6-2023

Essays on stakeholder economy

Hanyu ZHANG
Singapore Management University, hanyu.zhang.2018@pbs.smu.edu.sg

ESSAYS ON STAKEHOLDER ECONOMY

HANYU ZHANG

SINGAPORE MANAGEMENT UNIVERSITY

2023

Essays On Stakeholder Economy

HANYU ZHANG

Submitted to Lee Kong Chian School of Business
in partial fulfillment of the requirements for the
Degree of Doctor of Philosophy in Finance

Dissertation Committee:

Hao LIANG (Supervisor/Chair)
Associate Professor of Finance
Singapore Management University

Jianfeng HU
Associate Professor of Finance
Singapore Management University

Rong WANG
Associate Professor of Finance
Singapore Management University

Peter JOOS
Associate Professor of Accounting and Control
INSEAD

Singapore Management University
2023

I hereby declare that this PhD dissertation is my original work
and it has been written by me in its entirety.
I have duly acknowledged all the sources of information
which have been used in this dissertation.

This PhD dissertation has also not been submitted for any degree
in any university previously.

张涵宇

Hanyu ZHANG

1 June 2023

Essays on Stakeholder Economy

Hanyu ZHANG

Abstract

The dissertation consists of two chapters on stakeholder economy. It looks at how firms interact with the stakeholders, including not only investors, employees, customers, governments, but also the broader community and society at large, and examines how such interactions affect corporate behavior in China and the global setting. The first chapter studies how societal culture shapes firm behavior and growth by analyzing the trade-off of relying on trust in acquiring stakeholder resources, and testing with data on the number of historic Confucian schools surrounding a current firm's location in China. Companies more exposed to Confucianism have greater social contributions and stakeholder protection, and more business courtesy expenses, patents, and trade credits, which match the five basic virtues of Confucianism: benevolence, righteousness, courteousness, wisdom, and trustworthiness. Our results cannot be explained by other cultural traits and are robust to using the distance to the prototypical Confucian academies in the Song Dynasty and the intensity of rivers in the local region as instrumental variables. The effects are likely to be transmitted via a firm's interaction with market participants, politicians' ideology, and board of directors. Stronger Confucianism is associated with greater profitability and growth. Our paper contributes to the literature by providing more granular evidence on how culture affects economic activities through *firm-level* channels, which have not been systematically explored in the literature.

In the second chapter, we employ a novel firm-level dataset on monetized value of unpriced earnings losses due to climate-related transition risks to study the magnitudes, determinants and consequences of a firm's carbon earnings risks across different scenarios based on national pledges to Paris Agreement targets and different time horizons. We find carbon earnings risks on average account for about 15 percent of a firm's total earnings and are largely driven by unobservable

industry- and firm-level heterogeneities. We also find that companies with greater carbon earnings risks tend to have more green innovations, discretionary accruals, and outsourced productions. We use the staggered introduction of country-level carbon tax and emission trading system, as well as state-level climate-related disasters as instrumental variables to address potential endogeneity issues. Our findings highlight the importance of accounting for transition risks in a firm's financial statements. Our work complements the growing climate finance literature on the effect of climate risks on corporate policies by providing more comprehensive evidence on the motivation of corporate reaction, driven by material carbon earnings risks that are reflected on a firms financials.

Contents

Acknowledgements iii

1 Culture and Firms 1

1.1 Introduction 2

1.2 Conceptual Framework and Hypothesis Development 8

1.2.1 Conceptual Framework 8

1.2.2 Hypothesis Development 11

1.3 Data and Sample 14

1.3.1 Confucianism Measure 14

1.3.2 Dependent Variables 17

1.3.3 Controls 18

1.3.4 Validation Test 19

1.4 Main Results 20

1.4.1 Baseline Results 20

1.4.2 Alternative Culture Measures and Specifications 22

1.4.3 Instrumental Variable Analysis 24

1.5 Exploring Channels 28

1.5.1 Interaction with Market Participants 29

1.5.2 Politicians' Ideology 30

1.5.3 Board of Directors 31

1.6 Culture and Firm Performance 32
1.7 Post-Hoc Results 34
1.8 Conclusion 36

2 Accounting for Carbon Earnings Risks **39**
2.1 Introduction 39
2.2 Data and Methodology 47
2.2.1 A Firm's Carbon Earnings Risks 47
2.2.2 Firm-level Actions 49
2.2.3 Other Variables 51
2.2.4 Summary Statistics 51
2.3 Unbundling Carbon Earnings Risks 52
2.3.1 Scenario Breakdown of Carbon Earnings Risks 53
2.3.2 Industry and Country Distributions of Carbon Earnings Risks 53
2.3.3 Variance Decomposition of Carbon Earnings Risks 56
2.3.4 Determinants of Carbon Earnings Risks 57
2.3.5 External Validation 59
2.3.6 Variances across Three Scenarios and Forecast Years 60
2.3.7 Physical Risk Measures 61
2.4 How Firms Respond to Carbon Earnings Risks 62
2.4.1 Firm's Response: Baseline Results 62
2.4.2 Instrumental Variable Analysis 64
2.4.3 Cross-Sectional Heterogeneities 67
2.5 Conclusion 68

References **70**

3 Appendix **80**

Acknowledgements

First and foremost, I would like to express my deepest gratitude and appreciation to my advisor, Professor Hao LIANG, whose guidance, expertise, and unwavering support have been instrumental in the completion of this dissertation and my Ph.D. journey. His exceptional mentorship and invaluable insights have shaped my research and propelled me towards academic excellence. His patience, dedication, and commitment to my intellectual growth have been truly remarkable, and I am immensely grateful for his guidance throughout this journey.

I would also like to extend my heartfelt thanks to my research committee, Professor Jianfeng HU, Rong WANG, and Peter JOOS, for their constant support, encouragement, and willingness to assist me whenever needed. Their guidance, insightful discussions, and valuable feedback have been vital in refining my ideas, strengthening my research, and broadening my academic horizons. I am also grateful for the contributions of the faculty at SMU who have generously shared their knowledge, time, and expertise.

Furthermore, I am indebted to my parents for their unconditional love, unwavering belief in my potential, and the sacrifices they have made to support my educational pursuits. Their unwavering support and encouragement have been the cornerstone of my academic journey and given me the confidence to pursue my passions and overcome challenges.

Lastly, I am grateful to all my friends for accompanying me, through ups and downs. Thank you for being my pillars of support, cheerleaders, and partners in this incredible adventure.

Chapter 1

Culture and Firms*

Culture as a critical informal institution has drawn significant interest from economic and business researchers. In this paper, we develop a conceptual framework for how trust-based societal culture can help a firm gain supports from its key stakeholders but also posit an expropriation risk by the entrepreneur, which can either lower or raise transaction costs, with different implications for firm value and overall stakeholder welfare. Employing a granular measure of a firm's exposure to a culture that persists over a long history, this paper examines the role of societal culture in shaping business activities through influencing corporate policies. We find that firms more influenced by Confucianism make more social contributions, provide greater stakeholder protection, spend more on courtesy and etiquette, and have more patents and trade credits. These five firm-level policies and outcomes match with the five core virtues of Confucianism that are all related to trust with stakeholders: benevolence (*Ren*), righteousness (*Yi*), courteousness (*Li*), wisdom (*Zhi*), and trustworthiness (*Xin*). Overall, our findings suggest a more systematic but also nuanced view on the effects of societal culture on firms.

*This is a joint work with Zhihui GU and Hao LIANG.

1.1 Introduction

Economic activities are shaped by culture (Weber, 1930). In economic terms, culture refers to deeply held general values and beliefs or even intuitions about right or wrong (Nunn, 2012). Extant studies have documented systematic differences among people with distinct cultural backgrounds in their decision-making, even in the same environment, due to their different preferences and beliefs (e.g. Nisbett and Masuda, 2003; Talhelm et al., 2014). These differences are further associated with varying levels of economic development across regions (e.g. Guiso et al., 2003; Algan and Cahuc, 2010; Nunn, 2008; Nunn and Wantchekon, 2011). A growing body of the economics literature has focused on the role of societal culture as an important determinant of socio-economic outcomes, such as long-run growth and political institutions (e.g. Alesina and Giuliano, 2015; Michalopoulos and Papaioannou, 2015; Nunn et al., 2020). Despite the abundance of studies documenting cultural effects, it remains unclear how societal culture can shape business activities and influence corporate policies. Studying the firm-level channel is crucial for understanding how culture affects the broader economy and society, especially given the large differences in corporate practices across firms and countries (Bertrand and Schoar, 2003; Bloom and Van Reenen, 2007).

The limited studies on how cultures affect firms mostly focus on corporate culture and the cultures of their CEOs, instead of societal culture. Conceptually, corporate and CEO cultures can be considered as a stock of shared knowledge and beliefs that are communicated and interpreted between leaders and employees, and can be reflected in firm reputation and behavior (Van den Steen, 2010; Gorton and Zentefis, 2020; Gorton et al., 2021). This perspective focuses on the formation of corporate culture but remains silent on how societal values are initially formed, especially through a firm's interaction with various stakeholders, including consumers, suppliers, community, regulators, and even the public at large. A broader perspective requires a focus on the role of societal culture, which shapes corporate cultures as well as the cultural values of corporate leaders and employees within a given society (Hofstede and Peterson, 2000).

In this study, we fill the above gaps and investigate how societal culture affects firms. To this end, we first develop a conceptual framework in which culture is represented by trust among a firm's stakeholders (Guiso et al., 2004, 2006, 2008a,b; Alesina and Giuliano, 2015), not just investors, employees, and customers but the broader community and society at large. Specifically, we consider trust as an important input of a firm's production that is supplied by its stakeholders. Firms with higher stakeholder trust will have greater access to stakeholder support, such as lower cost of capital from investors and lower wage demands by employees. Gaining stakeholder trust is, however, costly, and thus a firm faces a cost-benefit trade-off. In an environment with a strong societal culture that emphasizes trust and reputation, a firm is more likely to gain trust from its key stakeholders at lower cost (Allen et al., 2005). However, trust may replace formal institutions (e.g., laws and contracts), which leads to authoritarianism within the firm (Coase, 1937) and the risk of stakeholders being expropriated by the entrepreneur, increasing the cost of gaining stakeholder supports. Consequently, such low (high) cost of acquiring this important input leads the firm to generate a higher (lower) output, given a fixed budget. This has significant implications on the welfare of both stakeholders and firms depending on the relative strength of stakeholder support and expropriation risk.

We then test it empirically by exploiting the Chinese setting and leveraging a unique dataset on the dominant and historically enduring culture in China, namely Confucianism, which has shaped practical affairs in China for about two thousand years. We construct a novel dataset from historical archives in the Great Qing, the last dynasty in the imperial history of China, which ruled the country for almost three centuries until it was succeeded by the Republic of China in 1912. Specifically, we hand-collect information about 1,547 Confucian academies in the Qing Dynasty by referring to county-level local chronicles between 1796 and 1840.[*] We then count the number of

[*]We choose this period because the most comprehensive and complete chronicles are only available after 1796, and, after 1840 (after the Opium War), Westerners established municipal authorities, schools, and judiciaries in some cities of China (Jia, 2014). Confucian academies were the private schools, and one of the only places where most children, including those from poor families, could then receive proper education. It has been documented that these academies attracted talented young men who were keen for more out of their Confucian educations than just the rote mental preparation provided in government schools for the civil service examinations (Elman, 1989). During the Qing Dynasty, Confucian academies gained both local and governmental support and flourished as centers of education.

Confucian academies in the Qing Dynasty in the firm's adjacent region, i.e., within a 100-kilometer radius around the coordinates of the corporate headquarter, as a measure of a firm's exposure to Confucianism.

We next identify the core values of Confucianism, which are commonly summarized as the five virtues, namely benevolence (*Ren*), righteousness (*Yi*), courteousness (*Li*), wisdom (*Zhi*), and trustworthiness (*Xin*), and are the foundation of Confucian ethics that still prescribe interpersonal relations in China today (Hwang, 1987; Huang, 2003). We map these virtues into five major firm-level behaviors that best represent the five core values, including social contribution (benevolence), stakeholder protection (righteousness), courtesy expenses (courteousness), patenting (wisdom), and trade credits (trustworthiness). We find these five behaviors are positively correlated with the intensity of a listed firm's exposure to Confucianism. This finding holds after employing alternative measures of Confucianism, including that of the CEO, and controlling for other cultural traits, including Taoism, Buddhism, and foreign values, and key geographical and demographic characteristics in the region in Qing.

Although our key explanatory variable lagged our dependent variables by several centuries, there is still concern that the presence of Confucian academies could be correlated with regional economic development in the Qing Dynasty, which could persist and explain today's economic activities. Meanwhile, confounding factors correlated with both Confucianism and economic activities could drive the above results. To mitigate these concerns, we employ an instrumental variable (IV) approach. First, we use the shortest distance between a listed firm and the nearest academy established by the renowned Confucian scholar Zhu Xi (1130—1200 A.D) to teach and promote Confucian philosophies. These *Zhu Xi Academies* had played a crucial role in popularizing and spreading Confucianism among the grassroots, through prototyping and inspiring the establishment of other Confucian schools across China since the twelfth century (Chen et al., 2022). The high cost of transport during ancient China ensured that Confucian schools tend to cluster around those *Zhu Xi Academies* (Chen et al., 2022). As a result, regions closer to a *Zhu Xi Academy* tend to have more Confucian schools thus greater exposure to Confucianism. Meanwhile, the locations of these *Zhu Xi Academies* and subsequent Confucian schools around them were not determined by the economic conditions during that time but instead were results of Zhu Xi's personal experience, mourning rituals and government official appointment (Gu et al., 2021; Chen et al., 2022). We present evidence on this exclusion restriction, which will be explained later in greater detail.

Our second IV is the number or the total length of rivers in the region where a firm is headquartered. We argue and show evidence that Confucian schools were usually established in areas further away from rivers (except major ones that cross many regions, such as Yangtze River and Yellow River) in the ancient China to reduce potential inundation risk and protect the books. Such choice of location also ensures a peaceful environment for education, as areas near rivers usually had more trades, transportation, and wars. Therefore, we expect a negative correlation between the number of Confucian schools and the number or length of rivers in a region. Meanwhile, this IV is unlikely to affect contemporary firm policies additionally after we control for local economic development. Our IV estimates confirm that Confucianism has a large and significant effect on corporate policies.

We next explore potential channels through which societal culture functions on firms—other than the CEO's cultural background—by investigating the roles of market participants, politicians and board of directors who are major external and internal stakeholders that affect corporate decision making. To this end, we partition our sample based on the degree of regional market-orientation, city leaders' ideology against Confucianism, and whether there are non-Chinese board directors in a firm. First, several scholars (e.g. Tabellini, 2008; Alesina and Giuliano, 2015) argue that culture and formal institutions such as the market can influence each other, and their impacts on economic activities are usually substitutive. We thus conjecture that the effect of societal culture on firms is weaker in more market-oriented regions, and we find support from data using province-level marketization scores. Second, Marquis and Qiao (2020) find that people who joined the Communist Party of China (CPC) before 1978 were more likely to adopt Mao's ideology ("*Maoist*"), which suppressed Confucianism, especially in the "Cultural Revolutions" (Gold, 1985), compared to those who joined after 1978 and thus adopted Deng's ideology ("*Dengist*"). Liang et al. (2022) find systematic differences in corporate behavior between firms governed by *Maoist* politicians and those governed by *Dengist* politicians. Our results show that the effects of Confucianism are stronger in cities with *Dengist* leaders, confirming the politician channel. Third, the effect of Confucianism should be attenuated if the firm is also exposed to foreign cultures in its decision-making body, such as having more non-Chinese directors on the board. The results are again consistent with our prediction.

Finally, to test the value implications of societal culture predicted by our theoretical framework, we relate Confucianism to firm performance and find that firms with greater exposure to Confucian culture have higher returns on equity, greater operating profit growth, and greater corporate social responsibility (CSR). Consistent with our conjecture, such value effects are explained by reduced cost of capital and employee growth at the firm-level. These results collectively suggest that firms influenced by Confucianism gain more stakeholder support at lower costs, despite the potential expropriation risk, thus have greater growth potential on average.

Our study mostly relates to the work on how societal cultures shape economic activities. The study of culture in economics can be categorized in the following ways. First, culture influences the behavior of individuals and organizations. For example, Guiso et al. (2004) show that trust, one of the most important cultural traits, is positively associated with households' use of check, proportion of stocks in asset allocation, and access to institutional credit. Second, culture can affect macroeconomic outcomes and financial markets. For instance, cultural differences in terms of individualism can explain the cross-country differences in innovation and long-term economic growth (Gorodnichenko and Roland, 2017), as well as the momentum strategy profits and price co-movement (Chui et al., 2010; Eun et al., 2015). Third, culture can significantly shape formal institutions. This literature has documented the cultural effect on government regulation, labor market outcomes, political institutions, and international trade and openness (e.g. Aghion et al., 2010; Algan and Cahuc, 2010; Nunn et al., 2020; Guiso et al., 2009; Stulz and Williamson, 2003).

Different from these studies, we focus on *how* culture shapes economic activities via influencing firm behavior—beyond the corporate culture—by investigating its substitutional effect on other formal and informal institutions, such as the market and ideology. In this way, we show the boundaries of cultural influence, a topic underexplored elsewhere. Regarding Confucianism more specifically, while Chen et al. (2022) argue that such substitutional effect hinders China's financial development due to its negligence of relying on formal institutions, we focus on its positive role in gaining stakeholder trust which appears to be more prominent, leading to overall lower transaction costs. More broadly, our work also complements the studies on how historically formed institutions and norms (such as laws, political institutions, trust among people) systematically affect contemporary economic or financial outcomes (e.g., La Porta et al., 1998; Acemoglu et al., 2001, 2002; Nunn, 2008; Michalopoulos and Papaioannou, 2016; Pierce and Snyder, 2018; Levine et al., 2020; Lowes and Montero, 2021). The effects we document are likely firm-level channels through which culture as a historically formed informal institution affects economic activities.

Another major contribution we make to the literature is to introduce a more granular and objective measure of societal culture. The most commonly used measures of societal culture are based on survey data, such as the Hofstede cultural dimensions (e.g. Hofstede, 1980, 2001), the Schwartz measures (e.g. Schwartz, 1994, 2006), the World Values Survey (Inglehart, 2000), and the GLOBE cultural scores (House et al., 2004). These country-level survey-based measures facilitate the cross-country analysis, especially in exploring the effects of specific cultural characteristics on individual behaviors and economic activities across the world (e.g. Guiso et al., 2006, 2008b; Fisman and Miguel, 2007; Gorodnichenko and Roland, 2011). However, these measures do not allow for investigating the significant within-country variations in culture (Guiso et al., 2006; Karolyi, 2016; Nunn, 2020), and it is inappropriate to equate nation with culture. In addition, such measures suffer from the sample selection issue and the concern that people often fail to act in accordance with their stated intentions in surveys (Ajzen et al., 2004). Some recent studies combine ethnic background of top executives in the United States and survey-based measures of national culture to measure the corporate culture, which enables them to investigate within-country, cross-firm cultural effects (e.g. Liu, 2016; Nguyen et al., 2018; Pan et al., 2020). Nevertheless, such an approach faces similar challenges to those of survey-based methods and does not measure the direct impact of societal culture on firms. Another strand of research employs religion and language as proxies for societal culture (e.g. Stulz and Williamson, 2003; Hilary and Hui, 2009; Kumar et al., 2011). Regarding language, researchers consider people speaking the same language to share the same culture. With regard to religion, some studies focus on whether Catholics and Protestants exhibit significant differences in their preferences and economic behavior (e.g. Kumar et al., 2011, 2016; Stulz and Williamson, 2003). However, religions are complex institutions that comprise conflicting views on many issues, and people both within and across countries may have heterogeneous degrees of religious belief (Siegel et al., 2011). Thus, using religion as a measure for culture does not capture the significant within-region or within-country heterogeneities of cultural effects. In contrast, our coordinate-based measure for societal culture provides fine-grained, within-country variation of societal culture and is based on historical documents, which are objective and stable and can capture the intensity of cultural influence at the firm level.

The remaining of the paper proceeds as follows. Section 2 develops a conceptual framework and testable hypotheses. Section 3 describes the data and sample construction. Section 4 discusses the main results. Section 5 presents several cross-sectional analyses in exploring potential channels through which societal culture affects firm behavior. Section 6 explores the performance consequences of the culture impact. Section 7 provides results of several post-hoc tests. The final section concludes.

1.2 Conceptual Framework and Hypothesis Development

1.2.1 Conceptual Framework

In this section, we integrate the classical demand-and-supply and cost-minimization analyses into our conceptual framework. Specifically, we view societal culture as a form of trust in a firm by its stakeholders, which is an important input for the firm's production, and can substitute other inputs. We treat the firm as the demander and its stakeholders as the suppliers of this input. However, gaining trust from stakeholders is costly, and a firm faces a cost-benefit trade-off when making production decisions.

On one hand, firms are more likely to gain support from stakeholders at lower cost in a society that has a strong culture of valuing trust (Allen et al., 2005). Consequently, such low costs of acquiring the important input lead firms to generate higher output, given a fixed budget. As a result, the welfare of both stakeholders and shareholders can improve. On the other hand, trust as an informal institution may substitute other inputs that are dictated by formal institutions such as markets and contracts (Han and Ling, 1998; Chen et al., 2022). This substitutional effect gives rise to authoritarianism within a firm, as people have to rely on the authority of the entrepreneur in allocating resources in the absence of formal rules (Coase, 1937). In the absence of strong legal protection, such authoritarianism may expose stakeholders to greater expropriation risks by the entrepreneur (Bae et al., 2002; Baek et al., 2006), resulting in lower trust by stakeholders thus higher transaction costs. Therefore, the net effect of the trust-based societal culture depends on the relative strength of stakeholder supports and expropriation risks. We graphically illustrate this framework by analyzing the equilibrium outcomes under different scenarios with varying intensities of culture.

Figure 1(a) shows the supply and demand of trust from a firm's stakeholders, with a focus on its positive effect. The X-axis represents the "quantity" of trust from stakeholders on the firm, and the Y-axis represents the cost of acquiring such stakeholder trust on the firm. The downward curve is the demand curve, D, which represents the quantity of trust demanded given the "price" of trust. We assume a constant marginal utility of trust for the firm, which can be relaxed easily. The upward dashed lines are the supply curves representing the quantity of trust supplied, given its price. The initial equilibrium quantity of trust on a firm is Q_0, and the equilibrium price of trust is P_0, the quantity and the price at which the demand curve intersects with the initial supply curve (S_0). A greater strength of trust-based culture in the society helps provide more assurance to stakeholders and thus gains more trust from them. This is manifested by a shift of the supply curve toward the right, due to an increased supply of trust. With the new supply curve, S_1, the new equilibrium quantity of trust on a firm increases to Q_1, and the new equilibrium price of trust becomes P_1. We further assume that the intersection point is above Point E, which is the point of unit elasticity. Hence, an increase in the quantity of trust and a decrease in the price of trust leads to the rise of welfare of stakeholders ($P_1 \times Q_1 > P_0 \times Q_0$) and an increase in "consumer surplus" ($P_1 < P_0$, and we define $\Delta P_1 = P_0 – P_1$)), which captures the value of the firm as it is the consumer of stakeholder trust.

Figure 1(b) shows the similar supply-demand curves of stakeholder trust, but focusing on its negative effect. Different from Figure 1(a), a greater strength of trust-based societal culture substitutes rule-based institutions (Aghion et al., 2010; Pevzner et al., 2015), which leads to stronger authoritarianism within the firm that exposes stakeholders to greater risk of expropriation by the entrepreneur. Such expropriation risk reduces stakeholders' supply of trust to the firm, which is manifested by a shift of the supply curve toward the left. With the new supply curve, S_2, the new equilibrium quantity of trust on a firm decreases to Q_2, and the new equilibrium price of trust is P_2. We again assume the intersection point to be above the point of unit elasticity, E. Hence, a decrease in the quantity of trust and an increase in the price of trust leads to a decline of stakeholders welfare ($P_2 \times Q_2 < P_0 \times Q_0$) and a decrease in "consumer surplus" ($P_2 > P_0$, and we define $\Delta P_2 = P_2 – P_0$).

<Figure 1 here>

Figure 1(c) combines the previous two figures to illustrate the net effect of societal culture on the supply of trust from a firm's stakeholders. The initial equilibrium quantity of trust on a firm is Q_0, and the equilibrium price of trust is P_0. When $\Delta P_1 > \Delta P_2$, that is, when the effect of stakeholder support is greater than that of the expropriation risk, the supply curve will shift to right (S_{3a}), manifesting a positive effect of trust-based culture. The equilibrium quantity of stakeholder trust increases to Q_{3a} and the equilibrium price of trust decreases to P_{3a} in this case (and $P_{3a} \times Q_{3a} > P_0 \times Q_0$), reflecting an increase in overall welfare. In contrast, when $\Delta P_1 < \Delta P_2$, that is, when the expropriation risk overweighs the stakeholder support, the supply curve will shift to left (S_{3b}) which reflects a negative effect of trust-based culture. With the new equilibrium quantity Q_{3b}, and price P_{3b} ($P_{3b} \times Q_{3b} < P_0 \times Q_0$), the overall welfare decreases.

Figure 2 illustrates the production decision of firms facing different prices of trust. The isocost line, L_0, represents the initial combinations of trust and other inputs that can be acquired with a fixed amount of capital when the price of trust is P_0, which is tangent to the isoquant curve, U_0, that represents similar combinations of inputs needed to produce the same level of output. The point of tangency represents the equilibrium quantity of output (Q_0) that is determined by equating the marginal rate of technical substitution to the ratio of the prices of the two factors, given a fixed budget. Two alternative isoquant curves, U_1 and U_2, indicate a higher output (Q_1) and a lower output (Q_2). With a greater intensity of trust-based culture, the isocost line will shift depending on the cost of acquiring stakeholder trust. When the stakeholder support outweighs the expropriation risk (i.e., $\Delta P_1 > \Delta P_2$), the price of trust decreases and the trust input increases, assuming the prices of other inputs to be fixed. As a result, the new isocost line L_1 becomes flatter and is tangent to a higher isoquant curve U_1, implying that stronger culture leads to a higher output of the firm, given the same budget, which further generates higher profit for the firm. In contrast, when the expropriation risk outweighs the stakeholder support (i.e., $\Delta P_1 < \Delta P_2$), the price of trust increases and the supply of trust as an input decreases, leading to a steeper isocost line, L_2, tangent to the lower isoquant curve, U_2. This implies a lower output of the firm, given the same budget, which further leads to less profit.

<Figure 2 here>

1.2.2 Hypothesis Development

We next describe the institutional background of our empirical setting and how we match the core values of Confucianism to firm behaviors. Confucianism originates from the teachings of the Chinese philosopher Confucius (551 B.C – 479 B.C) and has been the predominant value system governing the practical affairs in China since the Han Dynasty, for almost two thousand years. Confucian values also spread widely across other countries in Asia, such as Singapore, Vietnam, South Korea, and Japan. The core of Confucian values consists of five virtues, namely, benevolence (*Ren*), righteousness (*Yi*), courteousness (*Li*), wisdom (*Zhi*), and trustworthiness (*Xin*). These virtues define the principles of being a decent person and the norms for interacting with others which help establish social trust.

Benevolence (*Ren*) refers to compassion and altruism, and mostly concerns a person's caring and love for others, even at the cost of her own wellbeing. From a corporate perspective, a benevolent firm cares about the welfare of its society and various stakeholders and is willing to contribute to the society at a cost to itself. Therefore, a benevolent firm would spend more on social contributions. We therefore take a broad perspective and link benevolence to various forms of social contribution (or contributions to various stakeholders) by examining the combination of tax payments to the government, wage payments to employees, interest payments to debt holders, profit attributable to shareholders, and donations. In this way, we aim to capture how much a firm cares for its broad group of stakeholders.

Righteousness (*Yi*), often being referred together with benevolence in the ancient Chinese literature, is about respecting and helping the others, especially the virtuous, friends, and the weak in the society. From a firm's perspective and similar to benevolence, a righteous firm protects its internal and external stakeholders. To this end, we focus on a firm's protections of its employees and supply-chain partners, which are often vulnerable and disadvantaged stakeholders, relative to the firm and its shareholders. These protections may include stepping up safety measures for employees and ensuring fair competition among suppliers.

