Damert et al., 2017; Wang et al., 2014).

Despite the above view, we argue that CCP is negatively correlated with COD for several reasons. Firstly, firms can rely on corporate environmental performance (CEP) and CCP, as strategic tools, to create tangible and intangible value and achieve sustainable economic success. According to stakeholder theory (Donaldson & Preston, 1995; Jones, 1995), when a firm effectively manages a better relationship with its key stakeholders, thereby building a better reputation, it is more likely to achieve economic success (Brammer & Millington, 2008); thus, COD will decrease. Secondly, firms with higher carbon risk are more vulnerable to potential change in environmental regulations and obligations, increasing the uncertainty of current and future business conditions and increasing their financial distress risk, resulting in higher interest rates (Attig et al., 2013; Chava, 2014; Sharfman & Fernando, 2008). Finally, lending institutions are more likely to require a higher premium when they finance a carbon-intensive project as compensation for their potential reputational losses. Against the backdrop of these opposing arguments, we empirically examine COD as a channel through which CCP affects CFP in the long run. Specifically, we argue that high carbon performing firms are more likely to have lower cost of debt (COD).

Regarding the role of country-level governance, the second aspect of our study, we argue that the negative effect of CCP on COD is stronger in countries with a poor governance mechanism for two reasons. The first reason is that the globalisation of financial markets increases the awareness of environmental issues in countries with poor governance (Cole et al., 2006). As financial institutions increasingly consider environmental performance in their lending decisions (Chava, 2014), especially in countries where environmental regulation is weak, firms with high CEP can easily access these sources of funds at lower interest rates (whereas firms with low CEP are likely to incur higher interest rates). The second reason is that, as financial institutions are less confident about the ability of firms to mitigate carbon risks in countries with a poor governance mechanism, firms with lower CCP in developing countries usually suffer from higher risks (Schmidt, 2014). Thus, carbon risk could receive more consideration in countries with a weak governance mechanism. Therefore, we argue that a country-level governance mechanism and debt markets are substitutes in addressing corporate carbon performance (CCP).

The Asia-Pacific countries provide a useful setting in which to examine the relationship between CCP and COD for three reasons. Firstly, as many of these countries are among the largest industrial countries in the world, they significantly contribute to global GHG emissions and exacerbate the climate change problem. Figure 2.1 shows the percentage of emissions from these countries that included in the sample of global carbon dioxide (CO_2) emissions over the period 1960–2014. In 2014, these countries emitted approximately 44% of the world's CO_2, while in 1960, they only emitted around 14% of global CO_2, even though their percentage of the world population slightly decreased over the same period (World Bank, 2019). Secondly, as most of these countries ratified the Kyoto Protocol, many are adopting stringent carbon-related legislation and policies with which firms must comply (Shyu, 2014). This will increase firms' exposure to carbon risks. Finally, some previous studies investigate this relationship in the United States (US) or European contexts (e.g. Caragnano et al., 2020; Chava, 2014). However, owing to legal, social and/or economic factors, the results may not be generalisable to other countries.

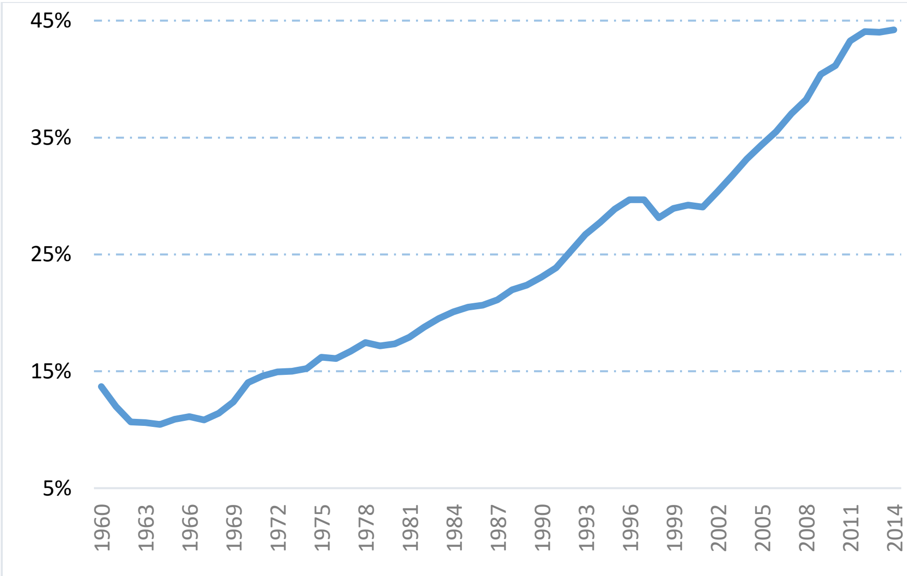

Figure 2.1. Percentage of global CO_2 emissions from countries included in the sample over the period 1960–2014

Source: developed by authors based on data from World Bank databases (World Bank, 2019)

This study examines the CCP–COD relationship by using a sample of firms from 14 Asia-Pacific countries. The sample covers the period 2003–2018 and comprises non-financial publicly listed companies. Our analysis shows that COD is lower when firms have higher carbon performance (CCP). We find evidence that, in addressing carbon performance (CCP), a country-level governance mechanism and debt markets are substitutes, and that CCP produces greater reduction in COD for firms from countries with poor government effectiveness, weak regulatory quality and weak rule of law. In general, we provide evidence that lending institutions are likely to consider CCP in their lending decisions. The results emphasise the importance of CCP and the adoption of long-term environmental strategies for businesses and their creditors.

We run a battery of robustness checks to reinforce our main finding. Firstly, to control for potential sample selection bias and endogeneity problems, we use alternative model specifications, such as Heckman's (1979) two-stage approach, propensity score matching (PSM) analysis, firm fixed-effects and country fixed-effects models. We find that our main result continues to hold. Secondly, to address the potential heterogeneity problems, we re-run the baseline model using sub-samples. We find a negative relationship between CCP and COD in sub-samples from Japan, Australia, South Korea, all countries without Japan, all countries without the top three countries and all countries without the bottom five countries. However, in a sub-sample of 344 firm-year observations from Taiwan, we find that two proxies of CCP have a significant positive relationship with cost of debt (COD). It is noteworthy that Taiwan is one of the countries that has not ratified the United Nations Framework Convention on Climate Change (UNFCCC) or the Kyoto Protocol (Shyu, 2014), suggesting that firms' exposure to carbon risk in Taiwan is relatively minimal. Thirdly, we re-run the baseline regression model using credit rating (CR) as an alternative measurement for COD, finding that the higher the level of CCP, the higher the company's credit rating (CR). Fourthly, in an additional analysis, we address potential simultaneous causality between COD and CCP by lagging the independent variables one and two years behind cost of debt (COD). We find that the four proxies for CCP at *t-1* and *t-2* are negatively and significantly associated with COD, which increases our confidence in the direction of the relationship. Finally, to address the effect of the Global Financial Crisis (GFC) (2007–2008) on firms' environmental and financial performance, we re-run the baseline regression model after excluding the GFC years, with the results reinforcing our main finding.

This study contributes to the literature in several ways. Firstly, as few studies in the literature examine whether and how debt markets price CCP and whether this assessment is different with differences in country-level governance, many more empirical studies are required to draw a conclusion about this relationship in different contexts (Busch & Lewandowski, 2018; Lee et al., 2015; Wang et al., 2014). According to Dixon-Fowler et al. (2013), "[w]hile establishing a link between CEP and CFP provides an important contribution, the specific boundary conditions surrounding the relationship remain unclear" (p. 353). Secondly, due to the lack of carbon information for the long term, most previous studies examine the CCP–CFP relationship over the short term (e.g. Fujii et al., 2013; Gallego-Álvarez et al., 2015; Ganda, 2018; Li et al., 2014; Wang et al., 2014). However, in this study, we investigate the relationship between CCP and COD using data that cover a relatively longer time span (2003–2018). This makes our results more meaningful as CEP is considered a strategic investment and can achieve financial benefits in the long run (Damert et al., 2017;

Harjoto & Jo, 2015; Sharfman & Fernando, 2008). Thirdly, as this is a contemporary issue, studies that investigate the CCP–COD relationship in a multi-country setting are rare (Caragnano et al., 2020). To the best of our knowledge, no study has examined the CCP–COD relationship using a comprehensive sample from the Asia-Pacific region. Jung et al. (2018) and Li et al. (2014), for example, examine the CCP–COD relationship in a single country setting (Australia). However, their findings cannot be generalised to other countries in the Asia-Pacific region. In our study, for instance, we find a positive relationship between CCP and COD using a sub-sample from Taiwan, suggesting that this relationship is probably different in different contexts. Finally, studies in the existing literature that link firm performance to environmental or carbon performance have yielded mixed findings (Busch & Lewandowski, 2018). Therefore, in the current study, we shed light on a possible reason for this difference. We examine whether the lenders' evaluation of the firm's carbon risk is different with different country-level governance characteristics. To the best of our knowledge, this study is the very first to provide empirical evidence on the effect of a country-level governance mechanism on the relationship between carbon performance and financial performance.

The remainder of this paper is organised as follows. Section 2.2 reviews the related literature on corporate environmental and carbon performance and the CCP–COD impact. Section 2.3 presents the hypotheses development, while Section 2.4 discusses the research design and data. Section 2.5 presents our study's findings, with Section 2.6 drawing conclusions and presenting the implications.

2.2 Literature review

2.2.1 Corporate environmental performance (CEP)

For several decades, the impact of CEP on CFP has been a widely discussed issue and a worthwhile topic and subject for theoretical and empirical research. Some studies have examined the association between CEP and CFP (e.g. Iwata & Okada, 2011; Lannelongue et al., 2015; Misani & Pogutz, 2015); firm risk (Cai et al., 2016; Muhammad et al., 2015a); dividend policies (Balachandran & Nguyen, 2018); and the cost of financing (El Ghoul et al., 2018; Fonseka et al., 2019; Sharfman & Fernando, 2008). Studies on this topic have yielded mixed results. For instance, some studies found a negative relationship between CEP and CFP (e.g. Hatakeda et al., 2012; Wang et al., 2014), while many others have shown a positive CEP–CFP relationship and that better CEP leads to benefits for both society and firms (e.g. Cai et al., 2016; Chakrabarty & Wang, 2013; El Ghoul et al., 2018).

Environmentally friendly projects may be a double-edged sword. They can bring benefits through three main paths: (i) decreasing the direct effect of environmental regulation and environmental protection activities, consequently decreasing the probability of fines or liabilities for environmental violations (Hatakeda et al., 2012); (ii) increasing demand for environmentally friendly products and then increasing sales (Subramaniam et al., 2015); and (iii) decreasing production costs by enhancing production efficiency through reductions in resources use, improvements in production operation and optimum utilisation of wastes and recycling (Busch & Lewandowski, 2018; Kuo et al., 2010). Conversely, these projects may require initial investment costs, such as the installation of energy-efficient plants, which may affect the firm's profitability and cash flow. They may also increase agency costs if these activities are accompanied by information asymmetry between stakeholders and conflicts of interest (Cho et al., 2013; Hatakeda et al., 2012). Companies, therefore, may incur additional costs without observing direct profits.

In terms of the effect of CEP on financial policies and the cost of debt financing, researchers have addressed this relationship in different contexts. For example, Cheng et al. (2014) investigated the impact of corporate social and environmental responsibility on firms' financial constraints. They used a sample of 10,078 firm-year observations from 49 countries worldwide over the period 2002–2009. The authors investigated the relationship of the corporate social responsibility (CSR) index, and its three pillars: environmental, social and corporate governance, with financial constraints. The study found that companies with superior CSR performance within the three pillars had lower capital constraints and, therefore, were more able to access finance. In a similar study, Sharfman and Fernando (2008) examined the relationship between CEP and both COD and cost of equity (COE). They found, as expected, a negative relationship between environmental risk management and both weighted average cost of capital (WACC) and COE, but they unexpectedly found a positive relationship between environmental risk management and cost of debt (COD). In addition, they found that superior environmental risk management was associated with more leverage and more tax advantage from debt financing. In that study, the authors called for more empirical research to be conducted on this relationship in markets where governmental and societal pressure about environmental issues is high. In response to that call, our sample includes some major industrialised countries such as China, Japan, Indonesia, India and Australia, in addition to the four 'Asian tigers', namely, Hong Kong, Singapore, South Korea and Taiwan. As previously mentioned, in the past few decades, these countries have exacerbated the climate change problem, experiencing a gradual increase in their GHG emissions as a percentage of global GHG emissions. They are facing increasing pressures from the international community with the aim of mitigating the climate change problem. Firms and banks in this setting are therefore more vulnerable to carbon risk.

2.2.2 Corporate carbon performance (CCP)

Previously, data on carbon emissions at firm level were limited to United States (US) data, where the Toxics Release Inventory (TRI) program is one of the most available sources of data used for measuring CEP (Lee et al., 2015). At the current time, as environmental issues have become a global concern, a new field of study has arisen, known as carbon accounting, with carbon data now available for many companies in countries worldwide. For example, in 2000, the Carbon Disclosure Project (CDP) emerged as a non-profit organisation based in the United Kingdom (UK). The largest companies worldwide are requested by CDP to disclose their carbon-related information through an annual survey. The voluntary reporting scheme run by CDP has become one of the most popular, being widely used in the literature (e.g. Busch & Hoffmann, 2011; Delmas et al., 2015; Misani & Pogutz, 2015; Trumpp & Guenther, 2017; Wang et al., 2014).

In light of the increased focus on carbon emissions, numerous studies have investigated the impact of CCP on corporate financial performance (CFP). Fujii et al. (2013) examined the CCP–CFP relationship using a sample of 758 firm-year observations in the manufacturing sector in Japan for the period 2006–2008. They found a statistically significant positive relationship between CEP, including CO_2 emissions, and return on assets (ROA). In their study, Balachandran and Nguyen (2018) reported that carbon risk has a negative impact on the stability of earnings, affecting dividend payments. According to that study, Australia has initiated strategies to reduce its carbon emissions as a commitment to the Kyoto Protocol, thus increasing the carbon-related risk of high polluting firms. The authors used a difference-in-differences (DiD) model to examine the exogenous effect of adopting the Kyoto Protocol on dividend policy. The results showed that, after ratification of the Kyoto Protocol, the payout ratio and the propensity of paying dividends decreased among firms classified as high emissions firms. From a sample of US firms, Delmas et al. (2015) found that improved CCP caused a decrease in CFP (ROA) in the short term. Conversely, they found that it increased long-term financial performance (Tobin’s Q), suggesting that investors saw the potential benefits of CEP in the long run.

2.2.3 Impact of corporate carbon performance (CCP) on cost of debt (COD)

It is noteworthy that some studies have examined the CCP–COD relationship (Caragnano et al., 2020; Jung et al., 2018; Lee & Choi, 2019; Li et al., 2014; Maaloul, 2018; Zhou et al., 2018). However, the questions of whether and how carbon performance affects firm financial policies have not been satisfactorily answered for some reasons. Firstly, as differences are found between the previous studies (Busch & Lewandowski, 2018), it is important to examine whether the debt markets' assessment of carbon risk differs with differences in governance mechanisms between developed and developing countries. To the best of our knowledge, this study is the first to explore this aspect. Secondly, previous studies have mainly used carbon intensity and industry-adjusted carbon intensity as proxies for corporate carbon performance (CCP). However, in the current research, in addition to these proxies, we apply additional proxies for carbon performance (*CCP3* and *CCP4*). Finally, in addition to the endogeneity problem, we extensively address many empirical challenges that could potentially affect our results, such as sample selection bias; sensitivity to the use of alternative model specifications and alternative measurements for key variables; the heterogeneity problem; endogeneity stemming from simultaneous causality; and the effect of the Global Financial Crisis (GFC).

Using a sample of Canadian firms over the period 2012–2015, Maaloul (2018) found that total carbon emissions and carbon intensity were positively related to cost of debt (COD). The author advised lenders and other market participants to take GHG emissions into account as part of the financial decision-making process. Jung et al. (2018) used a sample of 78 Australian firms during the period 2009–2013 and found a positive association between carbon risk and cost of debt (COD). They also found this relationship was negated for firms with high carbon risk awareness. They measured carbon risk using a firm's historical carbon emissions and its carbon awareness using data from CDP reports. In a similar study, Li et al. (2014) investigated the influence of the Australian carbon emissions reduction plan on the cost of capital. Based on Heckman's (1979) two-stage approach, they found a positive relationship between high carbon risk and cost of debt (COD).

Lee and Choi (2019) used a sample of South Korean firms during the period 2010–2015 and found a negative association between carbon risk management and cost of debt (COD). Zhou et al. (2018) employed a sample of 191 Chinese firms operating in high-carbon industries during the period 2011–2015 to find a significant U-shaped relationship between carbon risk and cost of debt (COD). In a sub-sample of privately-owned firms, they found this relationship was more pronounced when a firm had higher media attention. Otherwise, the U-shaped relationship was flatter, indicating the importance of public opinion and a country-level governance mechanism in the CCP–COD relationship. In our study, we extend the existing literature by extensively addressing the role of country-level governance in this relationship. Finally, very few studies have examined the relationship between a firm's carbon risk and COD in a multi-country context. In one example, Caragnano et al. (2020) found carbon risk to be positively related to COD using a multi-country sample from the region of Europe over the period 2010–2017.

In conclusion, as previously discussed, several studies have examined the influence of CEP and CSR on cost of debt (COD). As carbon performance is an essential component of corporate social and environmental responsibility, the question of which dimensions of environmental responsibility might impact on COD is left open and subject to further investigations (Nguyen & Phan, 2020). Therefore, the current study provides significant international insights about long-term business responses to the effectiveness of corporate environmental actions, in the case of carbon emissions, and the role of country-level governance in this relationship.

2.2.4 Role of country-level governance

The prior literature has addressed the effect of country-level governance on firm performance in different contexts. For example, Gupta (2018) found that the negative relationship between better CEP and implied COE is stronger in countries where country-level governance is weak. Qi et al. (2010) found that greater political rights, in general, and better freedom of the press, in particular, are negatively associated with cost of debt (COD). They also found that this relationship is more pronounced in countries with weaker creditor rights. Ernstberger and Grüning (2013) found that the positive relationship between corporate governance and firm disclosure is more pronounced in weak legal environments. They argued that, for firms to legitimise their activities, they respond to weak country-level governance by improving their level of disclosure. Chen et al. (2009) found that the negative effect of corporate governance on COE is more pronounced in emerging markets where the legal protection of investors is weak. In the current study, we attempt to fill a gap in the literature when we examine the effect of country-level governance on the relationship between corporate carbon performance (CCP) and financial performance (CFP).

2.3 Hypotheses development

Given that CCP is an important part of CEP, we begin by reviewing the CEP literature. As discussed in Section 2.2, several scholars have emphasised the importance of environmental responsibility not only for society, but also for firms themselves. For example, previous studies found that better environmental management and performance are associated with higher profitability and better economic performance (Al-Tuwaijri et al., 2004; Chava, 2014; Muhammad et al., 2015b; Sharfman & Fernando, 2008); lower idiosyncratic risk (Cai et al., 2016; Goss & Roberts, 2011; Muhammad et al., 2015a); lower cost of equity capital (Gupta, 2018; Kim et al., 2015; Ng & Rezaee, 2015); higher payout ratio (Balachandran & Nguyen, 2018); and better access to finance (Cheng et al., 2014; El Ghoul et al., 2018; Muhammad et al., 2015b).

As it is not possible to fully observe the indirect costs and benefits of environmental investment, the relationship between CCP and COD is regarded as unclear *ex ante*. In line with neoclassical economics (Friedman, 1970), the unnecessary increase in costs from green projects places the firm at a competitive disadvantage (Aupperle et al., 1985), with these projects possibly viewed as a costly diversion of the firm's resources. To the extent that CCP negatively affects CFP, thereby increasing the financial distress risk, the firm's ability to pay off debt is jeopardised (Damert et al., 2017; Wang et al., 2014). To bear this risk, lenders may demand more compensation by charging a higher interest rate.

In contrast, other scholars have argued that higher carbon-related risk (lower CCP) leads to higher interest rates for several reasons. Firstly, firms can count on CEP and CCP, as strategic tools, to create tangible and intangible value and achieve sustainable economic success. According to stakeholder theory (Donaldson & Preston, 1995; Jones, 1995), when a firm effectively manages a better relationship with its key stakeholders, thereby building a better reputation, it is more likely to achieve economic success (Brammer & Millington, 2008). Conversely, if they do not respond to mounting environmental pressure from diverse stakeholders, such as the media, public opinion, regulators and environmental activists, they may experience a loss in their reputation, clients may boycott their products and they may face costly environmental fines. Accordingly, their CFP will be negatively affected and, in turn, their COD will increase.

Secondly, firms with lower carbon performance are more vulnerable to carbon risk, making them more vulnerable to potential changes in environmental regulations and obligations. This increases the uncertainty of current and future business conditions and increases firms' financial distress risk, resulting in higher interest rates (Attig et al., 2013; Chava, 2014; Sharfman & Fernando, 2008). Finally, financing a high carbon intensity project which has a negative impact on the environment may create an agency problem between borrowers and lenders (Jung et al., 2018; Maaloul, 2018). It may cause an unequal pay-off. If the project is economically successful, the borrower would receive most of the benefits/gains, while the lender would not receive any excess as they would have a fixed claim. However, the lender would still face a reputational risk if the borrower was responsible for a negative environmental performance. If a lending project was unsuccessful, the lender might be subject to "the risk-shifting effect", obviously bearing most of the costs, especially if they take over mortgaged assets that have lost their market value for environment-related reasons.

An agency problem, in the case of carbon emissions, may occur when lenders' expectations are not aligned with those of borrowers. As carbon risk may be transferable to creditors, they would expect the adoption of more steps and actions by borrowers to mitigate the carbon-related risk, with this possibly not aligned with management's prospects. The fundamental assumption is that lenders normally demand higher interest rates as compensation for agency costs resulting from the manager's involvement in environmentally irresponsible actions that may benefit shareholders at the expense of lenders (Fonseka et al., 2019; La Rosa et al., 2018). According to agency theory, information asymmetry (to benefit shareholders at the cost of debtholders) increases agency costs which then increase capital constraints and cost of debt (COD). Even when information asymmetry is at a minimal level, a higher COD is likely to be charged when current and future business conditions are uncertain.

Based on the previous discussion and in line with the theoretical arguments and empirical evidence, the premise in this paper is that CCP, as an essential component of CEP, is negatively associated with cost of debt (COD). Thus, we propose the following hypothesis:

H1: A negative relationship exists between corporate carbon performance (CCP) and cost of debt (COD).

Next, we investigate the role of country-level governance in the CCP–COD relationship. Country-level determinants, such as legal, social and economic factors, are known to influence a firm's actions towards environmental responsibility (Gupta, 2018). The following two arguments lead to different impacts of country-level governance on the CCP–COD relationship. The first argument states that financial institutions penalise firms with high carbon risk and charge a higher interest rate; thus the CCP–COD relationship is more pronounced in countries with strong governance for the following two main reasons. Firstly, when firms operate in a country with stringent environmental regulations which has greater ability to enforce the law and effective government, they are more susceptible to expensive environmental costs (carbon-related costs), leading to increased sensitivity to future changes in environmental regulations, as well as increased uncertainty of future cash flows. Thus, financial institutions are more likely to overprice environmental risk in these settings. Secondly, stringent environmental regulations are more likely to be accompanied by more attention given to environmental issues in the media, and from public opinion and environmental activists. The failure to respond to local community pressure leads to a steeper reputational loss for firms with high carbon risk, compared to what firms face in countries with weak environmental regulations. Thus, as compensation for potential reputational losses, financial institutions charge a higher interest rate to firms with a high level of carbon risk if they operate in countries with strong governance, compared to firms with a similar high level of carbon risk operating in countries with weak governance.

The second argument states that financial institutions penalise firms with high carbon risk by charging a higher interest rate in countries with weak governance for two main reasons. Firstly, the globalisation of financial markets increases the awareness of environmental issues in countries with poor governance. For example, Cole et al. (2006) found that growth in international trade and foreign direct investment (FDI) increases firms' environmental management. As financial institutions increasingly consider environmental performance in their lending decisions (Chava, 2014), especially in countries where environmental regulation is weak, firms with high CEP can easily access these sources of funds at a lower interest rate, with this considered an incentive for firms to improve their environmental performance (Gupta, 2018). Secondly, as financial institutions are less confident about firms' abilities to mitigate carbon risks in countries with a weak governance mechanism, firms with lower CCP usually suffer from high carbon risks in developing countries (Schmidt, 2014). Thus, carbon risks could receive greater consideration in countries with a weak governance mechanism. Based on the above discussion, we investigate the following hypotheses:

H2a. *Ceteris paribus*, the effect of corporate carbon performance (CCP) on cost of debt (COD) is stronger in countries with poor government effectiveness.

H2b. *Ceteris paribus*, the effect of corporate carbon performance (CCP) on cost of debt (COD) is stronger in countries with weak regulatory quality.

H2c. *Ceteris paribus*, the effect of corporate carbon performance (CCP) on cost of debt (COD) is stronger in countries with weak rule of law.

2.4 Research design and data

2.4.1 Sample construction and data

The initial sample comprises all publicly listed firms on the Australian Securities Exchange (ASX); Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE) in China; Hong Kong Stock Exchange (SEHK); Bombay Stock Exchange Ltd (BSE) and National Stock Exchange of India (NSE) in India; Indonesia Stock Exchange (IDX); Tokyo Stock Exchange (TSE), Nagoya Stock Exchange (NSE) and Japan Association of Securities Dealers Automated Quotation (JASDAQ); Malaysia Stock Exchange (MYX); New Zealand Stock Market (NZX); Philippines Stock Market (PSE); Singapore Stock Exchange (SGX); South Korea Stock Exchange (KRX); Colombo Stock Exchange (CSE) in Sri Lanka; Taiwan Stock

Exchange (TWSE); and Thailand Stock Market (SET). We extracted data from the different database sources as described in Appendix A. This research employed unbalanced panel data consisting of 3,666 firm-year observations over the 2003–2018 period. Table 2.1, Panel A provides details of the sample selection process. We exclude financial firms from the sample as they are subject to industry-specific regulations, which make their capital structure decisions and debt financing substantially different in comparison with non-financial firms (La Rosa et al., 2018; Nguyen & Phan, 2020). Table 2.1, Panel B shows the sample distribution by industry and year. The industries are classified based on the Industrial Classification Benchmark (ICB) as provided by Thomson-Reuters databases. The continuous variables were winsorised at the 5th and 95th percentiles to reduce the potential misleading caused by outliers.

2.4.2 Empirical model

To test our first hypothesis (H1), we used the following regression model:

$$COD_{it} = \alpha + \beta_1 \, CCP_{it} + \sum_{j=2}^{n} \beta_j \, CONTROL_{jit} + \text{year and industry FE} + \varepsilon_{it} \quad (1)$$

where i denotes firms; t denotes time; *COD* is the cost of debt; *CCP* is corporate carbon performance, calculated based on four proxies discussed in detail in the next section (*CCP1–CCP4*); and $CONTROL_{jit}$ is the control variable *j* of firm *i* at year *t.* Based on Hypothesis 1 (H1), we expect β_1 in Equation (1) to be positive. The list of firm-level and country-level control variables is discussed in Section 2.4.3.

Table 2.1. Sample selection and distribution

Panel A – Sample selection

Details	Obs.
Firm-year observations in Thomson-Reuters databases for carbon data	6,535
Less: Firm-year observations with insufficient financial data	(1,954)
Less: Financial firms	(915)
Firm-year observations in final sample	**3,666**

Panel B – Sample breakdown by industry and year

ICB industry classification	Obs.	% of sample	Year	Obs.	% of sample
Oil and Gas	103	2.81	2003	11	0.30
Basic Materials	598	16.31	2004	15	0.41
Industrials	911	24.85	2005	55	1.50
Consumer Goods	711	19.39	2006	94	2.56
Health Care	241	6.57	2007	112	3.06
Consumer Services	307	8.37	2008	152	4.15
Telecommunications	147	4.01	2009	184	5.02
Utilities	244	6.66	2010	213	5.81
Technology	404	11.02	2011	283	7.72
Total	**3,666**	**100.00**	2012	294	8.02
			2013	317	0.30
			2014	351	0.41
			2015	381	1.50
			2016	407	2.56

2017	419	3.06
2018	378	4.15
Total	**3,666**	**100.00**

Notes: This table presents the sample selection process (Panel A), and the sample distribution by industry based on the Industrial Classification Benchmark (ICB) and by year (Panel B).

To test Hypothesis 2a (H2a), which examines the effect of country-level government effectiveness (*GE*) on the relationship between *CCP* and *COD*, we estimate the following regression model. Based on H2a, we expect β_3 in Equation (2) to be positive:

$$COD_{it} = \alpha + \beta_1 CCP_{it} + \beta_2 GE_{it} + \beta_3 GE_{it} * CCP_{it} + \sum_{j=4}^{n} \beta_j CONTROL_{jit} + \text{year and industry FE} + \varepsilon_{it} \quad (2)$$

To test Hypothesis 2b (H2b), which examines the effect of regulatory quality (*RQ*) on the relationship between *CCP* and *COD*, we estimate the following regression model. Based on H2b, we expect β_3 in Equation (3) to be positive:

$$COD_{it} = \alpha + \beta_1 CCP_{it} + \beta_2 RQ_{it} + \beta_3 RQ_{it} * CCP_{it} + \sum_{j=4}^{n} \beta_j CONTROL_{jit} + \text{year and industry FE} + \varepsilon_{it} \quad (3)$$

To test Hypothesis 2c (H2c), which examines the effect of rule of law (*RL*) on the relationship between *CCP* and *COD*, we estimate the following regression model. Based on H2c, we expect β_3 in Equation (4) to be positive.

$$COD_{it} = \alpha + \beta_1 CCP_{it} + \beta_2 RL_{it} + \beta_3 RL_{it} * CCP_{it} + \sum_{j=4}^{n} \beta_j CONTROL_{jit} + \text{year and industry FE} + \varepsilon_{it} \quad (4)$$

The actual interest rate may not be significantly associated with CCP activities in the presence of other important factors, such as any potential business or financial risk/opportunity, which are most likely to dominate lending decisions. To be able to test whether CCP, as distinct from other factors, is associated with COD, we control for the major factors identified as determinants of COD in the literature in our multivariate regression models. Following previous studies (Al-Tuwaijri et al., 2004; Attig et al., 2013; La Rosa et al., 2018), we include the following control variables in our econometric model: *LOG_SIZE*, the natural logarithm of total assets recorded in billions of US dollars; *LOG_COV*, the natural logarithm of the coverage ratio; *ROA*, return on assets; *LEVERAGE*, the ratio of total liabilities to total assets; *CAPINT*, the capital intensity ratio; *BETA*, the systematic risk beta; *LIQUIDITY*, the current ratio which is equal to current assets divided by current liabilities; *GROWTH*, the sales growth rate; *LOSS*, a dummy variable equal to 1 if the firm reports losses in the last two years, and 0 otherwise; and *MARGIN*, the operating income divided by net sales. Finally, we include a set of country-level variables to control for potential cross-country differences: *LOG_GDPC* is the natural logarithm of gross domestic product (GDP) per capita in US dollars to control for differences in economic development between countries (El Ghoul et al., 2018; Luo & Tang, 2016), while *COMMONLAW* is an indicator variable equal to 1 if the company is based in a common-law country, and 0 otherwise (Djankov et al., 2008; Gallego-Álvarez et al., 2015). As documented by La Porta et al. (2008), the legal origin of countries is highly correlated with economic outcomes such as financial development, unemployment, investment and international trade. Following Krishnamurti et al. (2018) and Espenlaub et al. (2020), we use the revised Anti-Director Rights Index (*ADR*) from Djankov et al. (2008) to control for country-level governance, with a higher value for *ADR* indicating a higher level of shareholder protection. The variable *LOG_MCAP* is the natural logarithm of country-level stock market capitalisation. We use this variable to control for country-level stock market development. All variables are defined in more detail in Appendix A.

2.4.3 Definition of variables

2.4.3.1 Corporate carbon performance (CCP)

In the literature, carbon risk or carbon performance is measured by the absolute or relative value of carbon emissions. The absolute measure is the amount of emitted GHG in tonnes of CO_2 and CO_2-equivalent per year which indicates the firm's individual contribution to climate change. The relative measure (or emissions intensity) links the absolute measure to sales, revenue or any other business metric. In the current study, we use the relative measure of carbon emissions. This helps us to control for any sudden events that may change total emissions, such as mergers and acquisitions (M&As) or any changes in the overall economy (Busch & Lewandowski, 2018). In addition, given the variation between firms in economic output, size and industry, the relative measure makes an applicable comparison between firms.

Four proxies for CCP are used in this study: *CCP1*, *CCP2*, *CCP3* and *CCP4*. *CCP1* is carbon emissions intensity, measured by the ratio of total carbon emissions (Scopes 1 and 2)[9] to total sales multiplied by -1. Following Luo and Tang (2014) and Jung et al. (2018), *CCP2*

[9] The Greenhouse Gas Protocol is one of the carbon accounting tools that is widely applied internationally. This protocol defines three scopes of carbon emissions according to their sources. Scope 1 refers to direct emissions of GHG caused by the company, such as fuel combustion or emissions from operational processes owned or controlled by the company. Scope 2 refers to emissions caused by purchasing electricity. Scope 3 refers to emissions from sources not owned or controlled by the company (see Busch & Lewandowski, 2018).

refers to carbon emissions intensity minus the country–industry mean, as per the following formula:

$$CCP2_i = CCP1_i - \frac{1}{n}\sum_{k=0}^{Nk} CCP1_i,$$

where Nk is the number of firms i in sector k and *CCP3* is an index used to measure the firm's performance in mitigating its carbon risk. The index is calculated as follows: 3 points are awarded if the firm's *CCP1* value is higher than the previous year ($CCP1_{it} > CCP1_{i(t-1)}$); 2 points are awarded if the firm's *CCP1* value is higher than the country–sector median; 1 point is awarded if the firm has an environment management team; 1 point is added if the firm has a policy to improve its energy efficiency; 1 point is added if the firm sets targets or objectives to be achieved on emissions reduction; 1 point is added if the firm is aware that climate change could represent commercial risks and/or opportunities; 1 point is added if the firm makes use of renewable energy; 1 point is added if the firm reports on initiatives to reduce, reuse, recycle, substitute or phase out sulphur oxides (SOx) or nitrogen oxides (NOx) emissions; and 1 point is added if the firm reports on its environmentally friendly or green sites or offices. *CCP4* is the equally weighted score of *CCP3*. Higher values of *CCP1*, *CCP2*, *CCP3* and *CCP4* mean that the firm has better carbon performance (CCP).

2.4.3.2 Cost of debt (COD)

We use the weighted average cost of debt calculated by the Bloomberg Professional database as the measure of cost of debt (COD). According to Bloomberg (2013), this is calculated as follows:

$$COD = \left(\frac{SD * CS}{TD} + \frac{LD * CL}{TD}\right) AF\ (1 - TR)$$

where *SD* is short-term debt; *TD* is total debt; *CS* is the pre-tax cost of short-term debt; *AF* is the debt adjustment factor[10]; *LD* is long-term debt; *CL* is the pre-tax cost of long-term debt; and *TR* is the effective tax rate.

[10] According to Bloomberg (2013),

> [t]he debt adjustment factor represents the average yield above government bonds for a given rating class. The lower the rating, the higher the adjustment factor. The debt adjustment factor (AF) is only used when a company does not have a fair market curve (FMC). When a company does not have a credit rating, an assumed rate of 1.38 (the equivalent rate of a BBB+ Standard and Poor's long term currency issuer rating) is used. (p. 18).

Use of the Bloomberg database enables us to utilise the benefit of having COD calculated by a data specialist company. The Bloomberg Professional database has been adopted in the literature as a credible source of data (e.g. Desender et al., 2020; Huang & Shang, 2019; Maaloul, 2018; Sharfman & Fernando, 2008). It is also widely used by firm stakeholders and market participants and has gained high credibility among its users internationally.

2.4.3.3 Country-level governance variables

We use three indicators for governance mechanisms from World Bank databases (World Bank, 2019). Firstly, government effectiveness (GE) "captures perceptions of the quality of public services; the quality of the civil service and the degree of its independence from political pressures; the quality of policy formulation and implementation; and the credibility of the government's commitment to such policies". Secondly, regulatory quality (RQ) "captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development". Thirdly, rule of law (RL) "captures perceptions of the extent to which agents have confidence in and abide by the rules of society and, in particular, the quality of contract enforcement, property rights, the police and the courts, as well as the likelihood of crime and violence".

Table 2.2. Descriptive statistics for full sample and mean and median differences tests between two sub-samples

Panel A – Descriptive statistics

	Mean	Std. Dev.	Min	P25	Median	P75	Max
COD	1.128	1.362	-0.053	0.201	0.678	1.520	7.830
CCP1	-0.420	0.910	-5.856	-0.319	-0.070	-0.027	-0.002
CCP2	0.026	0.610	-3.431	-0.019	0.035	0.129	2.251
CCP3	6.623	2.439	1.000	5.000	7.000	8.000	12.000
CCP4	5.063	1.777	1.000	4.000	5.000	6.000	9.000
LOG_SIZE	9.660	10.563	0.934	2.570	5.471	11.866	40.266
LOG_COV	4.010	0.550	3.477	3.660	3.786	4.126	5.585
ROA	0.045	0.038	-0.022	0.020	0.039	0.066	0.128
LEVERAGE	0.248	0.156	0.007	0.126	0.238	0.358	0.557
CAPINT	0.371	0.194	0.100	0.217	0.337	0.484	0.800
BETA	1.002	0.423	0.250	0.673	1.000	1.300	1.790
LIQUIDITY	1.616	0.787	0.580	1.080	1.430	1.950	3.650
MARGIN	0.088	0.073	-0.002	0.036	0.067	0.118	0.277
GROWTH	0.044	0.103	-0.149	-0.017	0.039	0.100	0.268
LOSS	0.044	0.205	0.000	0.000	0.000	0.000	1.000
LOG_GDPC	10.431	0.557	7.022	10.417	10.582	10.698	11.134
COMMNLAW	0.183	0.387	0.000	0.000	0.000	0.000	1.000
ADR	4.301	0.478	3.000	4.500	4.500	4.500	5.000
LOG_MCAP	7.77	0.921	2.746	7.118	8.154	8.428	9.072

Panel B – Sub-samples separated based on the industry–country median of carbon intensity (*CCP1*)

	Low *CCP1*		High *CCP2*		Mean test (*p*-value)	MW test (*p*-value)
	Mean	Median	Mean	Median		
COD	1.434	0.861	0.993	0.628	0.000	0.000
LOG_SIZE	10.260	6.167	8.298	4.331	0.000	0.000
LOG_COV	3.943	3.732	4.039	3.820	0.000	0.000
ROA	0.043	0.039	0.046	0.040	0.020	0.028
LEVERAGE	0.278	0.273	0.234	0.225	0.000	0.000
CAPINT	0.454	0.435	0.334	0.298	0.000	0.000
BETA	1.018	1.010	0.995	1.000	0.143	0.212
LIQUIDITY	1.602	1.410	1.622	1.430	0.495	0.123
MARGIN	0.091	0.072	0.087	0.065	0.130	0.050
GROWTH	0.039	0.035	0.047	0.041	0.033	0.029
LOSS	0.062	0.000	0.036	0.000	0.002	0.001

Notes: Table 2.2, Panel A presents descriptive statistics for the variables in the full sample. Table 2.2, Panel B presents the univariate analysis results. The Mann–Whitney (MW) test and *t*-test have been used to examine the median and mean differences, respectively, between high and low carbon performance based on the industry–country median of *CCP1* (*p*-values are two-tailed). *LOG_SIZE* is reported in billions of US dollars. All variables are defined in Appendix A.

2.5 Results and discussion

2.5.1 Descriptive statistics and univariate analysis

Table 2.2 presents the descriptive statistics for the independent variables, dependent variables, and firm-level and country-level control variables employed in this study, as well as univariate analysis. Table 2.2, Panel A shows the variables' means, standard deviations, minimums, 25th percentiles, medians, 75th percentiles and maximum values for the full sample, comprising 3,666 firm-year observations from 2003–2018. For *COD*, the mean and median values are 1.128% and 0.678%, respectively, ranging from a minimum of -0.053% to a maximum of 7.83%. The reason for the negative *COD* value is that Bloomberg uses the 10-year government bond rate in *COD* calculations which was negative in Japan in some years (specifically in 2016 and 2019) as the central bank of Japan introduced negative interest rates. As presented in Table 2.3, the *COD* for Japanese firms was, on average, 0.399% which is relatively lower than that of other countries. In general, *COD* figures in Japan in the current study are relatively similar to the values reported in related studies (e.g. Shuto & Kitagawa, 2011; Suto & Takehara, 2017). The mean value of the first measure of corporate carbon performance (*CCP1*) is -0.42, which means that firms in the sample emit, on average, 0.42 tonnes of GHG emissions (Scopes 1 and 2) per US$1,000 of sales.[11]

To provide initial evidence on the CCP–COD relationship, as shown in Table 2.2, Panel B, we compare the mean and median values of the firm-level variables for sub-samples divided into firms with low carbon performance and firms with high carbon performance. The sub-samples are separated based on the industry–country mean value of carbon intensity (*CCP1*), where low and high carbon performance firms are those below and above the mean value of *CCP1*, respectively. The last two columns present the results of the Mann–Whitney test and *t*-test to examine differences in mean and median values. We find that the mean value of *COD* for firms with low carbon performance is 1.434%, while it is 0.993% for those with high carbon performance. The difference is statistically significant at the 1% level. The results also show statistically significant mean differences between high and low *CCP* for most variables, except for *BETA*, *LIQUIDITY* and *MARGIN*. Firms with low carbon performance (higher emissions intensity), on average, have higher cost of debt, lower size, lower coverage ratio, lower return on assets, higher leverage, higher capital intensity, lower sales growth and are more likely to report losses. When we examine the median differences between the two sub-samples, we find similar results.