Courteousness (*Li*) refers to common courtesy in one's daily life, representing the etiquette, norms, and protocols that influence interactions with others. Inspired by the *Analects*, which considers courtesy as "the lubricant for the societal harmony," Chinese society takes the pride of itself being a "state of etiquette." The pursuit of courtesy and etiquette is also reflected in business, as firms interact with and entertain their stakeholders, with varying degrees of strength across the society. A firm that is more exposed to a courteous culture would spend more on entertaining stakeholders and business partners. We therefore focus on a firm's courtesy expenditure to capture how the value of courteousness in Confucianism is reflected in its corporate behavior.

Wisdom (*Zhi*) refers to one's intellectual development and quality and is about the use of knowledge in a prudent way (Wang and Juslin, 2009). A firm that is more exposed to a culture that values intellectual capital will also commit resources to the development of intellectual property. To this end, we focus on a firm's innovative outputs, such as patents, to investigate the influence of Confucianism on a firm's pursuit of intellectual capital and outputs.

Lastly, trustworthiness (*Xin*) concerns one's credibility and the extent to which she keeps her promises in interpersonal relations. In business, trust among stakeholders is one of the most important factors in facilitating transactions. Therefore, a firm in an environment with a high level of trust is more likely to be viewed as credible and trustworthy by its external stakeholders, such as customers and suppliers. Consequently, they are more willing to grant the firm more trade credits. For example, a supplier can grant a firm that is perceived trustworthy a longer window for making payments after the delivery of products.

Overall, all these cultural aspects relate to establishing and maintaining trust with various stakeholders, with some being more explicit (e.g., benevolence, righteousness, trustworthiness) and others more implicit (e.g., courteousness and wisdom). In this way, we differ from the existing literature by comprehensively capturing the core elements of a culture and examine its effect on firms in totality, rather than only one aspect of it. In addition, we argue that firm-level influence of Confucianism can take place through shaping the behavior of a firm's various decision makers and stakeholders, such as the entrepreneur or CEO, the directors, the regulators, and the market participants. Some of them form the corporate culture, whereas others are related to a firm's institutional environment. In this way, we can more accurately delineate the mechanisms of cultural influence. We test these five core aspects of Confucianism and underlying mechanisms in subsequent sections.

1.3 Data and Sample

This study employs data from several different sources: (i) a firm's exposure to Confucianism based on its geographical coordinates and the number of Confucian academies from local chronicles (Chorography) in the Great Qing; (ii) survey data on people's general attitudes from China Family Panel Studies (CFPS); (iii) population divorce rates, city-level GDP, employment, total wage and FDI from China National Bureau of Statistics; (iv) firm headquarters location data from WIND database; (v) firm financial data and data on social contribution, employee and supplier/customer protection, and ownership structure from China Stock Market & Accounting Research (CSMAR) database; (vi) city-level politicians' backgrounds from CSMAR; (vii) province-level market orientation scores from the China Marketization Index by Fan et al. (2011); (viii) data on number and length of rivers from National Census for Water of China; (ix) data on regional Taoism and Buddhism cultures from Yang (2011); (x) information on intergenerational coresidence from China Population Census (2000 and 2010); (xi) data employee growth from RESSET; (xii) data on firm-level CSR score from *Hexun.com*; (xiii) other archival data from regional archives and historical documents.

1.3.1 Confucianism Measure

Our main explanatory variable is a firm's exposure to Confucianism, which we measure using historical data in archival resources. This approach has been used in examining the persistent effect of historical factors on contemporary economic outcomes (e.g., Acemoglu et al., 2001, 2002; Nunn, 2008; Nunn and Wantchekon, 2011; Lowes and Montero, 2021). Specifically, we count the number of private Confucian academies in the Qing Dynasty in the firm's adjacent region. Private Confucian academies were the main venues where people were indoctrinated with Confucian values, which formed the main part of education in pre-industrial China. By the middle of the sixteenth century, these academies held regular meetings to allow Confucian scholars to exchange knowledge and views. Through these repeated social interactions, Confucianism spread to the community. In addition, private academies were more accessible for most people and provided elementary Confucian education, whereas not everyone could go to government-funded official schools, which primarily focused on rote mental preparation for the civil service examinations (Elman, 1989). As a result, Confucian academies also gained local support and flourished as centers of learning in the Great Qing. Therefore, more Confucian schools suggest that a greater share of the local population was inculcated with Confucian culture, which was likely to be passed on over generations.

One may be concerned that having more Confucian schools more than a hundred years ago does not necessarily lead to stronger local Confucian culture today, as the cultural imprints may decay over long periods. In other words, cultural values may not persist and may not transmit stably over time. Although examples of drastic cultural change abound (Firth, 1959), we argue that this is unlikely to be the case in our setting. Following the anthropology literature, Giuliano and Nunn (2021) argue that an important determinant of cultural persistence is the similarity of the environment across generations. That is, cultural traits that have evolved from the previous generation are more likely suitable for the current generation in a less variable environment, measured by climatic variability over time. They document that China is among countries with the least environmental variability, implying that the strength of Confucianism should persist over time there. Environmental stability, combined with China's long continuous history, guarantees that Confucian values are deeply rooted in the Chinese society and are passed on over generations. This is consistent with the framework by Spolaore and Wacziarg (2013) in explaining how historically formed characteristics can be carried over intergenerationally via behavioral or symbolic transmission. Our validity tests (described in detail below) also confirm the persistence of the Confucianism across different regions in China.

To obtain data on Confucian academies, we construct a novel dataset by referring to local chronicles (*Difang Zhi*) from archives in different cities. Local chronicles documented nearly all aspects of a locality in China at the county level, including its history, geography, economy, administration, biography, and education. They were compiled by the local government and elites to describe local administrative matters and commemorate ancestors. They cover both populated and less-populated areas and have been updated ever since the twelfth century (Dennis, 2020). Thus these chronicles serve as an important source for historical information in China. Figure 3 provides a one-page snapshot of a local chronicle. A local chronicle typically includes a "school" section (*Xuexiao Zhi*) that describes the schools in the vicinity. This allows us to extract information on local Confucian academies.

<Figure 3 here>

To measure a firm's exposure to Confucianism, we proceed as follows. We first manually search for local chronicles in China from regional archives. Despite voluminous local chronicles, only those compiled during the Ming and Qing Dynasties are available for reference according to "*General Note on Chinese Local Chronicles*" by the renowned Chinese archivist Zhu Shijia (1958). When looking up local chronicles compiled in the Ming Dynasty, we found that there were missing records for several provinces, such as *Jilin* and *Heilongjiang*, as well as some autonomous regions. Hence, we choose to refer to the local chronicles compiled during the Qing Dynasty. Since the administrative regions in Qing Dynasty are different from those today, we exclude chronicles that documented information for regions beyond the borders of Mainland China. In addition, we focus on local chronicles compiled between 1796 A.D and 1840 A.D, prior to the First Opium War. The reason we choose this period is that the most comprehensive and complete chronicles are only available after 1796. We also exclude chronicles compiled in the late Qing Dynasty, during which the West established municipal authorities, schools, and judiciaries in some Chinese cities (Jia, 2014).

Next, we count the number of all Confucian academies documented in the local chronicles during the aforementioned period. In total, we obtain the information of 1,547 Confucian academies in Qing Dynasty, and their locations are based on their historical sites. Since the administrative division in the Qing Dynasty is different from that today, a city-level variable that directly records the number of Confucian academies within each city is infeasible and would introduce bias. Instead, we create a firm-level variable by counting the number of Confucian academies within a 100-kilometer radius around the firm, based on the geographical coordinates of both the firm and the school, and log-transform it to smooth distribution. Following prior studies (e.g., Hilary and Hui, 2009; Dessaint and Matray, 2017), we define a firm's location as the location of its headquarters. Information on firm headquarters is obtained from the WIND database. We further calculate the distance between the coordinates of corporate headquarters and historical Confucian academies based on the Baidu Map service.*

1.3.2 Dependent Variables

Our main dependent variables are five firm-level variables that match the core values of Confucianism and the corresponding hypotheses: (1) social contributions, (2) stakeholder protection, (3) courtesy expenses, (4) patenting, and (5) trade credit granted by other firms. Specifically, a firm's social contribution is defined as the ratio of the sum of total tax contribution, employee payments, interest expense, donations, and profit attributable to shareholders over its total assets. The data are extracted from CSMAR database, one of the most comprehensive databases for Chinese listed-firm research, and firm annual reports. This variable, to a large extent, reflects the firm's commitment to its stakeholders and society. Stakeholder protection is defined as whether the firm reports to have adopted measures to protect its employees and suppliers. The data are obtained from the firm's annual report and corporate social responsibility report. Courtesy expenses are defined as the natural logarithm of management fees after deducting total salaries of all executives, supervisors, and board directors plus one. Patenting is measured as the natural logarithm of the number of a firm's authorized patents plus one. Trade credit is defined as the sum of accounts payable and notes payable scaled by total assets. The data for the last three dependent variables also come from CSMAR database.

*Understandably, the geographical coordinates of historical Confucian academies extracted from local chronicles are not as accurate as the ones used today. Therefore, the coordinates of Confucian academies tend to be broader and fuzzier, and the same coordinate may correspond to several academies.

1.3.3 Controls

We control for firm-level covariates that might be correlated with both culture and corporate policies, including firm size (the logarithm of total assets), profitability (return of assets, ROA), leverage (debt-to-assets ratio), revenue growth, cash flow from operating activities (operating cash flows), and whether the firm is a state-owned enterprise (SOE). We further control for city-level macroeconomic variables to account for cross-regional variations in economic development, including GDP, city population, and total employee wages. All variables are defined in Appendix Table A1.* Our sample period is between 2007 and 2017, since the dependent variable, social contributions, only starts from 2007.

Table 1 presents the summary statistics of our main variables. Our sample contains 25,300 firm-year observations over the 2007–2017 period. The average number of Confucian academies around a firm (within a 100-kilometer radius) is 23. The mean (median) value of social contribution to asset ratio is 0.106 (0.095), with a standard deviation of 0.085, suggesting a significant variation in social contribution across firms. The average value of stakeholder protection is 0.329, and the standard deviation is 0.706, indicating that many listed firms do not report to have taken measures to protect their employees and suppliers. The mean and standard deviation of courtesy expenses are about 280 million and 576 million Chinese yuan (CNY) (40 million and 82 million USD), respectively. The average number and standard deviation of patents granted to a listed firm are seven and 27, while the mean value and standard deviation for trade credit to assets ratios are 0.123 and 0.098, respectively. At the city level, the average GDP is about 221 billion CNY (34 billion USD), the mean population is over 4 million, and average total employee wages are 26 billion CNY (4 billion USD).

*One may be concerned that our Confucianism measure based on the number of Confucian schools simply captures the effect of local education level—because in Ancient China, the contents of education were mostly about Confucianism and teaching was usually conducted in Confucian schools. To address this concern, we additionally control for the number of "Project 211 universities" in the firm's headquarter province to account for the local education level. Project 211 was a former project of high-level comprehensive universities and colleges initiated in 1995 by the Ministry of Education of China, with the intent of raising the research standards of high-level universities and cultivating strategies for socio-economic development. Project 211 members are regarded as the tier 1 universities in China. Our conclusions are still upheld with the inclusion of this control.

<Table 1 here>

1.3.4 Validation Test

To cross-validate that our coordinate-based measure indeed reflects time-persistent Confucian culture, we check whether there are significant cross-regional variations in people's life attitudes based on Confucian doctrines that are *not* directly related to the five virtues we test. This is essentially an out-of-sample test. To this end, we recognize that an important element of Confucianism is the importance of family and family values, which entail familial collectivism, i.e., the family, rather than individual, being viewed as the most revered societal building block (Cheng, 1944; Ip, 2009).

We first focus on old-age support, which, accordingly to Confucianism, advocates that people should support their elderly parents unconditionally. Chen et al. (2019) argue that receiving old-age support reflects the extent to which filial piety, an ethic promoted by Confucianism, can determine people's decision to have children.[*] We follow their approach and employ the family-level data from China Family Panel Studies (CFPS), which asks respondents "why do you want to have children?" to construct an index of old-age support. We then regress this self-constructed index on our coordinate-based measure of Confucianism in a province. In Column (1) of Table A2, we find that these two measures are positively correlated.

Second, we examine the regional divorce rate as another reflection of the family ethic. Confucianism advocates the importance of family and thus prioritizes keeping a family together even during difficult times, and divorce is usually viewed as a stigma for the whole family. Thus, if our coordinate-based measure indeed captures Confucian culture, it should be negatively correlated with the divorce rate in a region. We obtain divorce data at the province level between 2010 and 2017 from China National Bureau of Statistics. In Column (2) of Table A2, we find that the number

[*]The authors use survey data from China Household Finance Survey (CHFS) to calculate the proportion of respondents in a region who answer "for old-age support" in response to the question "why do you want to have children?".

of Confucian academies is negatively correlated with regional divorce rate, confirming our prior.

Third, we validate our coordinate-based measure by checking its correlation with how much a family spends on education. By employing the data from CFPS, we construct a family-level variable that measures the amount of money parents spend on children's education. If our measure captures Confucian culture, we expect it to be positively associated with educational expense. The result in Column (3) of Table A2 again confirms our prediction.

Finally, we examine the relation between our measure and the percentage of households with four generations living under the same roof in each province, constructed from the 2000 and 2010 China Population Census. Such intergenerational co-residence within a family reflects the reverence for parents and older generations, which is an important Confucian value and has been widely used in the sociology literature as a measure of filial piety (e.g., Luong, 1989; Chen et al., 2019). Hence, we expect a higher intergenerational co-habitation ratio in regions with greater Confucianism. In Column (4) of Table A2, we find that these two measures are positively correlated, consistent with our conjecture.

Collectively, these four validation tests suggest that our measure of Confucianism is indeed correlated with a region's societal norms, as prescribed by the Confucian culture. These results enhance the validity of using this measure as a proxy for a firm's exposure to Confucianism.

1.4 Main Results

1.4.1 Baseline Results

We first use an ordinary least squares (OLS) regression on our panel dataset to examine the relation between a firm's exposure to Confucian culture and its behavior. The specification is as follows:

$$Y_{i,t} = \alpha + \beta Confucianism_i + \gamma^{'} Controls_{i,t-1} + FE + \varepsilon_{i,t}$$

where the dependent variable, $Y_{i,t}$ denotes firm i's five policies described above, namely, social contribution (proxy for benevolence), stakeholder protection (proxy for righteousness), courtesy expenses (proxy for courteousness), the number of patents (proxy for wisdom), and trade credit (proxy for trustworthiness). The independent variable $Confucianism_i$, denotes a firm's exposure to Confucian culture, measured as the natural logarithm of one plus the number of Confucian academies within a 100km radius around the firm. $Controls_{i,t-1}$ denotes a set of firm- and city-level covariates as described in Section 3.3 and measured in year $t-1$. *FE* includes year fixed effects and industry fixed effects. Although our independent variable is at the firm level, it exhibits some regional clustering. Thus, we do not include location fixed effects in this regression, so that the effect of Confucianism is not absorbed by these location fixed effects. All standard errors are clustered at the city by year levels.

<Table 2 here>

We report the results of our baseline tests in Table 2, with the dependent variables in columns (1)—–(5) being the five firm-level policies, respectively. We find significant and positive coefficients of Confucianism in all five columns. This consistent result supports our hypothesis that a firm's exposure to Confucianism is strongly correlated with corporate behavior. The economic magnitudes of these effects are nontrivial. Specifically, the coefficient estimates in five columns imply that a 10% increase in the number of Confucian academies around the firm is associated with around 5 million yuan (approximately 742,500 USD) increase in the firm's social contribution, 0.6% increase in its stakeholder protection, around 920,000 yuan (approximately 136,620 USD) increase in the courtesy expenses, an increase in patent number by about 0.5%, and around 6 million yuan (approximately 891,000 USD) increase in its trade credit.

In summary, the above baseline regressions support our hypothesis that firms with a greater exposure to Confucian culture make greater social contributions, provide more protections to employees and suppliers, spend more on courtesy and etiquette, and have more intellectual output and trade credits. In other words, these firms have more robust stakeholder relationships.

Next, we conduct several robustness checks by examining other social values and employing an alternative measure for the exposure to Confucian culture.

1.4.2 Alternative Culture Measures and Specifications

In this section, we test the effects of alternative culture measures. First, one may be concerned that our results are not driven by Confucianism and instead our Confucianism variable captures the effect of religion or other prevailing cultural norms in China. It is well documented that religion also plays a critical role in individual decision-making and firm behavior (Stulz and Williamson, 2003; Kumar et al., 2011, 2016). To test this religion-based alternative explanation, we control for Buddhism and Taoism, two popular religions in China. Specifically, we employ the logarithm of the numbers of Buddhist temples and Taoist temples within 100km of the location of a firm as independent variables. In addition, to account for the influence of foreign culture and values on firm behavior, which usually happens through international trade, we additionally control for the amount of foreign direct investment (FDI) at city level to measure the extent to which a city is influenced by foreign values and norms. Panel A of Table 3 presents the result. Specifically, we run a horserace test by including both the Confucianism variable and measures for Buddhism, Taoism, FDI. We find that, after controlling for the intensity of Buddhism and Taoism as well as FDI, the effect of Confucianism is still significant for all five corporate policies. In unreported tests, when we include these three culture variables one by one into the regression, we find similar results. Therefore, the results in Panel A confirm it is Confucian culture that accounts for the differences in corporate behavior.

<Table 3 here>

Second, we use the number of Imperial Scholars (*Jinshi*) in Qing Dynasty with their hometown adjacent to a contemporary firm's headquarters as an alternative measure of the firm's exposure to Confucianism. *Jinshi* was the highest academic degree that a candidate could obtain from the civil service system of Imperial China and was typically selected for high-level government positions.

To be accredited as *Jinshi*, a candidate (usually a male) needed to attend a national examination that took place in the capital of his region, followed by a re-examination at the imperial palace to be ranked (Bai and Jia, 2016). This civil service exam system lasted for over 1,300 years in China and served as the primary channel for recruiting elites during the Ming (1368–1644) and Qing (1644–1911) Dynasties.* After becoming a *Jinshi*, the scholar would hold high-ranking civil positions and gain political and economic power. These scholars often sought to promote Confucianism by establishing Confucian schools and temples in their hometowns and providing resources for local people to study in the schools (Gu et al., 2021). In addition, families in regions where there were more *Jinshi* would be more motivated to let their children follow this career paths by enrolling in these Confucian schools.

Similar to our measure based on the number of Confucian schools, we refer to the historical documents in Qing Dynasty to measure the intensity of *Jinshi*. These documents include *A list of jinshi in Qing Dynasty, The Draft History of Qing, A List of Imperial Clan Jinshi in Qing Dynasty, The Collection of Keju Examination Papers in Qing Dynasty, and General History of Fengtian*. We manually look up the information of 25,735 *Jinshi*, such as their names and hometowns. This accounts for over 96% of the total *Jinshi* population in the Qing Dynasty. We then generate a firm-level variable, *Jinshi*, which is measured by the natural logarithm of one plus the number of *Jinshi* whose hometown is within a 100km radius around a firm's headquarters.

Panel B of Table 3 presents the result. Consistent with our prediction, the coefficients of *Jinshi* measure are all significant and share the same sign with those in our baseline analysis. Thus, our results for the effect of Confucianism are robust.

Third, one may be concerned that these results are explained by the culture of the CEO instead of the societal culture. We address this issue by replacing the original Confucianism measure with a measure of the exposure to Confucianism by the CEO of a firm (*CEO culture*). We measure *CEO culture* using the number of Confucian schools during the Qing Dynasty in the CEO's hometown or

*The central contents of the examinations were the Confucian classical texts — the "Four Books and Five Classics," which constituted the foundation of Confucianism (Elman et al., 2000). The exam thus provided powerful motivation for every family to learn Confucianism.

birthplace city (based on contemporary-day administrative division). To do so, we manually check the annual reports of each firm and the resume of each CEO in our sample for the information on their hometowns and birthplaces. In cases when such information is not available for a CEO, we use the number of Confucian schools of board chairperson's hometown or birthplace city.

Panel C of Table 3 presents the results. We find that the coefficients of *CEO culture* are not significant except the one for stakeholder protection. Hence, our results for the effect of Confucianism are unlikely to be driven by the culture of the CEO, but reflect the effect of societal cultures.

Lastly, we further control for historical economic development of a region by additionally including several proxies for key geographical and demographic characteristics in the region in Qing. Specifically, we include two variables capturing a city's distance to the coast and its average slope to capture the convenience of transportation which has been documented to be a key factor for economic prosperity in history. *Distance to coast* is measured as the (logged) distance between a city's centroid to the closest point of the coast. *Slope* is measured by matching CHGIS V4 DEM with city boundary in 2017 and calculating the average slope within each city. We further include two province-level variables that capture a region's population density and urbanization. *Population density* is calculated as the average population density among 1776, 1820, 1851, and 1910 (from early to late Qing), and *Urbanization* is calculated as the ratio of the urban extent area size in 1866 over the provincial area size. The detailed definitions are provided in Appendix 1, and the results are shown in Panel D of Table 3. The coefficients of Confucianism measure are still all significantly positive and quantitatively similar to our baseline results.

1.4.3 Instrumental Variable Analysis

Despite our efforts at controlling for various firm- and city-specific covariates and ruling out the potential effects of other cultural values, one may still be concerned that Confucian schools were established in regions with better economic conditions during the Qing Dynasty and that this pattern of development has endured until today. In addition, there may be unobservable factors that are correlated with both the strength of Confucianism in a region and corporate behavior. In this section, we follow the literature and use two geography-based instrumental variables to address these concerns.

The first IV is the shortest distance between a listed firm's headquarters and the nearest Zhu Xi Academy. Zhu Xi Academies are prestigious schools established by Zhu Xi (also spelled "Chu Hsi"), the renowned Confucian scholar in the Song Dynasty (1130—1200 A.D) and arguably the third most influential Confucian philosopher after Confucius (551–479 B.C.) and Mencius (372–289 B.C.) (Chan, 1989). He spread, promoted, and popularized the Confucian way of life at the grassroots level in China from the 12th century onward (Chen et al., 2022). His commentaries on the "Four Books," the Confucian classical texts that constituted the foundation of Confucianism (Elman et al., 2000), provided the standard interpretation of those texts for the next several hundred years (Gardner, 2007). The three academies he established (referred to as *Zhu Xi Academies*) are *Yuelu* Academy in *Changsha*, *Hunan* province; *Hanquan* Academy in *Jianyang*, *Fujian* province; and *White Deer Grotto* Academy in *Jiujiang*, *Jiangxi* province. These *Zhu Xi Academies* became the prototypes of Confucian academies across China.

The rationale of this IV is that, during the Song dynasty, Zhu Xi frequently gave lectures on his version of Confucianism at these three academies. He also invited other Confucian scholars to lecture to his students, and most of them were from prefectures close to these academies (Chan, 1982). In addition, Zhu Xi's disciples spread his teachings across several regions and compiled commentaries on Confucianism, which became required material in the imperial civil examination, which further helped spread Confucian cultures. Meanwhile, the high cost of transport and communication in that period prevented people in regions far from these scholars' academies from following their doctrine (Chen et al., 2022). Thus, regions near *Zhu Xi Academies* were more exposed to his influence and Confucian culture in the Song period, and this pattern persisted for hundreds of years and inspired local squires in latter periods (including in Qing) to build Confucian schools. Figure 4 shows the clustering of Confucian schools surrounding the coordinates of the three *Zhu Xi Academies*, with bigger circles indicating more Confucian schools at the same locations.

<Figure 4 here>

A valid IV must also satisfy the exclusion restriction. To this end, we argue that a region's distance to *Zhu Xi Academies* is orthogonal to economic development in both the Song era and today. In particular, the location of these academies was not driven by economic considerations. Indeed, *Zhu Xi Academies* were not located in economic centers or undeveloped areas (Chen et al., 2022). Their locations instead were decided by random factors. Specifically, Zhu Xi's mother was buried in *Jianyang*, *Fujian*. Confucian mourning rituals required a son to stay near the mother's tomb for at least one year (Liu, 2006). Zhu Xi resided there for over 10 years and established *Hanquan* Academy. Later he rebuilt the *White Deer Grotto* Academy in *Jiujiang*, after he was appointed as the prefect of the region. In 1193, he was appointed as the governor of relief in *Changsha*, *Hunan*, where he lectured at *Yuelu* academy.

Many economic historians have documented a discontinuity in economic development in China between the Song (1127 A.D.—1279 A.D.) and Qing (1644 A.D—1911 A.D) dynasties as well as between Imperial and Modern China. This discontinuity is largely driven by dramatic changes in resource bases, farming technology, peasant wealth, silver's purchasing power, and exogenous shocks, such as wars and natural disasters (e.g., Perkins et al., 1969; Brandt et al., 2014; Deng, 2015). Anecdotal evidence also shows that the regional economic development in ancient China differed from that in modern times. For example, van der Speenkel (1953) documents a gain of population in northern, western, and southwestern provinces of China and a loss of population in southern and southeastern China during the Ming, the dynasty preceding the Qing. As population growth is a common measure of long-term development (e.g., Acemoglu et al., 2002; Jia, 2014), this population change to some extent reflects that the economic activity in the southern and southeastern parts of ancient China could not sustain a stable population. However, this pattern has reversed in recent decades.* This evidence further suggests that the location of the *Zhu Xi*

*For example, You et al. (2021) find a negative population growth in northeast China in the past decade. Meanwhile, it is documented that three northern provinces, Hebei, Henan, and Shandong, accounted for 30% of

Academies is unlikely to be correlated with regional economic development today.

Our second IV is the number of small rivers with drainage areas above 10,000 square kilometers in the province where a firm is headquartered. The rationale is that small rivers posed significant threats of flooding to local schools and would have ruined books in the ancient China (Glomb et al., 2020) but did not provide much of a transportation advantage, which is inconsistent with the risk aversion doctrine of Confucianism (Chen et al., 2022). The location choice of Confucian academies usually follows the principles of solitude, quietness, and purity of nature (Gilgan, 2022), crucial factors in providing a peaceful environment for education. Thus, most academies were not built near rivers—around which most cities were built—but were instead located in secluded mountainous areas away from cities (Wu, 2005). As a result, Confucian schools were usually established in areas distant from non-major rivers. Therefore, we expect there to be fewer Confucian schools in regions with greater river coverage.

Meanwhile, this geographical factor is unlikely to affect contemporary firm policies directly or through other channels after controlling for local economic development. For example, Chen et al. (2020) argue that the number of small rivers is not associated with agricultural suitability for most common crops in China, which has a significant effect on population growth, social conflict, and economic activity. Although communities next to major rivers (such as Yangtze River and Yellow River) usually enjoy reduced transportation costs and more trade, this would not have been the case for those next to "small rivers," which do not bring the same transportation advantages (Bai and Jia, 2016). Nevertheless, we explicitly control for local economic development in the IV analysis to further alleviate this concern. In unreported tests we also use the total length of all rivers in a city as an alternative IV, which carries the same logic, and find similar results except for the coefficient of Courtesy Expenses being insignificant in the second stage.

We include the same set of control variables in our two-stage IV regressions. Table 4 presents the results, with Panel A using the shortest distance between a listed firm's headquarter and the nearest *Zhu Xi Academy* (*Distance to Zhu Xi Academy*) as the IV and Panel B using Number of

total land tax income, the most important type of tax in ancient times, during the Ming (Liang, 2008) but only 13% of total tax income as of 2018, according to the National Statistical Bureau.

Small Rivers as the IV. The first-stage results are shown in Column (1), and the second-stage results are shown in Columns (2)—(6) in both panels. The coefficients of the two IVs in the first stage are both negative and significant, suggesting that a firm's distance to a *Zhu Xi Academy* and the number of small rivers in the region are negatively associated with our firm-level Confucianism measure. These results are consistent with the notion that Confucian schools tend to be established closer to the centers of Confucian influence and away from rivers. In Columns (2)—(6) of Panels A and B, the coefficients on Confucianism are all positive and statistically significant, suggesting that a firm's exposure to Confucian culture is significantly and positively associated with its five corporate policies, again consistent with the baseline results.

<Table 4 here>

As a further robustness test, we use the regional death toll during the Taiping Rebellion as an alternative IV. The rebellion was a revolt by peasant rebels against the Qing Dynasty and one of the largest civil wars in world history. The rebellion advocated social reforms and the replacement of Confucianism with a form of Christianity, and was opposed by Confucian scholars as it challenged Chinese traditions. The turmoil and atrocities of the revolt left a strong imprint on the collective memories of people in affected areas over generations, making them cherish Confucian values more (Wright, 1962; Chen and Kung, 2020). In addition, massive reconstruction and restoration of schools in the affected regions after the war also strengthened local Confucian culture (Wooldridge, 2009). Appendix 3 provides more details on the setting, and results in Table A3 again confirm the effects of Confucianism on the five corporate policies.

1.5 Exploring Channels

We next explore several channels through which Confucianism at the societal level can influence firm-level behavior. Our earlier results indicate that CEO's culture is unlikely to explain the effect of Confucianism. In this section, we investigate the potential mechanisms more systematically. We argue that culture as an important informal institution can interact with other formal and informal institutions in shaping corporate behavior.[*] Societal culture can also directly influence the decision-makers of the firm. Specifically, we examine how the effects of Confucianism vary based on a firm's interaction with market participants, local politicians' ideology against Confucianism, and the cultural composition of the corporate board.

1.5.1 Interaction with Market Participants

We first examine whether the effects of Confucianism on corporate policies depends on the market orientation of the local economy, an important formal institution that allows firms to interact with various participants such as governments, financial institutions, suppliers and customers, product markets, lawyers and courts (North, 1990; Khanna and Palepu, 1997). Meanwhile, several seminal studies have shown that informal institutions, such as trust, a key element of culture, can substitute for market development and other formal institutions (e.g., Williamson, 2000; Guiso et al., 2004; Aghion et al., 2010; Pevzner et al., 2015). Therefore, we conjecture that the effect of Confucianism on firms is weaker in regions with stronger market orientation.

We use the marketization index for 31 Chinese provinces from Fan et al. (2011), which has been updated annually. This index captures the development of market systems via five aspects, including the relationship between government and the market, the development of private sector, the development of product markets, the development of factor markets, and the development of market intermediaries as well as the market-friendly legal environment (Fan et al., 2011). We partition our sample into high and low market-orientation groups based on whether the marketization index score for the focal province in each year belongs to the top or the bottom tercile. The results for high (low) market-orientation group are presented in of Table 5. We find that the effect of Confucianism is significant for all five corporate policies for firms in low marketization regions, while this is not the case for the high market-orientation group. These results suggest that Confucianism substitutes formal rules in influencing firm behavior, as alluded

[*] North (1990) classifies institutions into informal ones (sanctions, taboos, customs, traditions, and codes of conduct) and formal ones (constitutions, laws, property rights) and argues that formal and informal institutions usually interact in shaping economic activities. According to North's definitions, the Confucian culture in our context can be considered as an informal institution.

in our conceptual framework. In other words, the effect of Confucianism mainly take place when the formal institutions are lacking and firms rely more on trust when interacting with market participants, consistent with (Chen et al., 2022).

<Table 5 here>

1.5.2 Politicians' Ideology

We next investigate how the effects of Confucianism interact with the ideology of local politicians who wield their enormous regulatory power to govern firm behaviors. In particular, we identify a city leader's ideology with regard to Confucianism. To this end, we exploit a drastic change in Chinese political ideology in 1978, the transition from Mao's ideology to Deng's. During the Cultural Revolution, Mao's 10-year political and ideological campaign, which lasted until he died in 1976,[*] there were continuous efforts to eradicate traditional habits and attitudes, which were viewed as harmful to social development (Goldman, 1975). Mao launched repeated campaigns against Confucianism, which was thought to be the root of those habits and attitudes (Gold, 1985). Following Mao's death, Deng emerged as the dominant figure among the pragmatists in the Chinese leadership, and set out on nationwide economic reforms which no longer attach a social stigma to Confucianism.

Almost all major government officials in China are members of the Communist Party of China (CPC), and they usually receive intensive indoctrination upon joining the CPC. As a result, regional political leaders may have adopted strikingly different ideologies, depending on when they joined the CPC (Liang et al., 2022). We expect that politicians who joined during Mao's regime would be more likely to adopt Mao's ideology that is strongly against Confucianism, and that politicians who joined during Deng's regime would be less likely to adopt such an anti-Confucianism view, conditional on them having the same age.

[*]Mao's ideology did not fade immediately upon his death. In 1976, the "Gang of Four," jockeyed for power, continuing abusing Mao's ideology. In 1977, Hua Guofeng, the president then, published the so-called "Two Whatevers" propaganda campaign: Whatever Mao had said and whatever Mao had done should be treated as a binding precedent.

We conjecture that the effect of Confucianism on corporate policies should be less pronounced in cities with *Maoist* leaders. To capture a clean interaction effect, we split the sample based on whether the CPC secretary of the city (who is the top leader of the city) where a firm is headquartered joined the CPC before 1976 (*Maoist* leaders) or after 1979 (*Dengist* leaders) and run our baseline regression with the age of city secretary as an additional variable on the two subsamples, separately. The results in Table 6 confirm our conjecture. Across all specifications, the effect of Confucianism is significantly positive in the subsample of city secretaries who joined the CPC after 1979. In contrast, for the subsample of city secretaries who joined the CPC before 1976, the coefficients of Confucianism are mostly negative or insignificant. These results suggest that the effects of Confucianism on firms depend on the ideology of local politicians, possibly through imposing regulatory constraints and providing preferential treatments.

<**Table 6 here**>

1.5.3 Board of Directors

Finally, we examine how the effect of Confucian culture take place through influencing the key decision-making body of a firm, namely the board of directors. Specifically, we argue that Confucianism is more likely to shape the behavior of a firm when its directors are unanimously inherited with Confucian values, and identify firms in which there is at least one foreign director and those with all Chinese board members. Foreign directors are more likely to carry non-Confucian values, due to growing up in different places and inheriting the values of their home countries. The incongruence of their cultural backgrounds with that of Chinese directors would attenuate the effect of Confucianism on corporate policies. Therefore, we expect the effect of Confucianism to be stronger in firms with all-Chinese directors.

We report the results in Table 7. We partition our sample into two groups based on the composition of the board (i.e., whether the board consists of non-Chinese directors). The results show little correlation between Confucianism and corporate policies for the subsample of firms with foreign directors. The sign of the only significant coefficient on Confucianism for this subsample is even negative in column (3). However, all coefficients on Confucianism are significantly positive for the subsample of firms with only Chinese directors on board. This finding highlights that the importance of directors in explaining the cultural effect on firms.

<Table 7 here>

1.6 Culture and Firm Performance

We have shown that Confucianism has enduring and systematic influences on corporate behavior across China. A natural question is whether such culture-biased corporate behavior has value implications. In this section, we investigate whether differences in corporate behavior shaped by Confucianism persistently impact firm performance, such as profitability, growth, and stakeholder engagement, as well as the underlying mechanisms. Our conceptual framework posits that a strong trust-based societal culture can both help firms gain more stakeholder supports, and substitute formal rules, undermining stakeholder trusts. As a result, the net effect of societal culture on firm performance is unclear. It is also not entirely straightforward whether culture-induced behavioral differences would indeed translate into performance differences, as underperforming firms may already be out of the market in the long run due to the competition.

We study performance by employing a two-stage regression approach. We first regress a firm's policies—social contribution, stakeholder protection, courtesy expenses, the number of patents, and trade credit—on our Confucianism measure and get the "predicted" values of firm policies from the regression. We next construct a model relating three corporate performance measures—return on equity (ROE), operating profit growth, and CSR performance—to these "predicted" values of firm policies. This two-stage regression allows us to examine how Confucianism affects firm performance through its impact on firm policies. In both regressions, we keep the same set of control variables and fixed effects as in the previous baseline regressions. The regression model is specified as follows.

$$Policy_{i,t} = \alpha + \beta Confucianism_i + \gamma' Controls_{i,t} + FE + \varepsilon_{i,t}$$

$$Performance_{i,t+1} = \alpha + \beta \widehat{Policy}_{i,t} + \gamma' Controls_{i,t} + FE + \varepsilon_{i,t}$$

We also run a reduced-form regression in which the independent variable is our proxy for Confucian culture and the dependent variable is the corporate performance proxy. The estimates from this reduced-form approach reflect the overall impact of Confucianism on firm performance. The model is constructed as follows.

$$Performance_{i,t+1} = \alpha + \beta Confucianism_i + \gamma' Controls_{i,t} + FE + \iota_{i,t}$$

Table 8 reports the results. In Panel A, the dependent variable is ROE. We find that each of these five corporate policies is positively associated with a firm's ROE. In Column (6), the estimate from reduced-form still shows a positive correlation between Confucianism and ROE. Similarly, the results in Panel B show that there is a significantly positive relation between Confucianism and a firm growth. In Panel C of Table 8, the dependent variable is CSR score of a listed firm, which aims to capture the firm's stakeholder welfare. The data on firm-level CSR score is extracted from *Hexun.com*, a leading professional financial website and CSR rating provider in China. Again, the coefficients in all columns are significantly positive, consistent with the notion that Confucianism calls for virtuous behavior toward others. It is important to note that these results should be interpreted as the *net effect* of Confucianism on firm performance, taking into account both stakeholder supports and expropriation risks. On balance, the value implications of Confucianism appear to be positive.

<Table 8 here>

A key mechanism through which a societal culture that values stakeholder trusts can enhance firm value in our conceptual framework is by reducing the firm's cost of capital. In our context, firms with more exposure of Confucianism gain more stakeholder trusts and supports, which translate into lower cost of acquiring valuable stakeholder resources such as financial and human capitals. In other words, investors are more willing to finance and employees are more willing to work at firms with stronger Confucian culture. For the latter, trust can alleviate moral hazard problem and improve employees' satisfaction with their firms, leading to less turnover and greater productivity (Edmans, 2011; Guiso et al., 2015). We therefore examine whether firms more exposed to Confucianism have lower cost of capital and employee turnover (or greater employee growth).

To this end, we first follow Cline et al. (2014) and calculate a firm's cost of external financing by estimating its weighted average cost of capital (WACC). To avoid negative market risk premium, we extract equity premium from Damodaran (2019). Beta is estimated using daily stock returns of the previous twelve months and market returns. The exact definition and calculation of this variable are described in Table A1. The results in Columns (1)-(6) of Panel D show that the coefficients of the five firm-level policy variables as well as the Confucianism measure are all significantly negative, indicating that the cost of capital is indeed lower for firms with greater exposure to Confucian culture.

Second, we measure employee growth as the percentage change in a firm's total number of employees over a year, and consider it as a proxy for employee support, as greater employee satisfaction usually implies greater retention and growing workforce to support firm growth. The dependent variable in Panel E is therefore Employee Growth, and we find the coefficients on the five firm-level policy variables as well as the Confucianism measure in this regression are all positive and significant, consistent with our conjecture.

1.7 Post-Hoc Results

We have conducted several post-hoc tests to further demonstrate the enduring impact of Confucian culture on Chinese firms. In addition to the five core virtues (*Wuchang*), Confucianism also advocates other ethical standards and values, such as the "Three Cardinal Guides" (Sangang): ruler guides subject, father guides son, and husband guides wife. Therefore, in this section, we investigate how these additional values of Confucian culture affect other types of corporate behavior.

First, Confucianism emphasizes ruler–subject loyalty and filial piety, which indicate the acceptance of hierarchy. We match this norm to the firm-level hierarchical structure by examining the effect of Confucianism on board hierarchy. A unique feature of corporate board structure in China is that, unlike in the United States, where firms usually list their directors alphabetically on the board roster, many Chinese firms list directors according to their relative power in the company (Zhu et al., 2016). Directors with more power and longer tenure are more respected and thus listed at the top. Independent directors are usually placed behind executive directors in such hierarchical culture. In order words, firms that value hierarchy would not alphabetically list their directors on the roster. Following Zhu et al. (2016), we construct a dummy variable that equals 1 if all the firm's independent directors are placed at the bottom of the director list (that is, not in alphabetical order) and 0 otherwise. We then regress this dummy variable on our Confucianism measure as well as all the control variables and fixed effects. The results are reported in Column (1) of Panel A of Table 9. The coefficient of Confucianism is significantly positive, indicating that firms with greater exposure to Confucianism are more likely to list their independent directors at the bottom and thus are more hierarchical.

<Table 9 here>

Second, Confucianism emphasizes on male superiority and supports patriarchy by belittling the role of women.* It clearly specifies gender roles in society: women should stay at home and do housework to support their husbands and children, while men should work outside the home to feed the family. To test how such patriarchal culture influences firms, we focus on board gender diversity. We expect that firms with greater exposure to Confucianism have fewer female directors and thus less gender diversity. We show the results of regressing measures of board female representation on Confucianism and other control variables and fixed effects in Columns

*The Three Obediences and Four Virtues (*San Chong Si De*) are the ethical codes for women proposed by Confucianism. The Three Obediences require women to obey the father before marriage, obey the husband after marriage, and obey the first son after the death of husband. The Four Virtues are (sexual) morality, proper speech, modest manner, and diligent domestic work.

(2)–(4). The dependent variable is the ratio of female board directors in Column (2), an indicator of whether there is at least one female director in Column (3), and the Blau index, which captures the gender diversity on board in Column (4). Specifically, the Blau index is calculated as:

$$Blau = 1 - \sum_i P_i^2$$

Where P_i refers to the percentage of female or male board members (Blau, 1977). We find that the coefficients of Confucianism are all significantly negative, indicating that firms' with greater exposure to Confucianism have lower female representation on board.

As a further post-hoc test, we recognize that Confucianism also advocates the development of "preparedness for the unexpected and hardship," which stresses the importance of having consciousness of uncertainty and taking precautions. To test whether firms with greater exposure to Confucianism are more likely to have precautionary policies, we examine a firm's cash holdings when facing future uncertainty. A large literature has documented that firms may hold excess cash as a buffer for unexpected shocks (e.g., Kim et al., 1998; Opler et al., 1999; Bates et al., 2009). In particular, firms could hold cash to better cope with adverse shocks when there is the risk of a liquidity shortage (Acharya et al., 2012), such as exposure to natural disasters. To this end, we follow Dessaint and Matray (2017) and adopt a difference-in-difference identification approach using earthquakes as adverse shocks to firms' operations. Since the saliency and influence of an earthquake are magnified by its proximity, we can rely on a natural experiment framework by leveraging the distance between a firm and the epicenter of an earthquake. Appendix 4 describes our empirical setting and results for testing the precautionary cash holdings motive, and we again find strong support for the effects of Confucianism.

1.8 Conclusion

Culture as a critical informal institution has drawn significant interest from economic and business researchers. Studies mainly focus on cross-country differences in cultural values to investigate the effect of societal culture on national outcomes such as economic development. However, little is known about the impact of societal culture on firms, which lie at the center of the economic activities. In this paper, we develop a conceptual framework for how trust-based societal culture can help a firm gain supports from its key stakeholders but also posit an expropriation risk by the entrepreneur, which can either lower or raise transaction costs, with different implications for firm value and overall stakeholder welfare. Employing a granular measure of a firm's exposure to a culture that persists over a long history, this paper examines the role of societal culture in shaping business activities through influencing corporate policies. Specifically, we exploit the Chinese setting and leverage a unique dataset of Confucian academies established in the Qing Dynasty to construct a firm-level variable to measure corporate exposure to Confucianism. Using this firm-level measure, we find that firms more influenced by Confucianism make more social contributions, provide greater stakeholder protection, spend more on courtesy and etiquette, and have more patents and trade credits. These five firm-level policies and outcomes match with the five core virtues of Confucianism that are all related to trust with stakeholders: benevolence (*Ren*), righteousness (*Yi*), courteousness (*Li*), wisdom (*Zhi*), and trustworthiness (*Xin*).

The above findings survive a battery of robustness checks and are upheld by an instrumental variable approach. We also find the effects of Confucianism are likely to be transmitted to firms through influencing a firm's interaction with market participants, local politicians' attitudes, and the value of directors. Finally, we find that firms with greater exposure to Confucianism have higher returns on equity, greater operating profit growth, and higher CSR scores, as a result of lowered cost of capital and workforce growth. The latter findings are consistent with the notion that the net effect of trust-based culture is positive, taking into account both stakeholder support and expropriation risk by the entrepreneur.

Collectively, our findings suggest a more systematic but also nuanced view on the effects of societal culture on firms, which differs from corporate culture and other well-documented survey evidence. One cannot fully grasp the broader implications of culture on the economy and society at large without understanding its firm-level channels. Moreover, the cultural effect on firms and the economy has its boundary, as it interacts with other institutions, and policy design should take into account of such institutional complexity to enhance both shareholder value and stakeholder welfare.

Chapter 2

Accounting for Carbon Earnings Risks*

Climate change poses severe challenges to businesses and society at large. While a large literature has documented the significant price effect of climate risks across a number of asset classes, there is limited understanding of how significant such climate risks are for firms in terms of affecting their financial statements, and how firms response to such risks. In this study, we use newly available data on firms' exposure to climate risks—especially transition risks due to regulatory pressures, technological innovation, and changing consumer and investor preferences—to study their magnitudes in terms of affecting a firm's earnings and policies. We find carbon earnings risks can be substantial and vary significantly across countries, industries, different scenarios and time horizons. We also find that firms with greater carbon earnings risks have more environmental innovation, more negative discretionary accruals, and engage in more outsourcing.

2.1 Introduction

It has been scientifically proved and widely accepted that the world is facing climate change risks which are caused by human activities and can have catastrophic consequences for both lives and the economy (e.g. Burke et al., 2015; Hong et al., 2020; Shive and Forster, 2020). The importance and urgency of addressing climate-related risks and combating climate change call for coordinated

*This is a joint work with Hao LIANG.

efforts across the world (United Nations, 2015). On December 12, 2015, 196 parties represented by global leaders signed the Paris Agreement, which is a legally binding international treaty on climate change, with the goal of limiting global warming to well below 2, preferably to 1.5 degrees Celsius, compared to the pre-industry level. The Paris Agreement sets forth ambitious targets under different scenarios based on scientific estimations and pathways to achieve these targets. Countries submitted their plans for climate action (known as "nationally determined contributions", or NDCs), including policies, regulations, financing mechanisms, technology development, and capacity-building.

The climate change risks, as well as the mitigation actions, can have significant implications for corporations, which are at the center of economic activities that contribute most to global warming. These effects are usually classified into physical risks and transition risks. Physical risks refer to risks of the direct impairment of productive assets resulting from climate change. Transition risks refer to risks related to the process of adjustment towards a low-carbon economy, which can be further broken down into policy and legal risks, technology risks, market risks, and reputation risks. The latter may include, for example, the costs the energy industry faces in developing clean/low-carbon technologies, and reduction in the value of investments in carbon-heavy industries. Numerous studies have investigated how these physical and transition risks can affect firm value (e.g. Hong et al., 2019; Choi et al., 2020; Bolton and Kacperczyk, 2021a). However, most of these studies focus primarily on the discount rate channel, namely how climate change risks can affect a firm's cost of capital, usually through affecting the perceived risks by investors and demand by institutional investors, especially those with strong ESG preference. While the importance for companies to take into account of climate-related risks is widely recognized, this cash flow channel, i.e., how climate change can affect firms' future earnings and cash flows, remains underexplored in the literature.

The scarcity of research on the cash flow channel of climate change risk is partially due to data limitation, as existing data mainly measure a firm's climate-related actions and risks based on the natural units of their carbon emissions (e.g., in tons) or ESG ratings. These measures, while useful for comparing firms' carbon earnings risks and commitment to reducing GHG emissions ex post, fail to capture how a firm's future earnings and cash flows are affected by climate change based on different scenarios ex ante. If such "carbon earnings risks" are not properly priced and integrated in a firm's financial statements, they may not be well taken into account in managers' decision-making.

In this paper, we utilize a novel dataset on firm-level carbon earnings risks—especially those induced by transition risks—measured in monetary terms for publicly listed firms around the world to evaluate the extent to which carbon earnings risks affect a firm's earnings and behavior. In particular, the measure quantifies the potential impact to a company's earnings today if it has to pay a future price for its greenhouse gas (GHG) emissions based on estimations. Our starting point is to highlight the importance of using a monetary value of carbon earnings risks. To this end, we first quantify the magnitude of carbon earnings risks in relation to a firm's total earnings based on different scenario estimations for different future time horizons, and examine how such magnitude varies across regions and industries. We find that firm-level carbon earnings risks can be substantial, which on average would account for 5% (23%) of a firm's current EBITDA in 2025 (2050). If the government takes all possible measures to limit climate change to 2°C by 2100, carbon earnings risks will account for more than 8% (32%) of a firm's current EBITDA by 2025 (2050). We validate our measures with other firm-level carbon emission and climate risk exposure measures. The proportion of a firm's earnings that are subject to carbon risks varies significantly by industry and country to an extent much larger than that of other measures. Carbon earnings risks are highest among utilities and airlines companies, and in countries with great exposure to chemical and mining industries, such as Russia, Chile, and Colombia. We also find significant variations of such monetized carbon earnings risks across different scenarios based on scientific projections. These scenarios include low-, medium- and high-level of carbon costs to the firm. For completeness, we also report physical risk scores, which can be broken down into various climate-induced disasters such as cold wave, flood, heatwave, sea level rise, water stress and wildfire, and are projected for the years of 2020 (past), 2030, and 2050.

We then examine how firms respond to such carbon earnings risks. Specifically, we focus on three firm-level polices: green innovation, earnings management, and outsourcing behavior. First, firms facing increasing costs of using pollution-intensive resources and technologies are incentivized to lower pollution abatement expenditures and develop new technologies using renewable energies (Brunnermeier and Cohen, 2003). Such effort in green innovation represents a central aspect of organizational knowledge in the area of environmental technologies, which not only increases environmental performance but also has a potential to affect the entire trajectory of corporate innovation (Carrión-Flores and Innes, 2010; Aghion et al., 2010). It can potentially generate positive externalities and facilitate the adoption and diffusion of environmental technologies at broader levels through knowledge spillovers (Amore and Bennedsen, 2016). Since firms facing greater climate risks are more likely to receive pressure from governments and pay potential heightened regulatory costs, we conjecture that there is positive relation between a firm's exposure to climate risk and its green innovation.

Second, firms face great policy uncertainty related to climate change in recent years, which may cause large fluctuations in corporate earnings. For example, there are potential large write-downs, devaluations and conversion to liabilities due to both physical risks (e.g., destruction of plants from storms and floods, e.g., Labatt and White (2011)) and transition risks (e.g., stranded assets due to regulatory pressure and changing technology and consumer preferences, Giglio et al. (2021b)). In addition, the increasing pressure from governments on environmental issues may induce potential liability for firms, including clean-up costs for remediation of toxic sites (Akey and Appel, 2021). Hence, the climate risk-induced earnings volatility may result in several potentially negative consequences (Francis et al., 2004; Graham et al., 2005; Borghesi et al., 2014). Specifically, unstable earnings will harm managers' compensation and career (Graham et al., 2005), and will increase the perceived bankruptcy probability of the firm and thus its borrowing cost (Trueman and Titman, 1988). These all lead to a strong incentive of managers to manipulate earnings. In this sense, firms with greater carbon earnings risks face larger policy and environmental uncertainty and, hence, are more incentivized to engage in earnings management.

Therefore, we predict that a firm's greater carbon earnings risks leads the management to engage more in earnings management.

Third, when facing significant regulatory pressures on restricting carbon emissions, firms would have a strong incentive to outsource its production in order to avoid costly regulatory penalties—in both positive and negative ways. The product manufacturing process generates most of firms' greenhouse gas and emits different toxic chemicals, which are strictly regulated and scrutinized by authorities such as the U.S. Environmental Protection Agency (Xu and Kim, 2022). As climate-related regulations are fragmented across the countries and regions, there lacks sufficient coordination regarding how they are designed and implemented, which leads firms to strategically reallocate their production and emission across different regions (Ben-David et al., 2021; Bartram et al., 2022). Moreover, this also enables firms to outsource production activities (and carbon emission) to foreign business partners and suppliers from countries with less stringent environmental policies. Outsourcing not only helps firms focus on the more profitable parts of the production (Fu et al., 2019), but also serves as a less costly and faster strategy to reduce their carbon footprints (Dai et al., 2021). Hence, we hypothesize that firms exposed to greater climate risks engage in more outsourcing activities, which induces the direct emission reduction to cater to environmentally-conscious investors and consumers. Our analyses indeed show that firms with greater carbon earnings risks have more green innovations, higher discretionary accruals, and more carbon emissions from foreign suppliers, consistent with our conjectures.

While we have established a significant association between firms' carbon earnings risks and corporate policies, our causal inferences of this link may be subject to endogeneity concerns. For example, there may be unobservable heterogeneities across firms, sectors, and countries that jointly determine a firm's transition risks and its climate actions. To circumvent this problem, we employ an instrumental variable (IV) approach. Specifically, we use whether the country where a firm is headquartered has implemented emission trading scheme (ETS) or adopted a carbon tax as an instrumental variable for the firm's carbon earnings risks. Emission trading scheme is an approach to limit climate change by creating a market with limited allowances for emissions, whereas carbon taxes by the government directly put a price on greenhouse gas emissions produced by companies. In this way, the adoption of either emission trading scheme or a carbon tax will significantly increase the future price of carbon emission as governments impose tighter emission cap and firms face less supply of emission credits. Meanwhile, the adoptions of both policies are not firms' choices but are determined by governments. However, due to the fact that, in our sample, outsourcing activities are largely restricted to US firms, the country-level instrumental variable is not applicable to testing the relation between carbon earnings risks and outsourcing activity. Therefore, we use an alternative IV, which is the number of disasters associated with climate change (such as drought and flood) in the state where the firm is headquartered in the past 3 to 10 years. The rationale is that local people will form and revise their belief on climate change after experiencing climate-related disasters (Choi et al., 2020; Hsu et al., 2020). These disasters, while bringing physical risks faced by local community, do not happen with systematic patterns and are largely random. However, they would significant change local people's perception about the potential impacts of climate change thus their behavior. For example, more climate-conscious consumers may boycott products with greater carbon footprints, and green investors may sell stocks of carbon-intensive firms. Such increasing climate consciousness would lead to heightened estimated costs of a firm's transition risks. We therefore expect a positive relation between a firm's carbon earnings risks and the number of local climate-related disasters. To mitigate the concerns that climate-related disasters would impact firms' operation directly (the physical risk channel, which may violate exclusion restrictions), we exclude from our sample firms which experience climate-related disasters during the recent past three years. The IV results further confirm our hypothesis that firms do respond to their carbon earnings risks.

We further explore the cross-sectional variation in the effect of firms' carbon earnings risks on corporate policies. First, we focus on how corporate governance will affect the effect of climate risks exposure on corporate policies. We find that the baseline effect for environmental innovation and outsourcing is concentrated in firms with strong governance. The effects on discretionary accruals are present for firms with both strong and weak governance, which may suggest that our results are not purely driven by agency problem. Second, we examine whether the competitive environment faced by a firm affects how it responds to its carbon earnings risks. More fierce competition is associated with greater potential future cash flows variations and leads to some long-term projects, such as technological pollution abatement, being suspended if adverse shocks to future cash flows occur (Gu, 2016). We find that firms in countries or industries with high market concentration have better green innovation performance and engage in more outsourcing activities, while firms facing higher competition will response by engaging in earnings management, which is less costly compared to the other two policies. In sum, our cross-sectional analysis suggests that environmental policies are not mutually exclusive, and firms will actively select different policies in response to climate risks.

Two guideposts can be used to place our paper in the literature. First, our work is related to the growing climate finance literature. Extant studies mainly focus on whether financial markets can anticipate and efficiently price risks associated with climate change (Bolton and Kacperczyk, 2021a,b; Giglio et al., 2021a). Given investors' concerns of climate risk in the investment process (Krueger et al., 2020; Alok et al., 2020), firms with greater carbon emissions are usually valued at a discount (e.g. Bolton and Kacperczyk, 2021a; Choi et al., 2020). In addition, counties with greater exposures to climate-related risks pay more in underwriting fees and initial yields to issue long-term municipal bonds (Painter, 2020), and houses in a flood zone generally trade at a premium compared with otherwise similar properties (Giglio et al., 2021a). Other recent studies examine whether and how institutional investors react to climate risk. The long-term, larger, and ESG-oriented institutions tend to engage with their portfolio firms on climate risk matters (Krueger et al., 2020; Azar et al., 2021), which leads to a positive correlation between institutional ownership and corporate environmental performance (Dyck et al., 2019). However, how firms' earnings are affected by climate change and how firms respond to such carbon earnings risks receive far less attention in the literature. The limited studies on firm reactions (e.g. Li et al., 2020; Ben-David et al., 2021; Bartram et al., 2022; Dai et al., 2021) document that firms respond to localized climate-related pressures and regulations by shifting production and emissions to other states and overseas.