[11] *CCP1* is carbon emissions intensity, with this value multiplied by -1 so higher values represent better carbon performance.

Table 2.3 reports the sample distribution by country, as well as the mean values of the key variables by country. Most of the sample's observations (more than 61%) are from Japan. The reason is that Japan is one of the countries that responded early to the Kyoto Protocol. In addition to the voluntary disclosure of carbon emissions, the mandatory GHG accounting and reporting system obligates Japanese firms that exceed a specific level of emissions to report these amounts annually to the government. Therefore, Japan's carbon-related data are more available than data from other countries in our sample. This raises the problem of sample selection bias in our study. To deal with this concern, we use Heckman's (1979) two-stage model analysis and the PSM model for robustness tests, as reported in Section 2.5.3.

Table 2.3. Descriptive statistics of key variables across countries

Country	N	% of sample	*CCP1*	*CCP2*	*CCP3*	*CCP4*	*COD*
Australia	360	9.82	-0.629	0.323	5.672	4.069	3.438
China	13	0.35	-0.434	0.232	4.769	3.538	2.239
India	29	0.79	-3.681	-1.397	5.207	4.586	7.305
Indonesia	8	0.22	-0.893	-0.442	6.375	4.250	7.128
Japan	2237	61.02	-0.323	0.013	6.733	5.164	0.399
Malaysia	34	0.93	-1.937	-0.681	6.000	4.765	3.280
New Zealand	58	1.58	-0.420	-0.044	5.672	4.034	3.212
Philippines	35	0.95	-0.458	0.099	5.943	4.457	2.093
Singapore	12	0.33	-0.090	0.301	7.417	5.417	2.118
South Korea	358	9.77	-0.240	-0.008	7.313	5.721	1.445
Sri Lanka	5	0.14	-1.151	-0.175	7.200	5.600	2.179
Taiwan	344	9.38	-0.377	-0.010	6.709	5.250	1.014
Thailand	84	2.29	-0.841	-0.100	7.369	5.821	2.660
Hong Kong	89	2.43	-0.825	0.291	5.640	3.865	2.374
Total sample	**3666**	**100.00**	**-0.420**	**0.026**	**6.623**	**5.063**	**1.128**

Notes: Table 2.3 presents the number of observations, percentage of the full sample and the mean value of the key variables by country. Cost of debt (*COD*) is reported by percentage. All variables are defined in Appendix A.

Table 2.4. Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1) *COD*	1.00																		
(2) *CCP1*	**-0.30**	1.00																	
(3) *CCP2*	**-0.08**	**0.64**	1.00																
(4) *CCP3*	**-0.12**	**0.12**	**0.12**	1.00															
(5) *CCP4*	**-0.15**	**0.06**	0.02	**0.90**	1.00														
(6) *LOG_SIZE*	-0.01	**0.04**	0.00	**0.26**	**0.31**	1.00													
(7) *LOG_COV*	**-0.25**	**0.20**	**0.06**	**0.05**	0.02	**0.21**	1.00												
(8) *ROA*	**0.18**	**0.10**	**0.09**	**0.06**	-0.02	**0.32**	**0.52**	1.00											
(9) *LEVERAGE*	**0.16**	**-0.36**	**-0.17**	-0.02	0.02	**-0.08**	**-0.63**	**-0.31**	1.00										
(10) *CAPINT*	**0.31**	**-0.45**	**-0.09**	**-0.15**	**-0.12**	-0.04	**-0.30**	**-0.08**	**0.47**	1.00									
(11) *BETA*	0.00	0.04	-0.01	0.00	0.02	**-0.23**	**-0.22**	**-0.22**	0.04	**-0.07**	1.00								
(12) *LIQUIDITY*	**-0.15**	**0.18**	**0.09**	**-0.06**	**-0.07**	-0.02	**0.51**	**0.22**	**-0.57**	**-0.35**	-0.02	1.00							
(13) *MARGIN*	**0.26**	**-0.05**	**0.08**	-0.02	**-0.07**	**0.30**	**0.35**	**0.67**	**-0.13**	**0.18**	**-0.25**	**0.25**	1.00						
(14) *GROWTH*	**0.11**	-0.00	**0.04**	**0.13**	0.00	**0.12**	**0.12**	**0.36**	-0.02	-0.01	**-0.04**	-0.03	**0.25**	1.00					
(15) *LOSS*	**0.08**	**-0.07**	-0.02	**-0.04**	-0.03	**-0.13**	**-0.19**	**-0.32**	**0.14**	**0.11**	**0.13**	**-0.08**	**-0.21**	**-0.07**	1.00				
(16) *LOG_GDPC*	**-0.34**	**-0.23**	**-0.20**	0.02	-0.02	-0.04	0.04	**-0.18**	**-0.09**	**-0.05**	0.02	**0.08**	**-0.13**	**-0.09**	0.027	1.00			
(17) *COMMNLAW*	**0.76**	**-0.23**	**0.06**	**-0.14**	**-0.19**	**-0.07**	**-0.18**	**0.21**	**0.09**	**0.26**	-0.02	**-0.06**	**0.12**	**0.12**	0.02	**-0.09**	1.00		
(18) *ADR*	**-0.15**	-0.03	**-0.05**	0.02	0.02	**0.19**	0.04	**-0.09**	0.03	**-0.07**	-0.03	**0.04**	0.02	0.02	-0.03	**0.23**	**-0.06**	1.00	
(19) *LOG_MCAP*	**-0.59**	**0.11**	0.02	0.02	0.03	**0.15**	**0.20**	**-0.20**	**-0.10**	**-0.21**	-0.01	**0.13**	**-0.07**	**-0.07**	-0.02	**0.49**	**-0.50**	**0.53**	1.00

Notes: Table 2.4 presents Pearson's correlation between the variables. All variables are defined in Appendix A. Correlation coefficients reported in **bold** font are significant at the 1% level.

Table 2.4 reports Pearson's correlation coefficients between the regression variables. Note that the correlation coefficients between COD and CCP are in line with our study's expectations. Negative statistically significant correlations are found between *COD* and each of *CCP1*, *CCP2*, *CCP3* and *CCP4* (-0.30, -0.08, -0.12 and -0.15, respectively). As we do not find high value correlation coefficients between the firm-level control variables (between -0.70 and 0.70), this suggests that multicollinearity between the explanatory variables is unlikely to drive our multivariate regression results. For more investigation of this problem, we use variance inflation factor (VIF) values when we estimate the regression models and find that all VIF values are below 6 (un-tabulated); if the value is more than 10, this would indicate the presence of a multicollinearity problem (Rashid, 2013).

2.5.2 Multivariate regression analysis

In this section, we empirically examine the effect of CCP on COD in a multivariate setting after controlling for the factors most likely to influence cost of debt (COD). We regress COD on CCP and a set of control variables. We also use various econometric methods, including ordinary least squares (OLS), Heckman's (1979) two-stage model, the PSM model, and firm fixed-effects and country fixed-effects regressions to test our hypothesis. All models include year and industry dummies and a list of country-level control variables to control for unobserved variations or macroeconomic factors that could drive CCP and/or COD across country, industry or over years.

Table 2.5, Panel A reports the results for OLS regressions for the full sample of 3,666 firm-years from 14 countries. To mitigate concerns about the effect of omitted variables, we control for a set of firm-level and country-level variables, as explained and discussed in Section 2.4.3. The coefficients of the four proxies for CCP are consistent with our expectations. As shown in the results, *COD* is negatively associated with *CCP1* (-0.240), *CCP2* (-0.238), *CCP3* (-0.022) and *CCP4* (-0.024), with statistical significance at 5% (10%) level for *CCP1*, *CCP2* and *CCP3 (CCP4)*. This result implies that the higher the level of CCP, the lower the company's cost of debt (COD). The estimated coefficients for the CCP indices suggest that an increase of one standard deviation in *CCP1*, *CCP2*, *CCP3* and *CCP4* leads to a decrease in *COD* by 22, 15, 6 and 5 basis points, respectively. These estimates are also economically significant, as they equal approximately 17%, 11%, 5% and 4% of one standard deviation of the COD index, respectively.

One stream of the research explores the relationship between corporate governance and cost of debt (COD). For instance, Anderson et al. (2004) argue that board characteristics, such as board independence and board size, are negatively associated with cost of debt (COD). As shown in Table 2.5, Panel B, we re-estimate the baseline regression model after controlling for the corporate governance variables. We include board size (*BSIZE*), board independence (*BINDP*) and CEO duality (*DUALITY*) in the baseline regression model as additional control variables. The results suggest that the association between CCP and COD remains negative and statistically significant. The coefficients of *CCP1*, *CCP2*, *CCP3* and *CCP4* are -0.300, -0.300, -0.022 and -0.024, with statistical significance at 1%, 1%, 5% and 10% levels, respectively. Overall, the results shown in Table 2.5 provide evidence that CCP has a negative impact on COD beyond the firm-level risk characteristics.

Table 2.5. Ordinary least squares (OLS) regression results of CCP–COD association

Panel A – OLS regression models				
	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
CCP1	**-0.240****			
	(-2.42)			
CCP2		**-0.238****		
		(-2.39)		
CCP3			**-0.022****	
			(-2.45)	
CCP4				**-0.024***
				(-1.84)
LOG_SIZE	0.070***	0.077***	0.092***	0.094***
	(2.69)	(2.94)	(3.14)	(3.06)
LOG_COV	-0.240***	-0.231***	-0.189***	-0.189***
	(-3.85)	(-3.66)	(-3.10)	(-3.11)
ROA	3.899***	3.744***	3.549***	3.523***
	(3.42)	(3.36)	(3.23)	(3.21)
LEVERAGE	-0.102	-0.088	0.138	0.147
	(-0.44)	(-0.38)	(0.63)	(0.66)
CAPINT	0.439**	0.534***	0.569***	0.593***
	(2.39)	(2.87)	(3.04)	(3.15)
BETA	0.073	0.067	0.086	0.087
	(1.25)	(1.15)	(1.41)	(1.41)
LIQUIDITY	0.000	0.004	0.002	0.004
	(0.00)	(0.12)	(0.06)	(0.10)
MARGIN	-0.869	-0.924	-1.167*	-1.177*
	(-1.32)	(-1.45)	(-1.89)	(-1.89)
GROWTH	0.332**	0.358**	0.394**	0.329**
	(2.08)	(2.22)	(2.37)	(2.03)
LOSS	0.403***	0.401***	0.380***	0.379***
	(3.82)	(3.85)	(3.57)	(3.56)
LOG_GDPC	-0.549***	-0.568***	-0.604***	-0.606***
	(-3.98)	(-4.05)	(-4.00)	(-4.02)
COMMNLAW	2.083***	2.207***	2.158***	2.155***
	(15.52)	(14.08)	(13.85)	(13.72)
ADR	0.027	-0.009	0.026	0.028
	(0.29)	(-0.10)	(0.28)	(0.30)
LOG_MCAP	-1.024***	-0.907***	-1.010***	-1.010***
	(-4.97)	(-4.43)	(-4.74)	(-4.73)
Intercept	12.634***	12.200***	12.845***	12.815***
	(8.30)	(7.65)	(8.35)	(8.23)
Year fixed-effects	Yes	Yes	Yes	Yes
Table 2.5 *continued*				
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.7188	0.7152	0.7059	0.7055
Observations	3666	3666	3666	3666

Panel B – OLS regression results with controlling for corporate governance factors				
	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
CCP1	**-0.300***** **(-2.73)**			
CCP2		**-0.300***** **(-2.71)**		
CCP3			**-0.022**** **(-2.41)**	
CCP4				**-0.024*** **(-1.71)**
BSIZE	0.002 (0.32)	0.002 (0.33)	0.004 (0.52)	0.004 (0.52)
BINDP	0.514*** (3.18)	0.497*** (3.15)	0.449** (2.56)	0.445** (2.52)
DUALITY	0.097** (2.24)	0.102** (2.27)	0.103** (2.19)	0.102** (2.18)
LOG_SIZE	0.052* (1.83)	0.060** (2.16)	0.076** (2.49)	0.078** (2.40)
LOG_COV	-0.188*** (-2.95)	-0.178*** (-2.77)	-0.132** (-2.11)	-0.132** (-2.13)
ROA	3.866*** (3.32)	3.665*** (3.23)	3.509*** (3.08)	3.493*** (3.07)
LEVERAGE	-0.033 (-0.13)	-0.028 (-0.11)	0.241 (0.99)	0.248 (1.02)
CAPINT	0.335* (1.78)	0.461** (2.41)	0.521*** (2.69)	0.545*** (2.80)
BETA	0.061 (0.99)	0.056 (0.89)	0.081 (1.19)	0.081 (1.19)
LIQUIDITY	-0.006 (-0.14)	0.000 (0.00)	-0.001 (-0.02)	0.001 (0.03)
MARGIN	-0.726 (-1.13)	-0.787 (-1.27)	-1.124* (-1.82)	-1.130* (-1.82)
GROWTH	0.330** (2.05)	0.363** (2.22)	0.387** (2.31)	0.321* (1.95)
LOSS	0.361*** (3.34)	0.366*** (3.44)	0.347*** (3.20)	0.347*** (3.20)
LOG_GDPC	-0.742*** (-5.89)	-0.765*** (-5.92)	-0.813*** (-5.69)	-0.815*** (-5.71)
COMMNLAW	1.887*** (13.69)	2.045*** (12.15)	1.997*** (11.55)	1.997*** (11.43)
ADR	0.040 (0.41)	0.003 (0.03)	0.054 (0.50)	0.056 (0.51)
LOG_MCAP	-0.860*** (-3.49)	-0.706*** (-2.91)	-0.838*** (-3.23)	-0.839*** (-3.21)
Intercept	11.511*** (7.20)	10.998*** (6.66)	11.919*** (7.34)	11.871*** (7.23)
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.7392	0.7343	0.7201	0.7196
Observations	3179	3179	3179	3179

Notes: Table 2.5, Panel A presents the OLS regression results of the CCP–COD association. Panel B presents the OLS regression results after controlling for the corporate governance variables. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects, with *t*-statistics reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. All variables are defined in Appendix A.

As shown in Table 2.6, we examine whether the CCP–COD relationship is different with different country-level governance settings. We employ three country-level governance characteristics, as developed by World Bank databases, namely, government effectiveness (GE), regulatory quality (RQ) and rule of law (RL). In Table 2.6, Panel A, we test Hypothesis

2a (H2a) which examines the effect of government effectiveness (GE) on the relationship between CCP and cost of debt (COD). We find that the coefficients of the interaction term between *GE* and each of *CCP1*, *CCP2*, *CCP3* and *CCP4* are 0.250, 0.367, 0.121 and 0.168, which are statistically significant at the 1%, 1%, 1% and 5% levels, respectively. The results suggest that the association between CCP and COD is, *ceteris paribus*, stronger in countries with poor government effectiveness than in countries with strong government effectiveness.

As shown in Table 2.6, Panel B, we test Hypothesis 2b (H2b) which examines the effect of regulatory quality (RQ) on the relationship between CCP and cost of debt (COD). We find that the coefficients of the interaction term between *RQ* and each of *CCP1*, *CCP3* and *CCP4* are 0.215, 0.105 and 0.162, which are statistically significant at the 10%, 1% and 1% levels, respectively. In contrast, the coefficient of the interaction term between *RQ* and *CCP2* is statistically insignificant. The results suggest that the association between CCP and COD is stronger in countries with weak regulatory quality than in countries with strong regulatory quality.

As shown in Table 2.6, Panel C, we test Hypothesis 2c (H2c) which examines the effect of the rule of law (RL) on the relationship between CCP and cost of debt (COD). We find that the coefficients of the interaction term between *RL* and each of *CCP1*, *CCP2*, *CCP3* and *CCP4* are 0.220, 0.250, 0.108 and 0.166, which are statistically significant at the 1%, 10%, 1% and 1% levels, respectively. The results suggest that the association between CCP and COD is stronger in countries with weak rule of law than in countries with strong rule of law.

Overall, a positive coefficient suggests a substitution effect between a country-level governance mechanism and debt markets in addressing carbon performance, with CCP having a larger impact on COD for firms from countries with a weak governance mechanism (and having a smaller impact on COD in firms from countries with a strong governance mechanism). In the next section, we document results of the robustness tests that we use to verify the study's main results for the negative relationship between CCP and cost of debt (COD) (Table 2.5).

Table 2.6. Role of country-level governance indicators in CCP–COD association

Panel A – Government effectiveness (*GE*)				
	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
*GE*CCP1*	**0.250*****			
	(2.76)			
*GE*CCP2*		**0.367*****		
		(2.69)		
*GE*CCP3*			**0.121*****	

			(2.90)	
*GE*CCP4*				**0.168****
				(2.47)
CCP1	-0.456***			
	(-3.07)			
CCP2		-0.688***		
		(-3.12)		
CCP3			-0.195***	
			(-2.99)	
CCP4				-0.274**
				(-2.54)
GE	-0.573***	-0.787***	-1.691***	-1.768***
	(-2.90)	(-4.21)	(-4.23)	(-3.82)
Intercept	7.144***	6.438***	7.614***	7.727***
	(4.81)	(4.14)	(4.66)	(4.40)
Country-level control variables	Yes	Yes	Yes	Yes
Firm-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.757	0.756	0.748	0.748
Observations	3666	3666	3666	3666
Panel B – Regulatory quality (*RQ*)				
*RQ*CCP1*	**0.215***			
	(1.95)			
*RQ*CCP2*		**0.253**		
		(1.47)		
*RQ*CCP3*			**0.105*****	
			(2.80)	
*RQ*CCP4*				**0.162*****
				(2.72)
CCP1	-0.397**			
	(-2.40)			
CCP2		-0.509*		
		(-1.92)		
CCP3			-0.157***	
			(-2.94)	
CCP4				-0.241***
				(-2.80)
RQ	-0.325*	-0.526***	-1.268***	-1.400***
	(-1.88)	(-3.14)	(-3.51)	(-3.46)
Intercept	8.430***	7.741***	8.883***	9.187***
	(5.35)	(4.65)	(5.23)	(5.13)
Country-level control variables	Yes	Yes	Yes	Yes
Firm-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.743	0.739	0.734	0.735
Observations	3666	3666	3666	3666

Table 2.6 *continued*

Panel C – Rule of law (*RL*)				
	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
*RL*CCP1*	**0.220*****			
	(2.66)			
*RL*CCP2*		**0.250***		
		(1.88)		
*RL*CCP3*			**0.108*****	
			(2.96)	
*RL*CCP4*				**0.166*****

				(3.00)
CCP1	-0.392***			
	(-3.00)			
CCP2		-0.486**		
		(-2.34)		
CCP3			-0.148***	
			(-3.10)	
CCP4				-0.228***
				(-3.07)
RL	-0.334*	-0.567***	-1.341***	-1.471***
	(-1.79)	(-3.11)	(-3.67)	(-3.75)
Intercept	10.149***	9.769***	10.865***	11.048***
	(7.21)	(6.77)	(7.48)	(7.25)
Country-level control variables	Yes	Yes	Yes	Yes
Firm-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.747	0.742	0.737	0.737
Observations	3666	3666	3666	3666

Notes: This table presents the results of the country-level governance role in the CCP–COD association. We include the interaction terms between government effectiveness (*GE*), regulatory quality (*RQ*) and rule of law (*RL*) and the four proxies for CCP in the baseline model, with the results reported in Panels A, B and C, respectively. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. All variables are defined in Appendix A.

2.5.3 Robustness tests and additional analyses

As mentioned above, in this section, we investigate whether the results are robust after controlling for the sample selection bias problem, endogeneity concerns, the heterogeneity problem, sensitivity to alternative estimation for COD, potential simultaneous causality between COD and CCP, and the influence of the GFC years. In general, these investigations support our main finding regarding the negative association between CCP and cost of debt (COD).

2.5.3.1 Sample selection bias

One of the issues in our study is sample selection bias which occurs when the outcome of interest is only observed for a sample that is non-randomly selected. In our context, firms that chose to disclose their carbon emissions may have unobserved common characteristics that influence our findings; thus, the sample may not then correctly represent the population. To deal with this concern, we follow Krishnamurti et al. (2018) and Goss and Roberts (2011) and employ Heckman's (1979) two-stage model (reported in Table 2.7).

Table 2.7. Heckman's (1979) two-stage model analysis

	First stage	Second stage			
	DV=*DISC*	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
CCP1		**-0.134****			
		(-2.21)			
CCP2			**-0.150****		
			(-2.44)		

CCP3				**-0.012****	
				(-2.32)	
CCP4					**-0.018****
					(-2.47)
LOG_SIZE	0.596***	0.172***	0.168***	0.177***	0.182***
	[13.37]	(2.88)	(2.85)	(5.04)	(5.19)
LOG_COV	-0.193***	-0.278***	-0.275***	-0.250***	-0.250***
	[-2.59]	(-4.41)	(-4.35)	(-6.59)	(-6.60)
ROA	-1.195**	2.713**	2.646**	2.461***	2.423***
	[-2.03]	(2.49)	(2.43)	(3.51)	(3.46)
LEVERAGE	-0.867***	-0.441*	-0.442*	-0.321**	-0.314**
	[-2.60]	(-1.91)	(-1.96)	(-2.58)	(-2.53)
CAPINT	0.571**	0.801***	0.840***	0.878***	0.886***
	[2.07]	(4.28)	(4.42)	(7.82)	(8.02)
BETA	0.071	0.082	0.077	0.088**	0.090**
	[0.90]	(1.45)	(1.36)	(2.46)	(2.50)
LIQUIDITY	-0.066	-0.013	-0.011	-0.012	-0.012
	[-1.35]	(-0.41)	(-0.34)	(-0.57)	(-0.55)
MARGIN	-0.913	-1.155*	-1.139*	-1.287***	-1.297***
	[-1.44]	(-1.76)	(-1.75)	(-3.32)	(-3.35)
GROWTH	-1.585***	-0.108	-0.073	-0.069	-0.106
	[-9.59]	(-0.44)	(-0.30)	(-0.40)	(-0.62)
LOSS	0.037	0.392***	0.393***	0.380***	0.379***
	[0.27]	(3.76)	(3.81)	(4.87)	(4.84)
LOG_GDPC	0.518***	-0.420**	-0.446***	-0.480***	-0.482***
	[6.45]	(-2.55)	(-2.70)	(-5.80)	(-5.84)
COMMNLAW	-0.598***	2.207***	2.303***	2.283***	2.279***
	[-4.53]	(13.22)	(13.32)	(26.63)	(26.49)
ADR	0.232***	-0.003	-0.036	-0.017	-0.017
	[3.31]	(-0.04)	(-0.47)	(-0.41)	(-0.41)
LOG_MCAP	-0.281**	-0.415**	-0.354**	-0.366***	-0.369***
	[-2.10]	(-2.41)	(-2.01)	(-4.12)	(-4.14)
IMR		0.541*	0.513*	0.521*	0.523*
		(1.88)	(1.81)	(1.81)	(1.82)
Intercept	-1.317	10.118***	9.817***	10.163***	10.184***
	[-0.91]	(6.02)	(5.76)	(10.03)	(9.96)
Year fixed-effects	Yes	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes	Yes
R^2/Pseudo R^2	0.443	0.749	0.749	0.745	0.745
Observations	7141	3666	3666	3666	3666

Notes: Table 2.7 presents the results from Heckman's (1979) two-stage model. The first stage is the probit regression model with a dependent variable that equals 1 if the firm discloses its carbon data (*DISC*), and 0 otherwise. The second stage is the baseline regression model which includes the inverse Mills ratio (*IMR*) to control for selection bias. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects, with *t*-statistics (z-statistics) reported in parentheses (brackets). Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. All variables are defined in Appendix A.

In the first stage (Column 1), we use the probit regression model as a selection equation where the dependent variable (*DISC*) is a dummy variable equal to 1 if carbon data are available, and 0 otherwise. Next, we calculate the inverse Mills ratio (*IMR*) from the selection equation and include it as an additional control variable in the second stage. To conduct this test, we add 3,475 firm-year observations to our sample for firms that have all other variables but did not disclose their carbon data. The observation must have all other variables to enter this test, with the final sample in the first stage having 7,141 firm-year observations.

The results show significant positive coefficients of *IMR*, thus indicating the presence of upward-sample selection bias in our baseline model (Table 2.5). However, selection bias-corrected estimates, in Table 2.7, Columns 2–5, indicate that the coefficients of *CCP1, CCP2, CCP3* and *CCP4* are -0.134, -0.150, -0.012 and -0.018, respectively, which are statistically significant at the 5% level, suggesting that our baseline results are slightly upward-biased and that sample selection bias is a minor concern. Therefore, our main finding remains robust after controlling for potential sample selection bias, with the CCP variables having a statistically significant negative relationship with cost of debt (COD).

2.5.3.2 Propensity score matching (PSM) model

In non-experimental (observational) studies, endogeneity is an inherent problem and may be the most difficult task faced by researchers. Endogeneity occurs when the explanatory variables are correlated with the error term. In our context, this occurs when COD and CCP are driven by confounding unmeasured or unobserved factors (e.g., management characteristics or regulation effects). To address (or, at least, alleviate) the endogeneity concern, we use the PSM model. In the first stage, a logit model is used to match firms with higher CCP (treatment) and lower CCP (control) in the same industry and year using the nearest neighbour, within a 1% caliper and with no replacement matching algorithms. Table 2.8, Panel A reports the results of the first stage. To test whether our matching algorithms are valid, we perform the mean differences between treatment and control groups as a matching diagnostic test. The results reported in Panel B suggest no statistically significant mean difference exists between the control and treatment groups in our four models as the *p*-values are significantly high. Next, in the second stage, we run the baseline regression models using the propensity-matched sample from the first stage. All regressions in Panel C are estimated with clustered robust standard errors by firm and include year and industry fixed-effects. The results are reported in Table 2.8, Panel C and indicate that the coefficients of *CCP1*, *CCP2*, *CCP3* and *CCP4* are -0.142, -0.120, -0.084 and -0.068, which are statistically significant at the 1%, 5%, 5% and 10% levels, respectively. The results suggest that our main finding is robust to using an alternative model specification and rule out the likelihood that endogeneity drives our study's results.

Table 2.8. Propensity score matching (PSM) analysis

Panel A – Logit regression results (First stage)								
	DV=*HIGH_CCP1*		DV=*HIGH_CCP2*		DV=*HIGH_CCP3*		DV=*HIGH_CCP4*	
	Coeff.	*z*-stat	Coeff.	*z*-stat	Coeff.	*z*-stat	Coeff.	*z*-stat
LOG_SIZE	-0.166***	-3.800	-0.102**	-2.480	0.484***	11.60	0.688***	15.370
LOG_COV	0.192*	1.690	-0.239**	-2.220	0.155	1.460	0.212*	1.930
ROA	-1.502	-0.830	3.877**	2.290	-3.059*	-1.850	-3.864**	-2.270
LEVERAGE	-1.839***	-4.870	-1.884***	-5.230	0.565	1.610	0.693*	1.910
CAPINT	-6.377***	-19.850	-5.026***	-17.120	-2.013***	-7.910	-1.371***	-5.310

BETA	-0.075	-0.700	-0.098	-0.970	0.092	0.940	0.268***	2.650
LIQUIDITY	-0.609***	-8.570	-0.501***	-7.640	-0.199***	-3.190	-0.127**	-1.980
MARGIN	3.846***	4.080	3.010***	3.460	0.365	0.450	-0.355	-0.430
GROWTH	0.086	0.200	0.306	0.750	2.632***	6.520	0.293	0.720
LOSS	0.161	0.790	0.297	1.530	-0.005	-0.030	0.017	0.090
LOG_GDPC	1.178***	8.860	0.689***	7.060	-0.315***	-3.950	-0.226***	2.840
COMMNLAW	-1.158***	-7.320	0.669***	4.660	-0.343**	-2.530	-0.797***	-5.750
ADR	0.587***	5.140	-0.570***	-5.220	-0.111	-1.090	-0.023	-0.220
LOG_MCAP	-1.193***	-4.780	1.654***	6.660	-0.639***	-2.970	-1.135***	-5.020
Intercept	4.983***	2.650	2.499	1.410	-2.111	-1.250	-3.856**	-2.220
Year fixed-effects	Yes		Yes		Yes		Yes	
Industry fixed-effects	Yes		Yes		Yes		Yes	
Observations	3666		3666		3666		3666	
Pseudo R^2	0.172		0.113		0.068		0.092	
Log likelihood	-2103.744		-2252.825		-2329.398		-2223.163	

Panel B – Mean test between treatment and control groups

	Model 1			Model 2			Model 3			Model 4		
	Treat-ment	Control	*p*-value	Treat-ment	Control	*p*-value	Treat-ment	Control	*p*-value	Treat-ment	Control	*p*-value
LOG_SIZE	1.815	1.814	0.982	1.789	1.818	0.495	1.632	1.664	0.412	1.525	1.559	0.370
LOG_COV	4.021	4.009	0.622	4.022	4.023	0.949	4.001	4.012	0.612	3.985	4.011	0.228
ROA	0.046	0.045	0.584	0.046	0.047	0.570	0.044	0.045	0.758	0.044	0.044	0.798
LEVERAGE	0.240	0.245	0.424	0.241	0.247	0.338	0.247	0.248	0.900	0.250	0.248	0.764
CAPINT	0.357	0.370	0.096	0.364	0.372	0.325	0.377	0.375	0.719	0.379	0.382	0.727
BETA	1.003	0.983	0.287	1.004	0.997	0.678	1.011	0.996	0.387	1.014	1.001	0.428
LIQUIDITY	1.623	1.616	0.845	1.637	1.647	0.743	1.625	1.617	0.795	1.622	1.611	0.752
MARGIN	0.046	0.042	0.502	0.046	0.045	0.696	0.039	0.039	0.978	0.040	0.041	0.789
GROWTH	0.087	0.087	0.912	0.089	0.091	0.536	0.087	0.087	0.978	0.087	0.086	0.910
LOSS	0.037	0.037	1.000	0.038	0.040	0.832	0.044	0.043	0.845	0.042	0.043	0.919
LOG_GDPC	10.475	10.483	0.717	10.445	10.465	0.351	10.423	10.436	0.539	10.409	10.408	0.968
COMMNLA	0.178	0.172	0.723	0.190	0.196	0.715	0.186	0.181	0.719	0.191	0.179	0.461
ADR	4.324	4.318	0.764	4.329	4.335	0.736	4.303	4.318	0.411	4.278	4.288	0.605
LOG_MCAP	12.392	12.375	0.354	12.378	12.386	0.616	12.378	12.392	0.399	12.361	12.373	0.487

Table 2.8 *continued*

Panel C – OLS regression results (Second stage)				
	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
HIGH_CCP1	**-0.142*****			
	(-3.14)			
HIGH_CCP2		**-0.120****		
		(-2.29)		
HIGH_CCP3			**-0.084****	
			(-2.10)	
HIGH_CCP4				**-0.068***
				(-1.73)
LOG_SIZE	0.103***	0.080***	0.093***	0.099***
	(4.06)	(2.70)	(2.92)	(2.63)
LOG_COV	-0.216***	-0.161**	-0.160**	-0.259***
	(-2.68)	(-2.06)	(-2.51)	(-3.50)
ROA	4.192***	3.962***	3.683***	4.473***
	(3.18)	(2.65)	(2.85)	(3.44)
LEVERAGE	0.376	0.029	0.354	0.149
	(1.39)	(0.11)	(1.40)	(0.60)
CAPINT	0.501**	0.633***	0.660***	0.701***
	(2.28)	(2.59)	(2.86)	(2.79)
BETA	-0.011	0.126*	0.111*	0.140*
	(-0.15)	(1.74)	(1.75)	(1.75)
LIQUIDITY	0.039	0.005	0.018	0.036
	(0.86)	(0.11)	(0.38)	(0.74)
MARGIN	-1.502*	-1.496**	-1.379**	-1.452*
	(-1.96)	(-2.05)	(-2.03)	(-1.89)
GROWTH	0.539**	0.271	0.442**	0.348*
	(2.57)	(1.31)	(2.04)	(1.68)
LOSS	0.448***	0.427***	0.369***	0.423***
	(2.76)	(3.16)	(3.19)	(2.88)
LOG_GDPC	-0.451***	-0.360**	-0.557***	-0.604***
	(-2.89)	(-2.25)	(-3.82)	(-3.98)
COMMNLAW	1.990***	2.105***	2.222***	2.238***
	(12.79)	(12.01)	(12.18)	(11.20)
ADR	0.092	0.118	0.038	-0.030
	(1.07)	(1.05)	(0.36)	(-0.26)
LOG_MCAP	-0.998***	-0.965***	-1.083***	-1.126***
	(-4.40)	(-3.82)	(-4.57)	(-4.24)
Intercept	13.792***	13.211***	12.608***	9.496***
	(8.50)	(7.58)	(7.20)	(5.69)
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
Observations	1976	2364	2526	2392
R-squared	0.6938	0.7034	0.7111	0.6888

Notes: This table presents the regression results of the effect of CCP on COD using the propensity-matched sample. Panel A presents the first stage. A logit model has been used to match firms with higher CCP (treatment) and lower CCP (control) with the same industry and year using nearest neighbour, within a 1% caliper and no replacement matching algorithms. Panel B presents the mean differences between treatment and control firms as a post-match diagnostic test. Panel C presents OLS regression results using the propensity-matched sample from the first stage. All regressions in Panel C are estimated with clustered robust standard errors by firm and include year and industry fixed-effects, with *t*-statistics reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. All variables are defined in Appendix A.

2.5.3.3 Firm fixed-effects and country fixed-effects

In all previous model specifications, we use year and industry dummy variables to control for the unobservable effect of year and industry on cost of debt (COD). Although this is considered sufficient in panel data-based studies, we further estimate alternative model specifications and run firm fixed-effects and country fixed-effects regressions to control for time-invariant unobserved characteristics for firms or countries, with these correlated with both COD and CCP proxies. The coefficients are estimated through changes over time within a principal firm or within a particular country. The firm fixed-effects results are reported in Table 2.9 and show that *CCP1* and *CCP2* indices are negatively associated with COD (-0.165, *p*-value < 0.01), while the results are statistically insignificant for *CCP3* and *CCP4*. The estimated coefficients suggest that an increase of one standard deviation of *CCP1* (*CCP2*) leads to a decrease in *COD* by nearly 16 (11) basis points. As the country dummy variables are not included in the previous model specifications, we run the country fixed-effects model and report the results in Table 2.10. The results suggest that *CCP1* and *CCP2* indices are also negatively associated with *COD* and the coefficients are -0.060 (*p*-value < 0.05) and -0.115 (*p*-value < 0.01), respectively. The results are statistically insignificant for *CCP3* and *CCP4*. The results suggest that our main results (Table 2.5) are robust to using alternative specifications and that the baseline models are not driven by unobserved time-invariant characteristics by firms and countries (at least for *CCP1* and *CCP2*).

2.5.3.4 Robustness across sub-samples

In Table 2.11, we estimate the baseline regression model for a set of sub-samples separated by country to control for heterogeneity problems and to check the robustness of our results across countries. Panels A, B, C, D, E, F and G present the results for sub-samples from Japan; Australia; Taiwan; South Korea; all countries without Japan; all countries without the top three countries; and all countries without the bottom five countries, respectively. Firstly, we separately run the baseline regression model for the top four countries (with the highest number of observations) and report the results in the first four panels. In Panel A, the results of the sub-sample of 2,237 firm-year observations for Japanese firms suggest that *CCP1* and *CCP2* indices are negatively associated with *COD* at -0.012 (*p*-value < 0.10) and -0.015 (*p*-value < 0.05). However, the coefficients of *CCP3* and *CCP4* are statistically insignificant. Similarly, the results of a sub-sample of 360 firm-year observations for Australian firms suggest that our main results for *CCP1* and *CCP2* are robust and remain the same.

Table 2.9. Regression results of CCP–COD association: Firm fixed-effects

	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
CCP1	**-0.165***** **(-4.70)**			
CCP2		**-0.165***** **(-4.59)**		
CCP3			**0.003** **(0.71)**	
CCP4				**0.005** **(0.72)**
LOG_SIZE	0.066** (2.41)	0.066** (2.41)	0.062** (2.26)	0.062** (2.25)
LOG_COV	-0.003 (-0.09)	-0.004 (-0.12)	-0.001 (-0.03)	-0.001 (-0.03)
ROA	1.180** (2.43)	1.207** (2.48)	1.141** (2.34)	1.143** (2.35)
LEVERAGE	0.583*** (3.82)	0.585*** (3.84)	0.606*** (3.97)	0.604*** (3.95)
CAPINT	1.036*** (5.92)	1.034*** (5.91)	1.034*** (5.89)	1.033*** (5.89)
BETA	0.020 (0.58)	0.019 (0.57)	0.019 (0.56)	0.020 (0.58)
LIQUIDITY	0.111*** (4.46)	0.112*** (4.48)	0.115*** (4.61)	0.115*** (4.61)
MARGIN	-1.207*** (-3.84)	-1.226*** (-3.91)	-1.256*** (-3.99)	-1.258*** (-3.99)
GROWTH	-0.053 (-0.60)	-0.054 (-0.62)	-0.092 (-1.01)	-0.086 (-0.96)
LOSS	0.094** (2.19)	0.094** (2.19)	0.094** (2.19)	0.095** (2.20)
Intercept	-12.813*** (-3.30)	-12.914*** (-3.32)	-9.953** (-2.57)	-9.915** (-2.56)
Country-level controls	Yes	Yes	Yes	Yes
Firm fixed-effects	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	No	No	No	No
Country fixed-effects	No	No	No	No
Adj. R-squared	0.9069	0.9069	0.9063	0.9063
Observations	3666	3666	3666	3666

Notes: This table presents the firm fixed-effect regressions (within-firm). The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. All variables are defined in Appendix A.

Table 2.10. Regression results of CCP–COD association: Country fixed-effects

	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
CCP1	**-0.060****			
	(-2.52)			
CCP2		**-0.115*****		
		(-3.54)		
CCP3			**-0.001**	
			(-0.12)	
CCP4				**0.003**
				(0.46)
LOG_SIZE	0.026	0.027*	0.026	0.024
	(1.61)	(1.73)	(1.58)	(1.37)
LOG_COV	-0.079**	-0.083**	-0.070*	-0.071*
	(-2.17)	(-2.26)	(-1.91)	(-1.93)
ROA	1.677**	1.669**	1.587**	1.601**
	(2.31)	(2.32)	(2.18)	(2.20)
LEVERAGE	0.470***	0.422***	0.525***	0.523***
	(3.58)	(3.33)	(4.03)	(4.02)
CAPINT	0.238**	0.241**	0.277***	0.282***
	(2.31)	(2.39)	(2.67)	(2.74)
BETA	0.029	0.025	0.032	0.031
	(0.80)	(0.69)	(0.86)	(0.84)
LIQUIDITY	0.067***	0.067***	0.069***	0.070***
	(3.33)	(3.32)	(3.39)	(3.43)
MARGIN	-0.859**	-0.828**	-0.898**	-0.898**
	(-2.09)	(-2.03)	(-2.20)	(-2.20)
GROWTH	-0.084	-0.071	-0.082	-0.085
	(-0.73)	(-0.61)	(-0.70)	(-0.73)
LOSS	0.228***	0.231***	0.224***	0.224***
	(2.77)	(2.82)	(2.70)	(2.70)
Intercept	-5.676	-6.515	-5.228	-5.047
	(-0.60)	(-0.69)	(-0.54)	(-0.53)
Country-level controls	Yes	Yes	Yes	Yes
Firm fixed-effects	No	No	No	No
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
Country fixed-effects	Yes	Yes	Yes	Yes
Adj. *R*-squared	0.8663	0.8678	0.8655	0.8656
Observations	3666	3666	3666	3666

Notes: This table presents the country fixed-effect regressions (within country). All regressions are estimated with clustered robust standard errors by firm and include year, industry and country fixed-effects, with *t*-statistics reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. All variables are defined in Appendix A.

The coefficients are negative (-0.125 and -0.350, respectively) and statistically significant at 5% and 1% levels, respectively. However, the coefficients of *CCP3* and *CCP4* are statistically insignificant. In Panel C, we report the results for a sub-sample of 344 firm-year observations for Taiwanese firms. The coefficient is negative and statistically significant at the 5% level for *CCP1*, while it is statistically insignificant for *CCP2*. More interestingly, the coefficients for *CCP3* and *CCP4* are positive and statistically significant, which indicates that the results in this sub-sample and for these proxies are in the opposite direction to our main finding. The reason is probably that Taiwan is one of the countries that has not ratified the United Nations Framework Convention on Climate Change (UNFCCC) or the Kyoto Protocol (Shyu, 2014), suggesting that firms' exposure to carbon risk in Taiwan is relatively minimal. Next, we run the regression for a sample of 358 firm-year observations for South Korean firms with the results reported in Panel D. The coefficients are negative for *CCP2*, *CCP3* and *CCP4*, which are statistically significant at 5%, 1% and 1% levels, respectively. However, the coefficient of *CCP1* is statistically insignificant.

Secondly, as most observations (more than 61%) are from Japan, we run the regression after excluding Japanese firms. This sub-sample contains 1,429 firm-year observations from the remaining 13 countries. The results are reported in Panel E, with the coefficients remaining negative and statistically significant at the 1% level for *CCP1*, *CCP2*, *CCP3* and *CCP4*. Next, in Panel F, we exclude the top three countries (those with the highest number of observations) from our sample and estimate the baseline model. The coefficients are negative and statistically significant at the 1% level for *CCP1*, *CCP2* and *CCP3* and at the 5% level for *CCP4*, suggesting that our main results are robust. Finally, we exclude the bottom five countries, those with the lowest number of observations, namely, Indonesia, Sri Lanka, Singapore, China and India. The results in Panel G indicate that our main results are robust to using another sub-sample. The coefficients are negative for *CCP1*, *CCP2*, *CCP3* and *CCP4* and are statistically significant at 1%, 1%, 5% and 1% levels, respectively.

Table 2.11. Ordinary least squares (OLS) regression results for sub-samples

Panel A – Japan				
	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
CCP1	-0.012* (-1.90)			
CCP2		-0.015** (-2.15)		
CCP3			0.003 (1.38)	
CCP4				0.003 (1.12)
Firm-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.7614	0.7522	0.7612	0.7612
Observations	2237	2237	2237	2237

Panel B – Australia				
CCP1	-0.125** (2.20)			
CCP2		-0.350*** (4.95)		
CCP3			-0.025 (-1.17)	
CCP4				0.007 (0.23)
Firm-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.7623	0.7623	0.7624	0.7624
Observations	360	360	360	360

Panel C – Taiwan				
CCP1	-0.062** (-2.53)			
CCP2		0.037 (1.34)		
CCP3			0.015** (2.02)	
CCP4				0.023** (2.52)
Firm-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.5846	0.5846	0.5913	0.5953
Observations	344	344	344	344

Panel D – South Korea				
CCP1	-0.114 (1.17)			
CCP2		-0.270** (2.21)		
CCP3			-0.043*** (-2.70)	
CCP4				-0.062*** (-2.85)
Firm-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.4329	0.4329	0.4323	0.4322
Observations	358	358	358	358

Table 2.11 *continued*

Panel E – Excluding Japan

	DV=*COD*	DV=*COD*	DV=*COD*	DV=*COD*
CCP1	-0.485*** (3.94)			
CCP2		-0.419*** (2.78)		
CCP3			-0.102*** (-4.67)	
CCP4				-0.140*** (-4.29)
Firm-level control variables	Yes	Yes	Yes	Yes
Country-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.6384	0.6332	0.6057	0.6036
Observations	1429	1429	1429	1429
Panel F – Excluding top three countries				
CCP1	-0.387*** (3.51)			
CCP2		-0.384*** (2.67)		
CCP3			-0.077*** (-2.87)	
CCP4				-0.098** (-2.25)
Firm-level control variables	Yes	Yes	Yes	Yes
Country-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.5663	0.5574	0.5656	0.5691
Observations	725	725	725	725
Panel G – Excluding bottom five countries				
CCP1	-0.122*** (-4.56)			
CCP2		-0.085*** (-3.96)		
CCP3			-0.022** (-2.21)	
CCP4				-0.041*** (-2.68)
Firm-level control variables	Yes	Yes	Yes	Yes
Country-level control variables	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.7859	0.7863	0.7853	0.7852
Observations	3599	3599	3599	3599

Notes: This table presents the baseline regression results for the sub-samples. Panels A, B, C, D, E, F and G present the results for Japan; Australia; Taiwan; South Korea; all countries without Japan; all countries without the top three countries; and all countries without the bottom five countries, respectively, with *t*-statistics reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. All variables are defined in Appendix A.

2.5.3.5 Alternative measure of cost of debt (COD)

To check the sensitivity of our results for the selection of our main dependent variable (COD), we re-run the baseline regression model using credit rating (CR) as an alternative measurement for cost of debt (COD). We regress *CR* on *CCP* and a set of control variables and employ robust standard errors clustered by firm and include year and industry fixed-effects. Table 2.12 reports the results of OLS regressions for a sample of 870 firm-years from 12 countries where the *CR* variable is available. The coefficients are consistent with our expectations. The results show that *CR* is positively associated with *CCP1* (0.420), *CCP2* (0.565), *CCP3* (0.118) and *CCP4* (0.22) with statistical significance at the 5% level for *CCP2, CCP3* and *CCP4* and at the 10% level for *CCP1.* This result implies that the higher the level of CCP, the higher the company's credit rating (CR). Thus, our main results continue to hold and are robust when we use an alternative measure for cost of debt (COD). The estimated coefficients for CCP indices suggest that an increase of one standard deviation in *CCP1, CCP2, CCP3* and *CCP4* leads to an increase in CR by 0.38, 0.35, 0.29 and 0.39 units (CR measurement units), respectively. These estimates are also economically significant, as they are equal to approximately 15%, 14%, 12% and 16% of one standard deviation of the CR index, respectively. Note that the impact of CCP on the CR regressions is more economically significant than on the COD regressions, suggesting that rating agencies are relatively more sensitive to carbon risk.

2.5.3.6 Additional analyses

In this subsection, we report on the additional analyses used to support our main finding. Slack resource theory suggests that an increase in access to a debt at a lower cost may also increase CCP and that the exact direction of the relationship is uncertain. To alleviate potential simultaneous causality between COD and CCP, we follow previous studies (Busch & Hoffmann, 2011; Delmas et al., 2015; Lewandowski, 2017; Misani & Pogutz, 2015; Trumpp & Guenther, 2017) and lag the independent variables one and two years behind cost of debt (COD). This also helps to control for any delay in carbon performance disclosure and the fact that CEP can achieve financial benefits in the long run. The un-tabulated results reinforce our main results as we find that the lagged value of the four proxies for CCP at both *t-1* and *t-2* are negatively and significantly associated with COD, suggesting that endogeneity stemming from simultaneous causality is not influencing our main finding.

Table 2.12. Ordinary least squares (OLS) regression results for association between corporate carbon performance (CCP) and credit rating (CR)

	DV=*CR*	DV=*CR*	DV=*CR*	DV=*CR*
CCP1	0.420*			
	(1.88)			
CCP2		0.565**		
		(2.41)		
CCP3			0.118**	
			(2.14)	
CCP4				0.220**
				(2.47)
LOG_SIZE	0.967***	0.960***	0.908***	0.820***
	(4.17)	(4.32)	(3.96)	(3.61)
LOG_COV	0.933**	0.980**	0.870**	0.858**
	(2.09)	(2.20)	(2.04)	(2.05)
ROA	-12.038**	-12.273**	-11.373**	-10.702**
	(-2.16)	(-2.28)	(-2.19)	(-2.13)
LEVERAGE	-1.999	-1.999	-2.157	-2.066
	(-1.28)	(-1.28)	(-1.39)	(-1.34)
CAPINT	0.293	0.157	0.256	0.205
	(0.22)	(0.12)	(0.19)	(0.15)
BETA	-1.137***	-1.112***	-1.218***	-1.217***
	(-2.67)	(-2.65)	(-2.83)	(-2.78)
LIQUIDITY	0.797***	0.771***	0.755***	0.720***
	(2.98)	(2.98)	(2.87)	(2.78)
MARGIN	0.962	1.162	0.850	1.221
	(0.29)	(0.37)	(0.26)	(0.37)
GROWTH	-1.130	-1.230	-1.374	-1.050
	(-1.24)	(-1.37)	(-1.43)	(-1.14)
LOSS	-0.317	-0.283	-0.189	-0.175
	(-0.63)	(-0.57)	(-0.37)	(-0.34)
LOG_GDPC	1.734**	1.803**	1.752*	1.757*
	(2.08)	(2.30)	(1.92)	(1.93)
COMMNLAW	0.376	0.123	0.300	0.358
	(0.57)	(0.19)	(0.41)	(0.49)
ADR	-0.173	-0.022	-0.212	-0.151
	(-0.28)	(-0.04)	(-0.32)	(-0.23)
LOG_MCAP	-0.072	-0.446	-0.321	-0.303
	(-0.08)	(-0.55)	(-0.35)	(-0.34)
Intercept	-6.129	-3.155	-3.420	-3.841
	(-0.90)	(-0.47)	(-0.49)	(-0.56)
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
R-squared	0.5228	0.5331	0.5144	0.5202
Observations	870	870	870	870

Notes: This table presents the OLS regression results of the CCP–CR association. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects, with *t*-statistics reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. All variables are defined in Appendix A.

During the GFC, firms experienced instability in their profitability and were required to cope with financial distress, higher interest rates and credit constraints (La Rosa et al., 2018). Therefore, it may have been necessary to reduce their investment in environmental protection activities to reduce costs and increase financial performance. Consequently, the relationship between CCP and COD may be unstable during the GFC years (2007–2008). To address this concern, we re-estimate the baseline regression model after excluding the GFC years. The un-tabulated results reinforce our main finding as we find *CCP1* (-0.250), *CCP2* (-0.247), *CCP3* (-0.023) and *CCP4* (-0.027) are negatively associated with *COD*, with statistical significance at the 5% level for *CCP1*, *CCP2* and *CCP3* and at the 10% level for *CCP4*.

2.6 Discussion and conclusion

In this study, we empirically examine the debt markets' response to corporate carbon performance (CCP). Specifically, we examine the influence of CCP on COD for a comprehensive sample of 3,666 firm-year observations from 14 countries in the Asia-Pacific region over the 2003–2018 period. We find that COD is lower when a firm has higher carbon performance (CCP) (H1). We also find that CCP produces greater reductions in COD for firms from countries with poor government effectiveness (H2a), weak regulatory quality (H2b) and weak rule of law (H2c). Thus, a country-level governance mechanism and debt markets are substitutes in addressing corporate carbon performance (CCP). We also find that the CCP–COD relationship was either significantly negative or statistically insignificant in a list of sub-samples (separated by country). However, we unexpectedly find that two proxies for CCP are positively related to COD in a sub-sample of 344 firm-year observations from Taiwan. The reason is probably that Taiwan is one of the countries that has not ratified the United Nations Framework Convention on Climate Change (UNFCCC) or the Kyoto Protocol (Shyu, 2014), suggesting that firms' exposure to carbon risk in Taiwan is relatively minimal.

Firstly, we conduct a univariate analysis and then multivariate analysis using OLS regression models, while controlling for a set of firm-level and country-level variables. Secondly, to address potential sample selection bias, heterogeneity and endogeneity problems, we use several alternative model specifications: Heckman's (1979) two-stage approach, propensity score matching (PSM) analysis, and firm fixed-effects and country fixed-effects models. We find our main results are robust to these concerns and continue to hold (especially for *CCP1* and *CCP2*). The results are also robust after accounting for the GFC years, using credit rating (CR) as an alternative measure of COD, using sub-samples, controlling for simultaneous causality and controlling for corporate governance variables.

This study provides significant insights and has several implications for firms' financial management, policy makers, creditors and investors. It adds to research streams in the finance and management literature and complements related research by specifying CCP as a channel through which CEP affects firms' financing costs and corporate financial performance (CFP). In particular, firms can reduce their COD and thereby improve firm value by improving their carbon performance (CCP). In the current study, we provide evidence that lending institutions are likely to consider CCP in their lending decisions.

Our study provides additional insights for environmental policy makers. It assists them to handle carbon issues and mitigate this concern at the country level. Policy makers should consider firms' activities in mitigating the climate change problem and provide a cooperative relationship with their industry. In fact, firms' mitigation activities require sufficient funds to obtain new environmentally friendly technology and to increase their capabilities to mitigate climate change-related problems. Thus, more fiscal stimulus should probably be provided for environmentally responsible companies and direct lobbying should be directed at those which have assumed a lower level of environmental responsibility. In addition, policy makers need to be aware of the benefits of developing CCP information sources and of the importance of making carbon-related disclosures available to market participants. Indeed, the availability of such information will increase the market's efficiency. Here, the market mechanism could play an important role in addressing this concern (especially in countries with a weak governance mechanism), rather than being directly solved by government interventions. The government could then act as a guarantor and undertake complementary roles by enacting the required regulations and laws.

Our findings have two theoretical implications that explain the determinants of cost of debt (COD). Firstly, a win-win situation can be grounded in stakeholder theory. Supporters of stakeholder theory argue that when a firm effectively manages its relationships with key stakeholders, it will most likely achieve economic success and thus reduce cost of debt (COD). Conversely, if firms do not respond to mounting environmental pressure from diverse stakeholders, such as the media, the general public, regulators and environmental activists, they may experience a loss of their reputation; creditors may consider this an indicator of the presence of potential business risk; clients may boycott their products or services; or costly environmental fines may be charged; and, thus, their financial performance will be affected. Secondly, our results support the basic arguments of agency theory. Divergences in carbon-related policies and objectives between lenders and borrowers may lead to agency problems. As discussed earlier, management involvement in environmentally irresponsible actions may benefit shareholders at the expense of lenders and, thus, lenders are likely to demand higher interest rates.

This study has a few limitations. Firstly, as our data are limited to firms within the Asia-Pacific region, our results could not be generalised to other regions. Although we provide cross-country evidence of the CCP–COD relationship, we could not apply our findings to firms of other countries. Therefore, it would be fruitful for future research to be conducted in a different context. Secondly, in contrast with *CCP1* and *CCP2*, the adopted carbon performance measurements of *CCP3* and *CCP4* did not pass some of our robustness tests. Augmenting the coverage and the quality of carbon data would, in fact, contribute to the improvement of environmental management practices and environmental performance measurement. Thus, improvement in CCP measurements warrants further significant work. Finally, the availability of carbon data is lower in less-developed or developing countries, whereas our sample concentrates on countries like Japan and Australia. However, we provide evidence of a negative relationship between CCP and COD across almost all countries. Future increases in awareness in developing countries about the climate change problem will increase the availability of carbon data. It would be worthwhile for future research to conduct studies with a larger sample.

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Appendix A: Descriptions and sources of variables

Variable	Description	Source/Variable code
Firm-level variables		
COD	The cost of debt is calculated as follows: *COD* = [[(*SD*/*TD*)*(*CS* **AF*)] + [(*LD*/*TD*)*(*CL***AF*)]]*[1-*TR*], where *SD* is short-term debt; *TD* is total debt; *CS* is pre-tax cost of short-term debt; *AF* is the debt adjustment factor; *LD* is long-term debt; *CL* is pre-tax cost of long-term debt; and *TR* is effective tax rate.	Bloomberg/WACC_COST_DEBT
CR	The company's credit rating as provided by Fitch (AAA (24 points); AA+ (23 points); AA (22 points); AA- (21 points); A+ (20 points); A (19 points); A- (18 points); BBB+ (17 points); BBB (16 points); BBB- (15 points); BB+ (14 points); BB (13 points); BB- (12 points); B+ (11 points); B (10 points); B- (9 points); CCC+ (8	Thomson-Reuters/ECSLO05V

	points); CCC (7 points); CCC- (6 points); CC+ (5 points); CC (4 points); CC- (3 points); C (2 points); D (1 point); DD (1 point); and DDD (1 point).	
CCP1	Total carbon emissions in tonnes divided by sales volume in US dollars multiplied by -1.	Researchers' calculation based on data from Thomson-Reuters/ENERO03S
CCP2	*CCP1* minus country–sector mean.	As above
CCP3	A score calculated as follows: 3 points are added if CCP1 is higher than the previous year; 2 points are added if CCP1 is higher than the country–sector median; 1 point is awarded if the firm has an environment management team; 1 point is added if the firm has a policy to improve its energy efficiency; 1 point is added if the firm sets targets or objectives to be achieved on emissions reduction; 1 point is added if the firm is aware that climate change can represent commercial risks and/or opportunities; 1 point is added if the firm make use of renewable energy; 1 point is added if the firm reports on initiatives to reduce, reuse, recycle, substitute or phase out SOx (sulphur oxides) or NOx (nitrogen oxides) emissions; and 1 point is added if the firm reports on its environmentally friendly or green sites or offices.	Researchers' calculation based on data from Thomson-Reuters/ENERO03S, ENRRDP004, ENRRDP0122, ENERDP0161, ENERDP089, ENRRDP046, ENERDP033 and ENRRDP052
CCP4	Equally weighted score of *CCP3.*	As above
LOG_SIZE	Natural logarithm of total assets recorded in billions of US dollars.	Researchers' calculation based on data from Thomson-Reuters/WC08001
LOG_COV	Natural logarithm of the coverage ratio. Coverage ratio = (income before extraordinary items + interest expenses)/interest expenses.	Researchers' calculation based on data from Thomson-Reuters/WC01551
ROA	Return on assets, calculated as the ratio of net income to total assets.	Thomson-Reuters/WC08326
LEVERAGE	Total debt/total assets.	Thomson-Reuters/WC08236
CAPINT	Capital intensity, measured as the ratio of net property, plant and equipment (PPE) to total assets.	Researchers' calculation based on data from Thomson-Reuters/WC02501 and WC02999
BETA	Systematic risk beta based on monthly returns, which shows the relationship between stock volatility and market volatility.	Thomson-Reuters/897E
LIQUIDITY	Current assets/current liabilities.	Thomson-Reuters/WC08106
MARGIN	Ratio of operating income divided by net sales.	Thomson-Reuters/WC08316
GROWTH	((Net sales at year *t*/net sales at year (*t-1*)) - 1)*100.	Thomson-Reuters/WC08631
LOSS	Equal to 1 if net income is negative at year *t* and *t-1*, and 0 otherwise.	Researchers' calculation based on data from Thomson-Reuters/WC01751
BSIZE	Total number of board members at the end of the fiscal year.	Thomson-Reuters/CGBSDP060
BINDP	Percentage of independent directors to total number of directors.	Thomson-Reuters/CGBSO07S
DUALITY	Equal to 1 if the company's CEO is also chairman of the board, and 0 otherwise.	Thomson-Reuters/CGBSDP061

Appendix A *continued*

DISC	Equal to 1 if carbon data are available, and 0 otherwise	Researchers' calculation
IMR	The inverse Mills ratio, calculated from the first stage of Heckman's (1979) two-stage model.	Researchers' calculation
High_CCP1	Equal to 1 if *CCP1* is higher than the industry–year median, and 0 otherwise.	Researchers' calculation
High_CCP2	Equal to 1 if *CCP2* is higher than the industry–year median, and 0 otherwise.	Researchers' calculation
High_CCP3	Equal to 1 if *CCP3* is higher than the industry–year median, and 0 otherwise.	Researchers' calculation
High_CCP4	Equal to 1 if *CCP4* is higher than the industry–year median, and 0 otherwise.	Researchers' calculation
Country-level variables		
GE	According to (World Bank, 2019), "government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies"	World Bank
RQ	According to (World Bank, 2019), "regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development"	World Bank
RL	According to (World Bank, 2019), the "rule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society and, in particular, the quality of contract enforcement, property rights, the police and the courts, as well as the likelihood of crime and violence"	World Bank
LOG_GDPC	Natural logarithm of gross domestic product (GDP) per capita in US dollars (annually based).	International Monetary Fund (IMF), World Economic Outlook Database
COMMNLAW	Equal to 1 if the company is based in a common-law country, and 0 otherwise.	La Porta et al. (2008)
ADR	The revised Anti-Director Rights Index (annually based).	Djankov et al. (2008)
LOG_MCAP	Natural logarithm of stock market capitalisation of the listed domestic companies in billions of US dollars (annually based).	World Bank. For Taiwan, data are available on the Taiwan Stock Exchange (TWSE) website.

CHAPTER 3: SECOND PAPER

CARBON RISK AND COST OF EQUITY: THE ROLE OF COUNTRY-LEVEL GOVERNANCE

Eltayyeb Al-Fakir Al Rabab'a, Syed Shams, Afzalur Rashid

Abstract

This study examines the relationship between carbon risk (CRISK) and cost of equity (COE) and whether, and to what extent, this relationship is affected by country-level governance. Using a sample of 5,021 firm-year observations from 13 Asia-Pacific countries over the period 2002–2018, we find that firms with higher CRISK have higher implied COE, with this relationship stronger in countries with strong country-level governance. Our main findings are robust to addressing endogeneity, sample selection bias and heterogeneity problems through using alternative model specifications. They are also robust after using individual COE estimates, alternative and additional controls, and sub-sample analysis. Further analysis indicates that the CRISK–COE relationship is positive (neutral) before and after (during) the Global Financial Crisis (GFC). This study documents that investors and equity market participants are becoming more aware of firms' exposure to carbon risk (CRISK).

Keywords: Climate change, environmental performance, financial distress, greenhouse gas(GHG), sustainability, corporate social responsibility.

3.1 Introduction

In the past two decades, corporate environmental performance (CEP) and climate change issues have been hotly debated by diverse stakeholders, such as regulators, investors, the media and environmental activists, with firms required to improve their environmental performance, in general, and their carbon performance, in particular. The direct and indirect benefits (and costs) of firms' adoption of low carbon emissions practices are the central part of this debate. A huge amount of academic interest has been stimulated on this topic to explore the potential financial implications of firms' exposure to carbon risk (CRISK)[12] (Diaz-Rainey et al., 2017). A cursory search on the PubMed.gov database[13] reveals that the number of full-length papers published on this topic since 2000 has reached 61,407. In this study, we examine the relationship between CRISK and implied cost of equity (COE). We argue that COE could be a channel through which capital markets reward or penalise firms based on their exposure to carbon risk (CRISK).

The cost of equity (COE) is the expected rate of return required by shareholders from their investment and is the rate used by a firm to discount future cash flows. Thus, it is a key element in a firm's decisions on long-term investment. Understanding the COE determinants helps firms gain better access to equity capital (at a lower cost) which, in turn, affects their strategic plans. Regarding climate change as a firm's ongoing concern, a significant number of investors (e.g., green investors) increasingly consider a firm's climate change-related performance in their investment decision process. Consequently, as investors' tastes and preferences can affect asset prices (Fama & French, 2007), reluctance to invest in carbon-intensive stocks by a large and sufficient number of investors leads to lower stock prices, thus increasing the cost of equity (COE) capital (Chava, 2014; Heinkel et al., 2001).

In this study, we argue that CRISK is positively related to COE for several reasons. Firstly, the uncertainty of current and future business conditions, resulting from potential changes in environmental regulations, can increase a firm's overall risk (Cai et al., 2016; Gupta, 2018). Secondly, firms with higher carbon performance (i.e., lower CRISK) can benefit from reputational capital and reduce the probability of facing (or can reduce the impact of) environmentally adverse events (Godfrey et al., 2009). Thirdly, firms could legitimise themselves in the eyes of investors by improving their carbon performance. Investors' preferences for investing in low-CRISK firms can help to broaden firms' investor base, thereby reducing the cost of equity (COE) (Chava, 2014). Finally, firms with high CRISK cannot easily

[12] Carbon risk (CRISK) refers to concerns about uncertain future costs resulting from a firm's carbon emissions.
[13] https://pubmed.ncbi.nlm.nih.gov

access other sources of financing (e.g., the debt market) or, if they can, they must pay higher interest rates (Caragnano et al., 2020; Jung et al., 2018). Thus, to bear this risk, investors may demand more compensation and expect a higher rate of return.

We examine the CRISK–COE relationship using a sample of 5,021 firm-year observations of 833 unique firms over the period 2002–2018 from 13 countries in the Asia-Pacific region, namely: Australia, New Zealand, China, Japan, South Korea, Hong Kong, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan and Thailand. These countries provide a useful context in which to examine this relationship as most have ratified the Kyoto Protocol. In this context, firms could expect more stringent carbon-related legislation and policies to be adopted after this ratification, suggesting that they are more vulnerable to carbon risk (CRISK). In addition, these countries significantly contribute to global greenhouse gas (GHG) emissions. For example, in 2014, they emitted approximately 44% of the world's carbon dioxide (CO_2) whereas, in 1960, their level of global CO_2 emissions was around 14% (World Bank, 2019). Thus, they are facing increasing pressure from the international community as it aims to mitigate the problem of climate change. Firms in this context are, therefore, more vulnerable to CRISK, especially in the current era of the globalisation of financial markets.

Our study finds that firms' exposure to CRISK increases the implied cost of equity (COE), with equity markets likely to consider CRISK in their evaluation process. These results are robust after controlling for potential sample selection bias and endogeneity problems by using alternative model specifications, such as Heckman's (1979) two-stage analysis, propensity score matching (PSM), and firm fixed-effects, country fixed-effects, two-stage least squares (2SLS) and dynamic system generalised method of moments (GMM) models. The results are robust after using sub-samples, individual COE estimates, and alternative and additional control variables; controlling for the Global Financial Crisis (GFC); using the two-way clustering approach; and controlling for endogeneity stemming from simultaneous causality by using the lead–lag approach.

Furthermore, we find that CRISK leads to greater increases in COE for firms from countries with superior government effectiveness (GE), strong regulatory quality (RQ) and strong rule of law (RL), suggesting that a country-level governance mechanism and equity markets are complements in addressing carbon risk (CRISK). This is potentially due to a higher level of climate change awareness in countries with stringent environmental regulations, greater ability to enforce the law and more effective government. In our additional analyses, we find that the impact of CRISK on COE is stronger with higher economic impact for firms from the industrials, utilities and basic materials sectors. We also find that the CRISK–COE relationship is positive (neutral) before and after (during) the GFC years.

Our study contributes to the literature in several ways. Firstly, we add to the extant literature by examining the CRISK–COE relationship in a multi-country context. Although a few studies investigate the CRISK–COE relationship (Kim et al., 2015; Li et al., 2014), they are conducted based on single-country data and have mixed findings.[14] As the results of previous studies are context-specific or time-specific, they cannot be generalised. Secondly, in contrast to previous studies on the CRISK–COE relationship, we use four models to estimate firms' cost of equity (COE) capital to provide a more accurate estimate of COE and to moderate any estimation errors through using a particular model. Thirdly, to the best of our knowledge, this study is the first to provide evidence of the role of country-level governance on the CRISK–COE relationship. Finally, we address empirical challenges that potentially affect the robustness of our study's results, such as endogeneity concerns, sensitivity to using alternative model specifications and the problem of heterogeneity, as well as addressing robustness across sub-samples.

The rest of this paper is organised as follows: Section 3.2 presents the literature review and hypotheses development. Section 3.3 provides the research design and data, while Section 3.4 presents the empirical results. Section 3.5 concludes the paper, presenting the discussion and summary of the research findings and their implications.

3.2 Literature review and hypotheses development

3.2.1 Corporate environmental and financial performance

The impact of corporate environmental performance (CEP) and corporate carbon performance (CCP) on corporate financial performance (CFP) is the subject of both theoretical and empirical studies. Some studies examine the association between CEP and profitability (such as Iwata & Okada, 2011; Lannelongue et al., 2015; Misani & Pogutz, 2015); firm risk (Cai et al., 2016; Muhammad et al., 2015); and cost of financing (El Ghoul et al., 2018; Fonseka et al., 2019; Sharfman & Fernando, 2008). However, studies on this topic yield mixed results, with no agreed position about CEP's effect. One strand of the literature supports a negative CEP–CFP relationship. For instance, Lioui and Sharma (2012) report that both environmental strengths and concerns have a negative impact on CFP, arguing that investors consider environmental strengths as an additional cost. Wang et al. (2014) use data from a sample of Australian companies and find GHG emissions are positively related to corporate financial performance (CFP). Damert et al. (2017), however, find no significant relationship between carbon performance and financial performance. From a theoretical perspective, Aupperle et al.

[14] See Section 2.2 for more details.

(1985) and Friedman (1970) posit that an unnecessary increase in costs resulting from stringent environmental practices erodes a firm's competitiveness, and that such practices could be perceived as a costly diversion of the firm's resources.

In contrast, another strand of the literature argues that CEP leads to benefits for both society and firms. These studies argue that CEP leads to better CFP through generating revenue and diminishing environmental fines (Hatakeda et al., 2012); creating intangible resources, such as corporate reputation (Lannelongue et al., 2015); creating access to certain markets (Iwata & Okada, 2011); providing better access to finance (Cheng et al., 2014); and lowering a firm's idiosyncratic risk (Cai et al., 2016). For example, Fujii et al. (2013) find a significant positive relationship between CEP, based on CO_2 emissions, and return on assets (ROA). Balachandran and Nguyen (2018) present evidence that carbon risk (CRISK) has a negative impact on the stability of earnings, which affects the probability of paying dividends and the dividend payout ratio. Jung et al. (2018), using a sample of Australian firms during the period 2009–2013, find a positive association between cost of debt (COD) and carbon risk (CRISK). They also find that this relationship is negated for firms with high CRISK awareness.

From a theoretical point of view, a win-win situation between a firm's environmental performance and its financial performance can be grounded in two primary theories: stakeholder theory (Donaldson & Preston, 1995; Jones, 1995) and legitimacy theory (Suchman, 1995). Both theories originate from political economy theory. Gray et al. (1996, p. 47) defined political economy theory as "the social, political and economic framework within which human life takes place". These theories embrace the standpoint that society, politics and economics are inextricably linked and cannot be separated. Economic activities cannot be considered separately from the political and social framework in which these activities occur (Deegan, 2014).

Legitimacy theory can be used to explain the positive relationship between CRISK and cost of equity (COE). According to Suchman (1995, p. 574), "[l]egitimacy is a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions". The need to acquire legitimacy with stakeholders will motivate managers to engage in environmental management and improve environmental performance (Bui et al., 2020; Xue et al., 2020). Fulfilling stakeholders' expectations creates moral capital by providing 'insurance-like protection' for relationship-based intangible assets which, in turn, can increase shareholders' wealth (Godfrey, 2005).

Stakeholder theory assumes that a firm is inclined to engage in environmentally responsible practices and to direct its activities in line with stakeholders' expectations, possibly to an extent beyond shareholders' interests or legal and regulatory requirements, to build trust with its stakeholders. Stakeholder theory suggests that improving environmental performance and adopting proactive environmental strategies would assist the generation of moral capital or intangible assets and the creation of a better relationship with key stakeholders, resulting in economic success (Brammer & Millington, 2008). Conversely, failure to respond to mounting environmental pressure from diverse stakeholders, such as the media, public opinion, regulators and environmental activists, would lead to a loss of reputation. Consequently, investors may consider this an indicator of the presence of a potential business risk and, thus, they would expect higher rates of return.

3.2.2 Impact of carbon risk (CRISK) on cost of equity (COE)

Prior studies (El Ghoul et al., 2018; El Ghoul et al., 2011; Gupta, 2018; Ng & Rezaee, 2015; Sharfman & Fernando, 2008) document that better CEP, or lower environmental risk, reduces a firm's COE, as higher environmental risk may increase the uncertainty of future cash flows. They argue that socially and environmentally aware investors are less willing to include low-CEP firms in their portfolios. For example, Sharfman and Fernando (2008) examine whether COE is affected by environmental risk management for 267 United States (US) firms. Using *ex post* measurement of COE (the capital asset pricing model [CAPM]), they find a negative relationship between environmental risk management and both COE and the weighted average cost of capital (WACC). By employing a sample of manufacturing firms from 30 countries over the period 2002–2011, El Ghoul et al. (2018) provide international evidence about the negative CEP–COE relationship.

Despite the increased focus on climate change-related issues, few studies, to date, investigate the impact of CRISK on cost of equity (COE) capital. However, these studies do not provide an agreed position on this relationship. Kim et al. (2015), for instance, examine the relationship using a sample of South Korean firms over the period 2007–2011. They find a positive CRISK–COE relationship. The authors also find the CRISK–COE relationship to be more prominent in industries with lower GHG emissions. In contrast, Li et al. (2014) find a neutral relationship between CRISK and cost of equity (COE) capital. In a recent study, Bui et al. (2020) examine the effect of carbon disclosure and carbon risk on cost of equity (COE). They find that firms' carbon intensity is positively associated with COE, with this relationship able to be moderated by disclosing more carbon-related information. The extant literature also provides evidence on the effect of carbon disclosure on cost of equity (COE). Albarrak et al.

(2019), for example, find that when a firm broadly discloses its carbon information over a social media network (Twitter), COE will be negatively affected.

The premise in the current paper is that CRISK is positively related to COE for several reasons. Firstly, the influence of CRISK on COE could be through the effects of investors' choices. Investors are becoming more sensitive to environmental issues as a result of recent mounting pressure from the media, public opinion, regulators and environmental activists. Hong and Kacperczyk (2009), for example, find that when norm-constrained institutional investors, such as retirement plans, avoid investment in the 'sin stocks' (tobacco, alcohol and gambling industries), the prices of these stocks significantly decrease. They also find the expected rate of return for these stocks to be higher than that of other equivalent stocks. Therefore, if investors who desist from investing in a high-CRISK firm are sufficiently numerous, stock prices will decrease; thus, the expected rate of return (COE for a firm) will increase (Chava, 2014; Merton, 1987).

Secondly, investors consider firms with a lower level of carbon performance to be riskier than other firms. In their evaluation process, investors consider the uncertainty of business conditions resulting from potential changes in environmental regulations and obligations. For example, Cai et al. (2016) find that environmentally responsible activities significantly reduce a firm's risk. Gupta (2018) reports that environmentally friendly practices reduce the firm's risk, consequently lowering cost of equity (COE). Therefore, the level of exposure to CRISK is more likely to be priced by investors as they expect higher rates of return. Thirdly, firms with a higher level of carbon performance (low CRISK) can benefit from reputational capital which, in turn, could help firms to achieve economic success and mitigate the impact when facing environmentally adverse events. Stakeholders might not penalise a firm with a good reputation if an environmentally adverse event occurs to the same degree as they would a firm with a bad reputation (El Ghoul et al., 2018). For instance, Godfrey et al. (2009) find that when a firm with a high level of CSR faces adverse events, such as legal action or an environmental scandal, the abnormal stock returns are relatively higher, compared to returns to firms with a low level of CSR facing such events. Therefore, based on stakeholder theory, better carbon performance (lower CRISK) can be viewed as a hedging tool for a firm to build a better reputation, thus reducing its risk and cost of equity (COE).

Finally, lending institutions are becoming more aware of borrowers' social and environmental performance. For example, 118 financial institutions that cover approximately 80% of global lending volume have adopted a risk management framework called the Equator

Principles[15] (Chava, 2014). These principles aim to assess and manage environmental and social risks for financed projects and financial institutions. Therefore, a firm with high CRISK would face difficulties in gaining access to other financial markets. Recent studies also suggest that firms with relatively lower CEP face higher financial constraints (Cheng et al., 2014) and higher interest rates on their loans (Chava, 2014). As firms with higher CRISK cannot easily gain access to alternative sources of financing, investors may expect a higher rate of return to absorb this kind of risk, thus increasing cost of equity (COE). Based on the above discussion, we arrive at the following hypothesis:

H1. A positive association exists between carbon risk (CRISK) and cost of equity (COE) capital, *ceteris paribus*.

3.2.3 Role of country-level governance

The quality of country-level governance plays a pivotal role in a stock market's efficiency, stability and liquidity. Interest among policy makers, regulators, academics and investors in the implications of country-level governance mechanisms has recently heightened (Al Maqtari et al., 2020). For example, Chen et al. (2009) examine the effect of firm-level corporate governance on COE and whether the country-level governance mechanism affects this relationship. They find that the negative effect of corporate governance on COE is more pronounced in emerging markets where the legal protection of investors is weak. Ernstberger and Grüning (2013) also examine how the relationship between corporate governance and firm disclosure is affected by a country's regulatory environment. They find that the impact of corporate governance on a firm's disclosure is more pronounced in a weak legal environment. They argue that, to legitimise their activities, firms respond to weak country-level governance by improving their level of disclosure.

Extant literature also examines whether and how the role of country-level governance moderates or intensifies the CEP–CFP relationship. For example, Gupta (2018) finds that the negative relationship between CEP and COE is stronger in countries with weak country-level governance, which is inconsistent with our current study's findings. The author attributes this finding to the ease of access to debt financing in developing countries. As financial institutions increasingly consider environmental performance in their lending decisions, especially in countries where environmental regulation is weak, firms with high CEP can easily access these sources of funds at lower interest rates and, thereby, their COE is reduced.

[15] http://www.equator-principles.com/

As mentioned in the discussion in Sections 3.2.1 and 3.2.2, studies in one stream of the research explore the relationship between CFP and corporate carbon performance (CCP). However, they yield mixed findings (Busch & Lewandowski, 2018). In the current study, we attempt to explore the reasons for these different views. As the relationship between CEP and CFP may differ depending on economic, social, legal and political differences between countries, we examine whether the investor's evaluation of CRISK is different with different country-level governance characteristics. To the best of our knowledge, no previous study examines the effect of country-level governance on the CRISK–CFP relationship.

We argue that, for several reasons, investors expect higher rates of return from firms with a high environmental risk in countries with strong governance, compared to firms in countries with weak governance. Firstly, when firms operate in a country with more stringent environmental regulations, greater ability to enforce the law and more effective government, they are more susceptible to expensive environmental or carbon-related costs. Thus, investors are less confident in their predictions of future cash flows due to potential changes in environmental regulations. Secondly, stringent environmental regulations are more likely to be accompanied by more attention being given to environmental issues by the media, public opinion, environmental activists and investors. Due to their failure to respond to local community pressure, firms with high CRISK may experience more severe reputational loss in this strict legislative environment, compared to firms from countries with weak environmental regulations. Thus, as compensation for this risk, we argue that, at the same high level of CRISK, investors expect a higher rate of return from firms in countries with stronger governance compared to firms in countries with weak governance. Based on the above discussion, we investigate the following hypotheses:

H2a. The impact of carbon risk (CRISK) on the implied cost of equity (COE) is stronger in countries with strong government effectiveness, *ceteris paribus*.

H2b. The impact of carbon risk (CRISK) on the implied cost of equity (COE) is stronger in countries with strong regulatory quality, *ceteris paribus*.

H2c. The impact of carbon risk (CRISK) on the implied cost of equity (COE) is stronger in countries with strong rule of law, *ceteris paribus*.

3.3 Research design and data

3.3.1 Sample construction and data

The initial sample consists of all publicly listed firms in Australia, New Zealand, China, Japan, South Korea, Hong Kong, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan and Thailand. We extracted the sample from the following sources: (i) Thomson-Reuters databases, which provide the carbon and financial data; (ii) World Bank databases, World Economic Outlook database and Taiwan Stock Exchange (TWSE) website which provide the country-level variables (*LOG_GDPC* and *LOG_MCAP*) ; and (iii) the study by Djankov et al. (2008) which provides the Anti-Director Rights (ADR) Index. Appendix A provides more details about the descriptions and sources of our study's variables.

Table 3.1. Sample selection and distribution

Panel A – Sample selection

Details	**Obs.**
Firm-year observations in Thomson-Reuters databases for carbon data	6,535
Less: missing financial or earnings forecast data	(1,514)
Firm-year observations in final sample	**5,021**

Panel B – Sample breakdown by industry and years

ICB industry classification	**Obs.**	**% of sample**	**Year**	**Obs.**	**% of sample**
Oil and Gas	170	3.35	2002	13	0.26
Basic Materials	752	14.80	2003	14	0.28
Industrials	866	17.02	2004	61	1.20
Consumer Goods	720	14.17	2005	102	2.01
Health Care	266	5.24	2006	133	2.62
Consumer Services	355	6.99	2007	176	3.46
Telecommunications	231	4.55	2008	171	3.37
Utilities	336	6.61	2009	205	4.03
Financials	1,083	21.31	2010	307	6.04
Technology	303	5.96	2011	307	6.04
Total	**5,021**	**100%**	2012	344	6.77
			2013	400	7.87
			2014	444	8.74
			2015	515	10.14
			2016	561	11.04
			2017	672	13.23
			2018	656	12.91
			Total	**5,021**	**100%**

Notes: Panel A presents the sample selection process. Panel B presents the sample distribution by industry based on the Industrial Classification Benchmark (ICB) and by year.

Table 3.1, Panel A provides details of the sample selection process. Our initial sample consists of 6,535 firm-year observations for which carbon data were available. We next exclude observations that did not meet the requirement of the implied cost of equity (COE) capital models for firm-year observations to be positive in 1- and 2-year-ahead earnings forecasts and to be either positive in 3-year-ahead earnings forecasts or to have long-term growth (LTG) forecasts (Claus & Thomas, 2001; Ohlson & Juettner-Nauroth, 2005). We then exclude firm-year observations with insufficient financial data to construct the control variables. The final sample consists of 5,021 firm-year observations between 2002 and 2018. Table 3.1, Panel B shows the sample breakdown by industry and year. The industries are classified based on the Industrial Classification Benchmark (ICB). Our final sample is dominated by the financials, industrials, basic materials and consumer goods sectors, as they represent approximately 21.3%, 17%, 14.8% and 14.2% of our final sample, respectively. Conversely, the oil and gas sector has the least representation in the sample (3.35%). It should be noted that the progressive increase in the number of observations over the sample period reflects the increase in carbon-related disclosures over time.

3.3.2 Empirical model

To examine the relationship between carbon risk (CRISK) and the cost of equity (COE) capital (Hypothesis 1 [H1]), we use the following regression model:

$$COE_{it} = \alpha + \beta_1 CRISK_{it} + \sum_{j=2}^{n} \beta_j CONTROL_{jit} + year\ and\ industry\ FE + \varepsilon_{it} \quad (1)$$

where *i* denotes a firm and *t* denotes time, with *COE* being the implied cost of equity obtained from the average of at least two of the four models developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). The *CRISK* variable denotes carbon risk estimated based on two proxies (*CRISK1* and *CRISK2*), as discussed in Section 3.3.3.1. Equation (1) tests Hypothesis 1 (H1) in which β_1 is expected to be positive. Firm- and country-level control variables are represented by $CONTROL$, as later discussed in Section 3.3.3.3. Finally, we include year and industry dummies and a list of country-level control variables in all model specifications to control for any unobserved industry characteristics or macroeconomic factors that could drive our results. Appendix A outlines the definitions and sources of the variables.