Li et al. (2020) additionally find that firms facing significant transition risks tend to have more capital expenditures and increase employment. Our work complements this strand of literature on the effect of climate risks on corporate policies by providing more comprehensive evidence on the motivation of corporate reaction, driven by material carbon earnings risks that are reflected on a firm's financials.

Second, and perhaps more importantly, we add to the growing literature on measuring climate risk exposure at the firm level, which remains an important yet underexplored question in both academic and professional areas. Previous studies mainly use firms' own carbon emissions or ESG ratings as the proxy for climate risk exposure (e.g. Bolton and Kacperczyk, 2021a; Engle et al., 2020; Bartram et al., 2022; Dai et al., 2021) and self-constructed climate risk measure using earnings call data (Sautner et al., 2022; Li et al., 2020). Some other studies employ text-based measures using companies' filed documents, board minutes, and earnings calls. Our measure differs from that in previous research in several respects. First, traditional measures are mostly based on a firm's own carbon emission, rather than carbon earnings risks. Our measure takes into account how a firm's operations and earnings can be directly and indirectly affected by both physical and transition risks, including extreme weathers, regulatory pressures, and shift in consumer preference. Second, while the measure used in the extant literature is in the natural units of GHG emissions over a certain period, our proxy translates carbon risk exposure into monetary terms. The traditional cash-flow scenario analysis commonly used by financial analysts should drive managers to be more sensitive to pecuniary costs induced by climate risks. Third, our measure is forward-looking in nature. Although historical emission data employed in the previous literature are necessary to assess a firm's past business models, data capturing forward-looking views will be of more significance in evaluating the firm's climate exposure and adaptability in the transition toward an environmentally sustainable world (Li et al., 2020).

The remainder of this paper is organized as follows. Section 2 describes the data on firms' exposure to climate risk and presents a series of stylized facts. Section 3 examines the properties of our firm-level carbon earnings risks measure. Section 4 presents the results on the effect of climate risk exposure on corporate policies and explores the cross-sectional variation of the climate-risk effect. Finally, Section 5 concludes.

2.2 Data and Methodology

This study employs data from several different sources: (i) carbon earnings at risk data for global firms from S&P Global's Trucost; (ii) firm financial information from Compustat and Refinitive Datastream; (iii) environmental innovation scores from Asset4 dataset; (iv) the U.S. customs import data at the shipment-level from Panjiva; (v) firm-level ESG scores from Refinitiv Datastream; (vi) institutional holdings data from Worldscope and Refinitive Datastream; (vii) country-level economic and political development data from World Bank; (viii) country-level culture index data from Hofstede et al. (2005).

2.2.1 A Firm's Carbon Earnings Risks

Our main measure for a firm's carbon earnings risks is the unpriced carbon cost due to its transition risks, developed by S&P Global's Trucost database and estimated based on different projection periods and scenarios. A firm's unpriced carbon cost refers to the situation that it has to face the additional financial cost paid (per metric ton of emissions) on top of the price that is currently paid, due to potential future pricing or tax hikes. Such costs are "*unpriced*" because they have not been reflected in a firm's financial statements, but will be shown in the future. Specifically, Trucost first estimates a carbon price risk premium, which is the difference between the current price paid per metric ton of GHG emissions and the possible future price for a particular sector-geography-scenario-year combination. That is, this firm-level carbon price risk premium varies by sector, geography, year, and scenario. Next, Scope 1 emissions and Scope 2 emissions are multiplied by this carbon price risk premium to determine the direct and indirect carbon costs that could impact a firm's financial performance[*]. A firm's unpriced carbon cost (as a proxy for its carbon earnings

[*]According to Carbon Disclosure Project (CDP), GHG emissions are classified into Scopes 1, 2, and 3. Scope 1 covers direct GHG emissions generated from fossil fuel used in all production and operations of facilities owned or

risks) is the aggregate of both direct and indirect carbon costs. Hence, our measure is forward-looking in nature, which is important in evaluating the firm's climate exposure and adaptability in the transition toward a low-carbon world (Li et al., 2020).

There are three scenarios in the estimation of a firm's carbon price risk premium: High, Medium, and Low. In particular, the "High" scenario represents the implementation of policies that are considered sufficient to reduce GHG emissions in line with the goal of limiting climate change to 2 degrees Celsius above pre-industrial levels by 2100 according to the Paris Agreement. This scenario analysis is based on research by OECD and International Energy Agency (IEA). The "Medium" scenario assumes that policies will be implemented to reduce GHG emissions and limit climate change to 2 degrees Celsius in the long term, but with action delayed in the short term. This scenario draws on research by OECD and IEA along with assessments of the sufficiency of countries' own NDCs. Countries with NDCs that are not aligned with the 2°C goal in the short term are assumed to increase their climate mitigation efforts in the medium and long term. The "Low" scenario represents the full implementation of country NDCs under the Paris Agreement. Based on the three scenarios illustrated above, the future prices of carbon are calculated for the years of 2020, 2025, 2030, 2040, and 2050.

Trucost utilizes various public and proprietary financial and environmental data sources to estimate firm-level unpriced carbon cost. The future carbon prices are based on scenarios developed by IEA and International Renewable Energy Agency (IRENA). Current carbon prices are obtained from country-specific available sources. The rationale for scenario analysis is that there are uncertainties regarding the stringency of climate policies and their enforcement, especially given the economic turmoil recently, and that scenario analysis provides us with a more complete picture of firms' potential cost induced by climate risks. Firm-level emissions data and

controlled by the firm. Scope 2 accounts for emissions from the firm's consumption of purchased electricity, heat, or steam. Scope 3 refers to indirect GHG emissions caused by activities of the firm but occur from sources not owned or controlled by the firm. Because they are easier to measure, and because disclosure requirements are stricter, data on scope 1 and scope 2 have been more systematically reported and accurately estimated (Bolton and Kacperczyk, 2021). The reason why both Scope 1 and Scope 2 emissions are incorporate in the estimation is that regulations which lead to a higher price on greenhouse gas emissions from the direct operations of a business could have a financially material impact on firms and that firms also face indirect financial risks as suppliers seek to recover additional regulatory costs in part or in full through increased prices.

information of sectors that firms operate in are obtained from Trucost's Environmental database, which has been widely used in studying firm-level climate risks and emissions in the literature. Companies' geographical emissions breakdown are derived from public reporting to the Carbon Disclosure Project (CDP) and FactSet database. When companies do not report to the CDP, Trucost uses the geographical breakdown of companies' revenues as a proxy for emissions' distribution. Together, the sector exposure and country-level emissions profiles allow for bottom-up calculation of climate risks exposure at a granular level.

We then scale these measures by a firm's earnings before interest and taxes (EBIT), and also before depreciation and amortization (EBITDA). We conduct a battery of analyses to validate that our measure indeed is associated with the impact of climate change on firms, which will be described in detail below.

2.2.2 Firm-level Actions

Our variables capturing the three firm-level actions are: (1) green innovation; (2) earnings management; (3) outsourcing activity. To avoid the concern that measures for different data points from the same provider are hardwired, leading to spurious correlations, we use different data sources to measure these three firm-level variables. Specifically, first, a firm's green innovation is measured by its environmental innovation score from Refinitiv ESG ratings. This score reflects a company's ability to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes, or eco-designed products. It includes a company's product innovation, as well as its "green" revenues, research and development (R&D) spending and capital expenditures (CapEx).

Second, we use a firm's discretionary accruals to measure its earnings management. To do so, we first run the following modified Jones model (Dechow et al., 1995) within each fiscal year and Fama-French 48 industry and get the estimated coefficients:

$$\frac{TA_{i,t}}{ASSET_{i,t-1}} = \beta_0 + \beta_1 \frac{1}{ASSET_{i,t-1}} + \beta_2 \frac{\Delta REV_{i,t}}{ASSET_{i,t-1}} + \beta_3 \frac{PPE_{i,t}}{ASSET_{i,t-1}} + \varepsilon,$$

where i denotes firms and t denotes fiscal years. Total accruals $TA_{i,t}$ are defined as earnings before extraordinary items and discontinued operations minus operating cash flows for fiscal year t; $ASSET_{i,t-1}$ is total assets at the end of year $t-1$; $\Delta REV_{i,t}$ is the change in sales revenue from year $t-1$ to t. We require at least 10 observations to perform each cross-sectional estimation.

We then use the following model and the estimated coefficients from the equation above to compute the fitted value of normal accruals, $NA_{i,t}$:

$$\frac{NA_{i,t}}{ASSET_{i,t-1}} = \hat{\beta}_0 + \hat{\beta}_1 \frac{1}{ASSET_{i,t-1}} + \hat{\beta}_2 \frac{\Delta REV_{i,t} - \Delta AR_{i,t}}{ASSET_{i,t-1}} + \hat{\beta}_3 \frac{PPE_{i,t}}{ASSET_{i,t-1}},$$

where $\Delta AR_{i,t}$ is the change in accounts receivable from year $t-1$ to t. Following Dechow et al. (1995), we subtract the change in accounts receivable from the change in sales revenue, since credit sales might also provide a potential opportunity for accounting manipulation. After obtaining the fitted normal accruals $NA_{i,t}$ from the model above, we calculate firm-year-specific discretionary accruals as: $DA_{i,t} = (TA_{i,t}/ASSET_{i,t-1}) - NA_{i,t}$.

Third, we measure a firm's outsourcing activity by calculating the aggregated amount of estimated GHG emission imported from suppliers overseas. We follow Dai et al. (2021) and draw on Panjiva, a unique database of U.S. trades that documents transaction-level details of goods that cross the border, to analyze their outsourcing activities. Firms in the U.S. are required to report shipment details in cargo declarations to the U.S. Customs and Border Protection (CBP), which enables Panjiva to collect information on the shippers (i.e., suppliers or logistic companies), consignees (i.e., customers), origin and destination addresses, product descriptions, and container specifications of ocean freight shipments between U.S. firms and foreign entities in over 210 countries.

Specifically, this measure estimates the aggregated metric tons of equivalent into the air from the production of all imported goods based on a \$1 million worth of output over all shipment containers (in the unit of TEU) each year. We adopt the EIO-LCA GHG emission model from Carnegie Mellon to approximate the outsourced emission intensity at shipment level. The imported good's industry is based on the six-digit HS Code from Panjiva and the HS to NAICS table from Peter K. Schott Website, and the importer's primary industry NAICS code is from Compustat. The EIO-LCA GHG emission model is constructed from the BEA Input-Output model, the IPCC Second Assessment Report, and other resources. We exclude shipments from foreign subsidiaries of U.S. parent firms since these subsidiaries are within control of parent firms and should not be viewed as outsourcing practice. This granular measure of emission enables us to better capture a firm's carbon emissions outsourcing behavior. Following Bolton and Kacperczyk (2021b) and Dai et al. (2021), we employ log foreign suppliers' emissions our main analyses. Due to data availability, our data on this variable only cover U.S. firms.

2.2.3 Other Variables

We control for firm-level covariates that might be correlated with both a firm's carbon earnings risks and corporate policies, including firm size (the logarithm of total assets), profitability (return of assets, ROA), leverage (debt-to-assets ratio), market-to-book ratio of equity and blockholder ownership (including government held Shares, pension fund held shares, employee held shares, foreign held shares, and total strategic holdings). We further control for country-level variables that could impact firms' response to climate risk, including a country's Regulatory Quality index (which captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private-sector development), GDP per capital, legal origin (binary indicators for English common law, French civil law, German civil law, Scandinavian civil law, and socialist law). We winsorize all continuous variables at 1% and 99%. All variables are defined in Appendix Table A1.

2.2.4 Summary Statistics

Table 1 reports the summary statistics of our key variables. It summarizes the carbon earnings risks variables averaged across three different scenarios (High, Medium, Low) for all forecast years in raw form. On average, a firm bears the (unpriced) cost of approximately $17 million for its Scope 1 emissions, \$3 million for its Scope 2 emissions, and more than \$20 million in its total GHG emissions, if realized by 2025. This total amount of additional costs that have not been reflected in financial statements accounts for around 5% its current EBITDA. The maximum ratio of unpriced carbon cost over EBITDA for the year of 2025 is about 97%. These numbers suggest that firms face great pecuniary transition risks due to their GHG emissions in the near future when governments adopt policies to meet the Paris Agreement target and when consumers shift their purchasing behavior toward green products, which will heighten the price of carbon emissions and lower the valuation of carbon-intensive assets. In comparison, the median values of unpriced cost for Scope 1, Scope 2 emissions, and total GHG emissions for the year of 2025 are around \$302 thousand, \$360 thousand, and \$854 thousand, respectively, with much larger standard deviations (\$82 million, \$9 million, and \$90 million, respectively). This indicates right-skewed distributions of unpriced carbon costs which are driven by large companies. We see a similar pattern of unpriced carbon cost for the other forecast years.

<Table 1 here>

In Online Appendix, Table IA.1 reports the summary statistics of our firm-action variables and main control variables. The average environmental innovation score is around 25, with a standard deviation of 30 (on a scale of 100). The mean of a firm's discretionary accruals is -0.011, and the standard deviation is 0.071. The average value of (log-transformed) GHG emissions by its foreign suppliers is 268 ton (5.593), and its standard deviation is 99 (4.596). In our sample, an average (median) firm has total assets of \$18 million (\$1.5 million), a leverage ratio of 24.1% (22%), a ROA of 10.8% (10.0%), a market-to-book ratio of 0.2% (0.1%), and a ratio of CapEx over sales of 10.23% (4.02%).

2.3 Unbundling Carbon Earnings Risks

In this section, we examine the properties of our firm-level carbon earnings risks measure and validate it with several external datasets on climate risk measures.

2.3.1 Scenario Breakdown of Carbon Earnings Risks

First, we present descriptive statistics of this measure across different scenarios in Table 2. As illustrated above, the future prices of carbon for 2020, 2025, 2030, 2040, and 2050 are estimated under three different scenarios. Again, a "Low" scenario indicates the full implementation of country NDCs under the Paris Agreement. A "Medium" scenario represents actions taken to meet the 2°C target set forth by Paris Agreement in the long term (but with actions delayed in the short term), while a "High" scenario represents aggressive actions taken by the government to strictly stick to the 2°C target by 2100. We expect that the future carbon earnings risks, or a firm's unpriced carbon costs, will be the highest for the "High" scenario, as it represents greatest transition risks for the firm.

<Table 2 here>

Panels A, B and C of Table 2 reports the summary statistics of the Carbon Earnings Risks variables under "Low", "Medium" and "High" scenarios for all forecast years in the original values. Under the "Low" scenario, a firm on average bears a cost of around $8 million for its total GHG emissions in 2025, $17 million in 2030, $30 million in 2040, and $35 million in 2050 given its current level of emissions. Under the "Medium" scenario, the average total unpriced carbon cost is about $19 million in 2025, $40 million in 2030, $68 million in 2040, and $136 million in 2050. Under the "High" scenario, these numbers become around $37 million in 2025, $74 million in 2030, $119 million in 2040, and $156 million in 2050. If a firm does not cut its GHG emissions, its total unpriced carbon cost for 2025 makes up 1.75% of its current EBITDA under the "Low" scenario, 4% of its current EBITDA under the "Medium" scenario, and 8% under the "High" scenario.

2.3.2 Industry and Country Distributions of Carbon Earnings Risks

We present the distribution of firm-year observations in our sample with respect to the six-digit Global Industry Classification (GIC 6) and countries in Table 3. Banks, Real Estate Management

& Development, and Chemicals are the most represented industries, while United States, Japan, and China have the most observations in our sample.

<Table 3 here>

Industries differ significantly in their exposures to climate risks. We calculate the averages of unpriced carbon cost across three scenarios by GIC 6 industry and provide a list of industries with the highest values for the year of 2025 in Table 4. Figure 1 also provides a visualization of unpriced carbon cost for these industries. For brevity, we do not list values for other forecast years.

<Table 4 here>

<Figure 1 here>

Panel A of Table 4 reports the top 10 of GIC 6 industries in terms of their unpriced carbon costs for Scope 1 emissions for the year of 2025. Electric utilities industry is expected to have the highest unpriced carbon cost (around $259 million) for Scope 1 emissions by 2025 given its current GHG emissions. It is followed by multi-utilities (about $250 million) and airlines sectors (around $192million). Other industries with high levels of unpriced carbon costs include power, construction materials, oil, gas and consumable fuels, metal and mining, industrial conglomerates, chemical, and paper and forest products. Panel B presents the top 10 industries in terms of unpriced carbon cost for Scope 2 emissions for the year of 2025. The ranking in this panel is somewhat different from the previous one. Multi-Utilities (around $14 million), automobiles (around $13 million), wireless telecommunication services (about $9.9 million), food and staples retailing (around $8.5 million), and containers & packaging (about $7.5 million) are among those with highest carbon earnings risks for Scope 2 emissions. Panel C provides the top 10 industries in terms of their total unpriced carbon cost for the year of 2025. We find the same industry ranking in Panel C as in Panel A. This is because a firm's Scope 1 emissions are much larger than its Scope 2 emissions and thus its unpriced carbon cost for Scope 1 emissions dominates that for Scope 2 emissions.

Panel D of Table 4 reports the top 10 industries in terms of the ratio of total unpriced carbon cost to EBITDA for the year of 2025. The construction materials sector has the highest ratio of 46.44%, suggesting that its near-term carbon earnings risks account for more than 40% of its current EBITDA given its GHG emissions now. Other industries with significant carbon earnings risks include independent power and renewable electricity producers (around 32%), electric utilities (about 29%), and airline (around 23%). We further find that marine industry which does not appear in the three rankings above also has a relatively high ratio (about 9.4%).

Carbon earnings risks also vary significantly across countries, as they are largely driven by national policies and regulations. We calculate the averages of unpriced carbon costs across three scenarios by country or region and provide lists of countries with the highest climate risk exposure values for the year of 2025 in Table 5 and Figure 2.

<Table 5 here>

<Figure 2 here>

Panel A of Table 5 presents countries with the highest unpriced carbon cost for Scope 1 emissions for the year of 2025. Russia tops the list with the average unpriced carbon cost of around $196 million, which is likely due to its large number of listed companies in oil, gas and consumable fuels, metal and mining, and electric utilities industries in our sample. It is followed by Czech and Panama with much less unpriced carbon cost for Scope 1 emissions (about $94 million and $61 million, respectively). Both have large exposure of carbon-intense industries such as chemicals, gas utilities, and airlines. The rest of the countries in this ranking includes Colombia, Portugal, Argentina, Morocco, Poland, Chile, and Luxembourg, all with the mean value of unpriced carbon cost around $50 million. Panel B reports the ranking of top 10 countries in terms of unpriced carbon cost for Scope 2 emissions for the year of 2025. Russia still has the largest cost associated with Scope 2 emissions (about $13 million), followed by Mexico (around $9 million) and Luxembourg (around $8 million). Panel C presents the ranking of the top 10 countries in terms of total unpriced carbon cost for year of 2025, which is quite similar to that in Panel A. Russia, Czech and Portugal have the highest total carbon cost. Panel D provide lists of countries with the highest carbon cost ratio over EBITDA for the year of 2025. On average, total unpriced carbon cost amounts to nearly 20% of EBITDA for firms in Russia, which is the highest among all sample countries. Although not among the top 10 countries in terms of absolute unpriced carbon cost, Turkey, Oman, Egypt, Mongolia, Argentina, and Saudi Arabia have the highest average carbon cost to earnings ratio.

2.3.3 Variance Decomposition of Carbon Earnings Risks

To better explain what drives a firm's carbon earnings risks, we conduct a variance decomposition analysis on our measure of unpriced carbon cost. Table 6 reports the incremental explanatory power from regressing this measure on different fixed effects that might potentially explain its variations.

<Table 6 here>

In Panel A, we calculate the averages of unpriced carbon cost across three scenarios for the forecast year of 2025 and report the results of variance analysis. We find that year fixed effects explain little variation in unpriced carbon costs of Scope 1 emissions, Scope 2 emissions, and total emissions and carbon cost ratios for 2025, as the incremental R-squares are less than 1% across all measures. In contrast, industry fixed effects help additionally explain more than 20% of the variations for both values and ratios of unpriced carbon costs (except that for Scope 2 emissions). This indicates that a firm's carbon earnings risks are largely driven by its industry characteristics, corroborating the descriptions in Table 4. This is also consistent with the notion that policies which mostly target specific industries and technological innovations usually affect entire sectors (Sautner et al., 2022). We also introduce an interaction term between year and industry fixed effects in this analysis, but fail to find that it captures much variation for all measures (around 1%). Country fixed effects also explain little variation for most measures (about 2%), except for unpriced carbon costs associated with Scope 2 emissions (about 0.4%). This is unsurprising given that climate change is a global issue, and the Paris Agreement provides a unified framework for coordinating country actions, and after taking into account the sector characteristics, there appears to be little systematic difference of firms' carbon earnings risks across countries. Finally, we find that firm fixed effects have the greatest explanatory power for both the values and ratios of unpriced carbon costs, generating an incremental R2 of 60%—80%. There are similar patterns of variation for the other forecast years (For brevity, we do not report the results for other forecast years). This suggests that unobserved firm-specific heterogeneities explain most of how transition risks affect a firm's earnings, and echoes the significant role of similar firm fixed effects in explaining capital structure (Lemmon et al., 2008).

Panels B, C and D report the results of variance decomposition for unpriced carbon cost measure for 2025 under the Low, Medium, and High scenarios, respectively. Across the three different scenarios, we again find that 60%—85% of variation cannot be explained by year, industry, interaction of year and industry, and country fixed effects, but are captured by firm fixed effects.

2.3.4 Determinants of Carbon Earnings Risks

After documenting large unobserved firm-specific heterogeneities on how transition risks affect a firm's earnings in monetary terms, we next investigate the determinants of a firm's unpriced carbon cost, especially those that are observable. Specifically, we conduct regression analysis to assess the differences in unpriced carbon costs for Scope 1 emissions, Scope 2 emissions, total emissions, as well as the ratio of the total unpriced carbon cost scaled by EBITDA across firms.

Since there is little theory that can guide us on the determinants of the impact of transition risks on firms' earnings, we include several common firm-level financial and ownership variables in our regression analysis, such as firm size, leverage, ROA, market-to-book ratio, foreign block institutional ownership, government ownership, employee ownership, pension fund ownership, and total strategic institutional ownership. The reason for including these block ownership variables is that the extant literature has widely documented the impact of institutional ownership on portfolio firms' carbon emissions (e.g., Krueger et al., 2020; Azar et al., 2021). We also include country-level variables such as GDP per capita, Hofstede culture indexes (comprise *Power Distance*, *Individualism*, *Masculinity*, *Uncertainty Avoidance*, *Long-term Orientation*, and *Indulgence*), and law origins, which have been documented to be strong predictors of firm-level ESG practices (Liang and Renneboog, 2017).

For the ease of illustration, we use the unpriced carbon cost measure averaged across three scenarios for the year of 2025 only. Table 7 present the regression results. We find that larger, more profitable and more leveraged firms have higher absolute unpriced carbon cost for Scope 1 and Scope 2 emissions and total unpriced carbon cost, consistent with Bolton and Kacperczyk (2021a). There is also a negative correlation between total strategic institutional ownership or foreign ownership and the absolute averaged unpriced carbon cost, consistent with the institutional investors' role on curbing portfolio firms' carbon emissions (Azar et al., 2021). In addition, countries with higher GDP per capita have larger Scope 2 unpriced carbon cost, consonant with the idea that underdeveloped countries cannot afford having carbon-intensive projects or factories. A country's power distance and uncertainty avoidance cultures are positively correlated with firms' unpriced carbon cost in that country, while the long-term orientation index is negatively associated with absolute unpriced carbon cost. Echoing Liang and Renneboog (2017), we find countries with Scandinavian civil law have lower absolute unpriced carbon cost.

<Table 7 here>

We further find that a firm's leverage and profitability are significantly and positively associated with the ratio of unpriced carbon cost to EBITDA, while firms with high market-to-book ratio and greater pension fund ownership have lower unpriced carbon cost ratios. Countries with greater power distance culture have greater unpriced carbon cost ratio, while countries with stronger long-term orientation culture have lower carbon cost ratio. In untabulated results, we find similar results when we include country fixed effects or look at the carbon earnings risks under different scenarios.

2.3.5 External Validation

We next validate our unpriced carbon cost measure by employing two external benchmarks to show that it indeed captures a firm's carbon earnings risks. In particular, we look at how our unpriced carbon cost measure is correlated with measures of a firm's exposure to regulatory risks on climate change (e.g., Sautner et al., 2022) and of a firm's carbon emissions employing data from Trucost, which have been used in many studies.

The climate change exposure measures by Sautner et al. (2022) identify the attention paid by participants in a firm's earnings call to its exposures to risks associated with climate change. It is constructed using a keyword discovery algorithm with machine learning and captures exposures, risks, and sentiments related to opportunity, physical, and regulatory shocks related to climate change. We expect our measure to be closely related to its regulatory shocks measure, since the construction of our measure is based on the assumption that carbon prices will increase due to countries' commitment to tackle climate change based on Paris Agreement, which is significantly associated with carbon taxes and regulatory penalties.

We extract the regulatory shocks measures from Sautner et al. (2022) and regress our unpriced carbon cost measure averaged across three scenarios for year of 2025 on these external measures. Specifically, there are four regulatory shocks measures, corresponding to exposures, risks, positive sentiment, and negative sentiment, respectively. Following Sautner et al. (2022), we include industry, year, and country fixed effects in the regression. Panel A of Table 8 reports the regression results. The dependent variable is the natural logarithm of unpriced carbon cost for Scope 1 emissions in Column (1), the natural logarithm of unpriced carbon cost for Scope 2 emissions in Column (2), the natural logarithm of absolute total unpriced carbon cost in Column (3), and total unpriced carbon cost scaled by EBITDA in Column (4). We find that the coefficients of both the regulatory shocks exposure measure and regulatory shocks risk measure are significantly positive in all columns, consistent with our conjecture. We also find that regulatory shock negative sentiment is positively associated with Scope 1 and total unpriced carbon cost. We further find a significantly negative coefficient of positive sentiment measure related to regulatory shocks for unpriced carbon cost ratio, suggesting that a firm bears lower unpriced carbon costs when there is more positive sentiment about regulatory shocks during its earning conference.

<Table 8 here>

Second, we examine the correlation between a firm's GHG emissions and our unpriced carbon cost measure. A firm's carbon emission intensity is an important factor of its climate-related risks, especially those related to regulatory risks, as nations are committed to major curbs in emissions and those big emitters will be primarily affected by these curbs (Bolton and Kacperczyk, 2021a). We expect that our unpriced carbon cost measure to be positively associated with a firm's GHG emissions since they are more adversely influenced by carbon taxes or related regulations.

We employ GHG emission data provided by S&P Global's Trucost only for U.S firms between 2017 and 2018 due to data availability. Similarly, we regress our unpriced carbon cost measure averaged across three scenarios for the year of 2025 on the (logged) sum of a firm's Scope 1 and Scope 2 carbon emissions. Panel B of Table 8 presents the results. We find that all coefficients of a firm's carbon emission amount are significantly positive, suggesting that a firm's unpriced carbon cost are higher both in absolute and relative terms when it emits more GHG. This is again in line with our conjecture.

We also conduct similar validation tests using our unpriced carbon cost measure for the year of 2025 under the three different scenarios, and find similar results. Overall, our results above confirm that the unpriced carbon cost measure indeed captures a firm's Carbon Earnings Risks due to its climate-related transition risks.

2.3.6 Variances across Three Scenarios and Forecast Years

We further examine the variations in the unpriced carbon cost measure across different scenarios and for different forecast years.