To test Hypothesis 2a (H2a), which examines the effect of country-level government effectiveness (GE) on the relationship between CRISK and COE, we add *GE* and the interaction term of *GE* and *CRISK* to Equation (1). We expect β_3 in Equation (2) to be positive. The model is estimated as follows:

$$COE_{it} = \alpha + \beta_1 CRISK_{it} + \beta_2 \; GE_{it} + \beta_3 \; GE_{it} * CRISK_{it} + \sum_{j=4}^{n} \beta_j CONTROL_{jit} + year \; and \; industry \; FE + \varepsilon_{it} \quad (2)$$

To test Hypothesis 2b (H2b), which examines the effect of country-level regulatory quality (RQ) on the relationship between CRISK and COE, we add *RQ* and the interaction term of *RQ* and *CRISK* to Equation (1). We expect β_3 in Equation (3) to be positive. The model is estimated as follows:

$$COE_{it} = \alpha + \beta_1 CRISK_{it} + \beta_2 \; RQ_{it} + \beta_3 \; RQ_{it} * CRISK_{it} + \sum_{j=4}^{n} \beta_j CONTROL_{jit} + year \; and \; industry \; FE + \varepsilon_{it} \quad (3)$$

To test Hypothesis 2c (H2c), which examines the effect of country-level rule of law (RL) on the relationship between CRISK and COE, we add *RL* and the interaction term of *RL* and *CRISK* to Equation (1). We expect β_3 in Equation (4) to be positive. The model is estimated as follows:

$$COE_{it} = \alpha + \beta_1 CRISK_{it} + \beta_2 \; RL_{it} + \beta_3 \; RL_{it} * CRISK_{it} + \sum_{j=4}^{n} \beta_j CONTROL_{jit} + year \; and \; industry \; FE + \varepsilon_{it} \quad (4)$$

3.3.3 Definition of variables

3.3.3.1 Carbon risk (CRISK)

Previous studies used either absolute or relative carbon emissions to measure a firm's carbon risk exposure. The absolute measure is the amount of emissions of CO_2 and CO_2-equivalent in tonnes per year, while the relative measure is deflated by sales, total assets or other business metrics. In this study, we use the relative measure of carbon emissions for several reasons. Firstly, this design choice allows us to control for any firm-specific events that may change total emissions, such as mergers and acquisitions (M&As), or any significant changes in the overall economy (Busch & Lewandowski, 2018). Secondly, given the variation between firms in terms of economic output, size and/or industry, this design choice makes comparison between firms possible. We use the GHG emissions data from Thomson-Reuters databases to construct two proxies for a firm's carbon risk (CRISK). *CRISK1* is the natural logarithm of the ratio of total carbon emissions in tonnes (Scopes 1 and 2)[16] to total sales in US

[16] The Greenhouse Gas Protocol is one of the carbon accounting tools that is widely applied internationally. This protocol defines three scopes of carbon emissions according to their sources. Scope 1 refers to the direct emissions of GHG caused by the company, such as fuel combustion or emissions from operational processes owned or controlled by the company. Scope 2 refers to emissions caused by purchasing electricity. Scope 3 refers to emissions from sources not owned or controlled by the company (see Busch & Lewandowski, 2018).

dollars. *CRISK2* is the industry-adjusted carbon risk, which refers to carbon emissions intensity minus the country–industry mean (Luo & Tang, 2014). Higher values for *CRISK1* and *CRISK2* indicate that the firm has higher carbon risk (CRISK).

3.3.3.2 Estimation of cost of equity (COE)

Studies in the literature adopt two main ways to estimate cost of equity (COE): (i) the *ex post* measure of cost of equity (COE) capital using realised returns, such as the capital asset pricing model (CAPM) and Fama and French (1993) three-factor model and (ii) the *ex ante* (implied) measure of cost of equity (COE), based on analysts' earnings forecasts and current stock prices. Following Gupta (2018), El Ghoul et al. (2018), Chen et al. (2009), Hail and Leuz (2006) and El Ghoul et al. (2011), we use the implied cost of equity (COE) capital. We principally use the four different models proposed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005).[17] This design choice is motivated by several studies that advocate the use of the *ex ante* cost of equity (COE) and criticise the use of the *ex post* measure. For example, Pástor et al. (2008) show the superiority of *ex ante* COE estimation models, that rely on earnings forecasts, in detecting time variation in the risk–return relationship. Chen et al. (2009) show that *ex post* COE is more sensitive to shocks related to a firm's growth opportunities/challenges and to changes in investors' attitudes toward riskiness. Fama and French (1997) indicate that the *ex post* models, such as the CAPM and Fama and French (1993) three-factor model, are inaccurate estimations of cost of equity (COE). To moderate any estimation errors from using a particular model which may bias our results, we use the average of the above-mentioned models as the main estimate of implied cost of equity (COE)[18], with this used later in our main analysis.

3.3.3.3 Control variables

As important factors are known to dominate investors' decisions and cost of equity (COE), we include a list of firm-level control variables in our econometric models for testing whether CRISK is associated with cost of equity (COE). Firstly, we control for firm size (*LOG_SIZE*), calculated as the natural logarithm of total assets recorded in billions of US dollars (Bui et al., 2020; El Ghoul et al., 2018; Ng & Rezaee, 2015). Larger firms are more able to endure any potential deficit in future cash flows and are thus less likely to default (Goss & Roberts, 2011). Thus, investors consider larger firms to be less risky. In addition, larger firms receive more attention from the media and analysts, decreasing information asymmetry between investors

[17] Appendix B provides more details about the implied cost of equity (COE) capital models.
[18] Firms in our sample are required to have at least two estimates.

and managers and thus COE is reduced (Bowen et al., 2008). Secondly, we control for firm profitability (*ROA*), measured as the ratio of net income to total assets (Bui et al., 2020; Hail & Leuz, 2006). Thirdly, we control for leverage (*LEV*), defined as the ratio of total liabilities to total assets, as firm risk increases when the proportion of debt in the capital structure increases (Botosan & Plumlee, 2005). In addition, leveraged firms are more likely to later earn higher stock returns (Fama & French, 1992). Thus, investors expect a higher rate of return from a leveraged firm as compensation for the related high risk.

Fourthly, we control for systematic risk (*BETA*), estimated by regressing the firm's excess return on the market's excess return using CAPM, based on monthly returns over the previous 60 months. Fifthly, we control for forecast bias (*FBIAS*), defined as the difference between the mean of analysts' forecasts of 1-year-ahead earnings per share (EPS) and the realised earnings per share (EPS). As COE estimation models depend on earnings forecasts, the variation in forecasting patterns between countries could drive the results (Hail & Leuz, 2006). Easton and Sommers (2007) find that implied *COE* estimates are significantly upward-biased due to analysts' optimistic earnings forecasts. Therefore, if earnings forecasts were upward-biased and market participants downwardly adjust the stock price, we expect a positive coefficient for the *FBIAS* variable. Sixthly, we control for stock price volatility (*VOL*) with an index that measures price fluctuation over the previous 12 months. Finally, to control for analysts' forecast attributes, we use the long-term growth rate (*LTG*), calculated based on the median of analysts' forecasts. We expect these control variables to have the following predicted signs: *LOG_SIZE* (-), *ROA* (-), *LEV* (+), *BETA* (+), *FBIAS* (+), *VOL* (+) and *LTG* (+).

Following prior studies (Chen et al., 2009; Espenlaub et al., 2020; Hail & Leuz, 2006; Krishnamurti et al., 2018; La Porta et al., 2008), we include a set of country-level variables to control for potential differences between countries. Firstly, we use the natural logarithm of gross domestic product (GDP) per capita in US dollars (*LOG_GDP*) to control for differences in economic development. Secondly, we use the revised Anti-Director Rights Index (*ADR*) developed by Djankov et al. (2008), after being initially constructed by La Porta et al. (1998). A high *ADR* value indicates a high level of shareholder protection, with values ranging from 0 to 6. Thirdly, we use the natural logarithm of the country-level stock market capitalisation (*LOG_MCAP*). All variables are defined in more detail in Appendix A.

Table 3.2. Descriptive statistics for full sample and univariate analysis

Panel A – Descriptive statistics							
	Mean	**Std. Dev.**	**Min**	**P25**	**Median**	**P75**	**Max**
CRISK1	-2.490	1.964	-7.354	-3.694	-2.613	-1.153	1.935

CRISK2	-0.091	0.744	-2.852	-0.140	-0.033	0.015	3.697
COE	8.868	3.449	1.303	6.507	8.307	10.644	23.481
LOG_SIZE	13.299	18.507	0.457	3.164	6.788	15.340	126.087
ROA	0.055	0.043	0.003	0.021	0.044	0.077	0.160
LEV	0.236	0.158	0.003	0.106	0.228	0.352	0.547
BETA	0.995	0.417	0.280	0.680	0.981	1.300	1.790
FBIAS	0.061	0.415	-0.696	-0.084	0.001	0.111	1.283
VOL	25.425	7.722	11.120	19.700	24.800	30.400	45.630
LTG	0.116	0.121	-0.069	0.040	0.092	0.165	0.431
GE	1.411	0.529	-0.298	1.291	1.569	1.769	2.437
RQ	1.259	0.602	-0.654	1.162	1.421	1.682	2.009
RL	1.237	0.642	-0.473	1.099	1.218	1.786	2.261
LOG_GDPC	10.262	0.880	6.927	10.250	10.569	10.730	11.134
ADR	4.310	0.714	1.000	4.000	4.500	4.500	5.000
LOG_MCAP	12.309	0.422	10.384	12.074	12.494	12.657	12.940

Panel B – Sub-samples separated based on industry–country median of carbon risk (*CRISK1*)

	High *CRISK1*		**Low *CRISK1***		**Mean test (*p*-value)**	**M–W test (*p*-value)**
	Mean	**Median**	**Mean**	**Median**		
COE	9.147	8.616	8.597	8.033	0.000	0.000
LOG_SIZE	12.208	6.041	14.359	7.598	0.000	0.000
ROA	0.053	0.042	0.057	0.047	0.001	0.001
LEV	0.255	0.250	0.218	0.203	0.000	0.000
BETA	1.000	0.990	0.990	0.980	0.401	0.382
FBIAS	0.042	-0.002	0.079	0.003	0.002	0.000
VOL	25.235	24.670	25.609	24.920	0.086	0.140
LTG	0.118	0.090	0.113	0.093	0.107	0.874

Notes: Panel A presents descriptive statistics for the firm-level and country-level variables for the full sample of 5,021 firm-year observations. Panel B presents the *t*-test and Mann–Whitney test results to examine the mean and median differences, respectively, between high (above the median) and low (below the median) carbon risk (*CRISK1*); based on the industry–country median (*p*-values are two-tailed). Cost of equity (*COE)* is reported by percentage. *LOG_SIZE* is reported in billions of US dollars. Appendix A outlines the variables' definitions and sources.

3.4 Results

3.4.1 Descriptive statistics

Table 3.2, Panel A provides the descriptive statistics (mean and standard deviation, and minimum, 25th percentile, median, 75th percentile and maximum values) for the variables included in the above equations for the full sample.[19] The mean and median values of *CRISK1* (*CRISK2*) are -2.490 and -2.613 (-0.091 and -0.033), respectively, with the range being from a minimum of -7.354 (-2.852) to a maximum of 1.935 (3.697). We find the average implied *COE* is 8.9%, ranging from 1.3% to 23.5%. The mean values of *LOG_SIZE*, *ROA*, *LEV*, *BETA*, *FBIAS*, *VOL* and *LTG* are around 13.3, 5.5%, 23.6%, 1, 0.06, 25.5 and 11.6%, respectively. The distribution of percentiles does not show any extreme skewness in the variables. In general, the values are within the expected range.

3.4.2 Univariate analysis

This section reports the univariate analysis performed to compare the mean and median values for firm-level variables between firms with low CRISK (below the median) and firms with high CRISK (above the median). The sub-samples are divided based on the industry–country median value of carbon intensity (*CRISK1*). Table 3.2, Panel B presents the mean and median values in the first four columns, with the *t*-test (mean differences test) and Mann–Whitney test (median differences test) in the last two columns. We find that the mean (median) value of *COE* for firms with high CRISK is 9.15% (8.62%), while it is 8.60% (8%) for firms with low carbon risk (CRISK). This suggests that, on average, the mean (median) value of *COE* of firms with high CRISK is 55 (62) basis points higher than that of firms with low carbon risk (CRISK). Both the mean and median differences are statistically significant at less than the 1% level. The results also show that statistically significant mean and median differences are found between high CRISK and low CRISK for most of the variables (except for *BETA*, *VOL* and *LTG*). The univariate analysis suggests that, on average, firms with high CRISK are smaller and less profitable, and have a higher leverage ratio, lower analysts' forecast bias and lower stock price volatility.

[19] To reduce the potentially spurious effects of outliers, all continuous variables used in the analysis are winsorised at the 1st and 99th percentiles, except for the *FBIAS* and *LTG* variables that are instead winsorised at the 5th and 95th percentiles as their distributions are extremely skewed.

Table 3.3. Correlation matrix

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**
(1) *CRISK1*	1.000															
(2) *CRISK2*	0.181*	1.000														
(3) *COE*	0.232*	0.035*	1.000													
(4) *LOG_SIZE*	-0.170*	0.067*	-0.165*	1.000												
(5) *ROA*	0.120*	-0.088*	-0.201*	0.113*	1.000											
(6) *LEV*	0.315*	0.099*	0.237*	-0.077*	-0.213*	1.000										
(7) *BETA*	-0.011	0.000	0.327*	-0.114*	-0.225*	0.086*	1.000									
(8) *FBIAS*	0.026	-0.027	0.119*	0.015	-0.015	0.017	0.069*	1.000								
(9) *VOL*	0.054*	-0.065*	0.333*	-0.227*	0.011	0.049*	0.595*	0.048*	1.000							
(10) *LTG*	0.098*	0.007	0.361*	-0.070*	-0.129*	0.069*	0.157*	-0.040*	0.245*	1.000						
(11) *GE*	-0.066*	-0.039*	-0.049*	-0.061*	-0.154*	-0.074*	-0.008	-0.032	-0.152*	-0.081*	1.000					
(12) *RQ*	-0.053*	-0.075*	-0.017	-0.089*	-0.122*	-0.081*	-0.011	0.001	-0.141*	-0.064*	0.947*	1.000				
(13) *RL*	-0.031	-0.097*	-0.015	-0.104*	-0.048*	-0.068*	-0.015	-0.037*	-0.154*	-0.087*	0.894*	0.921*	1.000			
(14) *LOG_GDPC*	-0.088*	-0.059*	-0.001	-0.073*	-0.212*	-0.056*	0.004	0.035	-0.128*	-0.054*	0.911*	0.912*	0.855*	1.000		
(15) *ADR*	0.040*	0.009	-0.012	0.025	0.035	-0.047*	-0.018	0.000	-0.030	0.017	0.268*	0.297*	0.106*	-0.118*	1.000	
(16) *LOG_MCAP*	-0.120*	0.045*	-0.054*	0.151*	-0.247*	-0.029	0.029	-0.025	0.144*	0.060*	0.322*	0.262*	0.336*	0.739*	0.096*	1.000

Notes: Table 3.4 presents Pearson's correlation coefficients between the variables. Appendix A outlines the variables' definitions and sources. Superscript * indicates significance at the 1% level.

Table 3.3 reports the sample's composition by country as well as the mean values of key variables and country-level variables. Firms from Japan dominate the sample (43%), followed by Australia and Hong Kong (about 15% and 10%, respectively). Table 3.4 reports Pearson's correlation coefficients between the regression model variables. In line with our expectations, the correlation coefficients between *COE* and the carbon risk proxies, *CRISK1* and *CRISK2*, are positive and statistically significant at the 1% level (0.23 and 0.035, respectively). Correlation coefficients between the firm-level control variables are relatively low, suggesting the absence of multicollinearity between the explanatory variables. To further examine the multicollinearity concern, we follow Rashid (2013) and estimate the variance inflation factor (VIF) value for each model in our main analysis. We find that all VIF values are below 5 (un-tabulated), thus indicating that the multicollinearity problem does not exist in our multivariate estimation models (Dielman, 2001).

Table 3.4. Descriptive statistics across countries

Country	N	% of sample	*CRISK1*	*CRISK2*	*COE*	*LOG_GDPC*	*ADR*	*LOG_MCAP*
Australia	757	15.08	-2.149	-0.350	9.448	10.895	4.000	12.091
China	122	2.43	-3.245	-0.010	9.233	9.071	1.000	12.852
India	227	4.52	-1.995	-0.037	9.865	7.382	5.000	12.186
Indonesia	30	0.60	-1.234	-0.841	7.539	8.174	4.000	11.577
Japan	2,153	42.88	-2.669	-0.015	8.349	10.560	4.500	12.642
Malaysia	151	3.01	-1.699	0.045	7.700	9.231	5.000	11.613
New Zealand	86	1.71	-2.319	-0.362	7.820	10.558	4.000	10.834
Philippines	82	1.63	-1.751	-0.021	7.071	7.972	4.000	11.358
Singapore	142	2.83	-2.719	0.010	8.757	10.943	5.000	11.831
South Korea	329	6.55	-3.102	0.003	11.430	10.213	4.500	12.083
Taiwan	322	6.41	-2.625	-0.008	8.753	10.034	3.000	11.930
Thailand	137	2.73	-1.798	0.067	8.993	8.722	4.000	11.606
Hong Kong	483	9.62	-2.374	-0.225	8.974	10.642	5.000	12.519
Full sample	5,021	100.00	-2.490	-0.091	8.868	10.262	4.310	12.309

Notes: Table 3.3 presents descriptive statistics by country as follows: the number of observations, percentage of the full sample and the mean value of the country-level and key firm-level variables. Cost of equity (*COE*) is reported by percentage. Appendix A outlines the variables' definitions and sources.

3.4.3 Multivariate regression analysis

In this section, we empirically examine the effect of CRISK on COE (Hypothesis 1 [H1]) and the role of country-level governance in this relationship (Hypotheses 2a [H2a], 2b [H2b] and 2c [H2c]) in a multivariate setting. We use a panel data structure of 5,021 firm-year observations from 13 countries from 2002–2018. Table 3.5 reports our main results. All models are estimated using ordinary least squares (OLS) regressions with robust standard errors clustered at the firm level. The explanatory variables include two proxies for carbon risk, as well as firm- and country-level control variables, namely: *LOG_SIZE, ROA, LEV, BETA, FBIAS, VOL, LTG, LOG_GDPC, ADR* and *LOG_MCAP*, and year and industry dummies. All variables are defined and discussed in Section 3.3.3. To test Hypothesis 1 (H1), we regress *COE* on *CRISK1* (*CRISK2*) and on a list of control variables and report the results in Table 3.5, Model 1 (Model 2). We find that the estimated coefficients for *CRISK1* and *CRISK2* are 0.245 and 0.363, respectively, with statistical significance at the 1% level. The estimate is also economically significant; an increase of one standard deviation in *CRISK1* (*CRISK2*) leads to an increase in *COE* of approximately 48 (27) basis points. Together with the univariate results, this result implies that the higher the level of carbon risk (*CRISK1* and *CRISK2*), the higher the company's cost of equity (COE).

In Table 3.5, Models 3–8, we report the results of the role of country-level governance in the CRISK–COE relationship. World Bank databases provide governance indicators for most of the countries. In this study, we employ three country-level governance characteristics, namely, government effectiveness (GE), regulatory quality (RQ) and rule of law (RL). This helps in examining whether the CRISK–COE relationship is different in different institutional and governance settings. In Models 3 and 4, we test Hypothesis 2a (H2a) about the role of government effectiveness (GE) in the CRISK–COE relationship. We find the coefficient for the interaction term between *CRISK1* and *GE* (*CRISK2* and *GE)* is 0.138 (0.395), with statistical significance at the 1% level. The results suggest that the association between CRISK and COE is stronger in countries with strong government effectiveness (GE) than in countries with poor government effectiveness (GE). In Models 5 and 6, we test Hypothesis 2b (H2b), about the role of regulatory quality (RQ) in the CRISK–COE relationship. We find that the coefficient for the interaction term between *CRISK1* and *RQ* (*CRISK2* and *RQ*) is 0.113 (0.301), with statistical significance at the 1% level. The results suggest that the association between CRISK and COE is stronger in countries with strong regulatory quality (RQ) than in countries with weak regulatory quality (RQ). In Models 7 and 8, we test Hypothesis 2c (H2c), about the role of the rule of law (RL) in the CRISK–COE relationship. The coefficient for the interaction term between *CRISK1* and *RL* (*CRISK2* and *RL)* is 0.066 (0.282), with statistical significance at the 10% (1%) level. The results suggest that the association between CRISK and COE is stronger in countries with strong rule of law than in countries with weak rule of law.

Table 3.5. Ordinary least squares (OLS) regression results of association between carbon risk (CRISK) and cost of equity (COE)

	Main results		**Role of country-level governance**					
DV=*COE*	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
CRISK1	**0.245*****		0.061		0.104*		0.153***	
	(3.74)		(0.92)		(1.94)		(2.90)	

CRISK2		**0.363*****		-0.135		0.034		0.041
		(3.14)		(-0.91)		(0.27)		(0.36)
GE			0.567***	0.251***				
			(4.05)	(2.64)				
CRISK1 × GE			**0.138*****					
			(3.22)					
CRISK2 × GE				**0.395*****				
				(4.04)				
RQ					0.840***	0.813***		
					(3.65)	(3.89)		
CRISK1 × RQ					**0.113*****			
					(3.13)			
CRISK2 × RQ						**0.301*****		
						(3.37)		
RL							0.529**	0.732***
							(2.36)	(3.61)
CRISK1× RL							**0.066***	
							(1.84)	
CRISK2× RL								**0.282*****
								(3.71)
LOG_SIZE	-0.061	-0.087	-0.055	-0.077*	-0.052	-0.070*	-0.063	-0.081**
	(-0.84)	(-1.22)	(-1.40)	(-1.96)	(-1.32)	(-1.79)	(-1.59)	(-2.05)
ROA	-10.296***	-9.087***	-10.313***	-8.794***	-10.905***	-9.692***	-10.928***	-10.110***
	(-5.77)	(-5.18)	(-8.97)	(-7.67)	(-9.41)	(-8.34)	(-9.24)	(-8.47)
LEV	2.425***	2.773***	2.428***	2.739***	2.482***	2.757***	2.488***	2.741***
	(4.27)	(4.98)	(8.19)	(9.57)	(8.43)	(9.67)	(8.40)	(9.60)
BETA	0.650***	0.660***	0.678***	0.644***	0.667***	0.629***	0.689***	0.670***
	(2.86)	(2.86)	(4.72)	(4.43)	(4.63)	(4.32)	(4.73)	(4.55)
FBIAS	0.522***	0.487***	0.495***	0.481***	0.524***	0.510***	0.539***	0.537***
	(4.56)	(4.20)	(4.64)	(4.51)	(4.92)	(4.79)	(5.04)	(5.02)
VOL	0.079***	0.078***	0.080***	0.078***	0.080***	0.079***	0.076***	0.075***
	(5.49)	(5.28)	(9.19)	(8.85)	(9.15)	(8.98)	(8.59)	(8.34)
LTG	7.953***	8.064***	7.850***	8.129***	7.893***	8.128***	7.925***	8.118***
	(14.92)	(15.04)	(18.24)	(18.97)	(18.45)	(19.04)	(18.51)	(19.03)
LOG_GDPC	0.223**	0.219**	0.386***	0.364***	-0.157	-0.265*	-0.052	-0.263*
	(2.16)	(2.08)	(2.81)	(2.66)	(-1.14)	(-1.95)	(-0.34)	(-1.79)
ADR	0.002	0.011	0.076	0.037	-0.065	-0.137*	-0.037	-0.108*
	(0.02)	(0.11)	(1.15)	(0.56)	(-0.94)	(-1.94)	(-0.57)	(-1.65)
LOG_MCAP	-0.688***	-0.834***	-0.711***	-0.850***	-0.675***	-0.798***	-0.572***	-0.595***
	(-3.07)	(-3.57)	(-6.01)	(-7.02)	(-5.50)	(-6.36)	(-3.83)	(-3.97)
Intercept	11.559***	13.028***	10.956***	12.588***	15.562***	17.755***	13.534***	15.323***
	(4.34)	(4.77)	(6.44)	(7.27)	(9.55)	(10.57)	(9.66)	(10.76)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.377	0.375	0.379	0.378	0.380	0.379	0.379	0.379
Obs.	5021	5021	5021	5021	5021	5021	5021	5021

Notes: This table presents the main results of the CRISK–COE association and the role of country-level governance indicators (*GE, RQ* and *RL*) in this association for the full sample of 5,021 firm-year observations from 13 countries. All models are estimated using ordinary least squares (OLS) regressions with clustered robust standard errors by firm and include year fixed-effects and industry fixed-effects, with *t*-statistics reported in parentheses. In all regression models, the dependent variable is *COE*, which is obtained from the average of, at least, two of the four models of implied cost of equity (COE) developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). Appendix B provides more details about the implied cost of equity (COE) capital models. DV=dependent variable. FE=fixed effects. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. Appendix A outlines the variables' definitions and sources.

Table 3.6. Robustness test: Heckman's (1979) two-stage and propensity score matching (PSM) models

	Heckman's (1979) two-stage model				**Propensity score matching (PSM) model**			
	First stage		**Second stage**		**First stage**		**Second stage**	
DV=	***HIGH_R1***	***HIGH_R2***	***COE***	***COE***	***HIGH_R1***	***HIGH_R2***	***COE***	***COE***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
CRISK1			**0.226***** **(3.49)**					
CRISK2				**0.367***** **(3.18)**				
HIGH_R1							**0.433***** **(2.83)**	
HIGH_R2								**0.331**** **(2.10)**
LOG_SIZE	-0.115** [-2.47]	-0.147*** [-3.37]	0.771*** (3.46)	-0.372 (-0.91)	-0.169*** [-5.60]	-0.175*** [-5.96]	-0.028 (-0.34)	-0.055 (-0.69)
ROA	1.710 [1.62]	-2.139** [-2.08]	-22.514*** (-6.39)	-13.469** (-2.07)	1.435 [1.64]	-1.703** [-2.01]	-9.126*** (-4.55)	-9.054*** (-4.55)
LEV	1.617*** [5.33]	0.946*** [3.19]	-9.167*** (-3.11)	4.571* (1.81)	2.816*** [13.10]	1.672*** [8.11]	2.529*** (4.19)	2.897*** (4.92)
BETA	0.160 [1.40]	0.248** [2.20]	-0.485 (-1.32)	1.153 (1.57)	0.262** [2.57]	0.224** [2.26]	0.642*** (2.70)	0.878*** (3.45)
FBIAS	-0.131** [-2.56]	-0.051 [-0.97]	1.487*** (5.47)	0.387** (2.12)	-0.150** [-1.97]	-0.150** [-2.01]	0.442*** (3.35)	0.439*** (3.48)
VOL	-0.016** [-2.22]	-0.030*** [-4.35]	0.195*** (5.89)	0.018 (0.20)	-0.026*** [-4.52]	-0.028*** [-5.02]	0.082*** (5.37)	0.067*** (4.01)
LTG	0.423** [1.99]	0.257 [1.25]	4.824*** (5.10)	8.524*** (10.16)	0.754*** [2.85]	0.556** [2.16]	7.874*** (13.16)	7.852*** (14.24)
LOG_GDPC	-0.106* [-1.90]	-0.244*** [-4.16]	0.946*** (4.32)	-0.248 (-0.37)	-1.194*** [-11.37]	0.783*** [7.67]	0.121 (1.13)	0.176 (1.54)
ADR	0.013 [0.25]	-0.062 [-1.16]	-0.073 (-0.72)	-0.098 (-0.53)	-0.179*** [-3.88]	-0.008 [-0.17]	0.103 (1.00)	0.155 (1.40)
LOG_MCAP	-0.439*** [-2.98]	0.403*** [2.91]	2.269*** (2.97)	-0.057 (-0.05)	0.171 [1.35]	-0.376*** [-3.1]	-0.738*** (-3.06)	-0.823*** (-3.25)
IMR			-11.686*** (-3.99)	-15.844*** (-2.69)				
Intercept	6.597*** [3.92]	-1.385 [-0.88]	-23.747** (-2.53)	8.732 (1.34)	13.495*** [12.03]	-4.083*** [-3.92]	10.283*** (3.54)	10.676*** (3.64)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Pseudo R^2/R^2	0.078	0.068	0.383	0.375	0.080	0.068	0.378	0.356
Obs.	5021	5021	5021	5021	5021	5021	3806	4240

Notes: This table presents the results of the CRISK–COE association for the full sample of 5,021 firm-year observations. Models 1 and 2 report the first stage of Heckman's (1979) two-stage model, a probit regression model with the dependent variable equal to 1 for high CRISK firms, and 0 otherwise, based on the industry and year median values of CRISK (*High_R1* and *High_R2* are defined in Appendix A). Models 3 and 4 present the second-stage regressions, a baseline model regression including the inverse Mills ratio (*IMR*) which is calculated from the first stage. Models 5 and 6 present the first stage of the PSM model, with a logit model used to match firms that have higher CRISK (treatment) and lower CRISK (control) in the same industry and year using the nearest neighbour, within a 1% caliper and with no replacement matching algorithms. Models 7 and 8 present the baseline model using the propensity-matched sample from the first stage. In the second stage of both models, the dependent variable is *COE,* which is obtained from the average of, at least, two of the four models of implied cost of equity (COE) developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). Appendix B provides more details about the implied cost of equity (COE) capital models. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects. FE=fixed effects. DV=dependent variable. The *t*-statistics (*z*-statistics) are reported in parentheses (brackets). Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. Appendix A outlines the variables' definitions and sources.

In general, the results in Table 3.5 indicate that market participants expect a higher rate of return (high COE) for firms with high carbon risk (CRISK). Focusing on the interaction term, the results show a positive and statistically significant association between COE and interaction terms between CRISK proxies and country-level governance indicators, suggesting that firms could gain more benefit (from reduced COE) by reducing their emissions if they operate in a country with a stronger governance mechanism. The coefficients of control variables in all models are generally consistent with our expectations. For example, firms of larger size, with higher *ROA*, lower *LEV*, lower *BETA*, lower *VOL* and lower *LTG* seem to have lower implied cost of equity (*COE)*. Appendix B provides more details about the implied COE models. Appendix A outlines the variables' definitions and sources.

3.4.4 Robustness tests and additional analyses

We perform a set of sensitivity analyses to investigate the robustness of our main results (Table 3.5, Models 1 and 2). We test whether the results are robust to applying alternative model specifications; mitigating endogeneity concerns; using individual COE estimates; using sub-samples by country and industry; using alternative and additional control variables; and addressing potential simultaneous causality between the key variables. We also provide additional analyses by using two-way clustering (by firm and time) and by controlling for the Global Financial Crisis (GFC).

3.4.4.1 Heckman's (1979) and PSM models

As our sample comprises firms that decided to disclose their carbon-related data, they may have unobserved common characteristics that are different to those of other firms, especially in countries without mandatory carbon disclosure requirements. Thus, it is possible that firms in our sample are selected in a non-random manner, which raises the problem of self-selection bias in our study. To address this concern, we employ Heckman's (1979) two-stage model. Table 3.6, Models 1 and 2 report the first stage, the probit regression model (selection equation), where the dependent variable is a dummy variable equal to 1 if *CRISK1*/*CRISK2* is less than the industry–year median, and 0 otherwise (the variables *High_R1* and *High_R2* are defined in Appendix A). Next, from the selection equation, we save the residual term and transform it to the inverse Mills ratio (*IMR*). We then include *IMR* as an additional control variable in the second stage (Models 3 and 4). All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects. As shown in the results, the coefficient of *IMR* is significantly positive, thus suggesting the presence of sample selection bias. Therefore, the estimated coefficients, without correcting for self-selection bias

(Table 3.5, Models 1 and 2), are upward-biased. The selection bias-corrected estimates (Table 3.6, Models 3 and 4) indicate that the coefficients of *CRISK1* and *CRISK2* are 0.226 and 0.367, respectively, and that they are statistically significant at the 1% level, suggesting that our baseline results are slightly upward-biased and that sample selection bias is a minor concern. Therefore, our study's main findings remain robust after controlling for potential sample selection bias which is unlikely to affect our main findings.

When a firm has better access to capital at a lower cost, it has more ability to invest in green technology and reduce its carbon risk (CRISK). Therefore, the direction of the relationship between CRISK and COE may be opposite to the assumed direction in our empirical models, which gives rise to endogeneity concerns. To address this, we follow related studies (Matsumura et al., 2013; Nguyen & Phan, 2020; Shipman et al., 2016) and use the propensity score matching (PSM) technique. In this technique, we compare firms that are heavy carbon emitters, that is, those most susceptible to CRISK, with their peers in the same industry that are considered to be light carbon emitters. To do this, we create a dummy variable that equals 1 if the firm has a *CRISK1*/*CRISK2* higher than the industry–year median, and 0 otherwise (*HIGH_R1* and *HIGH_R2*). We then use the logit model to match firms that have higher CRISK (treatment) and lower CRISK (control) in the same industry and year using the nearest neighbour, within a 1% caliper and with no replacement matching algorithms. The first-stage results are reported in Table 3.6, Models 5 and 6. Next, to test whether our matching algorithms are valid, we perform two-sample *t*-tests as a matching diagnostic test to capture the mean differences between treatment and control groups. The matching test (un-tabulated) shows no statistically significant differences in the mean values of controls between the two groups (high *p*-value). In Models 7 and 8, we regress *COE* on *HIGH_R1* and *HIGH_R2*, respectively, along with other control variables using the propensity-matched sample from the first stage. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects. As we match treatment and control groups in the same industry, we do not include the industry dummy variables in the second stage of the PSM model. The results indicate that the coefficient of *HIGH_R1* (*HIGH_R2*) is 0.433 (0.331), which is statistically significant at the 1% (5%) level, suggesting that our findings are robust to using the PSM model as an alternative model specification. In Section 3.4.4.3, we further tackle the endogeneity concern by using two-stage least squares (2SLS) and dynamic system generalised method of moments (GMM) models.

Table 3.7. Robustness test: Firm fixed-effects and country fixed-effects models

	Firm fixed-effects		**Country fixed-effects**	
DV=*COE*	**(1)**	**(2)**	**(3)**	**(4)**

CRISK1	**0.237*** (3.17)**		**0.255*** (3.85)**	
CRISK2		**-0.144 (-1.63)**		**0.359*** (3.17)**
LOG_SIZE	-0.868***	-0.904***	-0.137*	-0.164**
	(-9.07)	(-9.46)	(-1.95)	(-2.38)
ROA	-3.417***	-3.527***	-11.115***	-10.673***
	(-2.60)	(-2.68)	(-6.01)	(-5.63)
LEV	1.324**	1.364**	2.249***	2.600***
	(2.45)	(2.52)	(4.02)	(4.76)
BETA	0.492***	0.501***	0.908***	0.939***
	(3.58)	(3.64)	(4.24)	(4.28)
FBIAS	0.012	-0.000	0.278***	0.263**
	(0.16)	(-0.00)	(2.72)	(2.54)
VOL	-0.025**	-0.027**	0.055***	0.052***
	(-2.35)	(-2.51)	(4.05)	(3.75)
LTG	7.566***	7.587***	7.600***	7.673***
	(27.97)	(28.01)	(15.13)	(15.21)
Intercept	10.721***	10.223***	25.448**	26.320**
	(27.38)	(28.53)	(2.20)	(2.27)
Country-level controls	No	No	Yes	Yes
Firm fixed-effects	Yes	Yes	No	No
Year fixed-effects	Yes	Yes	Yes	Yes
Industry fixed-effects	No	No	Yes	Yes
Country fixed-effects	No	No	Yes	Yes
R^2	0.774	0.773	0.4182	0.4149
Obs.	5021	5021	5021	5021

Notes: This table presents the results of the firm fixed-effects and country fixed-effects models to examine the CRISK–COE association for the full sample of 5,021 firm-year observations. Models 1 and 2 report the firm fixed-effects model (within-firm). In these two models, *ADR* is omitted owing to collinearity. Models 3 and 4 present the country fixed-effects model. The dependent variable is *COE*, which is obtained from the average of, at least, two of the four models of implied cost of equity (COE) developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). Appendix B provides more details about the implied COE models. All regressions are estimated with clustered robust standard errors by firm. DV=dependent variable. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. Appendix A outlines the variables' definitions and sources.

3.4.4.2 Firm fixed-effects and country fixed-effects

In this section, we report a further investigation about the CRISK–COE relationship using firm and country fixed-effects regressions as alternative model specifications. This helps us to control for time-invariant unobserved characteristics for firms or countries that are correlated with both the dependent and independent variables. Table 3.7, Models 1 and 2 report the results of the firm fixed-effects model, where the coefficient is estimated through changes over time and within a principal firm. The coefficient of *CRISK1* is 0.237, with statistical significance at the 1% level. However, the coefficient of *CRISK2* is statistically insignificant. Table 3.7, Models 3 and 4 report the results of the country fixed-effects model. The coefficients are estimated through changes over time, within a principal industry and within a particular country. The results suggest that *CRISK1* and *CRISK2* are positively associated with *COE*, with coefficients of 0.255 and 0.359, respectively, and a statistical significance at the 1% level. Therefore, our main results are robust to using firm and country fixed-effects regression models, with the baseline models not significantly driven by unobserved time-invariant characteristics by firms and countries.

3.4.4.1 Endogeneity

A critical concern in our study is endogeneity. In non-experimental (observational) studies, endogeneity commonly occurs in two cases: firstly, when the dependent and independent variables are correlated with unmeasured or unobserved variables. In our case, COE could be affected by CRISK but, at the same time, this effect could be jointly determined by other factors such as financial performance. In the second case, endogeneity occurs in the presence of simultaneous causality between COE and carbon risk (CRISK). Therefore, it is possible that the estimated coefficients in Table 3.5 are biased, with endogeneity affecting the interpretation of the CRISK–COE relationship. To address this problem, we use the instrumental variable (IV) approach: two-stage least squares (2SLS) and dynamic system GMM models.

Firstly, our study needs instrumental variables correlated with CRISK but uncorrelated with the error term. We use two instrumental variables: (i) *IV1*, *CRISK1* at *t-3* or *CRISK2* at *t-3*; using CRISK variables lagged by three years as instrumental variables helps to address the simultaneous causality problem; and (ii) *IV2* which, as the carbon mitigation score (*CMS*), measures corporate performance in mitigating CRISK (see Appendix A). Table 3.8, Models 1 and 2 report the first stage of the 2SLS model, where *CRISK* is regressed on the instrumental variables (*IV1* and *IV2*) and the control variables. As expected, the coefficients of the instrumental variables are highly significant (high *t*-value). For further investigation into the validity of the instrumental variables, we use Pearson's correlation test, *F*-test (unreported) and Sargan statistics. These tests are reported at the bottom of Table 3.8, Models 1 and 2. Pearson's correlation test results show that the instrumental variables are highly correlated with CRISK variables. The unreported *F*-test (weak identification test) results show that our instrumental variables are not weakly correlated with the endogenous regressors. The *p*-value of Sargan statistics is statistically insignificant, which indicates that we cannot reject the null hypothesis that the instruments are valid. Thus, based on these test results, our choice of instrumental variables is valid. The second stage of the 2SLS approach is reported in Table 3.8, Models 3 and 4. We find that our main findings are robust to using this approach to address the endogeneity concern as the coefficients for *CRISK1* and *CRISK2* are 0.316 and 0.502, respectively, and are statistically significant at the 1% level.

Table 3.8. Robustness to endogeneity

	2SLS				**System GMM**	
	First stage		**Second stage**			
DV=	***CRISK1***	***CRISK2***	***COE***	***COE***	***COE***	***COE***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
CRISK1			**0.316*** **(6.64)**		**0.754*** **(3.25)**	

CRISK2				**0.502*****		**-0.238**
				(4.31)		**(-1.14)**
$CRISK_{t-3}$ *(IV1)*	0.868***	0.770***				
	(77.53)	(20.04)				
CMS (IV2)	-0.056***	-0.025***				
	(-11.38)	(-6.00)				
LOG_SIZE	0.026***	0.003	-0.038	-0.063	-0.655	-1.034
	(2.86)	(0.42)	(-0.75)	(-1.24)	(-1.02)	(-1.18)
ROA	-1.239***	-0.848**	-12.536***	-10.754***	10.863	13.503**
	(-4.14)	(-2.36)	(-7.72)	(-6.63)	(1.26)	(2.48)
LEV	0.239***	0.197**	2.281***	2.686***	4.503	2.628
	(3.05)	(2.39)	(5.76)	(6.85)	(1.10)	(0.57)
BETA	0.009	0.032	0.759***	0.741***	0.188	2.416*
	(0.28)	(0.77)	(3.76)	(3.64)	(0.21)	(1.83)
FBIAS	-0.054**	0.011	0.542***	0.483***	-0.068	0.359
	(-2.44)	(0.51)	(4.09)	(3.65)	(-0.21)	(0.60)
VOL	0.003	-0.001	0.086***	0.088***	-0.068	-0.047
	(1.58)	(-0.29)	(6.75)	(6.81)	(-1.13)	(-0.48)
LTG	-0.113	0.096	7.268***	7.335***	6.264***	5.232***
	(-1.61)	(1.35)	(12.75)	(12.71)	(3.46)	(3.11)
COE_{t-1}					0.290***	0.262**
					(3.13)	(2.58)
Intercept	1.136***	0.089	13.406***	14.865***		
	(3.12)	(0.19)	(6.86)	(7.46)		
Country-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	No	No
Corr. of (*IV1*)	0.963***	0.807***				
Corr. of (*IV2*)	-0.117***	-0.113***				
Sargan test *p*	0.141	0.316			0.889	0.010
Hansen test *p*					0.905	0.959
AR(1) test *p*					0.000	0.000
AR(2) test *p*					0.130	0.999
Diff-in-Hansen test *p*					0.365	0.624
Obs.	2671	2671	2671	2671	1994	1994

Notes: This table presents the results of the association between CRISK and COE using two-stage least squares (2SLS) and dynamic system GMM models. The instrumental variables are: (1) *IV1*, which is *CRISK1* at *t-3* or *CRISK2* at *t-3*, and (2) *IV2*, which is the carbon mitigation score (CMS), and is defined in Appendix A. We report Pearson's correlation coefficients to test the validity of our instrumental variables (*IV1* and *IV2*). Sargan and Hansen statistics are tests under the null hypothesis that the instruments are valid. The AR(1) and AR(2) tests are used to test the first-order and second-order serial correlations in the first differenced residuals in the GMM model. The difference-in-Hansen test is a test under the null hypothesis that the instrumental variables used in the level equation are exogenous. The *ADR* variable is omitted in the GMM models owing to collinearity. In the second stage of the 2SLS and GMM models, the dependent variable is *COE*, which is obtained from the average of, at least, two of the four models of implied cost of equity (COE) developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). Appendix B provides more details about the implied COE models. All regressions are estimated with clustered robust standard errors by firm. DV=dependent variable. FE=fixed effects. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. Appendix A outlines the variables' definitions and sources.

Table 3.9. Individual estimates of cost of equity (COE)

DV=	***KCT***		***KGLS***		***KES***		***KOJ***	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
CRISK1	**0.178*****		**0.356*****		**0.293*****		**0.180****	
	(3.06)		**(3.83)**		**(3.42)**		**(2.47)**	
CRISK2		**0.289*****		**0.518*****		**0.324****		**0.291****
		(2.60)		**(3.35)**		**(2.44)**		**(2.17)**
LOG_SIZE	0.040	0.021	-0.243**	-0.280**	-0.140	-0.172*	0.068	0.047
	(0.60)	(0.31)	(-2.04)	(-2.39)	(-1.58)	(-1.93)	(0.94)	(0.65)
ROA	1.212	2.125	-18.753***	-16.947***	-16.769***	-15.493***	-7.299***	-6.215***
	(0.73)	(1.29)	(-6.94)	(-6.25)	(-6.61)	(-6.18)	(-3.43)	(-2.99)

LEV	2.635***	2.874***	1.979**	2.485***	3.031***	3.495***	2.360***	2.601***
	(5.11)	(5.73)	(2.43)	(3.15)	(4.06)	(4.75)	(3.92)	(4.41)
BETA	0.199	0.203	1.277***	1.289***	0.940***	0.969***	0.411	0.429
	(0.97)	(0.98)	(4.28)	(4.25)	(2.85)	(2.92)	(1.55)	(1.59)
FBIAS	0.424***	0.398***	0.918***	0.870***	0.534***	0.498**	0.253*	0.236
	(3.83)	(3.61)	(5.39)	(4.97)	(2.70)	(2.51)	(1.71)	(1.59)
VOL	0.077***	0.076***	0.063***	0.061***	0.111***	0.108***	0.087***	0.086***
	(6.17)	(6.02)	(2.98)	(2.84)	(5.53)	(5.34)	(5.41)	(5.24)
LTG	6.088***	6.170***	-1.289**	-1.117*	7.372***	7.538***	17.423***	17.568***
	(10.91)	(11.04)	(-2.03)	(-1.74)	(8.70)	(8.87)	(24.66)	(24.93)
LOG_GDPC	-0.197**	-0.197*	0.227	0.222	0.402***	0.385***	0.477***	0.483***
	(-2.01)	(-1.94)	(1.42)	(1.38)	(3.40)	(3.24)	(4.46)	(4.44)
ADR	0.046	0.051	0.378**	0.391**	-0.269**	-0.255*	-0.288***	-0.287***
	(0.47)	(0.52)	(2.43)	(2.47)	(-2.04)	(-1.93)	(-2.69)	(-2.65)
LOG_MCAP	-0.564***	-0.673***	0.000	-0.208	-0.946***	-1.104***	-1.417***	-1.519***
	(-2.69)	(-3.14)	(0.00)	(-0.63)	(-3.11)	(-3.46)	(-5.99)	(-6.17)
Intercept	13.905***	14.947***	0.422	2.485	14.385***	15.360***	19.744***	20.700***
	(5.73)	(6.10)	(0.11)	(0.64)	(4.01)	(4.14)	(6.97)	(7.15)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.287	0.286	0.282	0.278	0.289	0.285	0.457	0.456
Obs.	5010	5010	4961	4961	4302	4302	4195	4195

Notes: This table presents the baseline regressions results of the association between carbon risk and a list of individual COE estimates. The dependent variables, *KCT, KGLS, KES* and *KOJ*, are from the implied COE models developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005), respectively. Appendix B provides more details about the COE models. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects. DV=dependent variable. FE=fixed effects. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. Appendix A outlines the variables' definitions and sources.

Next, we run a dynamic system generalised method of moments (GMM) method following prior studies (El Ghoul et al., 2018; Jo et al., 2015), with the results reported in Models 5 and 6. We use this approach as it is less prone to endogeneity concerns caused by endogenous variables and time-invariant unobserved factors. As with the 2SLS method, we employ *CRISK1*/*CRISK2* lagged by three years and *CMS* as instrumental variables. We also report three specification tests. Firstly, we report the first-order and second-order serial correlation tests, AR(1) and AR(2), under the null hypothesis that no serial correlation exists. The AR(1) test yields a low *p*-value (less than 0.01), while the second test, AR(2), produces *p*-values of 0.130 and 0.999 in Models 5 and 6, respectively, suggesting no second-order serial correlation exists. Secondly, the Hansen and Sargan statistic (over-identification) tests are used to confirm the validity of our instrumental variables under the joint null hypothesis that the instrumental variables are valid and uncorrelated with the error term. Both the Hansen and Sargan tests yield high *p*-values (more than 0.10), suggesting that we cannot reject the null hypothesis and that our instrumental variables are valid.

Finally, we assess the exogeneity assumption of the dynamic system GMM method by applying the difference-in-Hansen test under the null hypothesis that the instrumental variables used in the level equations are exogenous. Failure to reject the stated null hypothesis would increase confidence in the model specification. However, a high *p*-value (over 0.95) would be considered a symptom of the invalidity of the instruments. The results of the difference-in-

Hansen test show *p*-values of 0.365 and 0.624, suggesting that the instruments in the level equations are exogenous. The coefficient of *CRISK1* is 0.754, at the 1% significance level. However, the coefficient of *CRISK2* is statistically insignificant. Therefore, at least for *CRISK1*, our main results of the positive relationship between *CRISK1* and *COE* are robust to the specific types of endogeneity captured by using the dynamic system GMM model.

3.4.4.2 Individual COE estimates

In the current study, we principally employ four different models to estimate the implied cost of equity (COE), namely, *KCT*, *KGLS*, *KES* and *KOJ*, which are derived as the internal rate of return in the models of Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005), respectively.[20] As the COE models adopt their own assumptions about forecast earnings growth rates and forecast horizons, they yield variations in their estimation of the implied cost of equity (COE). For example, the summary statistics (unreported) indicate variations between these measures. The mean values of our four cost of equity (COE) models, *KCT*, *KGLS*, *KES* and *KOJ*, are 8.1%, 6.6%, 10.8% and 10.9%, respectively[21]. Therefore, in our main analysis, we use the average of at least two estimates of the above-mentioned models as the main estimate of implied COE to moderate any estimation error from using a particular model. Here, as a robustness check, we extend our analysis by investigating the association between *CRISK* and individual estimates of *COE* to rule out the possibility that these variations affect our results. Specifically, in Table 3.9, we re-estimate our baseline regression model by looking at *KCT*, *KGLS*, *KES* and *KOJ* as dependent variables. We find that both *CRISK1* and *CRISK2* are positively associated with all individual *COE* estimates, suggesting that our main finding of the positive relationship between CRISK and COE remains intact when we use the individual *COE* estimates.

3.4.4.3 Sub-sample analysis

As our sample comprises firms from 10 ICB industry classifications from 13 countries, the strength and direction of the relationship between CRISK and COE could not be the same between all countries and industries, raising a heterogeneity problem that could render bias in the parameter estimates. To control for this problem and check the robustness of our results between countries or industries, we conduct sub-sample analyses described in this section. We

[20] Appendix B provides more details about the implied cost of equity (COE) capital models.

[21] To check that our study does not make calculation mistakes when estimating the COE models, we compare these figures with those in related studies (Hail & Leuz 2006; El Ghoul et al. 2011; El Ghoul et al. 2018). These figures are relatively similar, as the *KGLS* (*KOJ* and *KES*) model provides relatively lower (higher) values for the implied cost of equity (COE) estimates.

re-estimate the baseline regression model using a set of sub-samples separated by either country or industry.

Firstly, we separately run the baseline regression model for the top four countries with the highest number of observations (Japan, Australia, Hong Kong and South Korea) and report the results in Table 3.10, Panel A. Models 1 and 2 present the results for a sub-sample from Japan (2,153 firm-year observations). We find that the coefficients of *CRISK1* and *CRISK2* are positively associated with *COE* at 0.303 and 0.712, respectively (p-value < 0.01). Models 3 and 4 report the results of a sub-sample from Australia (757 firm-year observations). We find the coefficient of *CRISK1* is 0.310, with statistical significance at the 5% level; however, we find the coefficient of *CRISK2* is positive and statistically insignificant. Models 5 and 6 present the results for a sub-sample from Hong Kong (483 firm-year observations). We find the coefficients of *CRISK1* and *CRISK2* are also positively associated with *COE* at 0.343 (p-value < 0.10) and 0.687 (p-value < 0.01), respectively. Finally, Models 7 and 8 report the results of a sub-sample from South Korea (329 firm-year observations). We find the coefficients of *CRISK1* and *CRISK2* are 0.443 and 0.657, respectively, with statistical significance at the 1% level.

Table 3.10. Ordinary least squares (OLS) regression results for sub-samples

Panel A – Top four countries

	Japan		**Australia**		**Hong Kong**		**South Korea**	
DV=*COE*	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
CRISK1	**0.303*****		**0.310****		**0.343***		**0.443*****	
	(3.29)		**(2.41)**		**(1.72)**		**(2.73)**	
CRISK2		**0.712*****		**0.274**		**0.687*****		**0.657*****
		(3.15)		**(0.84)**		**(3.70)**		**(3.08)**
LOG_SIZE	0.074	0.046	-0.486***	-0.521***	-0.744**	-0.795**	0.222	0.201
	(0.74)	(0.49)	(-4.01)	(-4.18)	(-2.39)	(-2.61)	(0.78)	(0.71)
ROA	-14.916***	-13.497***	-10.323***	-10.108***	-6.096	-4.207	-25.781***	-23.852***
	(-4.70)	(-4.42)	(-3.74)	(-3.67)	(-0.82)	(-0.59)	(-3.97)	(-3.59)
LEV	2.739***	3.013***	-0.889	-0.666	5.533***	5.480***	0.696	0.760
	(3.52)	(3.92)	(-0.77)	(-0.56)	(2.81)	(2.82)	(0.35)	(0.38)
BETA	1.457***	1.521***	0.414	0.435	2.662***	2.659***	-0.132	0.025
	(5.25)	(5.40)	(0.94)	(0.96)	(3.52)	(3.43)	(-0.21)	(0.04)
FBIAS	0.206	0.189	0.974***	0.944***	-0.991	-0.953	0.163	0.178
	(1.52)	(1.38)	(2.86)	(2.75)	(-1.06)	(-1.16)	(0.76)	(0.82)
VOL	0.036*	0.028	0.072***	0.071**	-0.003	-0.019	0.136***	0.142***
	(1.87)	(1.45)	(2.65)	(2.50)	(-0.08)	(-0.49)	(2.69)	(2.95)
LTG	6.061***	6.197***	9.320***	9.319***	8.766***	8.855***	8.005***	8.235***

	(10.67)	(10.81)	(7.11)	(7.03)	(5.17)	(5.39)	(5.23)	(5.43)
Intercept	5.620***	4.531***	5.273***	3.126	3.982	6.965***	-3.972	-5.656**
	(5.98)	(5.19)	(3.61)	(1.51)	(1.63)	(2.75)	(-1.66)	(-2.46)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.531	0.534	0.508	0.498	0.525	0.540	0.493	0.491
Obs.	2153	2153	757	757	483	483	329	329

Panel B – Additional sub-samples

	Excluding Japan		**Excluding top three countries**		**Excluding bottom five countries**	
DV=*COE*	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
CRISK1	**0.150***		**0.189***		**0.247*****	
	(1.78)		**(1.75)**		**(3.58)**	
CRISK2		**0.362*****		**0.326****		**0.371*****
		(2.66)		**(2.19)**		**(3.03)**
LOG_SIZE	-0.251**	-0.290***	-0.265*	-0.310**	-0.090	-0.113
	(-2.47)	(-2.88)	(-1.86)	(-2.14)	(-1.20)	(-1.54)
ROA	-13.088***	-12.425***	-9.581***	-9.179***	-11.423***	-10.341***
	(-5.47)	(-5.17)	(-2.80)	(-2.63)	(-6.13)	(-5.58)
LEV	2.001***	2.075***	3.557***	3.742***	2.485***	2.788***
	(2.66)	(2.80)	(3.73)	(3.97)	(4.20)	(4.78)
BETA	0.687**	0.697**	1.333***	1.343***	0.723***	0.739***
	(2.41)	(2.42)	(3.41)	(3.43)	(3.12)	(3.13)
FBIAS	0.853***	0.813***	0.283	0.235	0.498***	0.460***
	(4.80)	(4.54)	(0.57)	(0.48)	(4.48)	(4.09)
VOL	0.061***	0.057***	0.011	0.005	0.086***	0.084***
	(3.18)	(2.97)	(0.41)	(0.18)	(6.00)	(5.79)
LTG	8.690***	8.728***	8.365***	8.431***	8.087***	8.204***
	(10.92)	(10.99)	(9.09)	(9.22)	(14.84)	(14.97)
Intercept	-2.583	-1.854	-2.331	-3.003	22.501***	23.995***
	(-0.65)	(-0.49)	(-0.53)	(-0.71)	(6.06)	(6.44)
Country-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.337	0.339	0.320	0.320	0.400	0.393
Obs.	2868	2868	1782	1782	4564	4564

Table 3.11. *continued*

Panel C – Sub-samples by industry

	Industrials		**Utilities**		**Basic materials**		**Consumer goods**	
DV=*COE*	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
CRISK1	**0.629*****		**0.599*****		**0.671*****		**0.139**	
	(5.27)		**(2.77)**		**(2.77)**		**(0.99)**	
CRISK2		**0.826****		**0.356****		**0.051**		**2.016**
		(2.52)		**(2.59)**		**(0.16)**		**(1.59)**
LOG_SIZE	-0.136	-0.215	0.203	0.211	-0.276*	-0.161	0.221	0.210
	(-0.63)	(-0.91)	(0.41)	(0.47)	(-1.76)	(-0.99)	(1.59)	(1.51)
ROA	-9.391**	-8.744**	-21.824***	-20.417***	0.008	-2.136	-15.210***	-14.152***
	(-2.31)	(-2.06)	(-2.97)	(-2.84)	(0.00)	(-0.50)	(-3.96)	(-3.67)
LEV	2.708**	3.521***	3.477*	4.825***	3.919**	5.162***	1.849	2.093*
	(2.15)	(2.80)	(1.78)	(2.74)	(2.48)	(3.04)	(1.56)	(1.78)
BETA	1.846***	1.999***	0.603	1.553	0.535	0.367	1.765***	1.630***
	(3.50)	(3.41)	(0.56)	(1.31)	(1.04)	(0.67)	(4.73)	(4.42)
FBIAS	0.320	0.212	1.205**	1.160*	0.321	0.329	0.420**	0.382**
	(1.26)	(0.81)	(2.03)	(1.88)	(1.29)	(1.32)	(2.24)	(2.03)
VOL	0.042	0.043	0.183***	0.116	0.062**	0.070**	0.105***	0.113***
	(1.11)	(1.06)	(2.68)	(1.65)	(2.11)	(2.28)	(4.53)	(4.90)
LTG	5.905***	6.279***	6.800***	6.159***	9.946***	10.020***	4.753***	5.081***

	-0.136	-0.215	0.203	0.211	-0.276*	-0.161	0.221	0.210
Intercept	10.325*	12.567**	10.109	6.607	7.647	17.742	26.972***	25.965***
	(1.85)	(2.01)	(1.33)	(0.92)	(0.87)	(1.66)	(3.62)	(3.50)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.409	0.366	0.404	0.383	0.400	0.376	0.508	0.516
Obs.	865	865	336	336	752	752	720	720

Notes: This table presents the baseline regression results of the CRISK–COE association for a set of sub-samples. Panel A presents the results using sub-samples from the top four countries in our sample, namely, Japan, Australia, Hong Kong and South Korea. Panel B presents the results of using sub-samples from all countries without Japan, all countries without the top three countries and all countries without the bottom five countries. Panel C presents the results of using sub-samples separated by industry, namely, industrials, utilities, basic materials, and consumer goods sectors, which are more sensitive to carbon risk (CRISK). The industry classifications are derived from the Industrial Classification Benchmark (ICB). The dependent variable is *COE*, obtained from the average of, at least, two of the four models of implied cost of equity (COE) developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). Appendix B provides more details about the COE models. All regressions are estimated with clustered robust standard errors by firm and include year and country fixed-effects. FE=fixed effects. DV=dependent variable. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. Appendix A outlines the variables' definitions and sources.

Next, in Panel B, we run the baseline regression using additional sub-samples. As most firm-year observations are for firms from Japan (more than 42% of the sample), we run the baseline regression model after excluding firms from Japan, with the results reported in Models 1 and 2. Using 2,868 firm-year observations, we find that the coefficients of *CRISK1* and *CRISK2* are 0.150 and 0.362, with statistical significance at the 10% and 1% levels, respectively. In Panel B, Models 3 and 4, we re-estimate the baseline model after excluding observations from the top three countries (those with the highest number of observations) in our sample. The coefficients of *CRISK1* and *CRISK2*, respectively, are 0.189 (p-value < 0.10) and 0.326 (p-value < 0.05). Finally, in the last two columns of Panel B (Models 5 and 6), we exclude observations from the five countries with the lowest number of observations, namely, Indonesia, New Zealand, Philippines, China and Thailand. The results indicate that the coefficients of *CRISK1* and *CRISK2* are 0.247 and 0.371, respectively, with statistical significance at the 1% level, suggesting that our main results are robust to the use of another sub-sample.

In Panel C, we run the baseline regression model for a set of sub-samples based on different industries. We select industries characterised by a higher sensitivity to CRISK (industrials, utilities, basic materials and consumer goods), derived based on the Industrial Classification Benchmark (ICB). Firstly, Models 1 and 2 report the results of a sub-sample of 865 firm-year observations from the industrials sector. We find that the coefficients of *CRISK1* and *CRISK2* are positively associated with *COE* at 0.629 (p-value < 0.01) and 0.826 (p-value < 0.5), respectively. Secondly, Models 3 and 4 report the results of a sub-sample of 336 firm-year observations from the utilities sector. We find that the coefficients of *CRISK1* and *CRISK2* are also positively associated with *COE* at 0.599 (p-value < 0.01) and 0.356 (p-value < 0.05), respectively. Thirdly, Models 5 and 6 report the results for a sub-sample of 752 firm-year observations from the basic materials sector. We find that the coefficient of *CRISK1* is 0.671, with statistical significance at the 1% level; however, the coefficient of *CRISK2* is statistically insignificant. Finally, Models 7 and 8 report the results of a sub-sample of 720 firm-year observations from the consumer goods sector. We find no statistically significant relationship between *COE* and both *CRISK1* and *CRISK2*. Compared with the main results, the impact of CRISK on COE is stronger and has a higher economic impact for firms from the industrials, utilities and basic materials sectors. For example, based on the estimations in Panel C, Models 1 and 2, a one standard deviation increase in *CRISK1* (*CRISK2*) for firms in the industrials sector leads to an increase in *COE* by approximately 93 (50) basis points.[22] However, based on the baseline model, a one standard deviation increase in *CRISK1* (*CRISK2*) leads to an increase in *COE* by approximately 48 (27) basis points. Overall, our sub-sample analysis results indicate that the positive relationship between CRISK and COE holds in almost all sub-samples, with the economic impact of CRISK not homogenous across countries or industries.

3.4.4.4 Alternative and additional control variables

In Table 3.11, as an additional robustness check, we re-run the baseline regression model after using alternative or additional control variables. In Models 1–4, we control for the firm's profitability by, instead of *ROA*, using *TOBINSQ* (Models 1 and 2) and *MTB* (Models 3 and 4). The results suggest that the association between CRISK and COE remains positive and statistically significant.

Table 3.12. Robustness to alternative and additional control variables

	Alternative control variables				**Additional control variables**	
DV=*COE*	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
CRISK1	**0.182***** **(2.73)**		**0.136**** **(2.14)**		**0.235***** **(3.56)**	
CRISK2		**0.379***** **(3.46)**		**0.354***** **(3.36)**		**0.377***** **(3.43)**
TOBINSQ	-0.567*** (-5.77)	-0.579*** (-5.99)				
MTB			-0.491*** (-11.23)	-0.498*** (-11.56)		
BDIND					1.418*** (3.49)	1.404*** (3.45)
BDSIZE					0.025 (1.29)	0.024 (1.23)
DUALITY					0.134 (0.92)	0.117 (0.80)
ROA					-11.017*** (-5.92)	-10.321*** (-5.42)
LOG_SIZE	-0.110 (-1.63)	-0.133** (-1.98)	-0.054 (-0.84)	-0.071 (-1.12)	-0.158** (-2.15)	-0.188** (-2.56)
LEV	2.455*** (4.41)	2.569*** (4.66)	2.868*** (5.53)	2.912*** (5.67)	2.242*** (3.96)	2.535*** (4.57)
BETA	0.792***	0.778***	0.666***	0.645***	0.774***	0.791***

[22] Standard deviations for *CRISK1* and *CRISK2* for firms in the industrials sector are 1.47 and 0.598, respectively.

	(3.47)	(3.39)	(3.08)	(2.99)	(3.41)	(3.41)
FBIAS	0.572***	0.557***	0.571***	0.562***	0.416***	0.388***
	(4.95)	(4.81)	(5.04)	(4.95)	(3.58)	(3.32)
VOL	0.062***	0.062***	0.068***	0.069***	0.068***	0.066***
	(4.54)	(4.49)	(5.26)	(5.29)	(4.70)	(4.46)
LTG	8.531***	8.535***	8.744***	8.742***	7.948***	8.024***
	(16.37)	(16.33)	(16.99)	(16.96)	(15.14)	(15.20)
Intercept	5.398***	5.673***	6.187***	6.212***	3.416**	3.428**
	(4.00)	(4.09)	(4.66)	(4.71)	(2.26)	(2.16)
Country-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.395	0.397	0.420	0.420	0.396	0.395
Obs.	5021	5021	5021	5021	4422	4422

Notes: This table presents the baseline regression results of the CRISK–COE association after using alternative and additional control variables. *ROA* is substituted by *TOBINSQ* (Models 1 and 2) and *MTB* (Models 3 and 4). In Models 5 and 6, we add *BDSIZE*, *BDIND* and *DUALITY* as additional control variables. All models are estimated with clustered robust standard errors by firm and include year and industry fixed-effects. In all regression models, the dependent variable is *COE* obtained from the average of, at least, two of the four models of implied cost of equity (COE) developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). FE=fixed effects. DV=dependent variable. Appendix B provides more details about the COE models. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. Appendix A outlines the variables' definitions and sources.

One stream of studies investigates the impact of corporate governance on both the cost of financing and environmental, social and governance (ESG) performance. Lagasio and Cucari (2019), for example, find that firms with better corporate governance have a better level of ESG disclosure. El Ghoul et al. (2011) and Chen et al. (2009) find that firm-level corporate governance has a negative effect on cost of equity (COE). Anderson et al. (2004) find that board characteristics, such as board independence and board size, are negatively associated with cost of debt. This indicates that the level of corporate governance could be a confounding variable in our baseline model and that omitting the associated variables from our regression model could bias the coefficient estimates. Therefore, to investigate whether our main results are robust to including potentially confounding variables, we re-run the baseline model after adding board independence (*BDIND*), board size (*BDSIZE*) and CEO duality (*DUALITY*) as additional control variables. The results (Models 5 and 6) show that the CRISK-COE relationship is still positive and statistically significant, which is consistent with our main findings.

3.4.4.5 Additional analyses

In Table 3.12, we report our study's additional analyses. We firstly examine the macroeconomic effects of the Global Financial Crisis (GFC) on the CRISK–COE relationship. Specifically, we investigate whether this relationship is different in three sub-periods: in the pre-GFC years, during the GFC and in the post-GFC years. In Models 1 and 2, we run the baseline model using a sub-sample covering the period from 2002–2006 (315 firm-year observations). We find the coefficient of *CRISK1* is 0.310, with statistical significance at the 5% level; however, the coefficient of *CRISK2* is statistically insignificant. In Models 5 and 6, we also find both *CRISK1* and *CRISK2* are positively and significantly related to *COE* in the post-GFC period from 2009–2018 (4,364 firm-year observation). In contrast, using a sub-sample covering the GFC years from 2007–2008 (342 firm-year observation), we find no statistically significant relationship between CRISK and COE (Models 3 and 4). The results imply that investors during the GFC years preferred short-term results at the expense of long-term interests. Therefore, during the GFC, they were unlikely to take CRISK into consideration when evaluating the expected rate of return. These findings are in line with the findings of El Ghoul et al. (2018).

Secondly, to alleviate potential simultaneous causality between CRISK and COE and to confirm that CRISK is the cause but not the result of COE, we lag the independent variables by one and two years behind *COE*. We also perform this check to control for any delay in carbon disclosure. The results are reported in Table 3.12, Models 7–10 and reinforce our main results. We find that *CRISK1* and *CRISK2* at *t-1* and *t-2* are positively associated with *COE*, suggesting that endogeneity stemming from simultaneous causality does not drive our main findings.

Table 3.13. Additional analyses

	Global Financial Crisis (GFC)						Addressing simultaneous causality				Two-way clustering	
	Before		During		After		IND-Vs at *t-1*		IND-Vs at *t-2*			
DV=*COE*	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
CRISK1	**0.31****		**0.14**		**0.23*****		**0.27*****		**0.31*****		**0.24*****	
	(2.24)		**(0.94)**		**(3.40)**		**(3.81)**		**(4.07)**		**(3.78)**	
CRISK2		**0.15**		**0.28**		**0.38*****		**0.41*****		**0.45*****		**0.34*****
		(0.77)		**(1.15)**		**(3.03)**		**(3.26)**		**(3.09)**		**(3.15)**
LOG_SIZE	-0.11	-0.20	0.01	-0.02	-0.07	-0.09	-0.03	-0.06	0.02	-0.02	-0.05	-0.08
	(-0.59)	(-1.17)	(0.04)	(-0.14)	(-0.87)	(-1.17)	(-0.34)	(-0.75)	(0.21)	(-0.25)	(-0.61)	(-0.91)
ROA	-3.97	-1.14	-13.27***	-11.83**	-10.91***	-9.86***	-13.39***	-11.99***	-14.36***	-12.61***	-10.27***	-9.07***
	(-0.76)	(-0.23)	(-2.69)	(-2.33)	(-5.90)	(-5.38)	(-6.89)	(-6.19)	(-7.12)	(-6.24)	(-4.80)	(-4.19)
LEV	3.60***	4.18***	1.90	2.13	2.34***	2.64***	2.41***	2.78***	2.05***	2.53***	2.41***	2.76***
	(3.02)	(3.47)	(1.46)	(1.64)	(4.03)	(4.62)	(4.12)	(4.86)	(3.31)	(4.13)	(3.78)	(4.19)
BETA	0.31	0.57	0.32	0.43	0.79***	0.79***	0.61**	0.63**	0.55*	0.62**	0.60**	0.61**
	(0.41)	(0.77)	(0.43)	(0.57)	(3.23)	(3.20)	(2.42)	(2.46)	(1.92)	(2.13)	(2.13)	(2.17)
FBIAS	0.12	0.06	0.23	0.22	0.60***	0.55***	1.12***	1.10***	0.90***	0.88***	0.83***	0.79***
	(0.25)	(0.12)	(0.77)	(0.74)	(5.09)	(4.66)	(7.59)	(7.40)	(6.23)	(6.07)	(5.66)	(5.49)
VOL	-0.00	-0.03	0.05	0.03	0.08***	0.08***	0.10***	0.09***	0.10***	0.10***	0.09***	0.09***
	(-0.08)	(-0.66)	(1.02)	(0.77)	(5.35)	(5.25)	(6.07)	(5.91)	(5.81)	(5.58)	(6.48)	(6.31)
LTG	5.68***	5.74***	4.46**	4.47**	8.21***	8.32***	3.13***	3.25***	1.80***	1.90***	7.88***	7.99***
	(3.91)	(3.86)	(2.35)	(2.34)	(15.03)	(15.14)	(5.74)	(5.94)	(3.06)	(3.18)	(11.92)	(11.97)
Intercept	50.03*	53.56**	40.94***	40.83***	9.59***	10.63***	12.50***	14.56***	13.47***	15.24***	14.01**	15.03***
	(1.82)	(2.04)	(4.87)	(4.78)	(3.64)	(3.96)	(4.50)	(5.10)	(4.43)	(4.87)	(2.76)	(2.94)
Country-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.44	0.43	0.37	0.37	0.39	0.39	0.34	0.34	0.34	0.33	0.35	0.34
Obs.	315	315	342	342	4364	4364	3911	3911	3209	3209	5021	5021

Notes: This table presents the baseline regression results of the CRISK–COE association after addressing the Global Financial Crisis (GFC) year (and pre- and post-), simultaneous causality and two-way clustering. All models are estimated with clustered robust standard errors by firm (by firm and year in Models 11 and 12) and include year and industry fixed-effects. The dependent variable is *COE* obtained from the average of, at least, two of the four models of implied cost of equity (COE) developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). Appendix B provides more details about the implied COE models. FE=fixed effects. IND-Vs=independent variables. DV=dependent variable. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. Appendix A outlines the variables' definitions and sources.

Finally, in the panel regressions, the year (firm) fixed-effects could steer the cross-sectional (time-series) correlation, resulting in estimation bias. One of the techniques used by prior studies is two-way clustering (Gupta, 2018; Ng & Rezaee, 2015; Oikonomou et al., 2014). Using this approach enables our study to adjust for residuals that are correlated between firms in the same year and in the same firm over years. In Table 3.12, Models 11 and 12, we find that the results are qualitatively similar: the coefficient of *CRISK1* (*CRISK2*) is 0.240 (0.340), with statistical significance at the 1% level.

3.5 Discussion and conclusion

This study mainly examines the relationship between CRISK and COE in a multi-country setting. We empirically examine the response of equity market participants (i.e., analysts and investors) to carbon risk (CRISK). We also examine the role of country-level governance mechanisms in moderating or intensify the CRISK–COE relationship. The implied COE is estimated using four models based on the market and book values of firms' stocks and analysts' earnings forecasts. Using a sample of 5,021 firm-year observations from 13 Asia-Pacific countries over the period 2002–2018, we find that firms with higher CRISK have higher implied cost of equity (COE). The results are also economically significant: one standard deviation increase in *CRISK1 (CRISK2)* leads to an increase in *COE* by approximately 48 (27) basis points. We also find that the impact of CRISK on COE is stronger in countries with strong government effectiveness (GE), strong regulatory quality (RQ) and strong rule of law (RL). Thus, country-level governance mechanisms and equity markets are complements in addressing carbon risk (CRISK). In our additional analyses, we find that the impact of CRISK on COE is stronger and has a higher economic impact for firms from industrials, utilities and basic materials sectors. We also find that the CRISK–COE relationship is positive (neutral) before and after (during) the GFC years.

To confirm our main finding, we run a series of robustness checks. We address the potential sample selection bias and endogeneity problems using alternative model specifications, such as Heckman's (1979) two-stage analysis, PSM analysis, and firm fixed-effects, country fixed-effects, two-stage least squares (2SLS) and dynamic system GMM models. Our main results are also robust after using sub-samples separated based on countries and industries; using individual COE estimates; using alternative and additional control variables; using two-way clustering; and controlling for potential simultaneous causality. We provide evidence that investors and equity market participants are becoming more aware of the effects of carbon risk (CRISK) and that they are likely to consider this kind of risk in their evaluation process. We provide new evidence that a strong country-level governance mechanism demonstrates the importance of CRISK in equity markets.

This study has several implications for policy makers, regulators, managers and equity market participants. According to our study's findings, stock markets are less sensitive to the climate change issue in a weak governance setting. Therefore, in the developing or less-developed country setting, government policy makers and regulators should push firms to move toward a low carbon economy instead of relying on the market mechanism. At the same time, policy makers and regulators need to raise awareness about carbon issues, targeting and influencing public opinion and encouraging firms to disclose their carbon-related information. Our study findings also have practical implications for managers and equity market participants. With CRISK now being valued by market participants, managers can increase their investor base, thus decreasing COE, by improving their carbon performance and reducing carbon risk (CRISK). Generally, this study complements related research and adds to the finance and management literature by examining CRISK as a channel through which corporate environmental performance (CEP) affects firms' costs of capital.

This study has some limitations. Firstly, we focus on the Asia-Pacific region due to data limitations. It would be worthwhile to investigate the CRISK–COE relationship in other geographical areas with different legal, social and economic characteristics and different levels of equity market efficiency. Secondly, future studies could examine whether different kinds of investors (e.g., institutional or foreign investors) drive the CRISK–corporate financial performance (CFP) relationship. Finally, further studies about the potential indirect effects of adopting green strategies would help to build a better understanding among firms and their stakeholders which, in turn, could encourage firms to move toward a low carbon economy.

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Appendix A: Descriptions and sources of variables

Variable	Description	Source/Variable code
Firm-level variables		
COE	The average of at least two of the four models of implied cost of equity developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005). Appendix B provides more details about the implied cost of equity (COE) capital models	Researchers' calculation based on data from Thomson-Reuters

KCT	The implied COE developed by Claus and Thomas (2001)	Researchers' calculation based on data from Thomson-Reuters
KGLS	The implied COE developed by Gebhardt et al. (2001)	As above
KES	The implied COE developed by Easton (2004)	As above
KOJ	The implied COE developed by Ohlson and Juettner-Nauroth (2005)	As above
CRISK1	Natural logarithm of carbon intensity calculated as the ratio of total carbon emissions to sales volume in US dollars	Researchers' calculation based on data from Thomson-Reuters/ENERO03S
CRISK2	= *CRISK1* minus country–sector mean	As above
CMS	Carbon mitigation score calculated as follows: 3 points are added if *CRISK1* is lower than the previous year; 2 points are added if *CRISK1* is lower than the country–sector median; 1 point is awarded if the firm has an environment management team; 1 point is added if the firm has a policy to improve its energy efficiency; 1 point is added if the firm sets targets or objectives to be achieved on emissions reduction; 1 point is added if the firm is aware that climate change can represent commercial risks and/or opportunities; 1 point is added if the firm makes use of renewable energy; 1 point is added if the firm reports on initiatives to reduce, reuse, recycle, substitute or phase out SOx (sulphur oxides) or NOx (nitrogen oxides) emissions; and 1 point is added if the firm reports on its environmentally friendly or green sites or offices.	Researchers' calculation based on data from Thomson-Reuters/ENERO03S, ENRRDP004, ENRRDP0122, ENERDP0161, ENERDP089, ENRRDP046, ENERDP033 and ENRRDP052
LOG_SIZE	Natural logarithm of total assets recorded in billions of US dollars	Researchers' calculation based on data from Thomson-Reuters/WC08001
ROA	Return on assets, calculated as the ratio of net income to total assets	Thomson-Reuters/WC08326
LEV	Total debt/total assets	Thomson-Reuters/WC08236
BETA	Systematic risk, estimated by regressing the firm's excess return on the market's excess return using CAPM, is based on the monthly returns over the previous five years	Thomson-Reuters/897E
FBIAS	The forecast bias, defined as the difference between the mean analysts' forecasts of 1-year-ahead earnings per share (EPS) and realised earnings per share (EPS) divided by realised earnings per share (EPS)	Researchers' calculation based on data from Thomson-Reuters/EPS1MN and WC05201
VOL	The stock return volatility over the previous 12 months	Thomson-Reuters/WC08806
LTG	The median analysts' forecasts for long-term earnings growth	Thomson-Reuters/LTMD
TOBINSQ	= (market value of equity + total liabilities + preferred stock + minority interest) divided by total assets	Researchers' calculation based on data from Thomson-Reuters/WC08001, WC03351, WC03451, WC03426 and WC02999
MTB	Market-to-book ratio	Researchers' calculation based on data from Thomson-Reuters/WC05491 and MVC
BDSIZE	Total number of board members at the end of the fiscal year	Thomson-Reuters/CGBSDP060
BDIND	Percentage of independent directors to total number of directors	Thomson-Reuters/CGBSO07S
DUALITY	Equal to 1 if the company's CEO is also chairman of the board, and 0 otherwise	Thomson-Reuters/CGBSDP061

Appendix A *continued*

HIGH_R1	Equal to 1 if *CRISK1* is higher than the industry–year median, and 0 otherwise	Researchers' calculation
HIGH_R2	Equal to 1 if *CRISK2* is higher than the industry–year median, and 0 otherwise	Researchers' calculation
IMR	The inverse Mills ratio, calculated from the first stage of Heckman's (1979) two-stage model	Researchers' calculation
Country-level variables		
GE	According to (World Bank, 2019), "government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from	World Bank

	political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies"	
RQ	According to (World Bank, 2019), "regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development"	World Bank
RL	According to (World Bank, 2019), the "rule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society and, in particular, the quality of contract enforcement, property rights, the police and the courts, as well as the likelihood of crime and violence"	World Bank
LOG_GDPC	Natural logarithm of gross domestic product (GDP) per capita in US dollars (annually based).	International Monetary Fund (IMF), World Economic Outlook database
ADR	The revised Anti-Director Rights index (annually based).	Djankov et al. (2008)
LOG_MCAP	Natural logarithm of stock market capitalisation of the listed domestic companies in billions of US dollars (annually based).	World Bank. For Taiwan, data are available on the Taiwan Stock Exchange (TWSE) website.

Appendix B. Implied cost of equity (COE) capital models

B.1 Common assumptions and definitions

To assist the discussion, we start by defining the variables and report the common assumptions that apply in all estimation models. The short-term and long-term earnings forecasts, the market and book value of the stock and the average dividends payout ratio are collected from Thomson-Reuters databases, while data on inflation rates are collected from World Bank databases.

p_t = Market value of the stock after 10 months of the fiscal year t

b_t = Book value per share at the beginning of period of the fiscal year t

$FEPS_t$ = Forecast earnings per share (EPS) available at year t. If FEPS is not available for the three, four or five years ahead, we substitute it with FEPS in the previous year and the long-term growth (LTG) forecast as follows: $FEPS_t = FEPS_{t-1}(1 + LTG_t)$

LTG_t = Long-term growth rate. If LTG_t is not available or is outside the range of 0–1, we alternatively use the percentage change of $FEPS$ between the most recent two years.

FD = Forecast dividends payout ratio calculated based on the average dividends payout ratio over the previous five years. If the ratio is missing, we substitute it with the country-year median.

BV_{t+j} = Forecast book value per share at the current year t (beginning of period) plus the forecasted year j, given as follows:

$$BV_{t+j} = BV_{t+j-1} + FEPS_{t+j}(1 - FD_{t+j})$$

g_t = Perpetual earnings growth rate computed based on the realised annual inflation rate at year *t+1*.

The models require $FEPS_{t+1}$ and $FEPS_{t+2}$ and either $FEPS_{t+3}$ or LTG_t to be both available and positive. All estimates are based on the mean analysts' forecasts as provided by Thomson-Reuters databases. The model requires p_t to be measured as of 10 months after the fiscal year to ensure that financial data are publicly available and reflected in the stock prices. The estimations (*KCT*, *KGLS*, *KES* and *KOJ*) are required to be positive; otherwise, they are set as a missing value.

B.2 Model-specific assumptions and valuation equations

B.2.1 Claus and Thomas (2001) model (*KCT*)

$$P_t = b_t + \sum_{j=1}^{5} \frac{FEPS_{t+j} - KCT * BV_{t+j-1}}{(1+KCT)^j} + \frac{FEPS_{t+5} - KCT * BV_{t+4} * (1+g_t)}{(KCT - g_t)(1+KCT)^5}$$

This model uses abnormal earnings and assumes that the current stock price (p) is determined by the current book value (b), forecast earnings per share ($FEPS$), the cost of equity (KCT), forecast book value (BV) and the perpetual growth rate (g). The abnormal earnings are calculated using earnings forecasts for five years ahead. Beyond the fifth year, the model assumes that the forecast residual earnings grow at a constant rate (g_t). It also assumes a 'clean surplus' relation, with future book values (BV) imputed from current book value (b), forecast earnings ($FEPS$) and dividends.