Panel A of Table 9 shows significant variations in unpriced carbon cost at the firm-level across three scenarios. The average standard deviation of the ratio of total unpriced carbon cost over EBITDA for the year of 2025 is around 3.36%, amounting to more than 70% of the mean value. Panel B of Table 9 shows significant variations across different forecast years. We also find a significant variation of our unpriced carbon cost measure across forecast years. The average standard deviation of the ratio of total unpriced carbon cost over EBITDA is about 3.25%, accounting for 80% of the mean value. In addition, a firm's unpriced carbon cost decreases over longer horizons.

<Table 9 here>

2.3.7 Physical Risk Measures

Besides transition risks, a firm also faces significant physical risks associated with climate change. In this section, we provide some descriptive statistics of a firm's physical risk exposure using measures provided by the same vendor, S&P Global Trucost, for completeness and further validation of our carbon cost measure.

It is worth noting that Trucost only provides numeric scores for a firm's physical risks, instead of a monetized value as for transition risks. Specifically, Trucost assigns each firm with scores that reflect its expected sensitivities to six key climate hazards. These hazards include cold wave, flood, heat wave, sea level rise, water stress, and wildfire. Similar to our unpriced carbon cost measure, the physical risk measure also includes three future climate change scenarios: Low, Medium and High. In particular, the "High" scenario represents aggressive mitigation actions to halve emissions by 2050, which is likely to result in warming of less than 2 degree Celsius by 2100. The "Medium" scenario denotes strong mitigation actions to reduce emissions to half of current levels by 2080. The "Low" scenario represents continuation of business as usual with emissions at current rates, which is expected to result in an increase of global temperature by more than 4 degrees Celsius by 2100. There are three forecast years, 2020, 2030 and 2050.

We present industry and country distributions of this physical risk measure in Table 10. For brevity, we only report the average physical risk scores across scenarios for the year of 2020.

We would expect rather different distributions of a firm's physical risk measure compared to its unpriced carbon cost measure, as the former is related to the location of a firm's production sites and insurance policies, rather than government policies and consumer tastes. Panel A shows the industry distribution in terms of six physical risk measures related to specific hazards and two composite physical risk scores for the year of 2020. Industries with the greatest risks of cold wave, flood and wildfire, heatwave, and sea level rise are aerospace and defense, air freight and logistics, semiconductors, and real estate management and development, respectively. The mortgage real estate investment trusts sector has the greatest exposure to water stress risks and also the highest composite score for physical risks in general. Panel B of Table 10 reports the country/region distribution with respect to physical risk measures. Specifically, Lithuania has the greatest exposure to cold wave disasters. Bangladesh has the highest exposure to flood. The country with the highest heatwave risk is Colombia. Macao has the highest sea level risk exposure. Pakistan is the most exposed to water stress risk. Chile and Australia have the greatest exposure to wildfire risk. Philippines tops the ranking for the composite score for physical risks. Overall, the industry and country distributions of physical risks look quite different from that of transition risks (i.e., carbon earnings risks).

<**Table 10 here**>

2.4 How Firms Respond to Carbon Earnings Risks

In this section, we first look at whether firms respond to the above-documented carbon earnings risks. We then explore the cross-sectional heterogeneity in terms of firms' response.

2.4.1 Firm's Response: Baseline Results

To test whether firms realize and react to their carbon earnings risks, we first conduct an ordinary least squares (OLS) analysis on our panel dataset using the following specification:

$$Y_{i,t} = \alpha + \beta CarbonCost_{i,t-1} + \gamma' Controls_{i,t-1} + FEs + \varepsilon_{i,t},$$

where the dependent variable, $Y_{i,t}$, denotes firm i's three policies described above, namely, environmental innovation score (proxy for green innovation), discretionary accruals (proxy for earnings management), and the aggregated amount of estimated GHG emission imported from suppliers overseas (proxy for outsourcing activity) in year t. As mentioned earlier, the outsourcing measure is only available for US firms, which significantly shrinks our sample size for the outsourcing analysis. The independent variable, $CarbonCost_{i,t-1}$, represents a firm's Carbon Earnings Risks, measured as total unpriced carbon cost scaled by its EBITDA in year $t-1$. $Controls_{i,t-1}$ denotes a set of firm-level covariates as described in Section 2.3 and measured in year $t-1$. FEs includes year fixed effects, industry fixed effects, and country fixed effects. All standard errors are clustered at the industry-by-year level.

We report the results of our baseline tests in Panel A of Table 11, with the dependent variables in column (1)–(3) being the three firm-level policies, respectively. We find significant and positive coefficients of unpriced carbon cost ratio in all three columns, suggesting that firms with higher unpriced carbon costs have higher environmental innovation score, more discretionary accruals, and larger amount of GHG emissions from foreign suppliers. The economic magnitudes of these effects are nontrivial. A one-standard-deviation increase in the unpriced carbon cost ratio is associated with an 8% increase in environmental innovation score, a 12.5% increase in discretionary accruals, and 5% increase in aggregated amount of estimated GHG emission imported from foreign suppliers. These results corroborate the idea that firms do respond to climate risks exposure. This consistent result supports our hypothesis that a firm indeed responds its such Carbon Earnings Risks.

<Table 11 here>

As a robustness check, we also use alternative measures of the three corporate policies above to replace the dependent variables. Specifically, we employ a firm's environmental R&D expenditure to proxy for green innovation using data from Refinitiv ESG (Environmental R&D Expenditure), discretionary accruals calculated by modified equation to proxy for earnings management (we rerun the modified Jones model ROA (Dechow et al., 1995) after dropping the intercept term), and the growth of a firm's Scope 3 emissions (Scope 3 Emission Growth) to proxy for its outsourcing activity. A caveat is that the use of R&D expenditure and Scope 3 emission growth significantly shrinks our sample size due to data limitation.

Panel B of Table 11 reports the results of our robustness tests. The dependent variables in columns (1)–(3) are the alternative measures of our three firm-level policies, respectively. Again, we find significantly positive coefficients of unpriced carbon cost ratio in all three columns, further confirming our conjectures on firm reaction.

2.4.2 Instrumental Variable Analysis

While we have found a significant correlation between a firm's carbon earnings risks and its corporate policies, our results are subject to endogeneity concerns. For example, a firm's carbon earnings risks may be reversely affected the its own policies, or both its carbon earnings risks and environmental policies may be driven by unobserved heterogeneities at the firm- and regional-levels, which obscure the identification of causality. To circumvent this problem, we employ an instrumental variable (IV) approach.

Specifically, we use whether the country has implemented emission trading scheme or adopted a carbon tax as an instrumental for its carbon earnings risks. Emission trading scheme is an approach to limit climate change by creating a market with limited allowances for emissions by the government. Given the fixed number of emission allowances/licenses, or the fixed amount that a country or sector can emit, companies and sectors within the economy will buy and sell carbon credits. Firms that emit more (beyond their emission quota) have to buy carbon credits from other firms that have not used up their quotas. Similarly, a carbon tax is imposed by a government to put a direct price on greenhouse gas emissions (per ton) produced by companies or industries. In this way, the adoption of either emission trading scheme or a carbon tax will significantly increase the future price of carbon emission as governments impose tighter emission cap and firms face less supply of emission credits. Meanwhile, the introduction of both types of policy is not determined by firms themselves but by governments, which is exogenous to firm decisions. In addition, they are unlikely to affect a firm's environmental policies through channels other than increasing their transition risks. Therefore, I argue that the exclusion restriction is likely satisified, as any effects of the adoption of both policies on firms' behavior should be through its impact on firm's Carbon Earnings Risks. The data on worldwide emission trading schemes and carbon taxes are extracted from Dolphin and Xiahou (2022).

One caveat with the IV above is that it may not be applicable to testing the relation between carbon earnings risks and outsourcing activity, as data for the latter are only available for U.S. firms. Hence, we employ another IV for this dependent variable, namely the number of climate-related disasters (such as drought and flood) at the state where the firm is headquartered in the past 3-10 years. The rationale behind this IV is as follows. First, climate-related natural disasters make people form and revise their beliefs about the impacts of climate change, thus influence their consumption and investing behavior. More climate-related disasters in a region raise local stakeholders' awareness of climate change (Choi et al., 2020; Hsu et al., 2020), which would lead to increased costs on the firm's polluting behavior. These increased costs may include local governments' regulatory actions, the shift in local consumers' preference toward low-carbon products, and local communities' boycotts against polluting firms. In order to verify this hypothesis of people's heightened attention to global warming after climate-related disasters, we test the relation between the number of climate-related disasters in one state and Google search volume index of the search topic of "global warming" in that region. The data on climate-related disasters are obtained from EM-DAT, a global database on natural and technological disasters (more than 21,000 disasters) around the world from 1900 to present. Similar to Choi et al. (2020), we employ topics searching instead of terms searching because Google's algorithms can group different searches that have the same meaning under a single topic. We extract from Google Trends a Search Volume Index of the topic "global warming" for each state from 2007 to 2017, which matches the data on disasters. In untabulated results, we find a positive association between these two variables. Thus, we would expect a positive correlation between a firm's climate risk exposure and the number of local climate-related disasters in recent years.

Meanwhile, we argue that natural disasters are unlikely to affect a firm's outsourcing activity through channels other than heightening a firm's perceived carbon earnings risks. Hsu et al. (2021) document that, globally, a firm's green innovation is driven by a firm's response to governmental pressures and societal expectations on the firm to address environmental externalities, which are exactly the key determinants of carbon earnings risks. A firm's outsourcing activities and earnings management are also unlikely related to natural disasters that happened a few years ago. To further alleviate the concern that disasters may directly influence local firms' operation, such as the destruction of plants (Dessaint and Matray, 2017), we exclude those observations of firms that experienced climate-related disasters during the most recent three years.

<Table 12 here>

Table 12 presents the results from the IV analysis. The first-stage result shows that the adoption of emission trading scheme or a carbon tax is positively and significantly associated with a firm's carbon earnings risks (Column (1)) and the number of local climate-related disasters is also significantly and positively correlated with a firm's carbon earnings risks (Column (2)). This is consistent with the potential carbon price hikes and the increased awareness of climate change by local residents and governments. The second-stage results (Columns (3)—(5)) show that the coefficients for environmental innovation, discretionary accruals, and outsourcing activity are still significantly positive. The economic magnitudes of these effects are nontrivial. A one-standard-deviation increase in the unpriced carbon cost ratio is associated with an increase of 8% of a standard deviation in environmental innovation score, an increase of 17% of a standard deviation in discretionary accruals, and an increase of 6% of a standard deviation in aggregated amount of estimated GHG emission imported from foreign suppliers. These results corroborate our hypothesis that firms do respond to climate risks exposure.

2.4.3 Cross-Sectional Heterogeneities

In this section, we further explore the cross-sectional variations in the effects of carbon earnings risks on corporate policies. As a firm's reaction can be for both good and bad causes and also depends on their capability of coping with the transition risks, we specifically focus on the role of corporate governance and market competition in driving our results.

First, well-governed firms may be better incentivized to improve their innovation capabilities in green technology and outsource their production, which could reduce domestic emissions and shift transition risks to suppliers overseas, when facing significant transition risks, instead of engaging in earnings management. Alternatively, they may also strategically manage their earnings to please regulators and investors at lower costs. We therefore test whether and how governance plays a role in corporate environmental policies. We measure firm-level corporate governance by extracting a firm's governance score from Refinitiv ESG ratings (Datastream) and partition our sample into those above and below the median of the governance score in our sample. We consider the former (latter) as high- (low-) governance firms and run our baseline regressions on these two subsamples separately. The regression results for these two groups are presented in Panel A of Table 13. We find that the baseline effects for environmental innovation and outsourcing are significant for firms with high governance scores, while the effect on discretionary accruals is significant for both high- and low-governance firms. These findings may suggest that better-governed firms are indeed incentivized to upgrade their production technology toward cleaner and greener, and that firms manage their earnings regardless of their governance quality. Thus, our results for the effect of climate risks exposure are not purely driven by agency problem. Another possible explanation might be that the governance score from Refinitiv—which adopts a kitchen sink approach by aggregating many dimensions together—may not accurately capture a firm's true governance quality.

<Table 13 here>

Second, we examine whether market competition affects how firms react to carbon earnings risks. Greater competition may undercut a firm's profit margin and force it to seek alternative ways to save costs. Competition is also associated with future cash flow volatility and exposes firms to the risk of not being able to finance long-term projects (Gu, 2016). We measure market competition by using the country-level Herfindahl-Hirschman Index (HHI) from World Integrated Trade Solution of World Bank when examining the relation between carbon earnings risks and green innovation and earnings management, while we use as the proxy for market competition industry-level CR4 ratio in U.S. which measures the revenue share of the four largest firms in an industry from Davis and zgür Orhangazi (2021) when examining the relation between carbon earnings risks and outsourcing activity. A high HHI value or a high CR4 ratio indicates greater market concentration (the inverse of market competition). We extract the HHI data in 2017, the most recent available one, from World Integrated Trade Solution of World Bank, and CR4 ratio data in 2012 from Davis and zgür Orhangazi (2021). We next partition our sample into two group based on the median value of HHI (CR4) measure in 2017 (2012), high-HHI (CR4) group and low-HHI (CR4) group, and rerun our baseline regression for two groups, respectively. Panel B of Table 13 reports the results. We find that firms in countries with high HHI or in industries with high CR4 ratio, i.e., facing less competition, tend to have more green innovations and engage in more outsourcing activities, while firms facing higher competition will response to do earnings management, which is less costly. In sum, our cross-sectional analysis suggests that environmental policies are not mutually exclusive, and firms will actively select different policies in response to climate risks.

2.5 Conclusion

Climate change poses severe challenges to businesses and society at large. While a large literature has documented the significant price effect of climate risks across a number of asset classes, there is limited understanding of how significant such climate risks are for firms in terms of affecting their financial statements, and how firms response to such risks. In this study, we use newly available data on firms' exposure to climate risks—especially transition risks due to regulatory pressures, technological innovation, and changing consumer and investor preferences—to study their magnitudes in terms of affecting a firm's earnings and policies. We find Carbon Earnings Risks can be substantial, i.e., on average account for about 15 percent of a firm's total earnings, and vary significantly across countries, industries, different scenarios and time horizons. We also find that firms with greater Carbon Earnings Risks have more environmental innovation, more negative discretionary accruals, and engage in more outsourcing. These results suggest that firms do realize their unpriced carbon risks—despite not being reflected in their financial statements yet—and proactively respond to it.

If we take these results at the face value, perhaps the most significant implication is that the path to carbon neutrality and achieving the Paris Agreement targets are extremely costly and can reshape the whole trajectory of a firm's growth if fully implemented. Firms as rational agents do respond to such pressures, in both positive and negative ways. Given the huge costs a firm has to bear and the strong incentives to buffer earning volatility in the future, many actions that may affect a firm's transition risks—such as divestment by institutional investors, boycotts by consumers, and penalties by regulators—may have significant unintended consequences. Policies aiming at promoting firm-level carbon neutrality should take into account of such positive and negative externalities.

References

Acemoglu, D., Johnson, S., and Robinson, J. A. (2001). The Colonial Origins of Comparative Development: An Empirical Investigation. *American Economic Review*, 91(5):1369–1401.

Acemoglu, D., Johnson, S., and Robinson, J. A. (2002). Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution. *The Quarterly Journal of Economics*, 117(4):1231–1294.

Acharya, V., Davydenko, S. A., and Strebulaev, I. A. (2012). Cash Holdings and Credit Risk. *The Review of Financial Studies*, 25(12):3572–3609.

Aghion, P., Algan, Y., Cahuc, P., and Shleifer, A. (2010). Regulation and Distrust. *The Quarterly Journal of Economics*, 125(3):1015–1049.

Ajzen, I., Brown, T. C., and Carvajal, F. (2004). Explaining the Discrepancy between Intentions and Actions: The Case of Hypothetical Bias in Contingent Valuation. *Personality and Social Psychology Bulletin*, 30(9):1108–1121.

Akey, P. and Appel, I. (2021). The limits of limited liability: Evidence from industrial pollution. *The Journal of Finance*, 76(1):5–55.

Alesina, A. and Giuliano, P. (2015). Culture and Institutions. *Journal of Economic Literature*, 53(4):898–944.

Algan, Y. and Cahuc, P. (2010). Inherited Trust and Growth. *American Economic Review*, 100(5):2060–92.

Allen, F., Qian, J., and Qian, M. (2005). Law, Finance, and Economic Growth in China. *Journal of Financial Economics*, 77(1):57–116.

Alok, S., Kumar, N., and Wermers, R. (2020). Do fund managers misestimate climatic disaster risk. *The Review of Financial Studies*, 33(3):1146–1183.

Amore, M. D. and Bennedsen, M. (2016). Corporate governance and green innovation. *Journal of Environmental Economics and Management*, 75:54–72.

Azar, J., Duro, M., Kadach, I., and Ormazabal, G. (2021). The big three and corporate carbon emissions around the world. *Journal of Financial Economics*, 142(2):674–696.

Bae, K.-H., Kang, J.-K., and Kim, J.-M. (2002). Tunneling or Value Added? Evidence from Mergers by Korean Business Groups. *The journal of finance*, 57(6):2695–2740.

Baek, J.-S., Kang, J.-K., and Lee, I. (2006). Business Groups and Tunneling: Evidence from Private Securities Offerings by Korean Chaebols. *The Journal of Finance*, 61(5):2415–2449.

Bai, Y. and Jia, R. (2016). Elite Recruitment and Political Stability: the Impact of the Abolition of China's Civil Service Exam. *Econometrica*, 84(2):677–733.

Bartram, S. M., Hou, K., and Kim, S. (2022). Real effects of climate policy: Financial constraints and spillovers. *Journal of Financial Economics*, 143(2):668–696.

Bates, T. W., Kahle, K. M., and Stulz, R. M. (2009). Why do US Firms Hold So Much More Cash than They Used To? *The Journal of Finance*, 64(5):1985–2021.

Ben-David, I., Jang, Y., Kleimeier, S., and Viehs, M. (2021). Exporting pollution: where do multinational firms emit co2? *Economic Policy*, 36(107):377–437.

Bertrand, M. and Schoar, A. (2003). Managing with Style: The Effect of Managers on Firm Policies. *The Quarterly Journal of Economics*, 118(4):1169–1208.

Blau, P. M. (1977). *Inequality and Heterogeneity*. New York: Free Press.

Bloom, N. and Van Reenen, J. (2007). Measuring and Explaining Management Practices Across Firms and Countries. *The Quarterly Journal of Economics*, 122(4):1351–1408.

Bolton, P. and Kacperczyk, M. (2021a). Do investors care about carbon risk? *Journal of financial economics*, 142(2):517–549.

Bolton, P. and Kacperczyk, M. (2021b). Global pricing of carbon-transition risk. *Working Paper*.

Borghesi, R., Houston, J. F., and Naranjo, A. (2014). Corporate socially responsible investments: Ceo altruism, reputation, and shareholder interests. *Journal of Corporate Finance*, 26:164–181.

Brandt, L., Ma, D., and Rawski, T. G. (2014). From Divergence to Convergence: Reevaluating the History Behind China's Economic Boom. *Journal of Economic Literature*, 52(1):45–123.

Brunnermeier, S. B. and Cohen, M. A. (2003). Determinants of environmental innovation in us manufacturing industries. *Journal of environmental economics and management*, 45(2):278–293.

Burke, M., Hsiang, S. M., and Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527(7577):235–239.

Carrión-Flores, C. E. and Innes, R. (2010). Environmental innovation and environmental performance. *Journal of Environmental Economics and Management*, 59(1):27–42.

Chan, W. (1982). Chu Hsi and Yüan Neo-Confucianism. In Chan, H. and Bary, W. T. D., editors, *Yüan Thought: Chinese Thought and Religion Under the Mongols*. Columbia University Press.

Chan, W.-T. (1989). *Chu Hsi: New Studies*. University of Hawaii Press.

Chen, T. and Kung, J. K.-S. (2020). The Rise of Communism in China. *Working Paper*.

Chen, T., Kung, J. K.-S., and Ma, C. (2020). Long live Keju! The Persistent Effects of China's civil Examination System. *The Economic Journal*, 130(631):2030–2064.

Chen, Y. J., Chen, Z., and He, S. (2019). Social Norms and Household Savings Rates in China. *Review of Finance*, 23(5):961–991.

Chen, Z., Ma, C., and Sinclair, A. J. (2022). Banking on the Confucian Clan: Why China Developed Financial Markets so Late. *The Economic Journal*, 132(644):1378–1413.

Cheng, C.-K. (1944). Familism the Foundation of Chinese Social Organization. *Soc. F.*, 23(1):50–59.

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

Chui, A. C., Titman, S., and Wei, K. J. (2010). Individualism and Momentum Around the World. *Journal of Finance*, 65(1):361–392.

Cline, B. N., Garner, J. L., and Yore, A. S. (2014). Exploitation of the Internal Capital Market and the Avoidance of Outside Monitoring. *Journal of Corporate Finance*, 25:234–250.

Coase, R. H. (1937). The Nature of the Firm. *Economica*, 4(16):386–405.

Dai, R., Duan, R., Liang, H., and Ng, L. (2021). Outsourcing climate change. *Working Paper*, (723).

Damodaran, A. (2019). Equity Risk Premiums (ERP): Determinants, Estimation and Implications. *Working Paper*.

Davis, L. and zgür Orhangazi (2021). Competition and monopoly in the u.s. economy: What do the industrial concentration data show? *Competition Change*, 25(1):102452942093401–.

Dechow, P. M., Sloan, R. G., and Sweeney, A. P. (1995). Detecting earnings management. *Accounting review*, pages 193–225.

Deng, K. G. (2015). A Swinging Pendulum: The Chinese Way in Growth and Development from 1800 to the Present Day. In *China's Many Dreams*, pages 94–131. Springer.

Dennis, J. R. (2020). *Writing, publishing, and reading local gazetteers in Imperial China, 1100–1700*. BRILL.

Dessaint, O. and Matray, A. (2017). Do Managers Overreact to Salient Risks? Evidence from Hurricane Strikes. *Journal of Financial Economics*, 126(1):97–121.

Dolphin, G. and Xiahou, Q. (2022). World carbon pricing database: sources and methods. *Scientific Data*, 9(1):573.

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

Edmans, A. (2011). Does the Stock Market Fully Value Intangibles? Employee Satisfaction and Equity Prices. *Journal of Financial Economics*, 101(3):621–640.

Elman, B. A. (1989). Imperial Politics and Confucian Societies in Late Imperial China: The Hanlin and Donglin Academies. *Modern China*, 15(4):379–418.

Elman, B. A. et al. (2000). *A Cultural History of Civil Examinations in Late Imperial China*. University of California Press.

Engle, R. F., Giglio, S., Kelly, B., Lee, H., and Stroebel, J. (2020). Hedging climate change news. *The Review of Financial Studies*, 33(3):1184–1216.

Eun, C. S., Wang, L., and Xiao, S. C. (2015). Culture and R^2. *Journal of Financial Economics*, 115(2):283–303.

Fan, G., Wang, X., and Zhu, H. (2011). NERI index of Marketization of China's Provinces 2011 Report. *Beijing: National Economic Research Institute*.

Firth, R. (1959). *Social Cange in Tikopia: Re-Study of a Polynesian community after a generation*. New York: George Allen and Unwin Ltd.

Fisman, R. and Miguel, E. (2007). Corruption, Norms, and Legal Enforcement: Evidence from Diplomatic Parking Tickets. *Journal of Political Economy*, 115(6):1020–1048.

Francis, J., LaFond, R., Olsson, P. M., and Schipper, K. (2004). Costs of equity and earnings attributes. *The accounting review*, 79(4):967–1010.

Fu, F., Huang, S., and Wang, R. (2019). Transformation in production technology and the dynamics of corporate investment. *Working Paper*.

Gardner, D. K. (2007). *The Four Books: The Basic Teachings of the Later Confucian Tradition*. Hackett Publishing.

Giglio, S., Kelly, B., and Stroebel, J. (2021a). Climate finance. *Annual Review of Financial Economics*, 13:15–36.

Giglio, S., Maggiori, M., Rao, K., Stroebel, J., and Weber, A. (2021b). Climate change and long-run discount rates: Evidence from real estate. *The Review of Financial Studies*, 34(8):3527–3571.

Gilgan, S. (2022). Grounding Classics-Reading Education in Ideal Learning Environments. In *Utopia in the Revival of Confucian Education*, pages 91–138. Brill.

Giuliano, P. and Nunn, N. (2021). Understanding Cultural Persistence and Change. *The Review of Economic Studies*, 88(4):1541–1581.

Glomb, V., Lee, E.-J., and Gehlmann, M. (2020). *Confucian Academies in East Asia*. Brill.

Gold, T. B. (1985). After Comradeship: Personal Relations in China Since the Cultural Revolution. *The China Quarterly*, 104:657–675.

Goldman, M. (1975). China's Anti-Confucian Campaign, 1973–74. *The China Quarterly*, 63:435–462.

Gorodnichenko, Y. and Roland, G. (2011). Which Dimensions of Culture Matter for Long-run Growth? *American Economic Review*, 101(3):492–98.

Gorodnichenko, Y. and Roland, G. (2017). Culture, Institutions, and the Wealth of Nations. *Review of Economics and Statistics*, 99(3):402–416.

Gorton, G. B., Grennan, J., and Zentefis, A. K. (2021). Corporate Culture. *Working Paper*.

Gorton, G. B. and Zentefis, A. K. (2020). Corporate Culture as a Theory of the Firm. *Working Paper*.

Graham, J. R., Harvey, C. R., and Rajgopal, S. (2005). The economic implications of corporate financial reporting. *Journal of accounting and economics*, 40(1-3):3–73.

Gu, L. (2016). Product market competition, r&d investment, and stock returns. *Journal of Financial Economics*, 119(2):441–455.

Gu, Z., Sun, W., and Zhou, F. (2021). The Cultural Roots of Economic Expropriation. *Working Paper*.

Guiso, L., Sapienza, P., and Zingales, L. (2003). People's Opium? Religion and Economic Attitudes. *Journal of Monetary Economics*, 50(1):225–282.

Guiso, L., Sapienza, P., and Zingales, L. (2004). The Role of Social Capital in Financial Development. *American Economic Review*, 94(3):526–556.

Guiso, L., Sapienza, P., and Zingales, L. (2006). Does culture affect economic outcomes? *Journal of Economic Perspectives*, 20(2):23–48.

Guiso, L., Sapienza, P., and Zingales, L. (2008a). Social Capital as Good Culture. *Journal of the European Economic Association*, 6(2-3):295–320.

Guiso, L., Sapienza, P., and Zingales, L. (2008b). Trusting the Stock Market. *Journal of Finance*, 63(6):2557–2600.

Guiso, L., Sapienza, P., and Zingales, L. (2009). Cultural Biases in Economic Exchange? *The Quarterly Journal of Economics*, 124(3):1095–1131.

Guiso, L., Sapienza, P., and Zingales, L. (2015). The Value of Corporate Culture. *Journal of Financial Economics*, 117(1):60–76.

Han, J. and Ling, L. H. (1998). Authoritarianism in the Hypermasculinized State: Hybridity, Patriarchy, and Capitalism in Korea. *International Studies Quarterly*, 42(1):53–78.

Hilary, G. and Hui, K. W. (2009). Does Religion Matter in Corporate Decision Making in America? *Journal of Financial Economics*, 93(3):455–473.

Hofstede, G. (1980). Culture and Organizations. *International Studies of Management & Organization*, 10(4):15–41.

Hofstede, G. (2001). Culture's Recent Consequences: Using Dimension Scores in Theory and Research. *International Journal of Cross Cultural Management*, 1(1):11–17.

Hofstede, G., Hofstede, G. J., and Minkov, M. (2005). *Cultures and organizations: Software of the mind*, volume 2. Mcgraw-hill New York.

Hofstede, G. and Peterson, M. F. (2000). Culture: National Values and Organizational Practices. *Handbook of Organizational Culture and Climate*, 3:401–416.

Hong, H., Karolyi, G. A., and Scheinkman, J. A. (2020). Climate finance. *The Review of Financial Studies*, 33(3):1011–1023.

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

House, R. J., Hanges, P. J., Javidan, M., Dorfman, P. W., and Gupta, V. (2004). *Culture, Leadership, and Organizations: The GLOBE Study of 62 Societies*. Sage publications.

Hsu, A., Brandt, J., Widerberg, O., Chan, S., and Weinfurter, A. (2020). Exploring links between national climate strategies and non-state and subnational climate action in nationally determined contributions (ndcs). *Climate Policy*, 20(4):443–457.