B.2.2 Gebhardt et al. (2001) model (*KGLS*)

$$P_t = b_t + \sum_{j=1}^{11} \frac{FROE_{t+j} - KGLS * BV_{t+j-1}}{(1+KGLS)^j} + \frac{FROE_{t+12} - KGLS * BV_{t+11}}{KGLS(1+KGLS)^{11}}$$

This model assumes that the current stock price (p) is determined by the current book value (b), forecast return on equity ($FROE$), the cost of equity ($KGLS$) and forecast book value (BV). It also assumes a 'clean surplus' relation. $FROE_{t+j}$ is explicitly calculated based on *FEPS* and *BV* for the first three years as follows: $FROE_{t+j} = \frac{FEPS_{t+j}}{BV_{t+j-1}}$. After the explicit forecast period (j = 4–12), the model assumes that $FROE$ will grow linearly or fade to reach the country–year–industry median return on equity (ROE) at year j=12. We compute the target ROE based on the average historical ROE for the previous three years. Negative country–year–industry medians are replaced by the country–industry median. If the figure is still negative, we replace it with the country–year median. Beyond the twelfth year, residual income remains at a constant rate.

B.2.3 Easton (2004) model (*KES*)

$$P_t = \frac{FEPS_{t+2} - FEPS_{t+1}(1 - \text{KES} * FD)}{\text{KES}^2}$$

This model assumes that the current stock price (p) is determined by one- and two-year-ahead earnings forecasts ($FEPS$), forecast dividends payout ratio (FD) and the cost of equity (KES). After the initial period (two years), the model assumes that the growth in forecast abnormal earnings will persist in perpetuity at a constant rate. To yield a positive root, the model requires a positive change in $FEPS$, for example, $\frac{FEPS_{t+2}-FEPS_{t+1}}{FEPS_{t+1}} > 0$

B.2.4 Ohlson and Juettner-Nauroth (2005) model (KOJ)

$$P_t = \frac{FEPS_{t+1}(STG_t - g_t + KOJ * FD_{t+1})}{KOJ(KOJ - g_t)}$$

where $STG_t = \frac{1}{2}\left(\frac{FEPS_{t+2}-FEPS_{t+1}}{FEPS_{t+1}} + LTG\right)$

This model assumes that the current stock price (P_t) is determined by one-year-ahead earnings forecasts ($FEPS_{t+1}$), short-term growth rate (STG_t), perpetual growth rate (g_t) and cost of equity (Koj). Following Gode and Mohanram (2003), STG is calculated as the average of the percentage change of $FEPS$ in the most recent two years and long-term growth (LTG). To yield a positive root, the model requires a positive change in $FEPS$, for example, $\frac{FEPS_{t+2}-FEPS_{t+1}}{FEPS_{t+1}} > 0$.

CHAPTER 4: THIRD PAPER

CORPORATE CARBON PERFORMANCE AND FIRM RISK: EVIDENCE FROM ASIA-PACIFIC COUNTRIES

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Abstract

This study examines the question of how and why corporate carbon performance (CCP) affects a firm's total, idiosyncratic and systematic risk and whether this effect varies by country-level governance quality. Using a sample of 5,753 firm-year observations from 13 countries in the Asia-Pacific region over the period 2002–2018, we find that CCP produces an adverse effect on a firm's total, idiosyncratic and systematic risk. We also find that CCP yields greater reductions in a firm's total and idiosyncratic (systematic) risk in countries with strong (weak) country-level governance. Our primary results are robust after using alternative model specifications to control for sample selection bias, and endogeneity and heterogeneity problems. They are also robust after using sub-samples by country, and controlling for the Global Financial Crisis (GFC) and for simultaneous causality. We document that investors and stock markets, in general, are becoming more aware of firms' environmental performance and are paying close attention to corporate carbon performance (CCP).

Keywords: Carbon risk, climate change, environmental performance, financial performance, financial distress risk, sustainability.

4.1 Introduction

Research on corporate environmental performance (CEP) has grown significantly in the last two decades. A cursory search on the PubMed.gov database[23] showed that 306,756 full-length papers have been published on this topic since 2000. The link between a firm's green practices and its economic success is a core topic in this debate. While some researchers affirm that CEP generally pays off for stakeholders and shareholders alike (e.g., Fujii et al., 2013; Trinks et al., 2020), others assume that firms incur additional costs for CEP at the expense of stockholders (e.g., Damert et al., 2017; Hart & Ahuja, 1996). The current study reconsiders the controversial question of 'does it pay to be green?' (Hart & Ahuja, 1996) both theoretically and empirically. Specifically, we add to the existing literature by examining whether and in what ways corporate carbon performance (CCP) affects firm risk and whether country-level governance quality moderates or strengthens this relationship. This study specifically focuses on the most important issues that threaten our planet's ecological and economic systems, namely, climate change and the global warming phenomenon.

To pave the way for a low carbon economy, efforts must be intensified by scholars, decision-makers, the media, legislators and the public. Financial markets can also play a fundamental role by rewarding or penalising firms based on their carbon performance. In recent years, companies have tended to improve their carbon performance and carbon-related disclosure to build a better reputation. These efforts have also met with increased attention by investors and creditors. For example, when Uber, a mobility services provider, announced that by 2030 it will only use cars with zero carbon emissions in the European and North American markets, in early trading after the announcement, its stock prices increased by approximately 2% (Heath & Rapier, 2021).

Our study belongs to the literature that proclaims the win-win relationship between a firm's social and environmental responsibility and its financial performance. The study utilises a multi-theoretical framework to explain why and how CCP affects firm risk, offering detailed empirical evidence. The negative relationship between CCP and firm risk can mainly be explained by two theoretical arguments. Firstly, based on stakeholder theory, firms usually adopt green strategies that align with stakeholders' expectations to build trust channels and attain a better reputation, increasing their competitive advantage and financial performance (Gallego-Álvarez et al., 2015; Xue et al., 2020). In addition, based on risk management theory, green practices also grant firms an 'insurance-like protection', as their better reputation will mitigate the negative effects of facing future environmental violations, if any, or facing future

[23] https://pubmed.ncbi.nlm.nih.gov

stricter environmental regulations (El Ghoul et al., 2018; Godfrey, 2005). Consequently, low CCP (high CCP) will decrease (increase) firm value and increase (decrease) firm risk.

Secondly, according to Fama and French (2007), asset prices will be affected when a stock is traded by investors as consumption goods. Thus, the existence of green investors with the marginal utility of holding green stocks above and beyond the utility of expected returns (Heinkel et al., 2001) will increase (decrease) the demand for green (polluters) stocks, thereby decreasing (increasing) risk and expected rates of return (as investors demand higher risk premiums as a compensation for higher risk). This argument is also in line with the investor recognition theory of Merton (1987).

The current study uses a sample of 5,753 firm-year observations (881 unique firms) over the period 2002–2018 from 13 countries in the Asia-Pacific region. We find that the CCP variables, namely, carbon intensity (*CCP1*) and carbon mitigation scores (*CMS1* and *CMS2*), are negatively related to a firm's total risk (*DEVRET*), idiosyncratic risk (*IDIO_RISK*) and systematic risk (*BETA*). These results are generally robust after running a series of robustness tests. To address the potential sample selection bias and endogeneity problems, we use alternative model specifications, namely, Heckman's (1979) two-stage analysis, propensity score matching (PSM), and firm fixed-effects, country fixed-effects and two-stage least squares (2SLS) models. In addition, we re-run the baseline model using sub-samples across countries to address the heterogeneity problem. We also run additional analyses to control for the Global Financial Crisis (GFC) and simultaneous causality.

This study also investigates the impact of country-level governance on the CCP–firm risk relationship. Two theoretical arguments could explain this impact: the globalisation view, which suggests the substitute effect of governance mechanisms and stock markets, and the environmental costs view, which suggests a complementary effect (see Section 4.2.2). Our empirical results reveal that CCP leads to a greater reduction in a firm's total and idiosyncratic risk in countries with good governance quality (Hypotheses 2a [H2a] and 2b [H2b]), which supports the environmental costs view. In contrast, we find that CCP has a greater impact on a firm's systematic risk in countries with weak governance quality than in countries with good governance quality (Hypothesis 2c [H2c]), which supports the globalisation view. The mitigation effect of governance quality on the relationship between CCP and systematic risk could also be explained by a higher level of customers' awareness of environmental issues in countries with strong governance which will increase their loyalty to green firms (Luo & Bhattacharya, 2006). This will lead to a firm having less price-elastic demand, higher pricing power and higher profit margins (Albuquerque et al., 2019). Consequently, firms are less sensitive to the market's overall performance and have a lower systematic risk.

This study makes clear contributions to the emerging literature. Firstly, it provides evidence on how CCP is dealt with by capital markets. While numerous studies have examined the effects of CEP on corporate financial performance (CFP)[24], studies are limited on how carbon performance, as a contemporary issue, influences firm risk (Huang et al., 2021; Trinks et al., 2020). Secondly, as the CCP–CFP relationship may vary across industries, in different time frames and across countries, the literature has produced mixed results. Therefore, utilising a multi-country sample with a horizon that is relatively long (16 years), the current study endeavours to explore one of the factors that cause these different views by examining whether and how country-level governance quality moderates or strengthens the CCP–firm risk relationship. This study is a pioneering effort to address this question. Finally, we perform a set of robustness tests to address the most common empirical challenges, that is, endogeneity, heterogeneity, simultaneous causality and sample selection bias.

The remainder of this paper is organised as follows: Section 4.2 reviews the existing literature and presents the hypotheses development; Section 4.3 provides the research design and data; followed by Section 4.4 which presents the results and discussion, while the final section (Section 4.5) concludes the paper.

4.2 Literature review and hypotheses development

4.2.1 Corporate social responsibility (CSR) and firm risk

As environmental performance and carbon performance are important components of corporate social responsibility (CSR), this section first reviews the various arguments in the CSR literature for why and how CSR practices affect firm risk. It is noteworthy that, being built on conflicting arguments, previous studies provide unstable empirical evidence on this relationship. For example, Albuquerque et al. (2019) examine the relationship between CSR and firm systematic risk and firm value. They find that the level of systematic risk (firm value) is lower (higher) for firms with higher CSR scores. In contrast, Sassen et al. (2016) find that CSR reduces a firm's total and idiosyncratic risk but not its systematic risk. They also find that CEP, as a segment of CSR, is negatively related to idiosyncratic risk in the full sample and to total and systematic risk only in environmentally sensitive industries. Oikonomou et al. (2012) also find a negative relationship between CSR and systematic risk, while El Ghoul et al. (2011) similarly find that CSR negatively affects the cost of equity (COE) capital.

Focusing on CSR's environmental aspect, Xue et al. (2020) examine the effect of environmental management performance (EMP) and environmental operational performance

[24] See Section 4.2.2 below.

(EOP) on a firm's total and idiosyncratic risk. They find EMP to be negatively related to firm risk; however, they find no significant relationship between EOP and firm risk. Conversely, Cai et al. (2016) find that CEP negatively affects total and systematic risk, while Benlemlih et al. (2018) find environmental and social disclosure to be negatively related to a firm's total and idiosyncratic risk. However, they find no significant relationship with systematic risk.

4.2.2 Corporate carbon performance (CCP) and firm risk

Another stream of the literature has studied CCP as a contemporaneous issue but with conflicting results. For example, Nguyen (2018) examines the effect of carbon risk on corporate financial performance (CFP). The author finds that polluters (firms that operate in the most carbon-intensive industries) are most likely to have a negative net income, lower Tobin's Q and lower return on equity (ROE) compared to non-polluters. Using the Australian ratification of the Kyoto Protocol as a carbon-related regulation shock, the author finds that the differences in financial performance between treatment and control groups are significantly larger after the ratification of the Kyoto Protocol, thus suggesting a higher regulatory risk for polluters.

Using a sample of United States (US) firms, Delmas et al. (2015) find that CCP increases a firm's long-term financial performance (Tobin's Q). However, they find that CCP causes a decrease in the firm's short-term financial performance (return on assets [ROA]), suggesting that investors see the potential benefits of CEP in the long run but not in the short run. Busch et al. (2020) re-conduct the study of Delmas et al. (2015) by extending the sample to include European firms and using another time frame (2005–2014). They find contradictory results, with CCP associated with lower financial performance in both the short term and the long term. In line with neoclassical economics (Friedman, 1970), they argue that the increase in costs resulting from CCP projects would be perceived as a costly diversion of a firm's resources and would place a firm at a competitive disadvantage (Aupperle et al., 1985). Some studies also examine the impact of carbon disclosure on corporate financial performance (CFP). For example, using a sample of global firms, Siddique et al. (2021) find that carbon disclosure reduces (increases) short-term (long-term) financial performance.

Although several studies have examined the CCP–CFP relationship, few studies have specifically examined the impact of carbon performance on firm risk (Alsaifi et al., 2021; Huang et al., 2021; Trinks et al., 2020). Therefore, many more empirical studies are needed to develop a clearer view of the CCP–firm risk relationship. To the best of our knowledge, no study has examined this relationship using a comprehensive sample from the Asia-Pacific region or has investigated the role of country-level governance in this relationship. Huang et al. (2021) examine the impact of carbon-related regulations on firm risk in China. Using environmental regulation shocks as a quasi-natural experiment, they find that the uncertainty arising from carbon-related costs and the political and regulatory risk increase a firm's total, systematic and idiosyncratic risk in regions that are faced with the low-carbon city (LCC) policy. Trinks et al. (2020) find that carbon efficiency[25] is positively related to ROA and negatively related to systematic risk. Meanwhile, they find a neutral relationship between carbon efficiency and Tobin's Q and total risk. Alsaifi et al. (2021) examine the relationship between carbon disclosure and firm risk. They find a significant negative relationship between voluntary carbon disclosure and a firm's total, systematic and idiosyncratic risk. They also find that this relationship is more pronounced in carbon-intensive industries.

Based on the CSR and CEP literature, two primary theoretical arguments can explain the negative relationship between CCP and firm risk. Firstly, stakeholder theory proposes a negative (positive) relationship between CCP (carbon risk) and firm risk. Firms usually adopt strategies that align with their stakeholders' expectations to build trust channels with them. Mounting pressure from environmental and climate change issues may force a firm to engage in environmentally friendly practices motivated by building a better reputation and generating intangible assets, thus increasing its competitive advantage and financial performance (Gallego-Álvarez et al., 2015; Xue et al., 2020). Based on risk management theory, an increase in moral capital will provide 'insurance-like protection' for firms through mitigating the negative effects if they cope with an environmentally adverse event (El Ghoul et al., 2018; Godfrey, 2005). For instance, Godfrey et al. (2009) find that high-CSR firms have higher abnormal returns than low-CSR firms if they face adverse events (e.g., legal action or an environmental scandal). Moreover, investors may consider high CCP (low CCP) to be an indication that the firm is less (more) prone to climate change risk and to any potential change in environmental regulations. Consequently, carbon risk (high CCP) could decrease (increase) firm value and increase (decrease) firm risk.

The second argument has an underlying assumption that the group of investors called green investors prefers (avoids) low-CCP (high-CCP) stocks. This assumes that green investors have the marginal utility of holding (not holding) stocks above and beyond the utility of anticipated returns (Heinkel et al., 2001). Socially responsible investing (Hong & Kacperczyk, 2009) and loyalty-based investing (Cohen, 2009) are also examples of investors having tastes and preferences for assets other than expected returns. The asset pricing models, such as the capital asset pricing model (CAPM) and Fama and French's (1993) three-factor model, and modern portfolio theory suppose that only systematic risk (e.g., the impact of macroeconomic

[25] Level of carbon emissions per unit of output compared to sector–year peers.

factors) matters in pricing assets, as idiosyncratic risk can be overtaken through diversification. Nevertheless, this assumption is unrealistic in the presence of market imperfections (e.g., investors having tastes and preferences). According to Fama and French (2007), asset prices will be affected when investors trade on a stock as consumption goods. Therefore, willingness (reluctance) to invest in low-CCP (high-CCP) stocks by a large number of investors will increase (weaken) demand, thereby decreasing (increasing) risk and expected rates of return (as investors demand higher risk premiums as compensation). This argument is also in line with Merton (1987) investor recognition theory. Based on the above discussion, we arrive at the following hypothesis:

H1. Corporate carbon performance (CCP) is negatively associated with firm risk.

4.2.3 Role of country-level governance mechanisms

Understanding the implications of governance mechanisms is quite important for policy makers, regulators and investors. Governance quality has a fundamental role in market efficiency and economic stability. Therefore, this study sheds light on the country-level governance impact on the CCP–firm risk relationship. To be specific, it is a comparison study that investigates whether stock markets' reaction to CCP differs between countries in terms of country-level governance quality.

Several studies have examined the potential effect of country-level governance on financial markets. For example, La Porta et al. (1997) find that countries with a good legal environment and a better quality of legal rules and law enforcement have larger and wider capital markets. Qi et al. (2010) find that firms from countries with strong creditor rights and political rights have a lower cost of debt (COD).

Regarding the role played by country-level governance in stock markets' responses to CSR and corporate environmental responsibility (CER), Benlemlih and Girerd-Potin (2017) find that the legal origin of countries matters in the CSR–firm risk relationship. They find that CSR is negatively related to a firm's idiosyncratic risk only in civil law countries. They also find that CSR reduces a firm's idiosyncratic and systematic risk in countries with lower shareholder protection scores and higher stakeholder protection scores. Jung et al. (2021) find that firms respond to environmental regulations by adding more directors with an environmental background, leading to increased environmental performance.

Two theoretical arguments explain how country-level governance influences the CEP–firm risk relationship: the globalisation view, which indicates the substitute effect of governance mechanisms and stock markets, and the environmental costs view, which indicates a complementary effect. The globalisation view predicts that carbon risk (low CCP) has a higher impact on firm risk in countries with weak governance than in countries with strong governance. This view states that the globalisation of financial markets increases awareness about environmental issues in countries with poor governance (e.g., developing countries). For instance, Cole et al. (2006) find that the increase in international trade and foreign direct investment (FDI) in Japan improves firms' awareness of environmental responsibility. In addition, financial markets' globalisation leads to lending institutions becoming more aware of borrowers' social and environmental performance, especially in countries with lenient environmental regulations. For example, 126 financial institutions, covering most of global lending volume, have adopted the Equator Principles[26], aiming to manage lending institutions' environmental and social risk which affect their lending strategies. Accordingly, if a firm operates in countries with a weak governance mechanism, uncertainty about that firm's ability to mitigate carbon risk will be higher; therefore, firms with lower CCP could suffer from higher price volatility and, thus, higher risk.

The environmental costs view states that firms from a country with strong governance are more likely to suffer from present and potential expensive environmental costs or fines due to exposure to stricter environmental regulations. Thus, market participants are less confident of firms' future cash flows, leading to overpricing of environmental risk. Also, in this governance setting, the media, public opinion and environmental activists give more attention to environmental issues; thus, firms with low CCP could experience a severe deterioration in their reputation. At the same low level of CCP, firms operating in countries with strong governance have higher price volatility (higher firm risk) than firms from countries with weak governance, *ceteris paribus* (all other things being equal). Based on the above discussion, either a moderating or intensifying effect of the governance environment is possible. Thus, we test the following null hypotheses:

H2a. No difference exists in the impact of corporate carbon performance (CCP) on total risk between countries in terms of governance quality.

H2b. No difference exists in the impact of corporate carbon performance (CCP) on idiosyncratic risk between countries in terms of governance quality.

H2c. No difference exists in the impact of corporate carbon performance (CCP) on systematic risk between countries in terms of governance quality.

Table 4.1. Sample selection and distribution

Panel A – Sample selection

[26] http://www.equator-principles.com/.

Details						Obs.
Firm-year observations in Thomson-Reuters databases for carbon data						6,535
Less: Firm-year observations with insufficient financial data						(782)
Firm-year observations in final sample						5,753
Panel B – Sample breakdown by industry and year						
ICB industry classification	Obs.	% of sample		Year	Obs.	% of sample
Oil and Gas	182	3.16		2002	13	0.23
Basic Materials	796	13.84		2003	15	0.26
Industrials	1,139	19.80		2004	65	1.13
Consumer Goods	908	15.78		2005	100	1.74
Health Care	306	5.32		2006	124	2.16
Consumer Services	437	7.60		2007	184	3.20
Telecommunications	250	4.35		2008	227	3.95
Utilities	331	5.75		2009	271	4.71
Financials	908	15.78		2010	366	6.36
Technology	496	8.62		2011	396	6.88
Total	5,753	100.00		2012	437	7.60
				2013	466	8.10
				2014	499	8.67
				2015	567	9.86
				2016	609	10.59
				2017	713	12.39
				2018	701	12.18
				Total	5,753	100.00

Notes: Table 4.1 presents the sample selection process (Panel A), and the sample distribution by industry, based on the Industrial Classification Benchmark (ICB), and by year (Panel B).

4.3 Research design and data

4.3.1 Sample construction and data

Our initial sample consists of all publicly listed firms in 13 countries in the Asia-Pacific region, namely: Australia, China, India, Indonesia, Japan, Malaysia, New Zealand, Philippines, Singapore, South Korea, Taiwan, Thailand and Hong Kong. Next, we merge data from the following sources: (i) Thomson-Reuters databases, which provide the carbon and financial data; (ii) World Bank databases, World Economic Outlook databases, Taiwan Stock Exchange (TWSE) website and the study by Djankov et al. (2008) which provide the country-level data. Appendix A provides more details about the descriptions and sources of our study's variables.

Table 4.1, Panel A shows the details of the sample selection process. In the first stage, we include all firm-year observations (6,535) for which carbon data were available on Thomson-Reuters databases. Next, we exclude firm-year observations (782) that have missing firm-specific controls. The final sample consists of 5,753 firm-year observations over the 2002–2018 period. Table 4.1, Panel B summarises the sample's composition by 10 industry classifications, based on the Industrial Classification Benchmark (ICB), and by year. The statistics show that most firms are from the industrials, financials, consumer goods and basic materials sectors, representing 19.8%, 15.8%, 15.8% and 13.8%, respectively, of our final sample, while the oil and gas sector, at 3.35%, has the least number of firms in the sample. The statistics also reveal that the number of observations gradually increased over the sample period, suggesting increasing awareness of the climate change issue over time and firms' increasing orientation to disclose their carbon-related information.

4.3.2 Definition of variables

4.3.2.1 Dependent variables: Firm risk

In line with previous studies, we estimate three measures of firm risk: total risk (*DEVRET*), idiosyncratic risk (*IDIO_RISK*) and systematic risk (*BETA*). Total risk, which captures systematic and idiosyncratic risk, is measured as the annualised standard deviation of a firm's daily stock returns (Cai et al., 2016; Jo & Na, 2012). Idiosyncratic risk (*IDIO_RISK*), or firm-specific risk, is the risk that is unrelated to changes in market returns. It is estimated as the standard deviation of residuals from CAPM, based on the previous year's daily return (Bouslah et al., 2018; Xue et al., 2020). According to modern portfolio theory, only systematic risk should be considered in asset pricing, as diversification can abolish the effect of idiosyncratic risk. However, idiosyncratic risk matters in the presence of investors who consider social and environmental issues in their investing decisions (Fama & French, 2007). Some studies show that idiosyncratic risk matters in the overall market return. For example, Ang et al. (2009) find that stocks with high firm-specific (idiosyncratic) risk have a lower future return. Goyal and Santa-Clara (2003) find that the average stock variance (idiosyncratic risk) is positively related to market returns. Systematic risk (*BETA*) is the type of risk that relates to changes in market returns. It measures how a stock's returns change compared to the change in the market's return. It is estimated by regressing a firm's excess returns on the market's excess returns, based on daily stock returns over the previous 12 months from CAPM (Alsaifi et al., 2021; Bouslah et al., 2018; Jo & Na, 2012). The CAPM is characterised by the following equation:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \qquad (1)$$

where R_{it} is excess returns for firm i at time t; α_i is the intercept term; β_i is the estimated systematic risk (beta); R_{mt} is the market's excess returns at time t; and ε_{it} is the stochastic error term.

4.3.2.2 Independent variables: Corporate carbon performance (CCP)

The current study employs three proxies for corporate carbon performance (CCP). Firstly, we use the relative measure of carbon emissions (*CCP1*), measured as the natural logarithm of the ratio of total carbon emissions (Scopes 1 and 2)[27] to total sales. The ratio is multiplied by -1 to create a higher number to indicate better carbon performance. We use a relative measure of carbon emissions, rather than an absolute measure, to control for any sudden change in total emissions due to firm-specific events, such as mergers and acquisitions (M&As), or any changes in the overall economy (Busch & Lewandowski, 2018). This also helps us to control for variation between firms in economic output, size and industry. Secondly, we use the carbon mitigation score (*CMS1*), as defined in Appendix A. Finally, we use *CMS2* as an equally weighted score of *CMS1:* higher values of *CCP1*, *CMS1* and *CMS2* indicate better carbon performance.

4.3.2.3 Control variables

To explain variation in firm risk owing to corporate carbon performance (CCP), we control for variables known to be associated with firm risk. Following previous studies (Albuquerque et al., 2019; Bouslah et al., 2013, 2018; Jo & Na, 2012; Xue et al., 2020), we include the following firm-level control variables: *SIZE*, the natural logarithm of total assets recorded in billions of US dollars; *ROA*, return on assets; *MTB*, market-to-book ratio; *LEV*, leverage ratio calculated as total liabilities divided by total assets; *COE*, implied cost of equity based on the average of at least two of the four models developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005); *CASH*, the ratio of cash and cash equivalents to total assets; *DISP*, the dispersion in analysts' forecasts measured as the coefficient of variation of one-year-ahead earnings estimates; *CAPEXP*, the ratio of capital expenditure divided by last year's total assets multiplied by 100; and *LOSS*, which is equal to 1 if the firm reports losses in the last two years, and 0 otherwise. We expect these control variables to have the following predicted signs: *SIZE* (-), *ROA* (-), *MTB* (+), *LEV* (+), *COE* (+), *CASH* (+), *DISP* (+), *CAPEXP* (+) and *LOSS* (+).

In line with previous multi-country studies (El Ghoul et al., 2018; Krishnamurti et al., 2018; La Rosa et al., 2018), we add a set of country-level variables to control for potential cross-country differences: *GDPC*, the natural logarithm of gross domestic product (GDP) per capita in US dollars; *ADR*, the revised Anti-Director Rights Index from Djankov et al. (2008), with higher values indicating more shareholder protection; and *LOG_MCAP*, the natural logarithm of stock market capitalisation. All variables are defined in Appendix A.

[27] According to the Greenhouse Gas Protocol, Scope 1 refers to direct emissions from operational processes owned or controlled by the company, Scope 2 refers to emissions from purchased energy and Scope 3 refers to indirect emissions related to a firm's value chain from sources neither owned nor controlled by the company (see Busch & Lewandowski, 2018).

4.3.2.4 Country-level governance variables

We use three indicators for governance mechanisms from World Bank databases. According to the World Bank (2019), government effectiveness (*GE*)

> captures perceptions of the quality of public services; the quality of the civil service and the degree of its independence from political pressures; the quality of policy formulation and implementation; and the credibility of the government's commitment to such policies.

Regulatory quality (*RQ*) "captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development". Rule of law (*RL*) "captures perceptions of the extent to which agents have confidence in and abide by the rules of society and, in particular, the quality of contract enforcement, property rights, the police and the courts, as well as the likelihood of crime and violence".

4.3.3 Model specification

To examine Hypothesis 1 (H1) about the relationship between CCP and firm risk, we use the following regression model:

$$FR_{it} = \alpha + \beta_1 CCP_{it} + \sum_{j=2}^{n} \beta_j CONTROL_{jit} + year\ and\ industry\ FE + \varepsilon_{it} \quad (2)$$

where *i* denotes a firm; *t* denotes time; and *FR* denotes firm risk (*DEVRET, IDIO_RISK* and *IDIO_RISK*). Corporate carbon performance (*CCP*) is calculated based on three proxies (*CCP1*, *CMS1* and *CMS2*). *CONTROL* is a vector of firm- and country-level control variables, as discussed in the previous section. We also add year and industry dummies to control for any unobserved industry and year characteristics resulting from fluctuations in market trends that may drive our results.[28] Based on Hypothesis 1 (H1), we expect β_1 in Equation (1) to be negative. Appendix A outlines the definitions and sources of the variables.

Table 4.2. Descriptive statistics for full sample and mean and median differences tests between two sub-samples

Panel A – Descriptive statistics							
	Mean	Std. Dev.	Min	P25	Median	P75	Max
CCP1	2.624	1.903	-1.935	1.286	2.838	3.879	7.339
CMS1	6.566	2.397	0.000	5.000	7.000	8.000	12.000
CMS2	4.825	1.843	0.000	4.000	5.000	6.000	9.000
DEVRET	0.299	0.104	0.111	0.229	0.283	0.348	0.738

[28] For example, Cai et al. (2016) find that the CEP–firm risk relationship is different across industries, with a negative (positive) relationship in the manufacturing (services) sector.

IDIO_RISK	15.058	6.101	1.711	10.000	13.000	20.000	40.000
BETA	0.977	0.329	0.190	0.760	0.990	1.185	1.975
SIZE	12.155	18.008	0.336	2.841	5.963	12.775	115.692
ROA	0.052	0.056	-0.118	0.019	0.042	0.075	0.264
MTB	2.013	1.956	0.370	0.960	1.400	2.240	13.050
LEV	0.246	0.165	0.000	0.119	0.235	0.353	0.721
COE	9.220	3.544	2.626	6.687	8.734	11.246	20.123
CASH	0.138	0.124	0.000	0.050	0.104	0.187	0.995
DISP	15.544	27.588	0.756	4.386	7.515	14.612	200.571
CAPEXP	5.600	5.020	0.030	2.160	4.570	7.380	27.140
LOSS	0.031	0.174	0.000	0.000	0.000	0.000	1.000
GDPC	10.284	0.849	6.927	10.266	10.569	10.730	11.134
ADR	4.302	0.702	1.000	4.000	4.500	4.500	5.000
MCAP	12.311	0.420	10.384	12.074	12.503	12.641	12.940

Panel B – Sub-samples separated based on the industry–country median of carbon intensity (*CCP1*)

	Low *CCP1*		High *CCP1*		Mean test (*p*-value)	M–W test (*p*-value)
	Mean	Median	Mean	Median		
DEVRET	0.297	0.285	0.300	0.283	0.455	0.920
IDIO_RISK	15.001	13.000	15.115	13.000	0.477	0.969
BETA	0.974	0.990	0.981	0.990	0.452	0.621
SIZE	12.728	6.139	11.569	5.800	0.014	0.324
ROA	0.055	0.043	0.049	0.041	0.000	0.049
MTB	2.193	1.500	1.829	1.29	0.000	0.000
LEV	0.233	0.220	0.260	0.248	0.000	0.000
COE	9.282	8.840	9.157	8.653	0.182	0.173
CASH	0.150	0.117	0.126	0.093	0.000	0.000
DISP	14.501	7.447	16.612	7.571	0.004	0.266
CAPEXP	4.914	3.760	6.304	5.210	0.000	0.000
LOSS	0.023	0.000	0.040	0.000	0.000	0.000

Notes: Table 4.2, Panel A presents descriptive statistics for the variables in the full sample. Table 4.2, Panel B presents the univariate analysis results. The Mann–Whitney (M–W) test and *t*-test are used to examine the median and mean differences, respectively, between high and low carbon performance based on the industry–country median of *CCP1* (*p*-values are two-tailed). All variables are defined in Appendix A.

To test Hypotheses 2a (H2a), 2b (H2b) and 2c (H2c) which examine the effect of country-level governance indicators (government effectiveness, regulatory quality and the rule of law) on the relationship between CCP and firm risk, we use the following regression models, with no prediction for the sign of β_3 :

$$FR_{it} = \alpha + \beta_1 CCP_{it} + \beta_2 \text{ governance indicator}_{it} + \beta_3 \text{ governance indicator}_{it} * CCP_{it} + \sum_{j=4}^{n} \beta_j CONTROL_{jit} + year\ and\ industry\ FE + \varepsilon_{it} \quad (3)$$

4.4 Results

4.4.1 Descriptive statistics and univariate analysis

Table 4.2 provides the descriptive statistics (Panel A) and the univariate analysis (Panel B) of this study's variables. The mean (median) values of our independent variables *CCP1*, *CMS1* and *CMS2* are 2.624 (2.838), 6.566 (7) and 4.825 (5), respectively. The mean (median) values of the three risk factors *DEVRET*, *IDIO_RISK* and *BETA* are 0.299 (0.283), 15.058 (13) and 0.977 (0.99), respectively. The explanatory variables have the following mean [median] values: *SIZE* (12.16 [5.96]), *ROA* (5.2% [4.2%]), *MTB* (2.01 [1.40]), *LEV* (24.6% [23.5%]), *COE* (9.2% [8.7%]), *CASH* (0.14 [0.10]), *DISP* (15.54 [7.52]), *CAPEXP* (5.60 [4.57]) and *LOSS* (0.03 [0]). The values are generally within the expected range and in line with previous studies. Panel A also reports the percentiles distribution (minimum, 25th percentile, 50th percentile, 75th percentile and maximum values). The continuous variables are winsorised at the 1st and 99th percentiles to mitigate potential misleading caused by extreme values.

Table 4.2, Panel B reports the mean and median differences for firm-level variables between two sub-samples separated based on the industry–country median of *CCP1*, with low-*CCP1* being below the median and high-*CCP1* being above the median. We report the mean and median values for the two sub-samples (Columns 1–4) and *t*-test and Mann–Whitney test results (last two columns). We find that the differences in mean and median values of the total, idiosyncratic and systematic risk between the two sub-samples are not statistically significant, providing initial evidence that, on average, a neutral relationship is found between CCP and firm risk. The results also show that mean and median differences between the two sub-samples are statistically significant for *ROA*, *MTB*, *LEV*, *CASH*, *CAPEXP* and *LOSS*. The results also show that the differences between two sub-samples in their mean (median) values of *SIZE* and *DISP* are statistically significant (insignificant). Finally, we find that both mean and median values of *COE* are not statistically different. To summarise, the univariate analysis suggests that firms with high *CCP1* are, on average, smaller and less profitable and have a lower market-to-book ratio, higher leverage ratio, lower cash holding, higher dispersion in analysts' forecasts, higher capital expenditure and higher probability of reporting negative net income.

Table 4.3 reports the number of observations across countries and the percentage of the full sample. It also presents the mean carbon performance values and firm risk variables by country. The figures show that 44.76% of the observations are from firms in Japan, followed by firms in Australia and Hong Kong, with approximately 14% and 9% of the sample, respectively. Indonesian firms are represented least in the sample with 33 firm-year observations (0.57% of the sample).

Table 4.4 reports Pearson's correlation coefficients. The correlation coefficients between CCP variables *(CCP1*, *CMS1* and *CMS2)* and total risk (*DEVRET*), idiosyncratic risk (*IDIO_RISK*) and systematic risk (*BETA*) are negative and statistically significant at the 1%

Table 4.3. Descriptive statistics of key variables across countries

Country	N	% of sample	*CCP1*	*CMS1*	*CMS2*	*DEVRET*	*IDIO_RISK*	*BETA*
Australia	812	14.11	1.991	6.185	4.362	0.304	16.375	1.001
China	129	2.24	3.106	5.248	3.426	0.315	15.856	1.032
India	240	4.17	2.050	7.613	5.754	0.302	16.257	0.991
Indonesia	33	0.57	1.546	6.788	4.727	0.367	20.016	1.041
Japan	2,575	44.76	2.843	6.654	4.989	0.305	14.354	0.988
Malaysia	161	2.80	1.926	5.857	4.137	0.227	12.341	0.976
New Zealand	105	1.83	2.752	6.029	4.048	0.235	12.644	0.974
Philippines	82	1.43	1.751	5.829	4.159	0.282	14.962	0.947
Singapore	143	2.49	2.783	7.007	5.189	0.227	11.695	0.951
South Korea	429	7.46	3.072	7.093	5.413	0.324	17.541	0.995
Taiwan	412	7.16	2.901	6.619	4.971	0.283	15.146	0.962
Thailand	140	2.43	1.967	7.379	5.536	0.269	12.961	1.054
Hong Kong	492	8.55	2.616	6.154	4.211	0.307	16.195	0.845
Total sample	**5,753**	**100**	**2.624**	**6.566**	**4.825**	**0.299**	**15.058**	**0.977**

Notes: Table 4.3 presents the number of observations, percentage of the full sample and mean value of the key variables by country. All variables are defined in Appendix A.

level (except between *CMS2* and *BETA)*. This provides initial evidence that CCP is negatively related to firm risk, which is consistent with our first hypothesis (H1). The correlation coefficient values between controls are relatively low, suggesting that multicollinearity is a significant issue in our regression models. We also use variance inflation factor (VIF) values to further examine this potential problem. Our test shows that VIF values (un-tabulated) for controls in the main regression models are below 3.1. According to Rashid (2013), the multicollinearity concern is raised if the VIF value is more than 10.

Table 4.4. Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) *CCP1*	1.000																
(2) *CMS1*	**0.153**	1.000															
(3) *CMS2*	0.031	**0.891**	1.000														
(4) *DEVRET*	**-0.181**	**-0.083**	**-0.077**	1.000													
(5) *IDIO_RISK*	**-0.199**	**-0.091**	**-0.103**	**0.738**	1.000												
(6) *BETA*	**-0.104**	**-0.044**	-0.015	**0.436**	**0.263**	1.000											
(7) *SIZE*	**0.113**	**0.241**	**0.296**	**-0.257**	**-0.293**	**-0.061**	1.000										
(8) *ROA*	**-0.035**	**0.080**	0.020	**-0.148**	**-0.071**	**-0.152**	**0.180**	1.000									
(9) *MTB*	**0.053**	**0.041**	-0.005	**-0.083**	**-0.042**	**-0.110**	**0.161**	**0.544**	1.000								
(10) *LEV*	**-0.250**	-0.006	**0.035**	**0.064**	**0.055**	**0.053**	**-0.074**	**-0.247**	**-0.069**	1.000							
(11) *COE*	**-0.068**	**0.046**	**0.056**	**0.214**	**0.195**	**0.251**	**-0.166**	**-0.189**	**-0.300**	**0.187**	1.000						
(12) *CASH*	**0.180**	-0.019	**-0.062**	**0.054**	**0.035**	0.006	0.002	**0.205**	**0.179**	**-0.350**	**-0.124**	1.000					
(13) *DISP*	**-0.142**	-0.031	-0.004	**0.261**	**0.233**	**0.142**	**-0.180**	**-0.286**	**-0.137**	**0.186**	**0.182**	**-0.038**	1.000				
(14) *CAPEXP*	**-0.374**	-0.032	-0.002	**0.170**	**0.162**	**0.082**	-0.006	**0.254**	**0.159**	**0.064**	**0.043**	**-0.056**	**0.050**	1.000			
(15) *LOSS*	**-0.113**	-0.030	-0.014	**0.179**	**0.186**	**0.098**	**-0.128**	**-0.275**	**-0.041**	**0.118**	**0.073**	-0.023	**0.310**	0.000	1.000		
(16) *GDPC*	**0.084**	**-0.038**	**-0.045**	0.016	-0.023	-0.020	**-0.086**	**-0.231**	**-0.245**	**-0.054**	-0.005	**-0.061**	0.032	**-0.054**	**0.034**	1.000	
(17) *ADR*	-0.020	**0.074**	**0.091**	-0.009	-0.032	**-0.047**	**0.047**	0.020	0.016	**-0.043**	-0.019	**-0.062**	-0.003	-0.023	0.004	**0.113**	1.000
(18) *MCAP*	**0.112**	-0.006	0.016	**0.075**	-0.023	-0.015	**0.151**	**-0.217**	**-0.188**	-0.027	**-0.050**	**0.091**	0.010	**-0.132**	-0.001	**0.334**	**0.125**

Notes: Table 4.4 presents Pearson's correlation coefficients between the variables. All variables are defined in Appendix A. Correlation coefficients reported in **bold** font are significant at the 1% level.

4.4.2 Multivariate regression analysis

4.4.2.1 Primary results

Table 4.5 presents results of the first hypothesis (H1) test. Based on the full sample (5,753 firm-year observations), all models are estimated using ordinary least squares (OLS) regressions with robust standard errors clustered at the firm level. We regress firm risk on CCP, a set of control variables, and year and industry dummies. Models 1–3 present the results for the relationship between CCP and total risk (*DEVRET*). We find that the estimated coefficients for *CCP1*, *CMS1* and *CMS2* are -0.003, -0.002 and -0.004, with statistical significance at 5%, 1% and 1% levels, respectively. The estimate suggests that a firm's score on the 75th percentile of *CCP1*, *CMS1* and *CMS2* has a total risk (*DEVRET)* value that is lower by 0.008, 0.006 and 0.008, compared to a firm that scores on the 25th percentile (approximately 7.7%, 5.8% and 7.7% of the standard deviation of *DEVRET*), respectively. Models 4–6 present the results for the relationship between CCP and idiosyncratic risk (*IDIO_RISK*). We find that the estimated coefficients for *CCP1*, *CMS1* and *CMS2* are -0.222, -0.096 and -0.199, with statistical significance at 1%, 5% and 1% levels, respectively. The estimate suggests that a firm's score on the 75th percentile of *CCP1*, *CMS1* and *CMS2* has an idiosyncratic risk (*IDIO_RISK*) value that is lower by 0.576, 0.288 and 0.398 compared to a firm that scores on the 25th percentile (approximately 9.5%, 4.7% and 6.5% of the standard deviation of *IDIO_RISK)*, respectively.

Finally, Models 7–9 present the relationship between CCP and systematic risk (*BETA)*. We find that the estimated coefficients for *CMS1* and *CMS2* are -0.007 and -0.008, with statistical significance at 1% and 5% levels, respectively. However, the coefficient of *CCP1* is -0.007, but without statistical significance. The estimate suggests that a firm that scores on the 75th percentile of *CMS1* and *CMS2* has a systematic risk (*BETA*) value that is lower by 0.021 and 0.016, compared to a firm that scores on the 25th percentile (approximately 6.4% and 4.9% of the standard deviation of *BETA)*, respectively. These results support our first hypothesis (H1), which states that CCP is negatively associated with firm risk.

4.4.2.2 Role of country-level governance

To test Hypotheses 2a (H2a), 2b (H2b) and 2c (H2c), we interact three governance indicators (*GE*, *RQ* and *RL*) with CCP variables. Firstly, as shown in all panels of Table 4.6, Models 1–3, we test Hypothesis 2a (H2a) about the role of the three country-level governance characteristics in the relationship between CCP and total risk (*DEVRET*). In Model 1, we find that the coefficients for the interaction terms between *CCP1* and *GE*, *RQ* and *RL* are negative and statistically significant at the 5% level or better. However, in Models 2 and 3, we find the coefficients for the interaction terms between *CMS1* and *CMS2*, and governance characteristics variables (*GE, RQ* and *RL*) to be statistically insignificant. The results suggest that, at least for *CCP1*, the relationship between CCP and total risk (*DEVRET*) is stronger in countries with strong governance mechanisms, compared to firms operating in countries with weak governance mechanisms. These results support the environmental costs view.

Table 4.5. Ordinary least squares (OLS) regression results of association between corporate carbon performance and firm risk

	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CCP1	**-0.003****			**-0.222*****			**-0.007**		
	(-1.99)			**(-2.60)**			**(-1.29)**		
CMS1		**-0.002*****			**-0.096****			**-0.007*****	
		(-2.97)			**(-2.50)**			**(-3.10)**	
CMS2			**-0.004*****			**-0.199*****			**-0.008****
			(-3.60)			**(-3.44)**			**(-2.17)**
SIZE	-0.017***	-0.016***	-0.015***	-1.169***	-1.096***	-1.028***	0.019***	0.024***	0.024***
	(-10.32)	(-9.40)	(-8.45)	(-10.15)	(-9.24)	(-8.33)	(2.60)	(3.18)	(3.21)
ROA	-0.081*	-0.080*	-0.087**	-0.164	-0.182	-0.592	-0.571***	-0.567***	-0.587***
	(-1.83)	(-1.81)	(-1.96)	(-0.06)	(-0.07)	(-0.21)	(-3.61)	(-3.60)	(-3.71)
MTB	0.004***	0.004***	0.004***	0.182**	0.172**	0.167**	0.008**	0.008*	0.007*
	(2.96)	(2.91)	(2.87)	(2.32)	(2.21)	(2.17)	(1.97)	(1.94)	(1.88)
LEV	0.029**	0.032**	0.034**	1.353	1.572*	1.662*	0.105**	0.114**	0.116**
	(2.14)	(2.37)	(2.48)	(1.60)	(1.85)	(1.96)	(1.98)	(2.17)	(2.20)
COE	0.003***	0.003***	0.003***	0.191***	0.190***	0.190***	0.008***	0.009***	0.008***
	(5.65)	(5.70)	(5.70)	(5.76)	(5.79)	(5.81)	(4.54)	(4.58)	(4.53)
CASH	0.075***	0.073***	0.071***	3.314***	3.169***	3.027***	0.032	0.024	0.021
	(4.93)	(4.82)	(4.67)	(3.33)	(3.21)	(3.07)	(0.57)	(0.44)	(0.38)
DISP	0.000***	0.000***	0.000***	0.016***	0.017***	0.017***	0.001***	0.001***	0.001***
	(5.68)	(5.72)	(5.75)	(4.85)	(4.87)	(4.89)	(3.22)	(3.29)	(3.30)
CAPEXP	0.002***	0.002***	0.002***	0.097***	0.110***	0.110***	0.005***	0.005***	0.005***
	(5.82)	(6.18)	(6.19)	(3.94)	(4.50)	(4.50)	(3.07)	(3.35)	(3.42)
LOSS	0.055***	0.056***	0.056***	3.748***	3.825***	3.807***	0.056	0.058	0.057
	(5.72)	(5.79)	(5.80)	(6.39)	(6.44)	(6.42)	(1.53)	(1.58)	(1.57)
GDPC	-0.005**	-0.006***	-0.006***	-0.275**	-0.331**	-0.340***	-0.000	-0.002	-0.002
	(-2.48)	(-2.84)	(-2.95)	(-2.02)	(-2.51)	(-2.60)	(-0.02)	(-0.20)	(-0.22)
ADR	-0.002	-0.001	-0.001	-0.173	-0.138	-0.113	0.003	0.005	0.005
	(-0.77)	(-0.55)	(-0.41)	(-1.20)	(-0.95)	(-0.78)	(0.26)	(0.45)	(0.47)
MCAP	0.037***	0.035***	0.035***	0.957***	0.844***	0.806***	-0.065***	-0.071***	-0.071***
	(7.45)	(7.23)	(7.15)	(3.14)	(2.75)	(2.63)	(-2.69)	(-2.97)	(-2.95)
Intercept	-0.022	0.003	0.009	12.353***	13.914***	14.422***	1.708***	1.800***	1.784***
	(-0.34)	(0.04)	(0.14)	(3.05)	(3.42)	(3.57)	(6.01)	(6.44)	(6.38)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.481	0.481	0.482	0.327	0.326	0.328	0.321	0.322	0.322
Obs.	5753	5753	5753	5753	5753	5753	5753	5753	5753

Notes: Table 4.5 presents the OLS regression results of the CCP–firm risk association for the full sample of 5,753 firm-year observations from 13 countries. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects, with *t*-statistics reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. FE=fixed effects. All variables are defined in Appendix A.

Table 4.6. Role of country-level governance indicators in CCP–firm risk association

Panel A – Government effectiveness (*GE*)

	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*GE*CCP1*	**-0.002****			**-0.257*****			**0.012*****		
	(-2.10)			**(-3.99)**			**(3.09)**		
*GE*CMS1*		**0.000**			**-0.082**			**0.007***	
		(0.23)			**(-1.55)**			**(1.95)**	
*GE*CMS2*			**0.001**			**-0.124***			**0.013*****
			(0.80)			**(-1.74)**			**(2.93)**
CCP1	0.000			0.116			-0.023***		
	(0.26)			(1.11)			(-3.67)		
CMS1		-0.002*			0.014			-0.016***	
		(-1.65)			(0.18)			(-3.11)	
CMS2			-0.005***			-0.030			-0.027***
			(-2.68)			(-0.27)			(-3.75)
GE	-0.009	-0.015*	-0.018**	-1.169***	-1.198**	-1.170**	0.007	-0.006	-0.027
	(-1.39)	(-1.91)	(-2.32)	(-2.73)	(-2.29)	(-2.23)	(0.27)	(-0.21)	(-0.89)
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.482	0.482	0.483	0.332	0.329	0.330	0.323	0.323	0.323
Obs.	5753	5753	5753	5753	5753	5753	5753	5753	5753

Panel B – Regulatory quality (*RQ*)

	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*RQ*CCP1*	**-0.003*****			**-0.239*****			**0.009*****		
	(-3.39)			**(-4.45)**			**(2.80)**		
*RQ*CMS1*		**-0.001**			**-0.106****			**0.003**	
		(-1.34)			**(-2.27)**			**(0.92)**	
*RQ*CMS2*			**-0.001**			**-0.119***			**0.007***
			(-0.96)			**(-1.92)**			**(1.77)**
CCP1	0.002			0.125			-0.021***		
	(1.20)			(1.42)			(-4.00)		
CMS1		-0.001			0.036			-0.010***	
		(-0.50)			(0.56)			(-2.59)	
CMS2			-0.002			-0.039			-0.017***
			(-1.40)			(-0.45)			(-3.09)
RQ	0.023***	0.023***	0.020***	2.473***	2.619***	2.428***	-0.121***	-0.108***	-0.123***
	(4.21)	(3.41)	(3.13)	(7.05)	(6.17)	(5.93)	(-6.09)	(-4.17)	(-4.99)
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.482	0.482	0.483	0.330	0.327	0.328	0.322	0.323	0.322
Obs.	5753	5753	5753	5753	5753	5753	5753	5753	5753

Table 4.6 *continued*

Panel C – Rule of law (*RL*)

	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*RL*CCP1*	**-0.002****			**-0.257*****			**0.009*****		
	(-2.39)			**(-4.44)**			**(2.71)**		
*RL*CMS1*		**-0.001**			**-0.106****			**0.004**	
		(-1.33)			**(-2.14)**			**(1.25)**	
*RL*CMS2*			**-0.001**			**-0.152****			**0.010****
			(-1.02)			**(-2.26)**			**(2.31)**
CCP1	0.000			0.089			-0.018***		
	(0.17)			(0.98)			(-3.46)		
CMS1		-0.000			0.037			-0.012***	
		(-0.39)			(0.54)			(-2.71)	
CMS2			-0.002			-0.005			-0.020***
			(-1.20)			(-0.05)			(-3.33)
RL	-0.012**	-0.011	-0.012*	0.282	0.361	0.369	-0.033	-0.032	-0.049*
	(-2.10)	(-1.51)	(-1.75)	(0.73)	(0.79)	(0.83)	(-1.47)	(-1.17)	(-1.84)
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.482	0.482	0.483	0.330	0.327	0.328	0.322	0.323	0.322
Obs.	5753	5753	5753	5753	5753	5753	5753	5753	5753

Notes: Table 4.6 presents the results of the country-level governance role in the CCP–firm risk association. In Panel A, we add the government effectiveness (*GE*) variable and the interaction terms between *GE* and each of *CCP1, CMS1* and *CMS2* to our baseline models. In Panel B, we add the regulatory quality (*RQ*) variable and the interaction terms between *RQ* and each of *CCP1*, *CMS1* and *CMS2* to our baseline models. In Panel C, we add the rule of law (*RL*) variable and the interaction terms between *RL* and each of *CCP1*, *CMS1* and *CMS2* to our baseline models. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. FE=fixed effects. CVs=control variables. All variables are defined in Appendix A.

Next, in Models 4–6, we test Hypothesis 2b (H2b) about the role of country-level governance on the relationship between CCP and idiosyncratic risk (*IDIO_RISK)*. We find that most of the coefficients for the interaction terms between CCP variables (*CCP1*, *CMS1* and *CMS2*) and governance characteristics variables (*GE, RQ* and *RL)* are negative and statistically significant at the 10% level or better.[29] The results suggest that the negative relationship between CCP and idiosyncratic risk (*IDIO_RISK)* is stronger in countries with strong governance mechanisms, compared to firms operating in countries with weak governance mechanisms, with this finding also supporting the environmental costs view.

Finally, in Models 7–9, we test Hypothesis 2c (H2c) regarding the role of country-level governance characteristics in the relationship between CCP and systematic risk (*BETA*). We find the coefficients for the interaction terms between *CCP1*, *CMS1* and *CMS2* and *GE* are positive and statistically significant at the 1%, 10% and 1% levels, respectively. Next, in Panel B, we find that the coefficient for the interaction term between *CCP1* (*CMS2*) and regulatory quality (*RQ*) is positive and statistically significant at the 1% (10%) level. Finally, in Panel C,

[29] Except the interaction term between *CMS1* and government effectiveness (*GE).*

we find the coefficient for the interaction term between *CCP1* (*CMS2*) and rule of law (*RL*) is also positive and statistically significant at the 1% (5%) level. The results indicate that CCP produces a greater reduction in firms' systematic risk (*BETA*) in countries with poor governance mechanisms, compared to firms operating in countries with strong governance mechanisms. These results support the globalisation view. The results could also be explained by the fact that customers' awareness of CSR, in general, and environmental issues, in particular, is higher in developed countries (which have strong governance), with this increasing customer loyalty for high CSR and high CEP firms (Luo & Bhattacharya, 2006). Customer loyalty will lead to a firm having less price-elastic demand, higher pricing power and higher profit margins (Albuquerque et al., 2019). Consequently, the firm is less sensitive to the market's overall performance and has lower systematic risk.

4.4.3 Robustness tests and additional analyses

4.4.3.1 Sample selection bias

Firms in our sample may have common characteristics, especially as our sample consists of firms that have decided to disclose their carbon data. This raises the sample selection bias problem. To address this, we follow Krishnamurti et al. (2018) and use Heckman's (1979) two-stage model. Table 4.7 presents the results of the CCP–firm risk association for the full sample of 5,753 firm-year observations by using this two-stage model. Model 1 reports the first stage, a probit regression model with a dependent variable that is equal to 1 if a firm discloses its carbon data (*DISC*), and 0 otherwise. To carry out this test, we use a larger available sample consisting of 12,277 firm-year observations. The first stage's results show that firms are more likely to disclose their carbon data if they are larger and have a lower ROA ratio, a lower market-to-book ratio, lower cost of equity, lower cash holding and lower dispersion in analysts' forecasts. Next, we save the residual term from the first stage, transform it into the inverse Mills ratio (*IMR*), and then include it as an additional control variable in the second stage (Models 2–10). In Models 5–7, the coefficients of *IMR* are significantly positive, suggesting the presence of sample selection bias in these models. The selection bias-corrected estimates indicate that the coefficients of *CCP1* and *CMS1* and *CMS2* are qualitatively similar to our primary results, suggesting that sample selection bias is a minor concern.

Table 4.7. Robustness test: Heckman's (1979) two-stage model analysis

	First stage	Second stage								
	DV=*DISC*	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CCP1		**-0.002****			**-0.221*****			**-0.007**		
		(-2.01)			**(-2.60)**			**(-1.29)**		
CMS1			**-0.002*****			**-0.095****			**-0.007*****	
			(-2.95)			**(-2.47)**			**(-3.07)**	
CMS2				**-0.003*****			**-0.194*****			**-0.008****
				(-3.54)			**(-3.36)**			**(-2.12)**
IMR		0.009	0.010	0.009	1.700*	1.772*	1.700*	0.020	0.023	0.020
		(0.59)	(0.64)	(0.57)	(1.70)	(1.78)	(1.71)	(0.37)	(0.42)	(0.36)
SIZE	0.415***	-0.015***	-0.014***	-0.013***	-0.860***	-0.775***	-0.722***	0.023*	0.028**	0.028**
	[13.97]	(-5.14)	(-4.63)	(-4.37)	(-4.18)	(-3.71)	(-3.43)	(1.85)	(2.26)	(2.25)
ROA	-2.992***	-0.088*	-0.088*	-0.094*	-2.197	-2.318	-2.618	-0.601***	-0.600***	-0.615***
	[-6.12]	(-1.75)	(-1.76)	(-1.86)	(-0.71)	(-0.74)	(-0.84)	(-3.17)	(-3.18)	(-3.25)
MTB	-0.018***	0.004***	0.004***	0.003***	0.164**	0.153**	0.149*	0.008*	0.007*	0.007*
	[-2.60]	(2.88)	(2.82)	(2.79)	(2.09)	(1.98)	(1.93)	(1.94)	(1.90)	(1.85)
LEV	-0.027	0.029**	0.032**	0.034**	1.342	1.561*	1.651*	0.105**	0.114**	0.115**
	[-0.14]	(2.14)	(2.37)	(2.47)	(1.59)	(1.84)	(1.95)	(1.97)	(2.16)	(2.19)
COE	-0.023***	0.003***	0.003***	0.003***	0.172***	0.170***	0.171***	0.008***	0.008***	0.008***
	[-3.48]	(5.35)	(5.38)	(5.40)	(5.20)	(5.21)	(5.25)	(4.35)	(4.36)	(4.34)
CASH	-1.019***	0.070***	0.068***	0.066***	2.401**	2.221**	2.120*	0.021	0.012	0.011
	[-4.26]	(4.33)	(4.17)	(4.06)	(2.22)	(2.06)	(1.96)	(0.34)	(0.20)	(0.18)
DISP	-0.001***	0.000***	0.000***	0.000***	0.016***	0.016***	0.016***	0.001***	0.001***	0.001***
	[-2.69]	(5.59)	(5.63)	(5.67)	(4.70)	(4.71)	(4.74)	(3.16)	(3.22)	(3.23)
CAPEXP	-0.001	0.002***	0.002***	0.002***	0.095***	0.108***	0.108***	0.005***	0.005***	0.005***
	[-0.40]	(5.76)	(6.13)	(6.14)	(3.89)	(4.46)	(4.45)	(3.05)	(3.34)	(3.41)
LOSS	0.122	0.056***	0.057***	0.057***	3.867***	3.948***	3.927***	0.058	0.060*	0.060
	[1.10]	(5.78)	(5.85)	(5.85)	(6.57)	(6.62)	(6.60)	(1.60)	(1.65)	(1.64)
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2/Pseudo R^2	0.370	0.481	0.481	0.482	0.328	0.327	0.329	0.321	0.322	0.322
Obs.	12277	5753	5753	5753	5753	5753	5753	5753	5753	5753

Notes: Table 4.7 presents the results of the CCP–firm risk association for the full sample of 5,753 firm-year observations. Model 1 reports the first stage of Heckman's (1979) two-stage model which is a probit regression model with a dependent variable that equals 1 if the firm discloses its carbon data (*DISC*), and 0 otherwise. Models 2–10 present the second-stage regressions which are the baseline model regression including the inverse Mills ratio (*IMR*), which is calculated from the first stage. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects. CVs=control variables. FE=fixed effects. DV=dependent variable. The *t*-statistics (*z*-statistics) are reported in parentheses (brackets). Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. All variables are defined in Appendix A.

Table 4.8. Robustness test: Propensity score matching (PSM) analysis

	First stage	Second stage								
	DV=*DISC*	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CCP1		**-0.005***** **(-5.10)**			**-0.368***** **(-5.58)**			**-0.011**** **(-2.50)**		
CMS1			**-0.002**** **(-2.07)**			**-0.033** **(-0.69)**			**-0.005*** **(-1.67)**	
CMS2				**-0.003***** **(-2.66)**			**-0.088** **(-1.39)**			**-0.005** **(-1.26)**
SIZE	0.747*** [28.82]	-0.021*** (-11.85)	-0.021*** (-11.12)	-0.020*** (-10.48)	-1.447*** (-12.80)	-1.438*** (-12.31)	-1.407*** (-11.73)	-0.000 (-0.04)	0.002 (0.24)	0.002 (0.27)
ROA	-5.618*** [-10.18]	-0.000 (-0.01)	0.006 (0.12)	0.000 (0.00)	5.623* (1.84)	5.961* (1.91)	5.791* (1.86)	-0.615*** (-3.60)	-0.600*** (-3.50)	-0.613*** (-3.57)
MTB	-0.276*** [-5.67]	0.016*** (4.48)	0.015*** (3.99)	0.014*** (3.91)	0.828*** (3.58)	0.700*** (3.02)	0.690*** (2.97)	0.002 (0.18)	-0.001 (-0.11)	-0.002 (-0.16)
LEV	-0.195 [-1.15]	-0.014 (-1.09)	-0.008 (-0.63)	-0.007 (-0.58)	-0.571 (-0.74)	-0.163 (-0.21)	-0.144 (-0.19)	-0.032 (-0.69)	-0.020 (-0.44)	-0.019 (-0.41)
COE	-0.045*** [-6.46]	0.006*** (9.88)	0.006*** (9.71)	0.006*** (9.72)	0.325*** (8.80)	0.319*** (8.56)	0.320*** (8.58)	0.019*** (8.85)	0.019*** (8.78)	0.019*** (8.76)
CASH	-0.234*** [-8.25]	0.009*** (4.90)	0.008*** (4.28)	0.008*** (4.29)	0.417*** (3.46)	0.343*** (2.85)	0.341*** (2.84)	0.022*** (3.01)	0.019*** (2.66)	0.020*** (2.69)
DISP	-0.083*** [-2.88]	0.020*** (8.77)	0.021*** (9.06)	0.021*** (9.05)	0.878*** (6.14)	0.934*** (6.46)	0.933*** (6.46)	0.052*** (6.48)	0.054*** (6.65)	0.054*** (6.65)
CAPEXP	0.168*** [7.47]	0.001 (0.94)	0.005*** (3.96)	0.005*** (4.22)	0.064 (0.74)	0.309*** (4.12)	0.323*** (4.26)	-0.004 (-0.83)	0.003 (0.77)	0.004 (0.87)
LOSS	0.276* [1.73]	0.028* (1.90)	0.033** (2.21)	0.033** (2.23)	3.679*** (4.38)	4.011*** (4.63)	4.025*** (4.65)	-0.016 (-0.31)	-0.004 (-0.08)	-0.005 (-0.09)
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	No	No	No	No	No	No	No	No	No
R^2/Pseudo R^2	0.370	0.437	0.432	0.433	0.305	0.297	0.298	0.129	0.127	0.127
Obs.	12,058	2483	2483	2483	2483	2483	2483	2483	2483	2483

Notes: Table 4.8 presents the regression results of the effect of CCP on firm risk using the propensity-matched sample. Model 1 presents the first stage of the PSM model. A logit model has been used to match a firm that discloses its carbon data with a non-disclosing firm in the same industry and year, using nearest neighbour, within a 1% caliper and with no replacement matching algorithms. Models 2–10 present OLS regression results using the propensity-matched sample from the first stage. All regressions in the second stage are estimated with clustered robust standard errors by firm, with *t*-statistics (*z*-statistics) reported in parentheses (brackets). Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. CVs=control variables. FE=fixed effects. DV=dependent variable. All variables are defined in Appendix A.

Table 4.9. Robustness test: Two-stage least squares (2SLS) model

	First stage			Second stage								
				Total risk			Idiosyncratic risk			Systematic risk		
DV=	*CCP1*	*CMS1*	*CMS2*	*DEVRET*			*IDIO_RISK*			*BETA*		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
IV1	0.111***	0.616***	0.383***									
	(5.11)	(17.57)	(15.13)									
IV2	0.792***	0.408***	0.340***									
	(56.46)	(26.68)	(31.06)									
CCP1				**-0.002*** **			**-0.267*** **			**-0.005**		
				(-2.65)			**(-4.25)**			**(-1.35)**		
CMS1					**-0.003*** **			**-0.260*** **			**-0.003**	
					(-2.66)			**(-3.43)**			**(-0.78)**	
CMS2						**-0.003** **			**-0.332*** **			**-0.003**
						(-2.40)			**(-3.42)**			**(-0.62)**
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Corr. of *IV1*	0.231***	0.374***	0.325***									
Corr. of *IV2*	0.933***	0.416***	0.472***									
Sargan test *p*				0.905	0.038	0.019	0.342	0.946	0.747	0.954	0.181	0.159
Endogeneity test				0.985	0.249	0.905	0.134	0.016	0.118	0.238	0.258	0.294
R^2				0.481	0.480	0.482	0.327	0.323	0.327	0.321	0.322	0.321
Obs.	5753	5753	5753	5753	5753	5753	5753	5753	5753	5753	5753	5753

Notes: Table 4.9 presents the regression results of the effect of CCP on firm risk using a two-stage least squares (2SLS) model. Models 1–3 present the first stage. The instrumental variables are: (1) *IV1*, which is the year–country median of *CCP1* or *CMS1*, and (2) *IV2*, which is the *CCP1* or *CMS1* score recorded when the firm enters the sample. Results from Pearson's correlation coefficients, Sargan's test and the endogeneity test are reported to confirm the validity of our instrumental variables (*IV1* and *IV2*). The Sargan statistic is a test of overidentifying restrictions under the null hypothesis that the instruments are valid. The endogeneity test is distributed as chi-squared under the null hypothesis that the specified endogenous regressors can actually be treated as exogenous. All regressions are estimated with clustered robust standard errors by firm, with *t*-statistics reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. CVs=control variables. FE=fixed effects. DV=dependent variable. All variables are defined in Appendix A.

4.4.3.2 Endogeneity

Endogeneity is a crucial challenge in observational (non-experimental) studies and represents a potential source of bias. Endogeneity could occur when the dependent and independent variables are bidirectionally correlated and/or explanatory variables are correlated with the error term (Endrikat et al., 2014; Lewandowski, 2017). To deal with this issue, we use propensity score matching (PSM) and instrumental variable (IV) techniques. Table 4.8 presents the regression results using PSM analysis. We aim, through using this method, to compare carbon data-disclosing firms with their non-disclosing peers in the same industry. We use a larger sample that includes both groups, with 12,277 firm-year observations consisting of disclosing firms (46.9%) and non-disclosing firms (53.1%). Table 4.8, Model 1 presents the first stage, where a logit model is used to match a firm that discloses its carbon data with a non-disclosing firm in the same industry and year, using nearest neighbour, within a 1% caliper and with no replacement matching algorithms.

Next, we run *t*-tests to capture the mean differences between the treatment group (disclosing firms) and control group (non-disclosing firms) as a matching diagnostic test. The matching test (un-tabulated) shows that no statistically significant differences exist in the mean values of the controls between the two groups (high *p*-value), suggesting the validity of our matching algorithms. In the second stage, Models 2–10, we regress the firm risk variables (*DEVRET*, *IDIO_RISK* and *BETA*) on the CCP variables (*CCP1*, *CMS1* and *CMS2*), using the propensity-matched sample from the first stage.[30] In Models 2–4, we find that the firm's total risk (*DEVRET*) is negatively related to *CCP1, CMS1* and *CMS2*, with statistical significance at the 5% level or higher. Next, we find that the firm's idiosyncratic risk (*IDIO_RISK*) is also negatively related to *CCP1* (*p*-value < 1%). However, the coefficients of *CMS1* and *CMS2* are statistically insignificant. Finally, we find that the firm's systematic risk (*BETA*) is negatively related to *CCP1* and *CMS1*, with statistical significance at the 10% level, while the coefficient of *CMS2* is statistically insignificant. Overall, the results suggest that our primary findings are robust and continue to hold.

As shown in Table 4.9, we further tackle the endogeneity concern using the instrumental variable (IV) technique in the two-stage least squares (2SLS) model. We use two instrumental variables: *IV1*, which is the year–country median of *CCP1* or *CMS1*, and *IV2*, which is the *CCP1* or *CMS1* score recorded when the firm enters the sample. For *CMS1* and *CMS2,* we use the same instrumental variables as they are highly correlated. Models 1–3 present the results

[30] We do not include industry fixed-effects in the second stage as, in the first stage, we match treatment and control groups in the same industry.

of the first stage, in which the CCP variables are regressed on the instrumental variables (*IV1* and *IV2*) and on the control variables. As expected, we find the instrumental variables are related to CCP, with a high statistical significance (high *t*-value). To investigate the validity of our instruments, we use Pearson's correlation coefficients, and Sargan's overidentification and endogeneity tests. Firstly, we find Pearson's correlation coefficients between the instrumental variables and CCP variables, with these ranging from 0.231–0.933 and statistical significance at the 1% level. Secondly, as almost all *p*-values of the Sargan test statistics are more than the 10% level, except in Models 5 and 6, we cannot reject the null hypothesis that the instruments are valid (i.e., our instrumental variables are valid). Finally, the endogeneity test is a test under the null hypothesis that the endogenous regressors can actually be treated as exogenous (i.e., a high *p*-value indicates the absence of endogeneity). We find that almost all *p*-values of the endogeneity test results are more than the 10% level, except in Model 8. Therefore, based on these tests, our choice of instrumental variables is valid. As shown in Models 4–9, the results of the relationships between CCP and a firm's total and idiosyncratic risk are qualitatively similar to our primary findings, with negative and statistically significant coefficients. However, in Models 10–12, the coefficients are statistically insignificant, indicating the presence of a neutral relationship between CCP and a firm's systematic risk (*BETA*).

4.4.3.3 Firm fixed-effects and country fixed-effects

Table 4.10 reports the results of firm fixed-effects (Panel A) and country fixed-effects (Panel B) models as alternative model specifications. We use these techniques to better account for firm/country heterogeneity and to address the time-invariant unobserved firm/country characteristics correlated with the explanatory variables, where coefficients are estimated through changes over time within a particular firm/country. Using these techniques, we mainly focus on the time-series pattern of the relationship between CCP and firm risk. As shown in Panel A, although the results of the firm fixed-effects model show that CCP appears to adversely affect total and systematic risk, it does not affect idiosyncratic risk. Next, as shown in Panel B, the results of the country fixed-effects model suggest that *CCP1*, *CMS1* and *CMS2* are negatively associated with total and idiosyncratic risk[31], with statistical significance at the 5% level or better (Models 1–6). The results also indicate that *CMS1* is negatively related to systematic risk, with statistical significance at the 5% level (Model 8). However, the coefficients of *CCP1* and *CMS2* are statistically insignificant (Models 7 and 9). In summary, most of our primary results are robust to using firm fixed-effects and country fixed-effects models. However, the result of the relationship between CCP and idiosyncratic risk is no longer

[31] Except the relationship between *CCP1* and *DEVRET* which is statistically insignificant.

robust after using the firm fixed-effects model. In the next section, we report the results of the sub-samples analysis to further investigate heterogeneity by country.

Table 4.10. Robustness test: Alternative model specifications

Panel A – Firm fixed-effects									
	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CCP1	**-0.001**			**-0.036**			**-0.023*** **		
	(-0.50)			**(-0.26)**			**(-3.38)**		
CMS1		**-0.001*** **			**-0.036**			**-0.007*** **	
		(-2.21)			**(-1.05)**			**(-4.25)**	
CMS2			**-0.002*** **			**-0.079**			**-0.011*** **
			(-2.50)			**(-1.36)**			**(-3.99)**
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs	No	No	No	No	No	No	No	No	No
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	No	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	No	No	No	No	No	No	No
Clustered robust SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.687	0.687	0.687	0.584	0.584	0.584	0.657	0.658	0.657
Obs.	5753	5753	5753	5753	5753	5753	5753	5753	5753
Panel B – Country fixed-effects									
	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CCP1	**-0.002**			**-0.177*** *			**0.000**		
	(-1.38)			**(-2.12)**			**(0.08)**		
CMS1		**-0.002*** *			**-0.083*** *			**-0.006*** *	
		(-2.47)			**(-2.07)**			**(-2.26)**	
CMS2			**-0.003*** **			**-0.154*** *			**-0.005**
			(-2.74)			(-2.54)			(-1.41)
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	No	No	No	No	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustered robust SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.480	0.481	0.481	0.339	0.339	0.339	0.264	0.265	0.264
Obs.	5753	5753	5753	5753	5753	5753	5753	5753	5753

Notes: Table 4.10 presents the regression results of the effect of CCP on firm risk for the full sample of 5,753 firm-year observations, using firm fixed-effects and country fixed-effects models. Panel A reports the results of the firm fixed-effects model (within-firm). Panel B reports the results of the country fixed-effects model (within-country). All regressions are estimated with clustered robust standard errors by firm. CVs=control variables. FE=fixed effects. DV=dependent variable. SE=standard error. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. All variables are defined in Appendix A.

4.4.3.4 Robustness across sub-samples

Table 4.11 reports the results of the sub-sample analysis. Panel A presents the results for a sub-sample from Japan, with Japanese firms constituting the highest number of observations in our sample (2,575 firm-year observations). We find that *CCP1* is negatively related to total and idiosyncratic risk (p-value < 0.01), and that the relationship between *CMS2* and *IDIO_RISK* is negative and statistically significant at the 10% level. However, no statistically significant relationship exists between the three measures of CCP and systematic risk (*BETA*). Panel B reports the results for a sub-sample from Australia (812 firm-year observations). We find that CCP is significantly (insignificantly) and negatively related to a firm's total and idiosyncratic risk (systematic risk). Australia and Japan have high scores for their level of governance indicators, with both sub-samples showing no CCP effect on systematic risk (*BETA*). These results are in line with Hypothesis 2c (H2c), about the effect of country-level governance on the relationship between CCP and systematic risk (*BETA*). These results are also similar to the findings of Sassen et al. (2016) and Benlemlih et al. (2018).

As 44.76% of the observations are from Japan, we next use a sub-sample after excluding firms from Japan. Panel C shows that CCP is negatively and significantly related to the three firm risk measures. However, no statistically insignificant relationships exist between *CCP1* and both *DEVRET* and *BETA*. Next, we exclude the countries with the top three numbers of observations (i.e., Japan, Australia and Hong Kong), with the results reported in Panel D. The relationship between CCP and firm risk is also negative and statistically significant. However, the relationship between *CCP1* and systematic risk is statistically insignificant. Finally, Panel E presents the sub-sample results after excluding the countries with the bottom five numbers of observations (i.e., Indonesia, Philippines, New Zealand, China and Thailand). The results are qualitatively similar to our primary results. Generally, the sub-sample analysis reveals that the negative relationship between CCP variables and a firm's total, idiosyncratic and systematic risk holds in almost all sub-samples.[32]

[32] Except the relationship between CCP and systematic risk for sub-samples from Australia and Japan.

Table 4.11. Robustness test: Sub-sample analysis

	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A Sub-sample from Japan									
CCP1	-0.003***			-0.325***			0.003		
	(-3.26)			(-4.69)			(0.81)		
CMS1		-0.000			-0.019			-0.002	
		(-0.46)			(-0.44)			(-0.84)	
CMS2			-0.001			-0.104*			-0.001
			(-0.96)			(-1.79)			(-0.34)
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.486	0.484	0.484	0.292	0.285	0.286	0.135	0.135	0.135
Obs.	2575	2575	2575	2575	2575	2575	2575	2575	2575
Panel B Sub-sample from Australia									
CCP1	-0.011***			-1.037***			-0.009		
	(-3.09)			(-4.18)			(-0.63)		
CMS1		-0.004**			-0.285***			-0.004	
		(-2.55)			(-2.62)			(-0.60)	
CMS2			-0.005*			-0.326*			0.001
			(-1.92)			(-1.84)			(0.09)
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.725	0.720	0.719	0.628	0.613	0.612	0.460	0.460	0.459
Obs.	812	812	812	812	812	812	812	812	812
Panel C Sub-sample after excluding firms from Japan									
CCP1	-0.001			-0.135**			-0.003		
	(-1.53)			(-2.13)			(-0.91)		
CMS1		-0.003***			-0.165***			-0.010***	
		(-4.32)			(-3.46)			(-3.09)	
CMS2			-0.005***			-0.241***			-0.013***
			(-4.77)			(-3.35)			(-2.60)
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.508	0.515	0.517	0.413	0.417	0.417	0.321	0.325	0.325
Obs.	3178	3178	3178	3178	3178	3178	3178	3178	3178
Panel D Sub-sample after excluding top three countries									
CCP1	-0.006***			-0.285***			-0.007		
	(-3.86)			(-2.90)			(-0.75)		
CMS1		-0.003***			-0.147**			-0.010**	
		(-3.03)			(-2.35)			(-2.35)	
CMS2			-0.005***			-0.229**			-0.014**
			(-3.52)			(-2.33)			(-2.16)
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.363	0.467	0.471	0.260	0.358	0.359	0.314	0.317	0.317
Obs.	1874	1874	1874	1874	1874	1874	1874	1874	1874

Table 4.11. *continued*

Panel E Sub-sample after excluding bottom five countries									
	Total risk (DV=*DEVRET*)			Idiosyncratic risk (DV=*IDIO_RISK*)			Systematic risk (DV=*BETA*)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CCP1	-0.002* (-1.89)			-0.187* (-1.96)			-0.006 (-1.04)		
CMS1		-0.001** (-2.24)			-0.078* (-1.89)			-0.006** (-2.56)	
CMS2			-0.002** (-2.44)			-0.162*** (-2.61)			-0.006 (-1.53)
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.499	0.499	0.500	0.336	0.335	0.336	0.351	0.352	0.351
Obs.	5264	5264	5264	5264	5264	5264	5264	5264	5264

Notes: Table 4.11 presents the baseline regression results using a set of sub-samples. Panels A, B, C, D and E present the results of sub-samples from Japan; Australia; all countries without Japan; all countries without the top three countries; and all countries without the bottom five countries, respectively. The *t*-statistics are reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. CVs=control variables. FE=fixed effects. DV=dependent variable. All variables are defined in Appendix A.

4.4.3.5 Additional analyses

In this subsection, we report the two additional analyses run to address endogeneity stemming from simultaneous causality between CCP and firm risk and the Global Financial Crisis (GFC) effect. In the first analysis, as shown in Table 4.12, Panels A and B, we report the baseline regression results after lagging the independent variables by one and two years behind CCP, respectively. This approach helps to confirm that CCP is a cause, not a result, of firm risk. In line with slack resource theory, firms with lower risk can access capital (debt and equity) at lower rates; thus, they can invest in green technology and increase their carbon performance. This approach assists in controlling for any delay in carbon disclosure. In general, we find that CCP variables at *t-1* are negatively associated with firm risk, with statistical significance at the 10% level or better.[33] In Panel B, we still find a negative relationship between CCP variables at *t-2* and firm risk variables but with lower robustness results. These results suggest that simultaneous causality does not affect our primary results.

In the second analysis, we control for the confounding impact of the GFC as it had different impacts on firms' stock price volatility. For example, Bouslah et al. (2018) find that the relationship between CSR and firm risk was significantly different during and after the GFC period compared to the pre-GFC period. They find that social performance mainly acts as a risk reduction tool and reduces volatility during a financial crisis. Alternatively, a firm might avoid investment in green projects to reduce costs and financial distress. Therefore, the CCP–firm risk relationship might be unstable during this period. To deal with this, we re-estimate

[33] Except for the relationships between both *CCP1* and *CMS2* and *BETA* which are statistically insignificant.

the baseline model after excluding the GFC years (2007 and 2008). We find that our primary results continue to hold, with relationships being more pronounced (coefficients are estimated with relatively higher *t*-statistics).

Table 4.12. Additional analyses

	Total risk (DV=*DEVRET* $_t$)			Idiosyncratic risk (DV=*IDIO_RISK* $_t$)			Systematic risk (DV=*BETA* $_t$)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A – Simultaneous causality (independent variables at *t-1*)									
$CCP1_{t-1}$	**-0.003****			**-0.249*****			**-0.005**		
	(-2.13)			**(-2.67)**			**(-0.86)**		
$CMS1_{t-1}$		**-0.001***			**-0.073***			**-0.004***	
		(-1.94)			**(-1.74)**			**(-1.77)**	
$CMS2_{t-1}$			**-0.003*****			**-0.175*****			**-0.006**
			(-3.10)			**(-2.83)**			**(-1.60)**
Firm-level CVs_{t-1}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs_{t-1}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.481	0.480	0.482	0.325	0.323	0.324	0.333	0.334	0.334
Obs.	4654	4654	4654	4654	4654	4654	4654	4654	4654
Panel B – Simultaneous causality (independent variables at *t-2*)									
$CCP1_{t-2}$	**-0.003***			**-0.191****			**-0.004**		
	(-1.81)			**(-1.97)**			**(-0.59)**		
$CMS1_{t-2}$		**-0.001**			**-0.025**			**-0.003**	
		(-0.76)			**(-0.53)**			**(-1.21)**	
$CMS2_{t-2}$			**-0.002***			**-0.078**			**-0.003**
			(-1.83)			**(-1.13)**			**(-0.87)**
Firm-level CVs_{t-2}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs_{t-2}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.485	0.484	0.485	0.322	0.321	0.321	0.336	0.336	0.336
Obs.	3895	3895	3895	3895	3895	3895	3895	3895	3895
Panel C- Global Financial Crisis (GFC)									
CCP1	**-0.003****			**-0.206****			**-0.008**		
	(-2.12)			**(-2.40)**			**(-1.52)**		
CMS1		**-0.002*****			**-0.103*****			**-0.008*****	
		(-3.00)			**(-2.61)**			**(-3.30)**	
CMS2			**-0.003*****			**-0.216*****			**-0.009****
			(-3.67)			**(-3.67)**			**(-2.39)**
Firm-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-level CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.486	0.486	0.487	0.329	0.328	0.330	0.315	0.316	0.316
Obs.	5342	5342	5342	5342	5342	5342	5342	5342	5342

Notes: Table 4.12 presents the OLS regression results of the CCP–firm risk association for the full sample of 5,753 firm-year observations from 13 countries. All regressions are estimated with clustered robust standard errors by firm and include year and industry fixed-effects, with *t*-statistics reported in parentheses. Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively. DV=dependent variable. FE=fixed effects. CVs=control variables. All variables are defined in Appendix A.

4.5 Discussion and conclusion

This study empirically investigates the response by stock markets to corporate carbon performance (CCP). In particular, we examine the relationship between CCP and firm risk. Using a sample of 5,753 firm-year observations from 13 countries in the Asia-Pacific region from 2002–2018, we find a negative relationship between CCP and total, idiosyncratic and systematic risk (Hypothesis 1 [H1]). We report that investors and stock markets are becoming more aware of firms' environmental performance and are paying close attention to corporate carbon performance (CCP). We also find that the influence of CCP on idiosyncratic risk is more pronounced than on systematic risk, as CCP activities are firm-specific in nature (e.g., energy efficiency, use of renewable energy and new green technology). To address the potential sample selection bias and endogeneity problems, we use alternative model specifications, namely, Heckman's (1979) two-stage analysis, propensity score matching (PSM), and firm fixed-effects, country fixed-effects and two-stage least squares (2SLS) models. In addition, we re-run the baseline model using sub-samples across countries to address the heterogeneity problem. We also control for the effect of the GFC and simultaneous causality. Generally, our main results are robust after running these robustness tests.

This study also examines whether and how country-level governance mechanisms moderate or intensify these relationships. We use three governance characteristics, namely, government effectiveness (GE), regulatory quality (RQ) and the rule of law (RL). We find that CCP produces a greater reduction in a firm's total risk (*DEVRET*) and idiosyncratic risk (*IDIO_RISK)* in countries with good country-level governance quality, compared with countries with poor governance quality (Hypotheses 2a [H2a] and 2b [H2b]). These results support the environmental costs view, suggesting that firms from a country with strong governance are more likely to suffer from current and potential expensive environmental costs or fines. Thus, market participants are less confident of firms' future cash flows, leading to environmental risk being overpriced.