Hsu, C.-C., Quang-Thanh, N., Chien, F., Li, L., and Mohsin, M. (2021). Evaluating green innovation and performance of financial development: mediating concerns of environmental regulation. *Environmental Science and Pollution Research*, 28(40):57386–57397.

Huang, Y. (2003). Cheng Brothers' Neo-Confucian Virtue Ethics: The Identity of Virtue and Nature. *Journal of Chinese Philosophy*, 30(3-4):451–467.

Hwang, K.-k. (1987). Face and Favor: The Chinese Power Game. *American Journal of Sociology*, 92(4):944–974.

Inglehart, R. (2000). World Values Surveys and European Values Surveys, 1981-1984, 1990-1993, and 1995-1997. *Institute for Social Research, ICPSR version, Ann Arbor, MI.*

Ip, P. K. (2009). Is Confucianism Good for Business Ethics in China? *Journal of Business Ethics*, 88(3):463–476.

Jia, R. (2014). The Legacies of Forced Freedom: China's Treaty Ports. *Review of Economics and Statistics*, 96(4):596–608.

Karolyi, G. A. (2016). The Gravity of Culture for Finance. *Journal of Corporate Finance*, 41:610–625.

Khanna, T. and Palepu, K. (1997). Why focused strategies. *Harvard business review*, 75(4):41–51.

Kim, C.-S., Mauer, D. C., and Sherman, A. E. (1998). The Determinants of Corporate Liquidity: Theory and Evidence. *Journal of Financial and Quantitative Analysis*, 33(3):335–359.

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

Kumar, A., Page, J. K., and Spalt, O. G. (2011). Religious Beliefs, Gambling Attitudes, and Financial Market Outcomes. *Journal of Financial Economics*, 102(3):671–708.

Kumar, A., Page, J. K., and Spalt, O. G. (2016). Gambling and Comovement. *Journal of Financial and Quantitative Analysis*, 51(1):85–111.

La Porta, Rafaeland Lopez-de-Silanes, F., Shleifer, A., and Vishny, R. W. (1998). Law and Finance. *Journal of Political Economy*, 106(6):1113–1155.

Labatt, S. and White, R. R. (2011). *Carbon finance: the financial implications of climate change*. John Wiley & Sons.

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

Levine, R., Lin, C., and Xie, W. (2020). The African Slave Trade and Modern Household Finance. *The Economic Journal*, 130(630):1817–1841.

Li, Q., Shan, H., Tang, Y., and Yao, V. (2020). Corporate climate risk: Measurements and responses. *Working Paper*.

Liang, F. (2008). *Statistics on Household, Farm, and Feudal Land Tax in Chinese Dynasties* (in Chinese). Zhonghua shuju.

Liang, H. and Renneboog, L. (2017). On the foundations of corporate social responsibility. *The Journal of Finance*, 72(2):853–910.

Liang, H., Wang, R., and Zhu, H. (2022). Finance and ideology: The firm-level channels. *Working Paper*.

Liu, Q. (2006). On Confucius' Principle of Consanguineous Affection: A Reading of the Dialogue about the Three-year Mourning in the Lunyu. *Asian Philosophy*, 16(3):173–188.

Liu, X. (2016). Corruption Culture and Corporate Misconduct. *Journal of Financial Economics*, 122(2):307–327.

Lowes, S. and Montero, E. (2021). The Legacy of Colonial Medicine in Central Africa. *American Economic Review*, 111(4):1284–1314.

Luong, H. V. (1989). Vietnamese Kinship: Structural Principles and the Socialist Transformation in Northern Vietnam. *The Journal of Asian Studies*, 48(4):741–756.

Marquis, C. and Qiao, K. (2020). Waking from Mao's Dream: Communist Ideological Imprinting and the Internationalization of Entrepreneurial Ventures in China. *Administrative Science Quarterly*, 65(3):795–830.

Michalopoulos, S. and Papaioannou, E. (2015). On the Ethnic Origins of African Development: Chiefs and Precolonial Political Centralization. *Academy of Management Perspectives*, 29(1):32–71.

Michalopoulos, S. and Papaioannou, E. (2016). The Long-run Effects of the Scramble for Africa. *American Economic Review*, 106(7):1802–48.

Nguyen, D. D., Hagendorff, J., and Eshraghi, A. (2018). Does a CEO's Cultural Heritage Affect Performance under Competitive Pressure? *The Review of Financial Studies*, 31(1):97–141.

Nisbett, R. E. and Masuda, T. (2003). Culture and Point of View. *Proceedings of the National Academy of Sciences*, 100(19):11163–11170.

North, D. C. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge university press.

Nunn, N. (2008). The Long-term Effects of Africa's Slave Trades. *The Quarterly Journal of Economics*, 123(1):139–176.

Nunn, N. (2012). Culture and the Historical Process. *Economic History of Developing Regions*, 27(sup-1):108–126.

Nunn, N. (2020). The Historical Roots of Economic Development. *Science*, 367(6485):eaaz9986.

Nunn, N., Qian, N., and Jaya, W. (2020). Distrust and Political Turnover. *Working Paper*.

Nunn, N. and Wantchekon, L. (2011). The Slave Trade and the Origins of Mistrust in Africa. *American Economic Review*, 101(7):3221–52.

Opler, T., Pinkowitz, L., Stulz, R., and Williamson, R. (1999). The Determinants and Implications of Corporate Cash Holdings. *Journal of Financial Economics*, 52(1):3–46.

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

Pan, Y., Siegel, S., and Yue Wang, T. (2020). The Cultural Origin of CEOs' Attitudes toward Uncertainty: Evidence from Corporate Acquisitions. *The Review of Financial Studies*, 33(7):2977–3030.

Perkins, D. et al. (1969). Agricultural Development in China, 1368-1968. *Agricultural development in China, 1368-1968.*

Pevzner, M., Xie, F., and Xin, X. (2015). When Firms Talk, Do Investors Listen? The Role of Trust in Stock Market Reactions to Corporate Earnings Announcements. *Journal of Financial Economics*, 117(1):190–223.

Pierce, L. and Snyder, J. A. (2018). The Historical Slave Trade and Firm access to Finance in Africa. *The Review of Financial Studies*, 31(1):142–174.

Sautner, Z., van Lent, L., Vilkov, G., and Zhang, R. (2022). Firm-level climate change exposure. *Forthcoming in Journal of Finance*.

Schwartz, S. (2006). A Theory of Cultural Value Orientations: Explication and Applications. *Comparative Sociology*, 5(2-3):137–182.

Schwartz, S. H. (1994). Are there Universal Aspects in the Structure and Contents of Human Values? *Journal of Social Issues*, 50(4):19–45.

Shive, S. A. and Forster, M. M. (2020). Corporate governance and pollution externalities of public and private firms. *The Review of Financial Studies*, 33(3):1296–1330.

Siegel, J. I., Licht, A. N., and Schwartz, S. H. (2011). Egalitarianism and International Investment. *Journal of Financial Economics*, 102(3):621–642.

Spolaore, E. and Wacziarg, R. (2013). How Deep Are the Roots of Economic Development? *Journal of economic literature*, 51(2):325–69.

Stulz, R. M. and Williamson, R. (2003). Culture, Openness, and Finance. *Journal of Financial Economics*, 70(3):313–349.

Tabellini, G. (2008). Institutions and Culture. *Journal of the European Economic Association*, 6(2-3):255–294.

Talhelm, T., Zhang, X., Oishi, S., Shimin, C., Duan, D., Lan, X., and Kitayama, S. (2014). Large-scale Psychological Differences within China Explained by Rice versus Wheat Agriculture. *Science*, 344(6184):603–608.

Trueman, B. and Titman, S. (1988). An explanation for accounting income smoothing. *Journal of accounting research*, pages 127–139.

Van den Steen, E. (2010). On the Origin of Shared Beliefs (and Corporate Culture). *The RAND Journal of Economics*, 41(4):617–648.

van der Speenkel, O. B. (1953). Population Statistics of Ming China. *Bulletin of the School of Oriental and African Studies*, 15(2):289–326.

Wang, L. and Juslin, H. (2009). The Impact of Chinese Culture on Corporate Social Responsibility: The Harmony Approach. *Journal of Business Ethics*, 88(3):433–451.

Weber, M. (1930). *The Protestant Ethic and the Spirit of Capitalism*. London: George Allen Unwin Ltd.

Williamson, O. E. (2000). The New Institutional Economics: Taking Stock, Looking Ahead. *Journal of Economic Literature*, 38(3):595–613.

Wooldridge, W. C. (2009). Building and State Building in Nanjing after the Taiping Rebellion. *Late Imperial China*, 30(2):84–126.

Wright, M. C. (1962). *The Last Stand of Chinese Conservatism, T'ung-chih Restoration, 1862–1874*. Stanford University Press.

Wu, X. (2005). Yeulu Academy: Landscape and Gardens of Neo-Confucian Pedagogy. *Studies in the History of Gardens & Designed Landscapes*, 25(3):156–190.

Xu, Q. and Kim, T. (2022). Financial constraints and corporate environmental policies. *The Review of Financial Studies*, 35(2):576–635.

Yang, F. (2011). *Religion in China: Survival and Revival under Communist Rule*. Oxford University Press.

You, H., Yang, J., Xue, B., Xiao, X., Xia, J., Jin, C., and Li, X. (2021). Spatial Evolution of Population Change in Northeast China during 1992–2018. *Science of The Total Environment*, 776:146023.

Zhu, J., Ye, K., Tucker, J. W., and Chan, K. J. C. (2016). Board Hierarchy, Independent Directors, and Firm Value: Evidence from China. *Journal of Corporate Finance*, 41:262–279.

Zhu, S. (1958). *General Note on Chinese Local Chronicles*. The Commercial Press.

Chapter 3

Appendix

In the Appendix, I attach the figures and empirical results of Chapter 1 and Chapter 2, respectively.

Pages 81 to 106 are the figures and empirical results of Chapter 1.

Pages 107 to 137 are the figures and empirical results of Chapter 2.

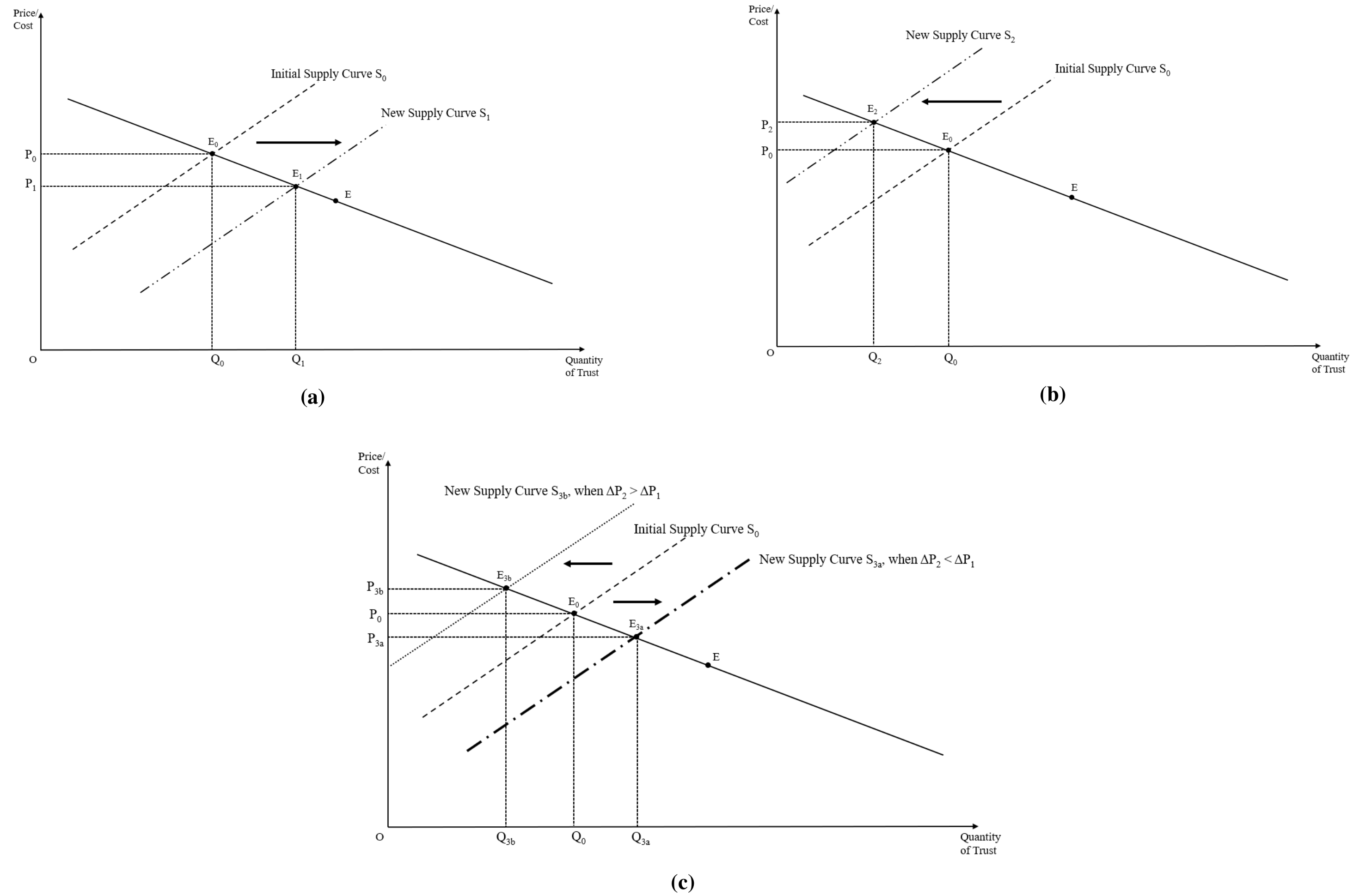


Figure 1: The Supply and Demand of Stakeholder Trust

Notes: This figure illustrates the supply and demand of trust from stakeholders on firms. The X-axis denotes the "quantity" of trust supplied by stakeholders to a firm, and the Y-axis represents the "price" of trust (i.e., cost of acquiring trust from stakeholders) to the firm. The downward curve is the demand curve, D, which represents the quantity of trust demanded by the firm given its "price". We assume a constant marginal utility of trust. The upward curves are the supply curves under the influence of varying intensities of societal culture, which represent the quantity of trust supplied to a firm given the "price" of trust. The initial equilibrium quantity of trust on a firm is Q_0 and the initial equilibrium "price" of trust is P_0, the quantity and the price at which the demand curve intersects with the initial supply curve S_0. With a stronger influence of societal culture, the supply of trust by stakeholders may change, leading to a new supply curve. All the intersection points between the supply and demand curves are above the point of unit elasticity E. Figure 1(a) (1(b)) illustrates the situation where societal culture increases (decreases) trust supplied by stakeholders, which shifts the dashed supply curve to the right (left). The solid upward curve is the new supply curve, S_1 (S_2). The new equilibrium "quantity" of trust on a firm increases to Q_1 (Q_2) and the new equilibrium "price" is P_1 (P_2). We further define $\Delta P_1 = P_1 – P_0$ and $\Delta P_2 = P_2 – P_0$. Figure 1(c) presents the net effect analysis. When $\Delta P_1 > \Delta P_2$, the supply curve shifts toward right to S_{3a}, and the new equilibrium quantity and price of trust are Q_{3a} and P_{3a}. When $\Delta P_2 > \Delta P_1$, the supply curve shifts toward left to S_{3b}, and the new equilibrium quantity and price of trust are Q_{3b} and P_{3b}.

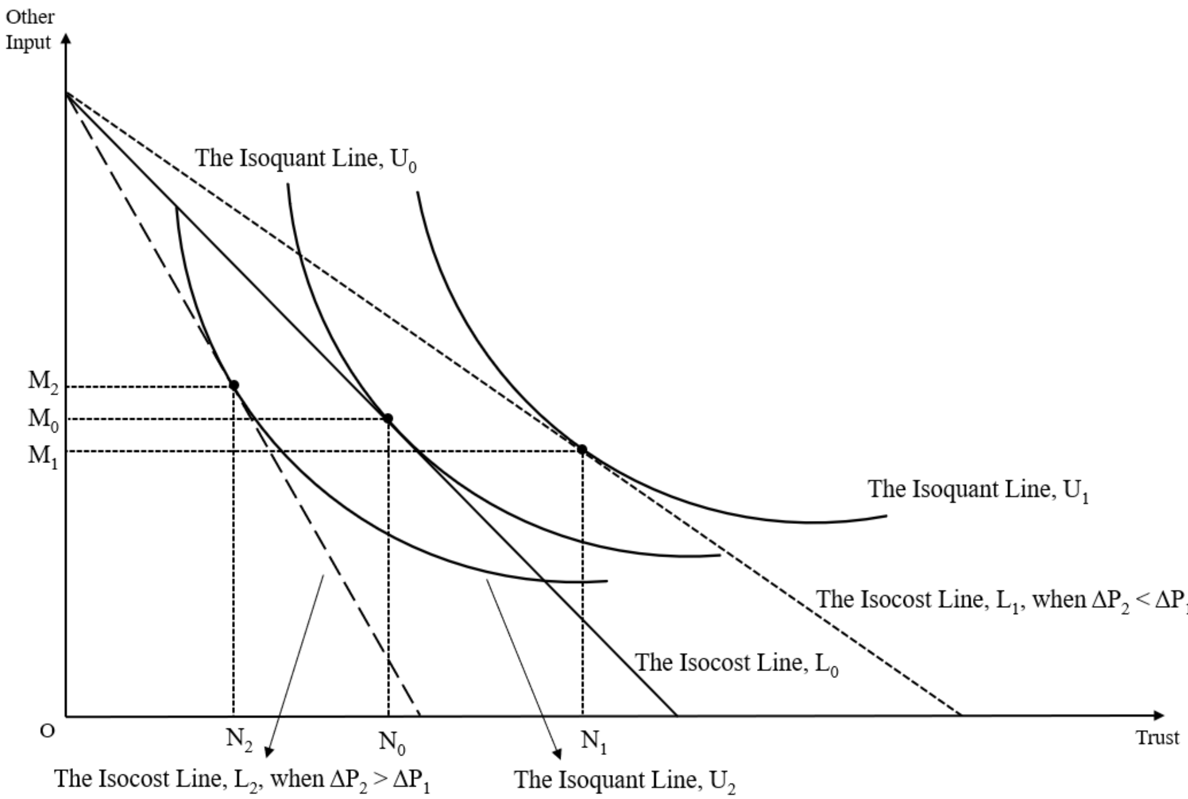


Figure 2: The Production Decision by a Firm under Stakeholder Trust

Notes: This figure illustrates the production decision for firms based on different "prices" of trust. The isocost lines, L_0, L_1, and L_2 represent combinations of stakeholder trust and other inputs that can be acquired with a fixed amount of capital when the "prices" of trust are P_0, P_1, and P_2, respectively. The isoquant curves, U_0, U_1, and U_2, represent all those combinations of trust and other inputs that are needed to produce the same level of output, whereas the higher curve indicates more outputs. The equilibrium quantity of output is determined by equating the marginal rate of technical substitution to the ratio of the prices of the two factors. The initial output of the firm given a fixed budget is Q_0 since the equal product curves, U_0, is tangent to the isocost line, L_0. With a stronger influence of trust-based societal culture, the "price" of trust can decrease or increase. When $\Delta P_1 > \Delta P_2$, the new isocost line (L_1) becomes flatter and is tangent to the higher isoquant line U_1, which implies that greater cultural influence leads to a higher output of the firm given the same amount of budget. When $\Delta P_2 > \Delta P_1$, the new isocost line (L_2) becomes steeper and is tangent to the lower isoquant line U_2, which implies that greater cultural influence leads to a lower output of the firm given the same amount of budget.

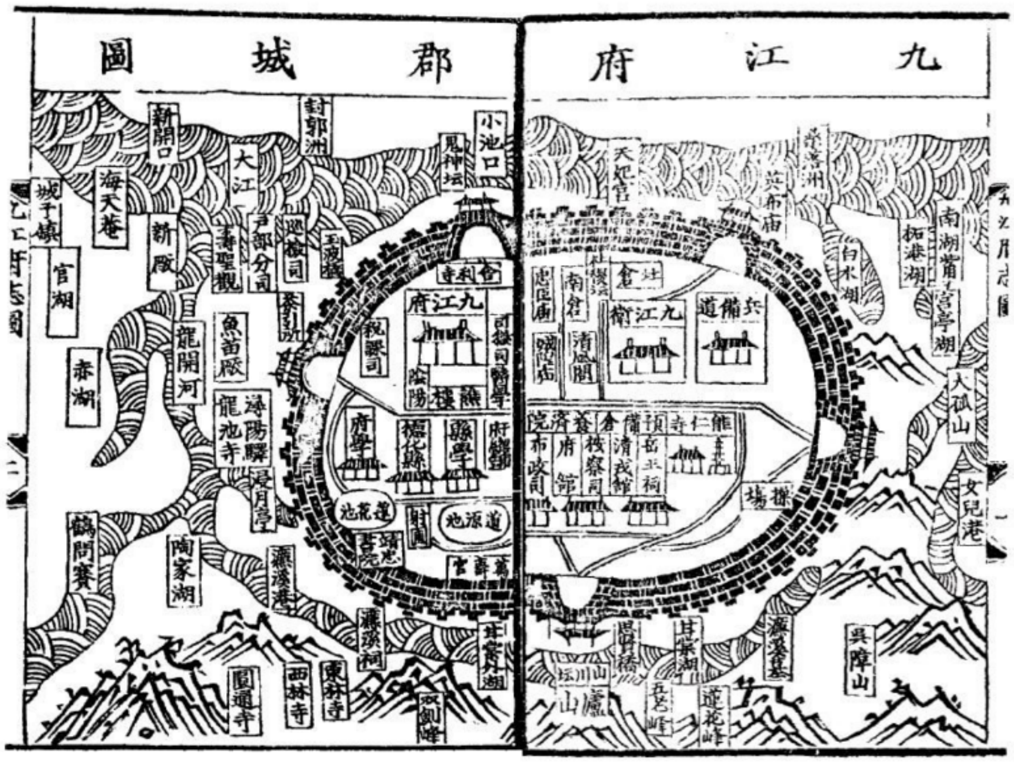


Figure 3: A One-page Snapshot of a Local Chronicle

Notes: This figure is a one-page snapshot of a Local Chronicle of *Jiujiang* county.

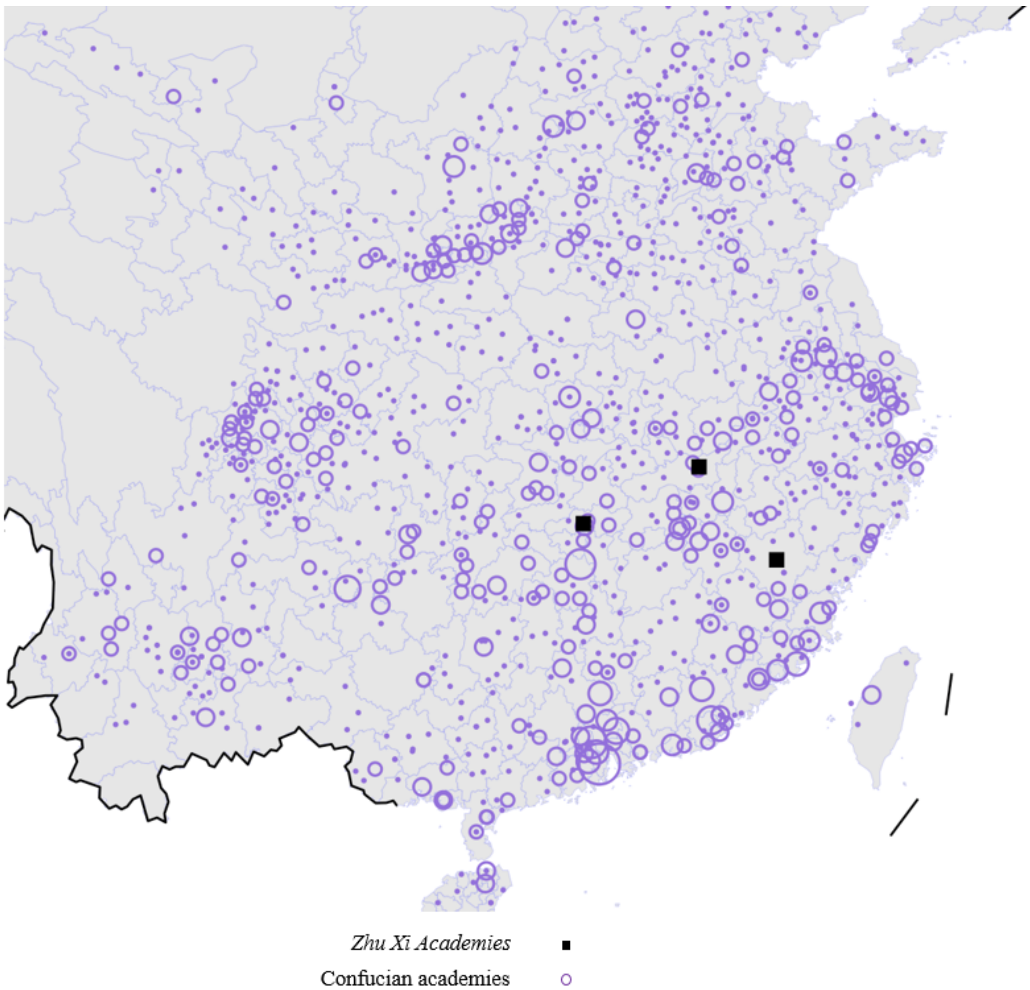


Figure 4: Geographical distribution of Confucian schools and *Zhu Xi Academies*

Notes: This figure plots the geographical distribution of Confucian schools and the three *Zhu Xi Academies* across different regions in China. Bigger circles indicating more Confucian schools at the same locations.

Table 1. Summary Statistics

Variables	Obs.	Mean	Std. Dev	Min	Median	Max
Firm-level variable						
Confucianism	25,389	2.909	0.899	0.000	3.136	4.205
Confucian Academies	25,389	23.685	15.760	0.000	22.000	66.000
Social Contribution	25,336	0.102	0.064	0.015	0.095	0.357
Stakeholder Protection	25,412	0.329	0.706	0.000	0.000	2.000
Courtesy Expenses (million CNY)	25,302	280.024	576.252	8.462	105.915	4103.418
Patents	25,412	6.936	27.401	0.000	0.000	201.000
Trade Credit	25,409	0.123	0.098	0.002	0.097	0.465
Size	25,412	21.871	1.313	19.021	21.724	25.818
Leverage (%)	25,409	44.552	22.568	4.671	43.684	109.952
ROA (%)	25,409	3.971	5.987	-22.463	3.811	21.193
Revenue Growth (%)	23,312	22.832	62.951	-65.602	12.051	465.467
Operating Cash Flow (%)	25,373	7.441	0.2242	-1.0667	0.0724	0.744
SOE	25,412	0.419	0.493	0.000	0.000	1.000
Buddhism	25,384	3.260	1.330	0.000	3.367	7.825
Taoism	25,384	1.986	0.989	0.000	1.946	6.650
ROE (%)	25,408	6.6960	14.1056	-75.4378	7.2058	52.3204
Operating Profit Growth	23,352	0.219	0.815	-1.047	0.141	1.769
CSR Score	16,916	3.129	0.757	-3.218	3.157	4.520
City-level variable						
City GDP (billion CNY)	2,564	220.886	297.641	6.597	125.023	3063.299
City Employment (thousand)	2,464	712.40	1,113.62	20.84	367.85	17,145.50
City Total Wage (billion CNY)	2,297	26.249	60.289	0.669	12.071	1018.284
FDI (million USD)	2,216	951.952	2087.428	0.160	264.075	30825.645

Notes: This table provides the summary statistics on firm- and city-level variables for the whole sample. Our sample period spans from 2007 to 2017. Statistics are summarized at the firm-year level for firm characteristics, and at the city-year level for city characteristics. All variable definitions are provided in Appendix Table A.1.

Table 2. The Effects of Culture on Firm Policies: Baseline Results

	Social Contribution (1)	Stakeholder Protection (2)	Courtesy Expenses (3)	Patents (4)	Trade Credit (5)
Confucianism	0.0044***	0.0171**	0.0327***	0.0456***	0.0048***
	(6.268)	(2.531)	(5.741)	(4.507)	(5.962)
Size	-0.0040***	0.2198***	0.7816***	0.1285***	0.0022***
	(-5.610)	(25.054)	(148.563)	(9.343)	(3.295)
Leverage	-0.0109**	-0.0679***	0.0726**	-0.1822***	0.1654***
	(-2.172)	(-2.715)	(2.288)	(-4.506)	(35.186)
ROA	0.5041***	0.9690***	1.2835***	0.5432***	0.0644***
	(25.715)	(10.863)	(11.702)	(3.440)	(4.436)
Revenue Growth	-0.0020**	-0.0419***	-0.0131	-0.0242**	0.0012
	(-1.971)	(-6.013)	(-1.619)	(-2.107)	(0.965)
Operating Cash flow	0.0222***	-0.0018	-0.0194	0.0045	-0.0188***
	(7.132)	(-0.086)	(-0.681)	(0.170)	(-6.609)
SOE	0.0124***	0.1108***	0.0991***	0.0884***	0.0124***
	(9.311)	(7.110)	(8.869)	(4.260)	(7.646)
City GDP	-0.0011	-0.0559***	-0.0431***	0.0370	0.0105***
	(-0.682)	(-3.039)	(-2.748)	(1.495)	(4.222)
City Employment	-0.0061**	0.1030**	-0.0610***	-0.0229	0.0137***
	(-2.455)	(2.060)	(-2.716)	(-0.411)	(4.260)
City Total Wage	0.0091***	-0.0336	0.1291***	0.0292	-0.0199***
	(3.796)	(-0.779)	(5.985)	(0.595)	(-6.256)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	18,762	18,769	18,747	18,769	18,768
R^2	0.2412	0.1972	0.7433	0.0873	0.3482

Notes: This table reports the results of running the following regression model:

$$Y_{i,t} = \alpha + \beta Confucianism_i + \gamma^{'} Controls_{i,t-1} + FE + \varepsilon_{i,t},$$

Where $Y_{i,t}$ represents five corporate policies, $Controls$ represents a vector of control variables, FE denotes fixed effects. Specifically, the dependent variables are firm-level social contribution to assets ratio (a proxy for *Benevolence*, Column (1)), stakeholder protection (a proxy for *Righteousness*, Column (2)), courtesy expenses (a proxy for *Courteousness*, Column (3)), patents (a proxy for *Wisdom*, Column (4)), and trade credit (a proxy for *Trustworthiness*, Column (5)), respectively. A firm's social contribution is the ratio of the sum of total tax contribution, employee payments, interest expense, donations, and profit attributable to shareholders over its total assets. Stakeholder protection is whether a firm reports to have taken measures to protect its staff and suppliers. Courtesy expenses are the natural logarithm of (one plus) management fees deducted by executives' and directors' wages. Patents is the natural logarithm of (one plus) the number of patents authorized by the government plus one. Trade credit is the sum of accounts payable and notes payable, scaled by total assets. The key explanatory variable is $Confucianism$, measured by the logarithm of Confucian academies in the Qing Dynasty that are within a 100-kilometer radius of a firm's headquarter based on their geographical coordinates. The OLS regression includes control variables for firm-level and city macro-economic characteristics, including firm size, leverage, ROA, revenue growth rate, operating cash flow, whether the company is a state-owned enterprise (SOE), as well as the logarithms of a city's GDP, number of employment, and total employee wages. All columns include industry and year fixed effects. Standard errors are clustered at the city by year levels. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Table 3. Alternative Culture Measures and Specifications

	Social Contribution	Stakeholder Protection	Courtesy Expenses	Patents	Trade Credit
	(1)	(2)	(3)	(4)	(5)
Panel A. The effects of other cultures					
Confucianism	0.0049***	0.0504***	0.0325***	0.0351**	0.0032***
	(4.816)	(5.001)	(4.041)	(2.381)	(2.850)
Buddhism	0.0006	0.0083	0.0278***	0.0314**	0.0012
	(0.716)	(0.784)	(3.972)	(2.537)	(1.028)
Taoism	-0.0014	-0.0499***	-0.0307***	-0.0200	0.0004
	(-1.024)	(-3.072)	(-3.149)	(-1.099)	(0.280)
FDI	0.0008	-0.0145**	0.0097	0.0149	0.0048***
	(0.936)	(-2.025)	(1.324)	(1.380)	(5.329)
Control Variables	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	18,259	18,266	18,244	18,266	18,265
R^2	0.2419	0.1995	0.7445	0.0879	0.3535
Panel B. Alternative measure of Confucianism					
Jinshi	0.0018***	0.0110***	0.0099***	0.0314***	0.0033***
	(4.688)	(2.885)	(2.864)	(5.574)	(7.065)
Control Variables	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	18,762	18,769	18,747	18,769	18,768
R^2	0.2404	0.1973	0.7429	0.0877	0.3489
Panel C. Measure of CEO's culture					
CEO culture	-0.0013	0.0287**	-0.0175	0.0215	0.0015
	(-1.116)	(2.236)	(-1.445)	(1.027)	(1.125)
Control Variables	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	6,769	6,773	6,767	6,773	6,773
R^2	0.2982	0.2344	0.7937	0.0991	0.3990

(Continued)

Table 3 *(Continued)*. Alternative Culture Measures and Specifications

	Social Contribution	Stakeholder Protection	Courtesy Expenses	Patents	Trade Credit
	(1)	(2)	(3)	(4)	(5)
Panel D. Additional Controls					
Confucianism	0.0032***	0.0180**	0.0296***	0.0473***	0.0048***
	(4.093)	(2.341)	(4.537)	(4.007)	(5.087)
Distance to Coast	-0.0175***	-0.3201***	-0.0602**	-0.1511***	-0.0011
	(-6.265)	(-7.736)	(-2.054)	(-3.457)	(-0.295)
Slope	0.0020***	0.0445***	0.0133***	0.0174**	-0.0007
	(4.887)	(5.865)	(3.278)	(2.550)	(-1.457)
Population Density	0.0147	-0.2766*	-0.0370	-0.3292*	-0.0124
	(1.526)	(-1.835)	(-0.464)	(-1.792)	(-0.817)
Urbanization	-0.0475**	0.0871	-0.0176	1.4583***	0.0696**
	(-2.054)	(0.267)	(-0.106)	(3.660)	(2.335)
Control Variables	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	18683	18690	18668	18690	18689
R^2	0.2433	0.2093	0.7436	0.0885	0.3485

Notes: This table reports the results of testing the effect of alternative culture measures. The dependent variables below ($Y_{i,t}$) are firm-level social contribution to assets ratio (a proxy for *Benevolence*, Column (1)), stakeholder protection (a proxy for *Righteousness*, Column (2)), courtesy expenses (a proxy for *Courteousness*, Column (3)), patents (a proxy for *Wisdom*, Column (4)), and trade credit (a proxy for *Trustworthiness*, Column (5)), respectively. These five dependent variables are measured in the same way as in Table 2. Panel A tests the following regression model:

$$Y_{i,t} = \alpha + \beta Confucianism_i + \rho Values_{i.t-1} + \gamma^{'} Controls_{i,t-1} + FE + \varepsilon_{i,t},$$

Where $Confucianism$ is measured in the same way as in Table 2, and $Values$ denotes a vector of other culture measures, including Buddhism (the logarithm of the number of (one plus) Buddhist temples within a 100km radius of a firm's headquarter), Taoism (the logarithm of the number of (one plus) Taoist temples within a 100km radius of a firm's headquarter), and FDI (the logarithm of the total foreign direct investment (plus one) in the city where the firm is headquartered). Panel B tests the following regression model:

$$Y_{i,t} = \alpha + \beta Jinshi_i + \gamma^{'} Controls_{i,t-1} + FE + \epsilon_{i,t},$$

Where the key explanatory variable is $Jinshi$, an alternative measure of Confucianism which is measured as the logarithm of the number of (one plus) imperial scholars (*Jinshi*) whose hometown are within a 100km radius of a firm's headquarter. In Panel C, we replace the original Confucianism measure with a measure of the exposure to Confucianism by the CEO of a firm (CEO culture) and employ CEO culture as independent variable. We measure CEO culture using the number of Confucian schools during the Qing Dynasty in the CEO's hometown or birthplace city (based on contemporary-day administrative division). In Panel D, we follow the specification in Table 2 and additionally control for a city's distance to coast and average slope, and a province's population density and urbanization in Qing. $Controls$ and FE represent the same set of control variables and fixed effects as in Table 2. Standard errors are clustered at the city by year levels. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Table 4. Instrumental Variable Regression

	Confucianism	Social Contribution	Stakeholder Protection	Courtesy Expenses	Patents	Trade Credit
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Using the Distance to *Zhu Xi Academy* as IV						
Distance to *Zhu Xi Academy*	-0.0012***					
	(-23.791)					
Confucianism		0.0108***	0.0832***	0.0608***	0.0928***	0.0053***
		(10.231)	(5.996)	(5.664)	(5.252)	(3.812)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,767	18,760	18,767	18,745	18,767	18,766
R^2	0.4932	0.2374	0.1922	0.7429	0.0865	0.3482
Panel B. Using the Number of Small Rivers as IV						
Number of Small Rivers	-0.0416***					
	(-10.762)					
Confucianism		0.0097***	0.1449***	0.0671***	0.2021***	0.0109***
		(4.173)	(5.944)	(3.162)	(6.246)	(4.162)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,769	18,762	18,769	18,747	18,769	18,768
R^2	0.2175	0.2386	0.1787	0.7427	0.0778	0.3458

Notes: This table reports the results of instrumental variable (IV) tests using two-stage least square regressions (2SLS):

$$Confucianism_i = \delta_0 + \delta_1 IV_{i/p} + \gamma^{'} Controls_{i,t-1} + FE + \varepsilon_{i,t},$$

$$Y_{i,t} = \beta_0 + \beta_1 \widehat{Confucianism}_i + \gamma^{'} Controls_{i,t-1} + FE +_{i,t},$$

Where the dependent variable in the first stage (Column (1) of Panels A and B) is $Confucianism$, measured in the same way as in Table 2, and the dependent variable $Y_{i,t}$ in the second stage represents five corporate policies measured in the same way as in Table 2. Specifically, for both Panel A and Panel B, the dependent variables are firm-level social contribution to assets ratio (a proxy for *Benevolence*, Column (2)), stakeholder protection (a proxy for *Righteousness*, Column (3)), courtesy expenses (a proxy for *Courteousness*, Column (4)), patents (a proxy for *Wisdom*, Column (5)), and trade credit (a proxy for *Trustworthiness*, Column (6)), respectively. IV represents the instrumental variables, which are: (1) *Distance to Zhu Xi Academy* in Panel A, and (2) *Number of Small Rivers* in the province where a firm is headquartered in Panel B. The control variables and fixed effects in the first-stage and second-stage models are the same as those in Table 2. Standard errors are clustered at the city by year levels. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Table 5. Interaction with Market Participants

	Social Contribution (1)		Stakeholder Protection (2)		Courtesy Expenses (3)		Patents (4)		Trade Credit (5)	
Market-orientation	Low	High	Low	High	Low	High	Low	High	Low	High
Confucianism	0.0055***	0.0015	0.0231*	-0.0315**	0.0612***	0.0043	0.0700***	-0.0727**	0.0066***	0.0065***
	(4.267)	(0.854)	(1.848)	(-2.041)	(5.778)	(0.352)	(3.987)	(-2.083)	(4.929)	(2.867)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,298	4,013	5,299	4,015	5,295	4,010	5,299	4,015	5,299	4,015
R^2	0.2518	0.2948	0.1725	0.2740	0.7080	0.7821	0.1002	0.1148	0.3431	0.3798

Notes: This table reports the results of testing the cross-sectional heterogeneity in the effect of Confucianism following the specification:

$$Y_{i,t} = \alpha + \beta Confucianism_i + \gamma' Controls_{i,t-1} + FE + \varepsilon_{i,t},$$

Where $Y_{i,t}$ represents five corporate policies, $Controls$ represents a vector of control variables, FE denotes fixed effects. Specifically, the dependent variables are firm-level social contribution to assets ratio (a proxy for *Benevolence*, Column (1)), stakeholder protection (a proxy for *Righteousness*, Column (2)), courtesy expenses (a proxy for *Courteousness*, Column (3)), patents (a proxy for *Wisdom*, Column (4)), and trade credit (a proxy for *Trustworthiness*, Column (5)), respectively. These five dependent variables, as well as the key explanatory variable, $Confucianism$, are measured in the same way as in Table 2. We partition the whole sample into a high- and a low-market-orientation group based on whether the marketization index score (compiled by Fan et al. (2011) and updated every year) for the focal province in each year belongs to the top or the bottom tercile. The control variables and fixed effects in all columns are the same as those in Table 2. Standard errors are clustered at the city by year levels. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Table 6. Interaction with Politicians' Ideology

	Social Contribution (1)		Stakeholder Protection (2)		Courtesy Expenses (3)		Patents (4)		Trade Credit (5)	
Politician ideology	*Dengist*	*Maoist*	*Dengist*	*Maoist*	*Dengist*	*Maoist*	*Dengist*	*Maoist*	*Dengist*	*Maoist*
Confucianism	0.0046***	0.0037*	0.0182**	-0.0062	0.0449***	0.0156	0.0528***	-0.0203	0.0061***	-0.0016
	(5.252)	(1.854)	(2.071)	(-0.351)	(5.920)	(1.181)	(3.708)	(-0.948)	(5.704)	(-0.761)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,574	3,675	9,576	3,677	9,567	3,674	9,576	3,677	9,576	3,677
R^2	0.2542	0.2291	0.1739	0.2632	0.7234	0.7606	0.0822	0.1180	0.3656	0.3571

Notes: This table reports the results of testing the cross-sectional heterogeneity in the effect of Confucianism following the specification:

$$Y_{i,t} = \alpha + \beta Confucianism_i + \gamma^{'} Controls_{i,t-1} + FE + \varepsilon_{i,t},$$

Where $Y_{i,t}$ represents five corporate policies, $Controls$ represents a vector of control variables, FE denotes fixed effects. Specifically, the dependent variables are firm-level social contribution to assets ratio (a proxy for *Benevolence*, Column (1)), stakeholder protection (a proxy for *Righteousness*, Column (2)), courtesy expenses (a proxy for *Courteousness*, Column (3)), patents (a proxy for *Wisdom*, Column (4)), and trade credit (a proxy for *Trustworthiness*, Column (5)), respectively. These five dependent variables, as well as the key explanatory variable, $Confucianism$, are measured in the same way as in Table 2. We partition the whole sample into two subsamples based on whether the CCP secretary of the city (who is usually the supreme leader of the city) where a firm is headquartered joined the CCP before 1976, the year of Mao' death ("*Maoist* leaders"), or after 1979, the starting year of China's adoption of "reform and opening up" policy ("*Dengist* leaders"). In addition to the control variables in Table 2, we also include a politician's age as an additional control in all columns. Fixed effects in all columns are the same as those in Table 2. Standard errors are clustered at the city by year levels. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Table 7. Board of Directors and Cultural Effect

	Social Contribution (1)		Stakeholder Protection (2)		Courtesy Expenses (3)		Patents (4)		Trade Credit (5)	
Presence of non-Chinese director	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Confucianism	0.0041***	0.0028	0.0170**	0.0087	0.0354***	-0.0300*	0.0544***	-0.0312	0.0053***	0.0014
	(5.437)	(1.263)	(2.440)	(0.420)	(6.073)	(-1.743)	(5.433)	(-0.701)	(6.400)	(0.592)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,563	2,197	16,569	2,198	16,553	2,192	16,569	2,198	16,568	2,198
R^2	0.2542	0.2291	0.1739	0.2632	0.7234	0.7606	0.0822	0.1180	0.3656	0.3571

Notes: This table reports the results of testing the cross-sectional heterogeneity in the effect of Confucianism following the specification:

$$Y_{i,t} = \alpha + \beta Confucianism_i + \gamma^{'} Controls_{i,t-1} + FE + \varepsilon_{i,t},$$

Where $Y_{i,t}$ represents five corporate policies, $Controls$ represents a vector of control variables, FE denotes fixed effects. Specifically, the dependent variables are firm-level social contribution to assets ratio (a proxy for *Benevolence*, Column (1)), stakeholder protection (a proxy for *Righteousness*, Column (2)), courtesy expenses (a proxy for *Courteousness*, Column (3)), patents (a proxy for *Wisdom*, Column (4)), and trade credit (a proxy for *Trustworthiness*, Column (5)), respectively. These five dependent variables, as well as the key explanatory variable, $Confucianism$, are measured in the same way as in Table 2. We partition the whole sample into two subsamples based on whether there is at least one non-Chinese director on the board or not. The control variables and fixed effects in all columns are the same as those in Table 2. Standard errors are clustered at the city by year levels. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Table 8. Confucianism and Firm Performance

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dependent variable = ROE						
Social Contribution	0.7717**					
	(2.312)					
Stakeholder Protection		0.2060**				
		(2.397)				
Courtesy Expenses			0.1069**			
			(2.373)			
Patents				0.0772**		
				(2.397)		
Trade Credit					0.7025**	
					(2.322)	
Confucianism						0.0035**
						(2.397)
Controls and Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,761	18,768	18,746	18,768	18,767	18,768
R^2	0.1174	0.1172	0.1175	0.1172	0.1169	0.1172
Panel B. Dependent variable = Operating profit growth						
Social Contribution	3.7207**					
	(2.164)					
Stakeholder Protection		0.9382**				
		(2.125)				
Courtesy Expenses			0.5059**			
			(2.190)			
Patents				0.3515**		
				(2.125)		
Trade Credit					3.3013**	
					(2.117)	
Confucianism						0.0160**
						(2.125)
Controls and Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,762	18,769	18,747	18,769	18,768	18,769
R^2	0.0768	0.0779	0.0777	0.0774	0.0775	0.0779

(Continued)

Table 8 *(Continued)*. Confucianism and Firm Performance

	(1)	(2)	(3)	(4)	(5)	(6)
Panel C. Dependent variable = CSR score						
Social Contribution	5.2025***					
	(2.849)					
Stakeholder Protection		1.3381***				
		(2.853)				
Courtesy Expenses			0.6936***			
			(2.828)			
Patents				0.5013***		
				(2.853)		
Trade Credit					4.7206***	
					(2.849)	
Confucianism						0.0229***
						(2.853)
Controls and Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,551	13,552	13,544	13,552	13,551	13,552
R^2	0.2447	0.2448	0.2448	0.2448	0.2447	0.2448
Panel D. Testing the mechanisms of the cultural effect on firm performance, DV = Cost of capital						
Social Contribution	-0.1330**					
	(-1.998)					
Stakeholder Protection		-0.0339**				
		(-1.981)				
Courtesy Expenses			-0.0177**			
			(-1.978)			
Patents				-0.0127**		
				(-1.981)		
Trade Credit					-0.1196**	
					(-1.981)	
Confucianism						-0.0006**
						(-1.981)
Controls and Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,350	18,356	18,334	18,356	18,356	18,356
R^2	0.0718	0.0715	0.0719	0.0719	0.0714	0.0720

(Continued)

Table 8 *(Continued)*. Confucianism and Firm Performance

	(1)	(2)	(3)	(4)	(5)	(6)
Panel E. Testing the mechanisms of the cultural effect on firm performance, DV = Employee growth						
Social Contribution	0.5648*					
	(1.692)					
Stakeholder Protection		0.1432*				
		(1.668)				
Courtesy Expenses			0.0767*			
			(1.706)			
Patents				0.0536*		
				(1.668)		
Trade Credit					0.5017*	
					(1.656)	
Confucianism						0.0024*
						(1.668)
Controls and Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,193	18,200	18,178	18,200	18,199	18,200
R^2	0.0711	0.0712	0.0712	0.0706	0.0711	0.0716

Notes: This table reports the results of testing the effect of culture-biased corporate policies on firm performance in two-stage least square (2SLS) regressions in Panels A-C. In the first stage, we regress a firm's social contribution, employee and supplier protection, courtesy expenses, the logged number of patents, and trade credit respectively on $Confucianism$, measured by the logarithm of the number of Confucian academies within a 100-kilometer radius around the a firm's headquarter. In the second stage, we regress firms' return on equity (ROE) (Panel A), Operating Profit Growth (Panel B), and CSR score (Panel C) on the predicted values of the five corporate policies obtained from the first stage regressions. Column (6) reports the "reduced form" results of directly regressing the above performance measures on $Confucianism$ and other variables. In Panel D and E, we run the above two-stage least square and reduced-form regressions with the dependent variables being weighted-average cost of capital (WACC) and employee growth respectively to test the mechanisms through which Confucianism affects firm performance. The control variables and fixed effects in all columns are the same as those in Table 2. Standard errors are clustered at the city by year levels. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Table 9. Post-hoc Tests

	Board Hierarchy	Female Directors Ratio	Female Director Dummy	Blau Index
	(1)	(2)	(3)	(4)
Confucianism	0.0601*	-0.0087***	-0.0988***	-0.0102***
	(1.685)	(-7.504)	(-4.946)	(-6.896)
Industry Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	13,295	18,364	18,364	18,364
R^2	0.0377	0.0779	0.0329	0.0743

Notes: This table reports the results of several post-hoc tests on hierarchy and gender diversity on board by running the following regression model:

$$Y_{i,t} = \alpha + \beta Confucianism_i + \gamma^{'} Controls_{i,t-1} + FE + \varepsilon_{i,t},$$

Where $Y_{i,t}$ represents firm-level structure or policy, $Controls$ represents a vector of control variables, FE denotes fixed effects. Panel A shows the results of testing within-firm hierarchy. The dependent variable in Column (1), is board hierarchy, a dummy variable that equals 1 if all the firm's independent directors are placed at the bottom rungs of the director list and 0 otherwise. The dependent variable in Column (2) is the female director ratio on board. The dependent variable in Column (3) is female directors dummy, a binary indicator that equals 1 if there is at least one female director on the board, and 0 otherwise. The dependent variable in Column (4) is the Blau index of female directors following Blau (1977). The key explanatory variable, $Confucianism$, the control variables and fixed effects in all columns are the same as those in Table 2. Standard errors are clustered at the city and year levels in Panel A, and at the city level in Panel B. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Appendix 1: Definitions of Variables

Table A1. Variable Definition

Variable	Source	Description
Confucianism	Local Chronicles in Qing Dynasty	The natural logarithm of (one plus) the number of Confucian academies within a 100km radius of a firm's headquarter.
Social Contribution	CSMAR	Social contribution (summing up total tax contribution, employee payment, interest expense, donations, and profit attributable to shareholders) divided by total assets.
Stakeholder Protection	CSMAR	The sum of binary indicators of whether a firm reports to have taken measures to protect its staff and suppliers.
Courtesy Expenses	CSMAR	The natural logarithm of management fees deducted by executives' and directors' wages plus one.
Patents	CSMAR	The natural logarithm of the number of patents authorized by the government plus one.
Trade Credit	CSMAR	The sum of accounts payable and notes payable divided by total assets.
Size	CSMAR	The natural logarithm of a firm's total assets plus one.
Leverage	CSMAR	The ratio of debt to total assets of a firm.
ROA	CSMAR	The ratio of a firm's net profit to total assets.
Revenue Growth	CSMAR	The annual revenue growth rate of a firm.
Operating Cash Flow	CSMAR	The cash flow generated by operating activity dived by total revenue.
SOE	CSMAR	A binary variable that equals 1 if the ultimate owner of the firm is the state, and 0 otherwise.
Buddhism	Yang (2011)	The natural logarithm of the number of Buddhist temples within a 100km radius around a firm's headquarter plus one.
Taoism	Yang (2011)	The natural logarithm of the number of Taoist temples within a 100km radius around a firm's headquarter plus one.
Jinshi	*A list of Jinshi in Qing Dynasty*	The natural logarithm of the number of imperial scholars (Jinshi) in Qing Dynasty whose hometowns are within a 100km radius around a firm's headquarter plus one.
Confucian Scholars	*History of Chinese Thought in the Ming Period*	The natural logarithm of the number of renowned Confucian scholars in the Ming Dynasty whose hometowns are within a 100km radius around a firm's headquarter plus one.
ROE	CSMAR	The ratio of a firm's net profit to its book value of equity.
Operating Profit Growth	CSMAR	The annual growth rate of a firm's operating profit.
CSR Score	*Hexun.com*	A firm's corporate social responsibility (CSR) score provided by Hexun.com

(Continued)

Table A1 *(Continued)*. Variable Definition

Variable	Source	Description
Cost of Capital	CSMAR, CCER	A firm's weighted average cost of capital (WACC), computed as $WACC = W_d R_d(1-T) + W_e R_e$, where W_d and W_e are the weights on a firm's debt and common equity, respectively. T is the firm's tax rate. R_d denotes the cost of debt and is equal to interest expense divided by total amount of debt. R_e represents the cost of common equity and is computed as the 10-year bond rate plus the product of beta and the market risk premium. Equity premium is extracted from Damodaran (2019) to avoid having negative market risk premium. Beta is estimated by using daily stock returns of the previous twelve months and market returns.
Employee Growth	RESSET	The percentage change in a firm's total number of employees over a year.
Board Hierarchy	Zhu et al. (2016)	A binary variable that equals 1 if all the firm's independent directors are placed at the bottom rungs of the director list and 0 otherwise.
Women Directors Ratio	CSMAR	The ratio of female directors to all directors on the board.
Women Directors Dummy	CSMAR	A binary variable that equals 1 if there is at least one female director on the board and 0 otherwise.
Blau Index	CSMAR	The Blau index of gender diversity in the board: $Blau = 1 - \sum_i P_i^2$ Where P_i refers to the percentage of female or male board members (Blau, 1977).
Cash ratio	CSMAR	The ratio of a firm's cash to its total assets.
City GDP	National Bureau of Statistics of China	The natural logarithm of the city's GDP (in billion RMB).
City Employment	National Bureau of Statistics of China	The natural logarithm of the number of residents who are currently employed in the city (in thousand).
City Total Wage	National Bureau of Statistics of China	The natural logarithm of total employee wages (in thousand RMB) of the city.
FDI	National Bureau of Statistics of China	The natural logarithm of total foreign direct investment (in million USD) plus one.
Distance to Coast	Self-Constructed	The natural logarithm of the distance between a city's centroid in Qing Dynasty to the closest point on the coast plus one.
Slope	Self-Constructed	The average slope within each city by matching CHGIS V4 DEM with city boundary in 2017.
Marketization index	Fan et al. (2011)	The index constructed by Fan et al. (2011) that captures the development of market-orientation of a province every year. This index is assessed in five fields with 23 component indicators. The five fields are the level of resource allocation by governments and the market, market intermediaries and the legal environment for the market, the development of the non-state enterprise sector, the development of the product market, and the development of labor, financial, and technology markets.

(Continued)

Table A1 *(Continued)*. Variable Definition

Variable	Source	Description
Population Density	Cao (2000)	The average of a province population density in 1776, 1820, 1851, and 1910.
Urbanization	Xue et al. (2021)	The ratio of provincial urban extent area size in 1866 over province area size.
Number of Small Rivers	National Census for Water of China	The number of small rivers (excluding major ones that cross many provinces, such as Yangtze River and Yellow River) with drainage area greater than 10,000 square kilometers in the province where a firm is headquartered.
Distance to *Zhu Xi Academy*	*Baidu Map*	The shortest distance between a listed firm's headquarters and the nearest *Zhu Xi Academy*. *Zhu Xi Academies* are prestigious schools established by Zhu Xi (also spelled "Chu Hsi"), the renowned Confucian scholar in the Song Dynasty (1130—1200 A.D.). The three *Zhu Xi Academies* are *Yuelu* Academy in *Changsha*, *Hunan* province; *Hanquan* Academy in *Jianyang*, *Fujian* province; and *White Deer Grotto* Academy in *Jiujiang*, *Jiangxi* province.
Perspectives on Raising Children	China Family Panel Studies	The percentage of respondents who choose "for old-age support" in response to the question "why do you want to have children?"
Divorce Population Ratio	National Bureau of Statistics of China	The percentage of divorced pairs to the average population at the provincial level.
Education Expenses	China Family Panel Studies	The natural logarithm of the amount of money that a family spends on children education plus one.
Intergenerational Coresidence Ratio	China Population Census in 2000 and 2010	The percentage of households with four generations living under the same roof in each province.