Next, we find that CCP generates a greater reduction in systematic risk in countries with weak governance mechanisms, compared to countries with strong governance mechanisms (Hypothesis 2c [H2c]). These results support the globalisation view which states that financial markets are becoming more aware of borrowers' social and environmental performance, especially in countries with lenient environmental regulation. With financial markets' globalisation, low-CCP firms from countries with a weak governance mechanism have difficulty accessing capital at lower rates, due to financial markets' uncertainty about their ability to mitigate carbon risk. Therefore, these firms could suffer from higher price volatility, thus experiencing higher risk. These findings could also be explained by the increase in customer awareness of CSR and environmental issues in developed countries which have strong governance. This awareness will increase customer loyalty for high-CSR and high-CEP firms (Luo & Bhattacharya, 2006); thus, it will lead to a firm having less price-elastic demand, higher pricing power and higher profit margins (Albuquerque et al., 2019). Consequently, these firms are less sensitive to the market's overall performance and have lower systematic risk.

Our study has important implications for firms, policy makers, regulators and equity market participants. Firstly, when a firm intends to establish a green project or a carbon-intensive project, it must consider the unobservable indirect benefits or costs of this type of project to conduct a more accurate feasibility study. This study helps firms and managers to understand and determine these indirect benefits/costs. Secondly, our findings help policy makers and regulators to determine the extent to which they can rely on the market mechanism, rather than direct intervention (e.g., incentivising or exerting pressure on firms based on their environmental performance). Understanding the effects of governance quality on the CCP–firm risk relationship is also important for quickly and safely transitioning to a low carbon economy. This study highlights the importance of carbon-related disclosure and having this kind of data extensively available. These findings also help equity market participants to conduct a better valuation of a firm's intrinsic value, with CCP considered as a risk factor.

Finally, this study opens opportunities for further research. As climate change is a source of global concern, future research could be conducted in different countries. As this concern will become more salient in coming years, future research could re-examine the CCP–CFP relationship as the economic significance of the effect of carbon performance is likely to become more severe.

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Appendix A: Descriptions and sources of variables

Variable	Description	Source/Variable code
Firm-level variables		
CCP1	Natural logarithm of carbon intensity calculated as the ratio of total carbon emissions to sales volume in US dollars	Researchers' calculation based on data from Thomson-Reuters/ENERO03S
CMS1	Carbon mitigation score calculated as follows: 3 points are added if *CRISK1* is lower than the previous year; 2 points are added if	Researchers' calculation based on data from Thomson-

	CRISK1 is lower than the country–sector median; 1 point is awarded if the firm has an environment management team; 1 point is added if the firm has a policy to improve its energy efficiency; 1 point is added if the firm sets targets or objectives to be achieved on emissions reduction; 1 point is added if the firm is aware that climate change can represent commercial risks and/or opportunities; 1 point is added if the firm makes use of renewable energy; 1 point is added if the firm reports on initiatives to reduce, reuse, recycle, substitute or phase out SOx (sulphur oxides) or NOx (nitrogen oxides) emissions; and 1 point is added if the firm reports on its environmentally friendly or green sites or offices	Reuters/ENERO03S, ENRRDP004, ENRRDP0122, ENERDP0161, ENERDP089, ENRRDP046, ENERDP033 and ENRRDP052
CMS2	Equally weighted score of *CMS1*	As above
DEVRET	Total risk measured as the annualised standard deviation of daily stock returns for the current year	Researchers' calculation based on data from Thomson-Reuters
IDIO_RISK	Idiosyncratic risk measured as the standard deviation of residuals from the capital assets pricing model (CAPM) based on daily stock return over one year	Researchers' calculation based on data from Thomson-Reuters
BETA	Systematic risk which is estimated by regressing the firm's excess return on the market's excess return, based on daily stock returns over the previous year from the CAPM	Researchers' calculation based on data from Thomson-Reuters
SIZE	Natural logarithm of total assets recorded in billions of US dollars	Researchers' calculation based on data from Thomson-Reuters/WC08001
ROA	Return on assets, calculated as the ratio of net income to total assets	Thomson-Reuters/WC08326
MTB	Market-to-book ratio	Thomson-Reuters/WC05491 and MVC
LEV	Total debt/total assets	Thomson-Reuters/WC08236
COE	The average of at least two of the four models of implied cost of equity developed by Claus and Thomas (2001), Gebhardt et al. (2001), Easton (2004) and Ohlson and Juettner-Nauroth (2005).	Researchers' calculation based on data from Thomson-Reuters.
CASH	The ratio of cash and cash equivalents to total assets	Thomson-Reuters/WC02005 and WC02999
DISP	The dispersion in analysts' forecasts measured as the coefficient of variation of one-year-ahead earnings estimates	Researchers' calculation based on data from Thomson-Reuters/EPS1CV
CAPEXP	The ratio of capital expenditure divided by last year's total assets multiplied by 100. *CAPEXP*=capital expenditure/total assets*100)	Researchers' calculation based on data from Thomson-Reuters/ WC08416
LOSS	Equal to 1 if net income is negative at year *t* and *t-1*, and 0 otherwise	Researchers' calculation based on data from Thomson-Reuters/WC01751
IMR	The inverse Mills ratio, calculated from the first stage of Heckman's (1979) two-stage model	Researchers' calculation
DISC	Equal to 1 if carbon data are available, and 0 otherwise	Researchers' calculation
IV1	Year–country median of *CCP1* or *CMS1*	Researchers' calculation
IV2	*CCP1* or *CMS1* score recorded when the firm enters the sample	Researchers' calculation

Appendix A *continued*

Country-level variables		
GE	According to (World Bank, 2019), "government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies"	World Bank databases
RQ	According to (World Bank, 2019), "regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and	World Bank databases

	promote private sector development"	
RL	According to (World Bank, 2019), the "rule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society and, in particular, the quality of contract enforcement, property rights, the police and the courts, as well as the likelihood of crime and violence"	World Bank databases
GDPC	Natural logarithm of gross domestic product (GDP) per capita in US$ (annually based)	International Monetary Fund (IMF), World Economic Outlook database
ADR	The revised Anti-Director Rights Index (annually based)	Djankov et al. (2008)
MCAP	Natural logarithm of stock market capitalisation of the listed domestic companies in billions of US dollars (annually based)	World Bank databases. For Taiwan, data are available on the Taiwan Stock Exchange (TWSE) website.

CHAPTER 5: CONCLUSION

5.1 Overview

This chapter synthesises and discusses the research findings and is organised into six sections. It begins with a general overview of the chapter (Section 5.1). Section 5.2 then presents a brief but comprehensive summary of the research findings for each research paper, with a summary of robustness checks. Section 5.3 provides the empirical and theoretical implications of this research, followed by Section 5.4 which outlines the current study's limitations, presents several suggestions and proposes new opportunities for future research.

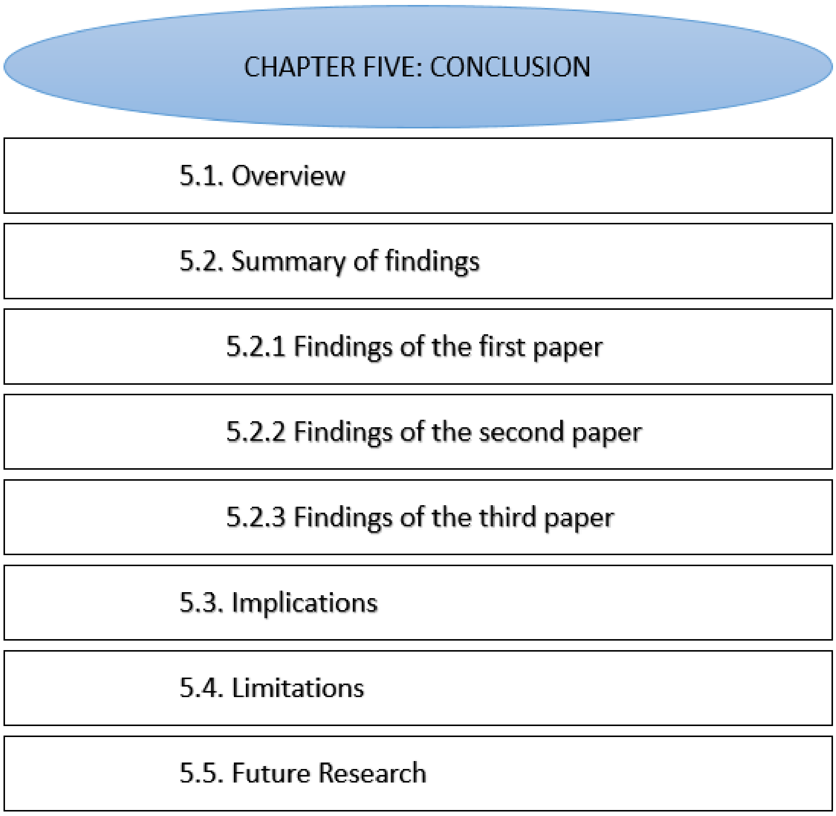

Figure 5.1. Flow chart for Chapter 5

Source: developed by the author

5.2 Summary of findings

This section briefly summarises the research questions, research design and the method with which the research has been conducted. It then presents the main findings and the results of the robustness checks. To facilitate the discussion, we provide a summary of each paper of this thesis independently in the next three subsections.

5.2.1 Findings of the first paper

The first paper reports on the examination of the debt markets' response to corporate carbon performance (CCP). Specifically, this study examines the influence of CCP on cost of debt (COD). The study employs unbalanced panel data consisting of 3,666 firm-year observations from 14 countries in the Asia-Pacific region, namely: Australia, China, India, Indonesia, Japan, Malaysia, New Zealand, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand and Hong Kong. The sample covers the period 2003–2018 and comprises non-financial publicly listed companies. We exclude financial firms from the sample as they are subject to industry-specific regulations, which make their capital structure decisions and debt financing substantially different in comparison with non-financial firms (La Rosa et al., 2018; Nguyen & Phan, 2020).

To provide initial evidence on the CCP–COD relationship, we run a univariate analysis by comparing the mean and median values of the firm-level variables between two sub-samples divided into firms with low carbon performance and those with high carbon performance. Next, we run Pearson's correlation coefficients and variance inflation factor (VIF) values to examine the fit of our model. We then examine the hypotheses in a multivariate setting after controlling for the factors most likely to influence dependent and independent variables. We regress COD on CCP and on a set of firm-level and country-level variables using ordinary least squares (OLS) models.

The main finding reveals that COD is negatively associated with corporate carbon performance (CCP) (Hypothesis 1 [H1]). This result implies that the higher the level of CCP, the lower the firm's cost of debt (COD), suggesting that debt markets are likely to consider climate change risk in their process of evaluating the firm's overall risk. The estimated coefficients for the baseline model suggest that an increase of one standard deviation in *CCP1*, *CCP2*, *CCP3* and *CCP4* leads to a decrease in *COD* by 22, 15, 6 and 5 basis points, respectively. These estimates are also economically significant, as they equal approximately 17%, 11%, 5% and 4% of one standard deviation of the COD index, respectively.

This study also examines whether, and to what extent, this relationship is affected by country-level governance. In other words, it examines whether the CCP–COD relationship is different with differences in country-level governance. We interact CCP variables with three governance indicators (i.e., government effectiveness [GE], regulatory quality [RQ] and rule of law [RL]). We find that CCP produces greater reductions in COD for firms from countries with poor government effectiveness (Hypothesis 2a [H2a]), weak regulatory quality (Hypothesis 2b [H2b]) and weak rule of law (Hypothesis 2c [H2c]). Thus, a country-level governance mechanism and debt markets are substitutes in addressing corporate carbon performance (CCP). Figure 5.2 presents a summary of the findings of this study, showing the relationships and the hypotheses, with estimated coefficients and the level of significance.[34]

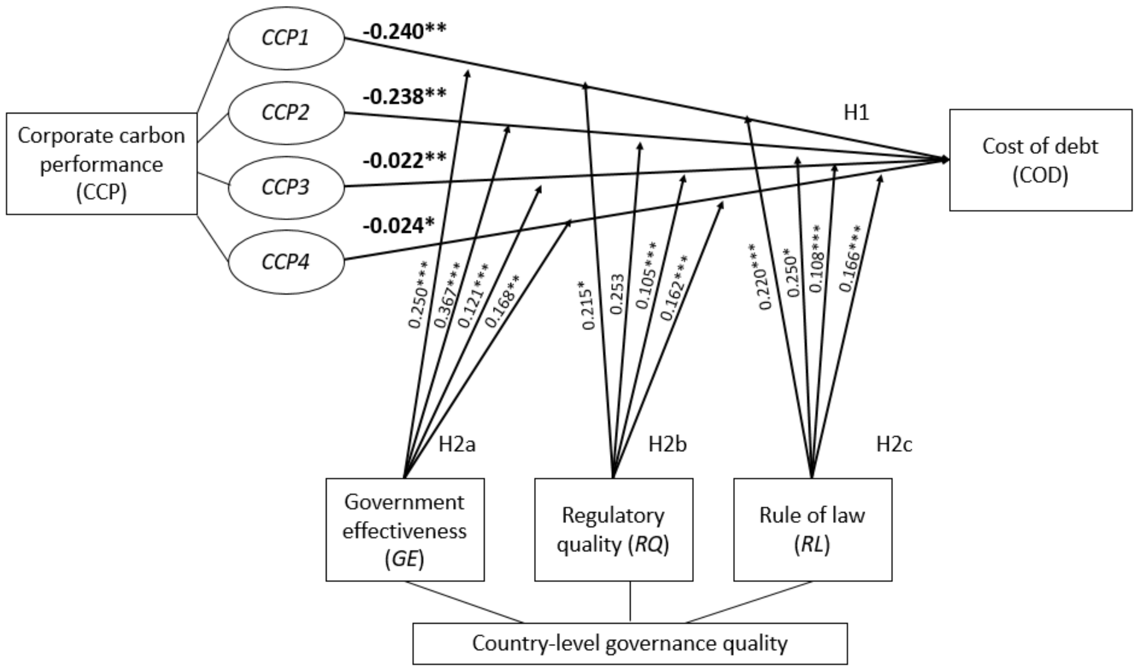

Figure 5.2. Summary of findings of first paper

Source: developed by the author

Next, we run a battery of robustness checks to reinforce our main finding. Firstly, we re-estimate the baseline regression model after controlling for the corporate governance variables. We include board size (*BSIZE*), board independence (*BINDP*) and CEO duality (*DUALITY*) in the baseline regression model as additional control variables. The results suggest that the association between CCP and COD remains negative and statistically significant. Secondly, to control for potential sample selection bias and endogeneity problems, we use alternative model specifications, namely, Heckman's (1979) two-stage approach, propensity score matching (PSM) analysis, and firm fixed-effects and country fixed-effects models. We find that our main result continues to hold. Thirdly, to address potential heterogeneity problems, we re-run the

[34] Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively; otherwise, the result is not statistically significant.

baseline model using sub-samples separated based on a country or a group of countries. We find that the CCP–COD relationship is either significantly negative or statistically insignificant in our list of sub-samples. However, we unexpectedly find that two proxies for CCP are positively related to COD in a sub-sample of 344 firm-year observations from Taiwan. The reason is probably that Taiwan is one of the countries that has not ratified the United Nations Framework Convention on Climate Change (UNFCCC) or the Kyoto Protocol (Shyu, 2014), suggesting that firms' exposure to carbon risk in Taiwan is relatively minimal. Fourthly, we re-run the baseline regression model using credit rating (CR) as an alternative measurement for COD. We find a positive association exists between the level of CCP and the company's credit rating (CR). Fifthly, we address potential simultaneous causality problems between COD and CCP by lagging the independent variables one and two years behind cost of debt (COD). We find that the four proxies for CCP at *t-1* and *t-2* are negatively and significantly associated with COD, which increases our confidence in the direction of the relationship. Finally, to address the effect of the Global Financial Crisis (GFC) (2007–2008) on firms' environmental and financial performance, we re-run the baseline regression model after excluding the GFC years, with the results reinforcing our main finding.

5.2.2 Findings of the second paper

The second paper reports on the examination of the response of equity market participants (i.e., analysts and investors) to carbon risk (CRISK). Specifically, it examines the relationship between carbon risk (CRISK) and cost of equity (COE) and whether, and to what extent, country-level governance mechanisms moderate or intensify the CRISK–COE relationship. This research employed unbalanced panel data consisting of 5,021 firm-year observations over the period 2002–2018 from 13 Asia-Pacific countries, namely: Australia, New Zealand, China, Japan, South Korea, Hong Kong, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan and Thailand.

To provide initial evidence on the CRISK–COE relationship, we run a univariate analysis by comparing the mean and median values of the firm-level variables between two sub-samples divided into firms with low carbon risk (CRISK) and firms with high carbon risk (CRISK). Next, we run Pearson's correlation coefficients and variance inflation factor (VIF) values to examine the fit of our model. We then examine the hypotheses in a multivariate setting after controlling for the factors most likely to influence dependent and independent variables. We regress COE on CRISK and on a set of firm-level and country-level variables using ordinary least squares (OLS) models.

The main finding reveals that firms' exposure to CRISK increases the implied cost of equity (COE) (Hypothesis 1 [H1]), with equity markets likely to consider CRISK in their evaluation process. These results suggest that investors and equity market participants are becoming more aware of firms' exposure to carbon risk (CRISK). The results are also economically significant: an increase of one standard deviation in *CRISK1 (CRISK2)* leads to an increase in *COE* by approximately 48 (27) basis points. We also find that the impact of CRISK on COE is stronger in countries with strong government effectiveness (GE) (Hypothesis 2a [H2a]), strong regulatory quality (RQ) (Hypothesis 2b [H2b]) and strong rule of law (RL) (Hypothesis 2c [H2c]). Thus, country-level governance mechanisms and equity markets are complementary in addressing carbon risk (CRISK). We provide new evidence that a strong country-level governance mechanism demonstrates the importance of CRISK in equity markets. Figure 5.3 presents a summary of the findings of this study, showing the relationships and the hypotheses, with estimated coefficients and the level of significance.[35]

To confirm our main finding, we run a series of robustness checks. Firstly, we test whether the main results are robust when applying alternative model specifications, namely, Heckman's (1979) two-stage analysis, PSM analysis, and firm fixed-effects, country fixed-effects, two-stage least squares (2SLS) and dynamic system GMM models. Secondly, as the main estimate of COE is calculated as the average[36] of the four models proposed by Claus and Thomas (2001); Gebhardt et al. (2001); Easton (2004); and Ohlson and Juettner-Nauroth (2005), we re-run the baseline model by using individual COE estimates. The results show that our main finding remains intact.

[35] Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively; otherwise, the result is not statistically significant.
[36] Firms in our sample are required to have at least two estimates.

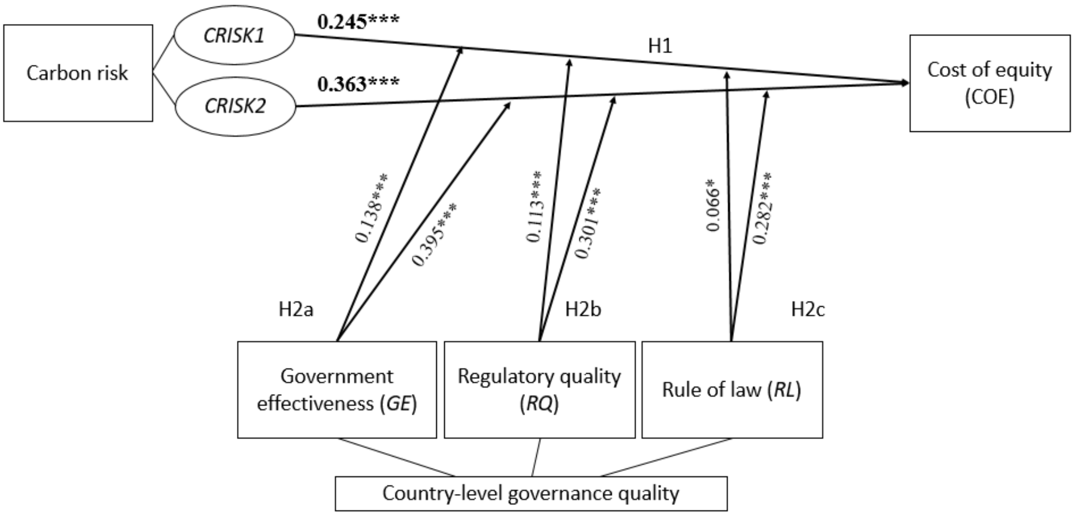

Figure 5.3. Summary of findings of second paper

Source: developed by the author

Thirdly, we conduct sub-sample analyses. We specifically re-estimate the baseline regression model using a set of sub-samples separated by country. We run the baseline regression models separately for: (i) the top four countries (those with the highest number of observations) (Japan, Australia, Hong Kong and South Korea); (ii) all firms after excluding firms from Japan; (iii) all firms after excluding observations from the top three countries (those with the highest number of observations); and (iv) all firms after excluding observations from the bottom five countries (those with the lowest number of observations). Next, we re-estimate the baseline regression model using a set of sub-samples separated by industry. We select industries characterised by a higher sensitivity to CRISK (industrials, utilities, basic materials and consumer goods). The results indicate that the positive relationship between CRISK and COE holds in almost all sub-samples, with the economic impact of CRISK not homogeneous across countries or industries. We find that the impact of CRISK on COE is stronger with a higher economic impact for firms from the industrials, utilities and basic materials industries, with these industries having more exposure to carbon risk.

Fourthly, we re-run the baseline regression model using alternative or additional control variables. The results show that the CRISK–COE relationship is still positive and statistically significant, which is consistent with our main finding. Fifthly, we examine the macroeconomic effects of the Global Financial Crisis (GFC) on the CRISK–COE relationship. We investigate the relationship in three sub-periods: in the pre-GFC years, during the GFC and in the post-GFC years. We find that the CRISK–COE relationship is positive (neutral) before and after (during) the GFC years. Sixthly, to alleviate potential simultaneous causality between CRISK and COE and to confirm that CRISK is the cause but not the result of COE, we use the lead–lag approach. We lag the independent variables by one and two years behind *COE*. The results indicate that endogeneity stemming from simultaneous causality does not drive our main finding. Finally, we use a two-way clustering approach to control for potential estimation bias resulting from the year (firm) fixed-effects that could steer the cross-sectional (time-series) correlation. We find that the main results are qualitatively similar.

5.2.3 Findings of the third paper

The third paper reports on the examination of the question of how and why corporate carbon performance (CCP) affects firm risk. In particular, this study investigates the relationship between CCP and a firm's total, idiosyncratic and systematic risk. The study also investigates the impact of country-level governance on the CCP–firm risk relationship and whether the response by stock markets to corporate carbon performance (CCP) is different with differences in country-level governance. This study employed unbalanced panel data consisting of 5,753 firm-year observations (881 unique firms) over the period 2002–2018 from 13 countries in the Asia-Pacific region, namely: Australia, New Zealand, China, Japan, South Korea, Hong Kong, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan and Thailand.

To provide initial evidence on the CCP–firm risk relationship, we run a univariate analysis by comparing the mean and median values of the firm-level variables between two sub-samples divided into firms with low corporate carbon performance (CCP) and high corporate carbon performance (CCP). Next, we run Pearson's correlation coefficients and the variance inflation factor (VIF) values to examine the fit of our model. We then examine the hypotheses in a multivariate setting after controlling for the factors most likely to influence dependent and independent variables. We regress firm risk variables on CCP and on a set of firm-level and country-level variables using ordinary least squares (OLS) models.

The main findings reveal that CCP produces an adverse effect on a firm's total, idiosyncratic and systematic risk (Hypothesis 1 [H1]). Specifically, we find that the CCP variables, namely, carbon intensity (*CCP1*) and carbon mitigation scores (*CMS1* and *CMS2*), are negatively related to a firm's total risk (*DEVRET*), idiosyncratic risk (*IDIO_RISK*) and systematic risk (*BETA*). We also find that the influence of CCP on idiosyncratic risk is more pronounced than on systematic risk, as CCP activities are firm-specific in nature (e.g., energy efficiency, use of renewable energy and of new green technology). We report that investors and stock markets are becoming more aware of firms' environmental performance and are paying close attention to corporate carbon performance (CCP).

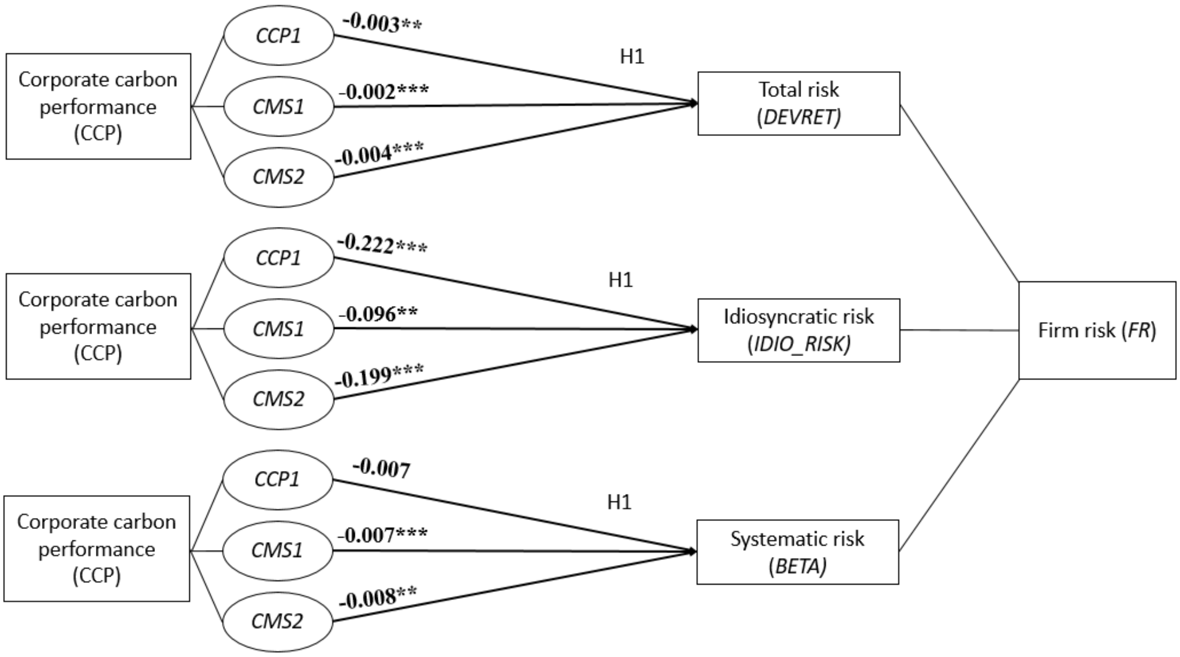

Figure 5.4. Summary of findings of Hypothesis 1 (H1) of third paper

Source: developed by the author

Figure 5.4 presents a summary of the findings for Hypothesis 1 (H1) of this study. It shows the estimated coefficients and the level of significance.[37] The results are also economically significant. The estimate suggests that a firm that scores on the 75th percentile of *CCP1*, *CMS1* and *CMS2* has a total risk (*DEVRET)* value that is lower by 0.008, 0.006 and 0.008, compared to a firm that scores on the 25th percentile (approximately 7.7%, 5.8% and 7.7% of the standard deviation of *DEVRET*), respectively. For idiosyncratic risk (*IDIO_RISK*), the estimate suggests that a firm that scores on the 75th percentile of *CCP1*, *CMS1* and *CMS2* has an idiosyncratic risk (*IDIO_RISK*) value that is lower by 0.576, 0.288 and 0.398 compared to a firm that scores on the 25th percentile (approximately 9.5%, 4.7% and 6.5% of the standard deviation of *IDIO_RISK)*, respectively. Finally, for systematic risk (*BETA*), the estimate suggests that a firm that scores on the 75th percentile of *CMS1* and *CMS2* has a systematic risk (*BETA*) value that is lower by 0.021 and 0.016, compared to a firm that scores on the 25th percentile (approximately 6.4% and 4.9% of the standard deviation of *BETA)*, respectively.

Regarding the role of country-level governance, the second aspect of this study, we find that CCP produces a greater reduction in a firm's total risk (*DEVRET*) and idiosyncratic risk (*IDIO_RISK)* in countries with strong country-level governance quality, compared with

[37] Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively; otherwise, the result is not statistically significant.

countries with poor governance quality (Hypotheses 2a [H2a] and 2b [H2b], respectively). Figures 5.5 and 5.6 summarise the findings for Hypotheses 2a and 2b, respectively, of this third study. They show the estimated coefficients and the level of significance.[38] These results support the environmental costs' view, suggesting that firms from a country with strong governance would be more likely to suffer from current and potential expensive environmental costs or fines. Thus, market participants in these countries are less confident of firms' future cash flows, leading to environmental risk being overpriced.

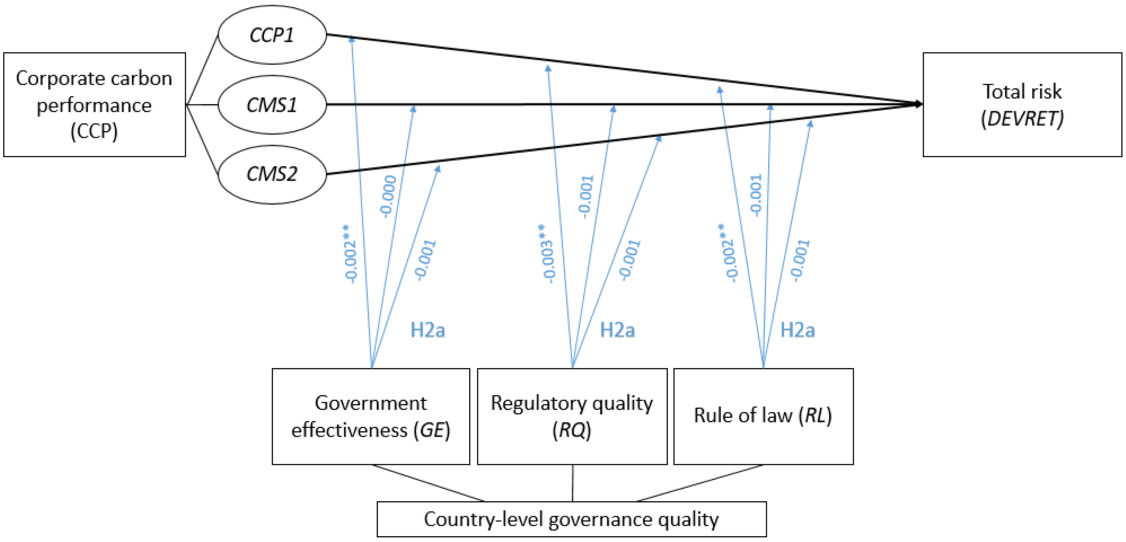

Figure 5.5. Summary of findings of Hypothesis 2a (H2a) of third paper

Source: developed by the author

[38] Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively; otherwise, the result is not statistically significant.

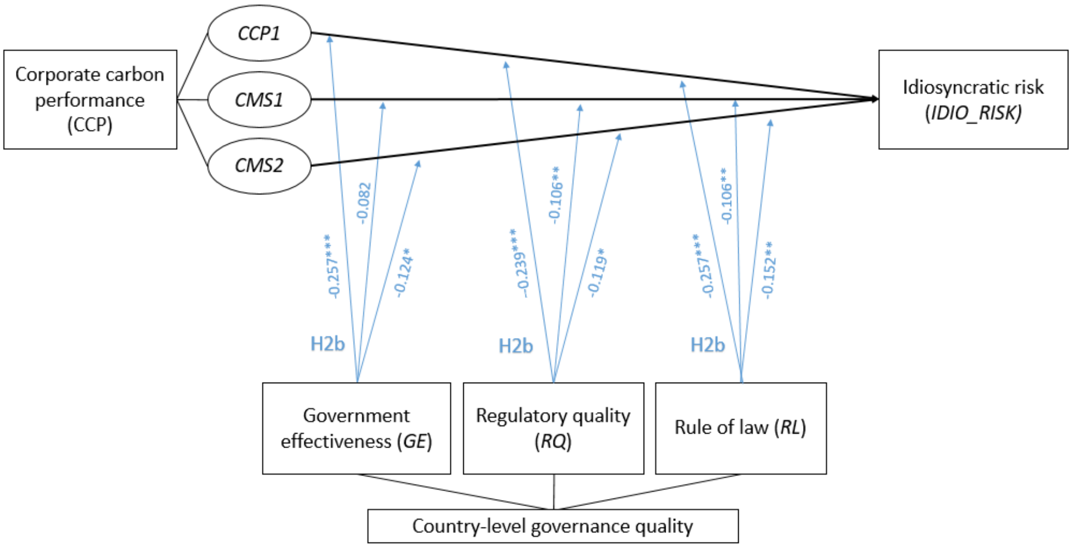

Figure 5.6. Summary of findings of Hypothesis 2b (H2b) of third paper

Source: developed by the author

Next, we find that CCP generates a greater reduction in systematic risk in countries with weak governance mechanisms, compared to countries with strong governance mechanisms (H2c). Figure 5.7 summarises the findings for Hypothesis 2c (H2c) of the third study. The figure shows the estimated coefficients and the level of significance.[39] These results support the globalisation view, which states that financial markets are becoming more aware of borrowers' social and environmental performance, especially in countries with lenient environmental regulations. With the globalisation of financial markets, low-CCP firms from countries with a weak governance mechanism would have difficulty accessing capital at lower rates, due to financial markets' uncertainty about the ability of these firms to mitigate carbon risk. Therefore, they could suffer from higher price volatility, thus experiencing higher risks. These findings could also be explained by the increase in customer awareness of CSR and environmental issues in developed countries which have strong governance. This awareness would increase customer loyalty for high-CSR and high-CEP firms (Luo & Bhattacharya, 2006); thus, it would lead to a firm having less price-elastic demand, higher pricing power and higher profit margins (Albuquerque et al., 2019). Consequently, these firms would be less sensitive to the market's overall performance and have lower systematic risk.

[39] Superscript *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively; otherwise, the result is not statistically significant.

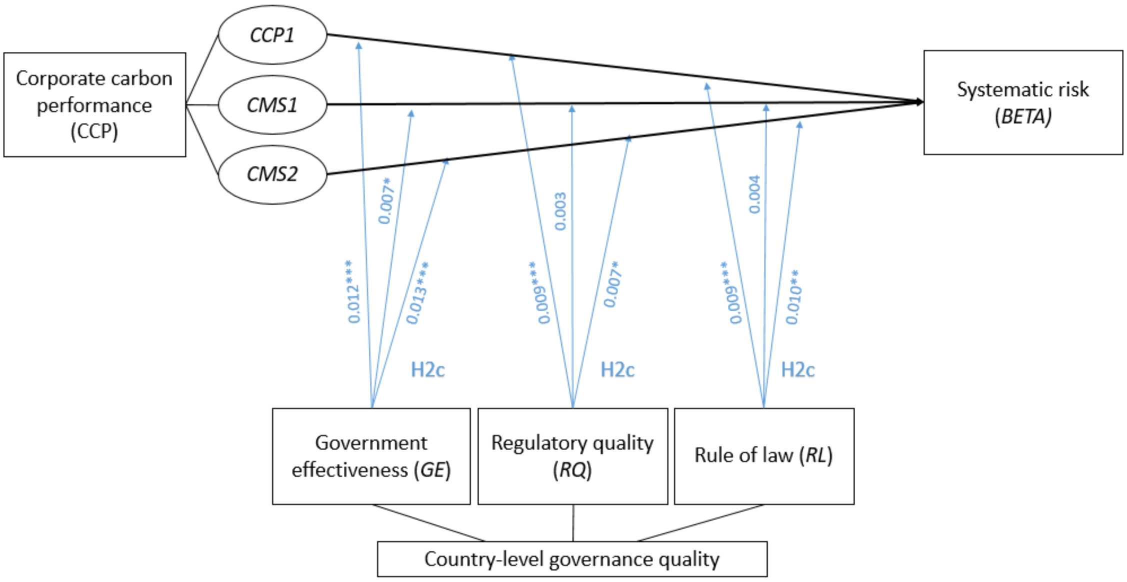

Figure 5.7. Summary of findings of Hypothesis 2c (H2c) of third paper

Source: developed by the author

Our primary results are generally robust after running a series of robustness tests. To address the potential sample selection bias and endogeneity problems, we use alternative model specifications, namely, Heckman's (1979) two-stage analysis, propensity score matching (PSM), and firm fixed-effects, country fixed-effects and two-stage least squares (2SLS) models. In addition, we re-run the baseline model using sub-samples across countries to address the heterogeneity problem. We also control for the effect of the Global Financial Crisis (GFC) and simultaneous causality. Generally, our main results are found to be robust after running these robustness tests.

5.3 Implications

This section presents the implications of the current research[40], providing significant insights and several implications for firms' financial management, policy makers, creditors and investors. The findings complement related research and add to research streams in the finance and management literature by specifying CCP as a channel through which CEP affects firms' financing costs and corporate financial performance (CFP). As previous studies have yielded mixed findings (Busch & Lewandowski, 2018), this research has endeavoured to interpret one of the factors that has caused these differences by examining whether and how country-level governance quality moderates or strengthens the CCP–CFP relationship. Our study shows that

[40] These implications are also mentioned in each of the three papers, as presented in Chapters 2, 3 and 4.

the sensitivity of financial markets to CCP depends on country-level government quality, regulatory quality and rule of law.

This research also provides additional insights for managers, and firms' investors and creditors. With carbon risk now being valued by debt and equity markets, firms can reduce their COD, COE and firm risk by improving their carbon performance and reducing carbon risk, resulting in the improvement of firm value. In addition, when a firm intends to establish a green project or a carbon-intensive project, it must consider the unobservable indirect benefits or costs of this type of project to conduct a more accurate feasibility study. Therefore, this study helps managers to understand and determine one aspect of the indirect benefits/costs of green projects.

An enhanced understanding of the CCP–CFP relationship helps a firm and its creditors and investors to conduct a better evaluation of its real market value. This study has contributed to the recognition of whether CCP is considered a risk/opportunity factor and whether it economically affects a firm's intrinsic value, thus affecting the firm's credit standing. In addition, understanding the role played by institutional and legal environments in the CCP–CFP relationship is important for firms and their stakeholders (Doidge et al., 2007). For example, understanding how stock markets deal with CCP in a country with low/high governance quality can help investors to evaluate their portfolio position in a firm and to construct their portfolio in an effective manner.

This research also presents some suggestions and guidance for policy makers related to the requirements and factors that should be considered when they are addressing carbon issues and seeking to mitigate these concerns at the country level. This study highlights the important role that the market mechanism can play in addressing climate change concerns (especially in countries with a weak governance mechanism). It reveals that CCP is now being priced by participants in financial markets. This study helps policy makers to determine the extent to which they can rely on the market mechanism in mitigating this problem, rather than having it directly solved by costly government interventions (e.g., incentivising and monitoring costs).

Understanding the effects of governance quality on the CCP–firm risk relationship is important for quickly and safely transitioning to a low carbon economy. Policy makers in a weak/strong governance setting can know the extent to which they can rely on the market mechanism to deal with the issue of carbon emissions. According to our study's findings, stock markets are less sensitive to the climate change issue in a weak governance setting. Therefore, in the developing or less-developed country setting, government policy makers and regulators should push firms to move toward a low carbon economy instead of relying on the market mechanism.

In addition, this study highlights the importance of carbon-related disclosure and having this kind of data extensively available. Policy makers need to be aware of the benefits of developing CCP information sources and of the importance of making carbon-related disclosure available to market participants. Indeed, the availability of this information will reduce information asymmetry between the firm and its stakeholders and therefore increase the market's efficiency.

5.4 Limitations and future research

This section outlines the limitations of the current study and the directions for future research. As with any research, this study is subject to constraints and limitations relevant to its scope, duration and resources.

As our data are limited to firms within the Asia-Pacific region, our results could not be generalised to other regions. Although we provide cross-country evidence of the CCP–COD relationship, we could not apply our findings to firms in other countries. In addition, the study sample concentrates on firms from developed countries, such as Japan and Australia, due to the lack of carbon data in less-developed or developing countries. Increases in awareness in developing countries about the problems associated with climate change would increase the enactment of legislation to regulate carbon emissions (e.g., a carbon reporting scheme): this, in turn, would increase the availability of carbon data in these countries. Therefore, it would be worthwhile for future research to investigate the implications and determinants of firms' exposure to climate change-related risk in other geographical areas, especially in developing countries. As this concern will be more salient in coming years, future research could re-examine the CCP–CFP relationship as the economic significance of the effect of carbon performance is likely to become more severe.

Although this study uses four proxies for CCP, they may not fully capture and reflect corporate carbon performance (CCP). As we use secondary data, the construction of CCP measurements could have some deficiencies. Augmenting the coverage and the quality of carbon data would, in fact, contribute to the improvement of environmental management practices and environmental performance measurements. Thus, achieving improvement in CCP measurements warrants further significant work. Future research could develop or create more accurate and comprehensive climate change–related metrics.

Further studies about the potential indirect effects of adopting green strategies would help to build a better understanding between firms and their stakeholders which, in turn, could encourage firms to move toward a low carbon economy. Future studies could also examine the impact of ownership structure on CCP (e.g., institutional or foreign investors) and governance structure (e.g., board characteristics and CEO characteristics) and on the relationship between CCP and corporate financial performance (CFP). Furthermore, future research may be conducted based on carbon performance in the eyes of large financial institutions and examine whether these institutions, in reality, consider the environmental performance of their clients. Future studies may also investigate the role of CSR disclosure on the CCP–CFP relationships by including CSR disclosure as a moderating variable.

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