Appendix 2: Validating the Confucianism Measure

Table A2. Validation Test of the Confucianism Measure

	Perspectives on Raising Children (1)	Divorce Population Ratio (2)	Education Expenses (3)	Intergenerational Coresidence Ratio (4)
Confucianism	0.0243**	-0.5437***	0.3176***	0.0011***
	(2.252)	(-4.584)	(10.116)	(4.301)
Controls	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes
Observations	8,675	248	1,2871	62
R^2	0.0059	0.4563	0.0609	0.3787

Notes: This table reports the results of validating the Confucianism measure as a proxy for Confucian culture. The dependent variables are survey-based ratings based on three major Confucian cultures that are not directly related to our firm policy variables: (i). perspectives on raising children (Column (1)), (ii). provincial divorce population ratio (Column (2)), (iii). a family's education expense (Columns (3)), and (iv). the ratio of intergenerational coresidence ratio (the percentage of population for which at least four generations live under the same roof) of the local province. The key explanatory variable Confucianism is the natural logarithm of (one plus) the number of Confucian academies in a province. In Column (1), Controls include father age, mother age, father education level, and mother education level. In Column (2), the year fixed effect is controlled, and the control variables include provincial GDP, provincial GDP per capita, the logarithm of total employee wages in the province, and logarithm of the total employment in the province. In Column (3), Controls include family's total saving, an binary indicator for whether the family holds financial securities, total annual income, and total annual expenses. Column (4) includes year fixed effects as well as provincial GDP, provincial GDP per capita, and logarithm of the total employment in the province. Total employee wages in provinces in 2000 are not available. Standard errors are clustered at the provincial level. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Appendix 3: IV Results Using Death Rate and Death Toll during Taiping Rebellion

As a further robustness check, we also employ the regional death rate in Taiping (and Nian) Rebellion as an alternative IV, which is measured as either the percentage death rate of the local population or the natural logarithm of (one plus) the death toll in each province between 1851 and 1865. The rebellion was a revolt against the Qing Dynasty and established the "Taiping Heavenly Kingdom" after the Taiping army won several battles against the Imperial Qing army. This rebellion induced the largest number of war deaths in human history, with over 40 million people killed (Wakeman, 1997).

The rebellion repulsed Confucianism and aimed to spread Christianity by destroying many Confucian temples, which triggered resistance by local Confucian gentry and suppression by the Qing government, which eventually defeated the rebellion army. We argue that the regional death toll caused by the rebellion is positively associated with the strength of Confucianism in the region. On one hand, the rebel's agenda included social reforms, such as shared "property in common," equality for women, and the replacement of Confucianism, Buddhism, and Chinese folk religion with a form of Christianity. This doctrine was generally questioned and opposed by Confucian scholars at the time and provoked the anger of local gentry because it violated traditional Chinese ethics and morals. The ruthless means of the Taiping Army in spreading their bogus religion did not leave an imprint of Christianity among the local people but only triggered strong resistance. It also inspired another major armed uprising in northern China, the Nian Rebellion, which happened around the same time also with the aim of toppling the Qing Dynasty, and caused immerse economic devastation and loss of life. The great turmoil of the revolt and memories of the atrocities, transmitted across generations, make residents in more affected areas value the stability that Confucianism emphasizes and helps mitigate the adverse effects of the negative events (Ke et al., 2019; Chen and Kung, 2020).

On the other, after repressing the rebellions, the Qing government started to rebuild the affected regions. Rawski (1979) documented that, in Ancient China, the government often spent enormous effort to rebuild schools in areas that recently experienced war and famine as a means of restoring the Confucian order and sustaining the monarchy. Wooldridge (2009) documents that Zeng Guofan, the governor general in charge of the reconstruction of Nanjing, attached great importance to the Confucian school and temple complex and considered education and ritual as palliatives for the rebellion, a view that justified the vast sum spent on the construction of the school. Similarly, Wright (1962) argues the Taiping Rebellion forced the reassertion of Confucian moral values and the revival of Confucian institutions. Hence, we expect the severity of damage caused by the rebellions to be positively related to the strength of Confucianism, due to local resistance and post-war restoration efforts. Meanwhile, it is unlikely that the regional death toll caused by the Taiping (and Nian) Rebellion will directly influence economic development today. Alternatively, we also employ the regional death toll in the Taiping (and Nian) Rebellion as an alternative instrumental variable. Mortality data during the rebellions is obtained from China Demographic History (Cao, 2000), which records population information at provincial level.

We include the same set of control variables in our two-stage IV regressions. Table A3 presents the results, with Panels A and B showing the results using the regional death rate and death toll in the Taiping (and Nian) Rebellion as the IV, respectively. For both panels, we report the first-stage results of regressing the Confucianism measure on the IV in Column (1), and the second-stage results of regressing the five corporate policy variables on the "predicted" Confucianism variable. We find that both regional death rate and death toll positively predict the firm's exposure to Confucianism (Column (1) of both panels), supporting our conjecture that regions that experienced suppression of Confucian culture had stronger Confucianism. In Columns (2)—(6) of both panels, we again find that a firm's exposure to Confucian culture is significantly and positively associated with its five corporate polices. These results further substantiate our key IV analysis in Table 4, and confirm the role of exposure to Confucianism on corporate behavior.

Table A3. IV Regression Using Death Rate and Death Toll during Taiping Rebellion

	Confucianism	Social Contribution	Stakeholder Protection	Courtesy Expenses	Patents	Trade Credit
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Using Regional Death Rate as IV						
Death Rate	0.0129***					
	(11.691)					
Confucianism		0.0126***	0.0477*	0.0896***	0.1926***	0.0194***
		(5.521)	(1.821)	(3.808)	(4.889)	(6.527)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,769	18,762	18,769	18,747	18,769	18,768
R^2	0.2327	0.2349	0.1961	0.7418	0.0789	0.3341
Panel B. Using Regional Death Toll as IV						
Death Toll	0.0854***					
	(11.516)					
Confucianism		0.0100***	0.0655**	0.0735***	0.1500***	0.0130***
		(4.790)	(2.231)	(3.716)	(4.128)	(4.833)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,769	18,762	18,769	18,747	18,769	18,768
R^2	0.2458	0.2382	0.1945	0.7425	0.0831	0.3438

Notes: This table reports the results of instrumental variable (IV) tests using two-stage least square regressions (2SLS):

$$Confucianism_i = \delta_0 + \delta_1 IV_{i/p} + \gamma^{'} Controls_{i,t-1} + FE + \varepsilon_{i,t},$$

$$Y_{i,t} = \beta_0 + \beta_1 \widehat{Confucianism}_i + \gamma^{'} Controls_{i,t-1} + FE +_{i,t},$$

Where the dependent variable in the first stage (Column (1) of Panels A and B) is $Confucianism$, measured in the same way as in Table 2, and the dependent variable $Y_{i,t}$ in the second stage represents five corporate policies measured in the same way as in Table 2. Specifically, for both Panel A and Panel B, the dependent variables are firm-level social contribution to assets ratio (a proxy for *Benevolence*, Column (2)), stakeholder protection (a proxy for *Righteousness*, Column (3)), courtesy expenses (a proxy for *Courteousness*, Column (4)), patents (a proxy for *Wisdom*, Column (5)), and trade credit (a proxy for *Trustworthiness*, Column (6)), respectively. IV represents the instrumental variables, which are: (1) death rate, measured as the death rate of the local population and (2) death toll, measured as the logarithm of (one plus) the total death toll at the provincial level during the Taiping (and Nian) Rebellion in late Qing. Controls represents a vector of control variables, and FE denotes industry fixed effects, which are the same as those in Table 2 and are included in both stages. Standard errors are clustered at the city and year levels. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

Appendix 4: Testing on Precautionary Savings

As a further post-hoc test, we recognize that Confucianism also advocates the development of "preparedness for the unexpected and hardship," which stresses the importance of having consciousness of uncertainty and taking precautions. To test whether firms with greater exposure to Confucianism are more likely to have precautionary policies, we examine a firm's cash holdings when facing unexpected shocks. A large literature has documented that firms may hold excess cash as a precaution (e.g., Kim et al., 1998; Opler et al., 1999; Bates et al., 2009) In particular, firms could hold cash to better cope with adverse shocks when there is the risk of a liquidity shortage (Acharya et al., 2012), such as exposure to natural disasters. To this end, we follow Dessaint and Matray (2017) and adopt a difference-in-difference identification approach using earthquakes as adverse shocks to firms' operations. Since the saliency and influence of an earthquake are magnified by its proximity, we can rely on a natural experiment framework by leveraging the distance between a firm and the epicenter of an earthquake.

We separate firms into three groups based on the distance between a firm and the epicenter of an earthquake: the affected firms, the firms in the neighborhood, and the unaffected firms. We define "affected firms" as those within 400 kilometers from the epicenters and "neighboring firms" as those that are over 400 kilometers and within 800 kilometers from the epicenters. We define an "Affected" dummy variable, which equals one if the firm is in the affected group over the past 12 months, and a "Neighboring" dummy, which equals one if the firm is in the neighboring firms group over the past 12 months in our difference-in-differences regression. Unaffected firms are treated as the baseline. Across all specifications, the dependent variable is a firm's quarterly cash holdings over assets. Since most of the usual firm-level control variables are themselves affected by the disaster proximity, we do not include them in the regression to avoid the "overcontrolling" problem, following Dessaint and Matray (2017).

Table A4 presents the results. Column (1) includes the Confucianism variable, the Neighboring dummy, the Affected dummy, and the interaction term between Confucianism and the Neighboring dummy. In Column (2), we replace the interaction term in Column (1) with the interaction between

Confucianism and the Affected dummy. Column (3) includes both interaction terms above. In all specifications, we control for firm-quarter fixed effects and year-quarter fixed effects to account for the seasonality in earthquake shocks and firms' cash holding patterns. The coefficient of the interaction Neighbor $\times$ Confucianism is significant and positive, whereas that of the interaction Disaster Zone $\times$ Confucianism is negative and statistically insignificant. The insignificance of the latter is likely due to the fact that firms in affected areas experience cash drain, due to their operations and supply chains being harmed by the earthquakes. These results suggest that firms with greater exposure of Confucianism in the neighboring area—which are supposedly not directly affected by the unexpected negative shocks on their operations—will accumulate more cash as a precaution, which is consistent with our prediction.

Table A4. Testing on Precautionary Cash Holding Motive

DV = Cash ratio	(1)	(2)	(3)
Neighbor	0.718*	0.723*	0.728*
	(1.79)	(1.82)	(1.83)
Disaster Zone	1.444***	1.404***	1.415***
	(3.11)	(3.04)	(3.06)
Confucianism	0.007	0.001	0.003
	(0.20)	(0.03)	(0.08)
Neighbor × Confucianism		0.014**	0.012*
		(2.34)	(1.94))
Disaster Zone × Confucianism	-0.011		-0.007
	(-1.61)		(-1.11)
Firm-quarter Fixed Effects	Yes	Yes	Yes
Year-quarter Fixed Effects	Yes	Yes	Yes
Observations	94,479	94,479	94,479
R^2	0.5051	0.5052	0.5052

Notes: This table reports the results of running the following regression model:

$$Y_{i,t} = \alpha_{i,q} + \delta_{t,q} + \beta_1 Neighbor_{i,t,q} + \beta_2 DisasterZone_{i,t,q} + \beta_3 Confucianism_i + \beta_4 Neighbor_{i,t,q} \times Confucianism_i + \beta_5 DisasterZone_{i,t,q} \times Confucianism_i + \varepsilon_{i,t},$$

Where i indexes firm, t indexes year, q indexes calendar quarter (1 to 4), the dependent variable is cash (to asset) ratio at the end of quarter q of year y, $\alpha_{i,q}$ are firm-quarter fixed effects, $\delta_{t,q}$ are year-quarter effects, $Neighbor$ is a dummy variable that equals one if the firm is headquartered in the neighborhood of an area (over 400 kilometers and within 800 kilometers from the epicenter) hit by an earthquake over the last 12 months and zero if not, $Disaster\ Zone$ is a dummy variable that equals one if the firm is headquartered within 400 kilometers from the epicenter of an earthquake over the last 12 months and zero if not. The key explanatory variable $Confucianism$, the logarithm of the number of Confucian academies within a 100-kilometer radius around a firm's headquarter. Since most of the usual firm-specific control variables are themselves affected by the disaster proximity, we do not include these control variables in the to avoid an "overcontrolling" problem (Dessaint and Matray, 2017). Standard errors are clustered at the city level. t-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively. All variable definitions are provided in Appendix Table A.1.

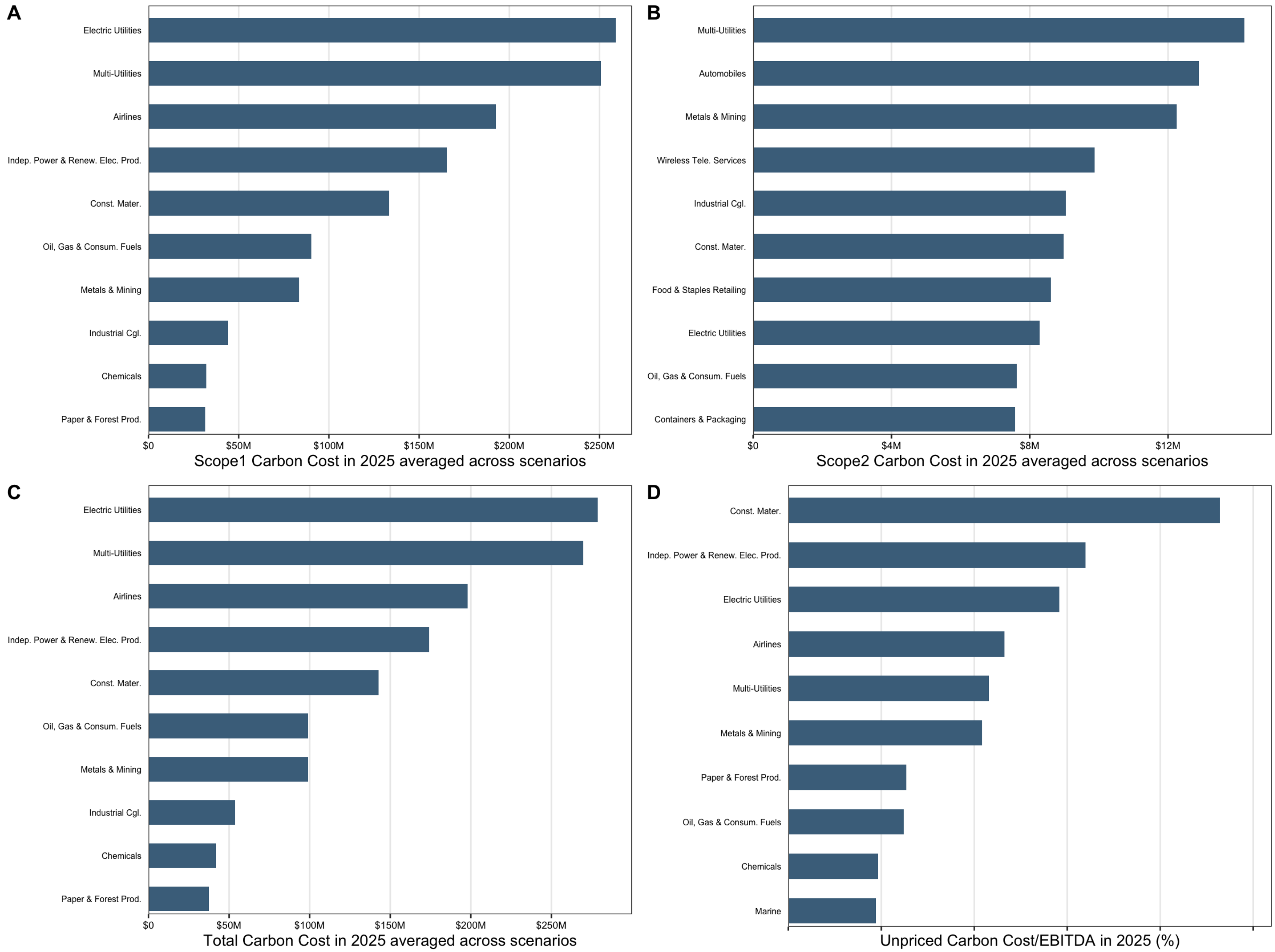


Figure 1: Carbon Earnings Risks: Industry Distribution

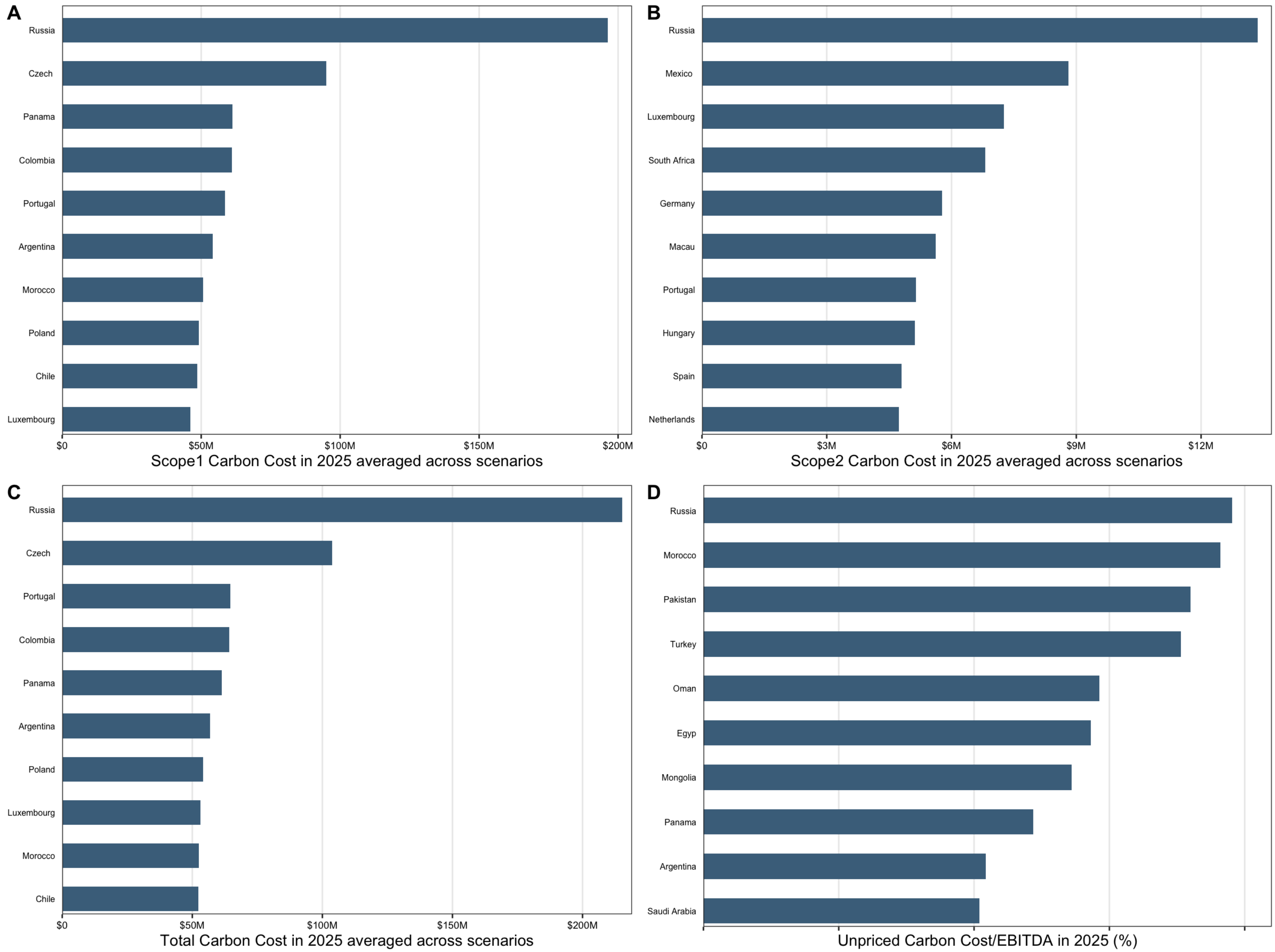


Figure 2: Carbon Earnings Risks: Country Distribution

Table 1. Carbon Earnings Risks: Summary Statistics

Variables	Mean	Std. Dev	p25	p50	p75	Min	Max	N
Scope1 Carbon Cost for 2020	2,485,582.90	12,015,413.88	1,827.21	27,809.87	225,372.84	0	100,812,744.00	40,565
Scope2 Carbon Cost for 2020	548,711.11	1,719,589.81	7,950.98	51,446.90	259,092.80	0	13,000,736.00	40,565
Total Carbon Cost for 2020	3,180,802.18	13,598,322.76	16,583.36	108,563.07	632,111.50	0	112,376,744.00	40,565
Unpriced Carbon Cost/EBIDTA for 2020 (%)	0.69	2.08	0.02	0.11	0.39	0	15.89	40,554
Scope1 Carbon Cost for 2025	17,811,158.83	82,560,579.22	52,736.55	302,979.94	1,862,697.00	71.47	670,871,680.00	40,565
Scope2 Carbon Cost for 2025	3,064,579.31	9,200,703.01	81,869.58	360,374.59	1,553,656.75	1,075.95	67,638,888.00	40,565
Total Carbon Cost for 2025	21,632,495.84	90,557,690.75	181,670.83	854,497.19	4,381,537.50	2,349.73	727,668,416.00	40,565
Unpriced Carbon Cost/EBIDTA for 2025 (%)	4.73	13.48	0.25	0.88	2.71	0	97.07	40,554
Scope1 Carbon Cost for 2030	36,630,516.26	166,432,382.57	123,234.84	661,549.50	3,952,516.50	553.56	1,331,731,200.00	40,565
Scope2 Carbon Cost for 2030	5,913,118.12	17,592,991.61	176,746.13	731,497.44	3,055,565.25	3,285.16	129,065,552.00	40,565
Total Carbon Cost for 2030	43,966,998.35	181,344,930.40	395,765.59	1,782,072.75	8,957,279.00	7,342.28	1,434,696,064.00	40,565
Unpriced Carbon Cost/EBIDTA for 2030 (%)	9.63	27.07	0.55	1.81	5.49	0.01	193.30	40,554
Scope1 Carbon Cost for 2040	60,365,721.70	274,584,665.31	207,655.70	1,083,455.38	6,469,264.50	1,963.10	2,188,134,400.00	40,565
Scope2 Carbon Cost for 2040	9,274,876.70	27,473,724.46	286,633.69	1,160,948.63	4,823,591.00	5,880.87	200,845,280.00	40,565
Total Carbon Cost for 2040	72,359,677.91	301,260,280.14	650,428.00	2,865,240.75	14,327,434.00	13,041.06	2,390,504,192.00	40,565
Unpriced Carbon Cost/EBIDTA for 2040 (%)	15.80	44.93	0.90	2.93	8.76	0.02	320.39	40,554
Scope1 Carbon Cost for 2050	86,546,643.64	394,437,664.90	299,706.75	1,556,253.75	9,224,133.00	3,703.16	3,137,621,504.00	40,565
Scope2 Carbon Cost for 2050	513,021,699.47	38,508,970.17	404,016.09	1,637,479.38	6,829,090.00	8,395.38	280,614,464.00	40,565
Total Carbon Cost for 2050	102,753,232.42	426,848,302.55	924,519.44	4,094,032.75	20,394,254.00	18,862.37	3,354,462,464.00	40,565
Unpriced Carbon Cost/EBIDTA for 2050 (%)	22.57	64.18	1.27	4.19	12.55	0.03	454.05	40,554

Notes: This table provides the summary statistics on firm-level unpriced carbon cost variables, the proxy for carbon earnings risks, averaged across three scenarios (Low, Medium, and High) for different forecast years (2020, 2025, 2030, 2040, and 2050) for the whole sample. Our unpriced carbon cost data sample period spans from 2017 to 2020. All variable definitions are provided in Appendix Table A.1.

Table 2. Carbon Earnings Risks: Scenario Breakdown

Variables	Mean	Std. Dev	p25	p50	p75	Min	Max	N
Panel A. Low Scenario								
Scope1 Carbon Cost for 2020	660,998.26	3,416,916.73	0	2,436.82	44,598.57	0	28,419,016.38	40,565
Scope2 Carbon Cost for 2020	184,582.43	630,285.91	52.02	7,719.62	66,797.06	0	4,729,702.46	40,565
Total Carbon Cost for 2020	897,940.15	4,029,730.89	352.97	15,899.15	148,736.23	0	32,861,696.96	40,565
Unpriced Carbon Cost/EBIDTA for 2020 (%)	0.19	0.64	0	0.02	0.09	0	5.00	40,554
Scope1 Carbon Cost for 2025	6,486,549.25	31,878,358.88	5,949.58	76,708.30	577,584.23	0	263,993,976.60	40,565
Scope2 Carbon Cost for 2025	1,261,616.78	3,903,313.30	20,237.56	126,518.91	612,407.47	0	28,720,330.11	40,565
Total Carbon Cost for 2025	8,060,608.49	35,227,787.38	44,577.69	273,508.13	1,525,664.98	0	285,989,015.60	40,565
Unpriced Carbon Cost/EBIDTA for 2025 (%)	1.75	5.34	0.06	0.29	0.97	0	38.84	40,554
Scope1 Carbon Cost for 2030	14,250,620.22	67,644,391.96	30,109.55	213,798.68	1,384,317.07	0	549,147,757.30	40,565
Scope2 Carbon Cost for 2030	2,532,416.51	7,684,760.00	54,521.79	278,248.62	1,262,610.97	0	56,291,358.42	40,565
Total Carbon Cost for 2030	17,379,159.17	74,065,235.62	122,600.63	641,622.42	3,408,030.63	0	591,721,992.74	40,565
Unpriced Carbon Cost/EBIDTA for 2030 (%)	3.83	11.26	0.17	0.67	2.15	0	80.60	40,554
Scope1 Carbon Cost for 2040	24,942,713.90	116,054,039.43	72,682.33	417,549.35	2,540,880.80	0	930,592,939.30	40,565
Scope2 Carbon Cost for 2040	4,158,833.16	12,412,538.09	116,013.85	497,707.24	2,120,754.26	2,262.65	90,260,796.40	40,565
Total Carbon Cost for 2040	30,099,371.34	126,435,589.72	253,078.65	1,177,185.43	5,979,975.43	5,278.14	1,000,877,675.60	40,565
Unpriced Carbon Cost/EBIDTA for 2040 (%)	6.66	19.29	0.34	1.21	3.73	0.01	137.76	40,554
Scope1 Carbon Cost for 2050	29,550,573.54	136,605,590.06	90,823.08	506,831.08	3,074,710.10	0	1,088,823,709.00	40,565
Scope2 Carbon Cost for 2050	4,816,164.43	14,330,411.14	139,047.98	587,964.46	2,479,082.66	2,800.69	104,271,121.90	40,565
Total Carbon Cost for 2050	35,586,683.06	149,047,034.30	308,230.02	1,401,787.00	7,055,612.23	6,418.30	1,175,227,553.59	40,565
Unpriced Carbon Cost/EBIDTA for 2050 (%)	7.88	22.75	0.42	1.43	4.36	0.01	161.23	40,554

(Continued)

Table 2. Carbon Earnings Risks: Scenario Breakdown *(Continued)*

Variables	Mean	Std. Dev	p25	p50	p75	Min	Max	N
Panel B. Medium Scenario								
Scope1 Carbon Cost for 2020	2,026,727.39	10,201,292.67	364.87	17,685.63	163,567.41	0	84,178,115.33	40,565
Scope2 Carbon Cost for 2020	466,301.87	1,499,382.48	3,529.74	36,865.64	205,916.96	0	11,071,476.87	40,565
Total Carbon Cost for 2020	2,608,064.51	11,473,249.21	9,909.43	77,706.38	484,901.62	0	92,951,010.21	40,565
Unpriced Carbon Cost/EBIDTA for 2020 (%)	0.56	1.82	0.01	0.08	0.30	0	13.87	40,554
Scope1 Carbon Cost for 2025	15,745,700.96	74,828,571.41	31,564.27	227,520.04	1,457,891.42	0	605,846,834.50	40,565
Scope2 Carbon Cost for 2025	2,713,541.54	8,271,804.29	64,442.10	302,315.15	1,336,307.31	0	60,819,845.37	40,565
Total Carbon Cost for 2025	19,139,368.38	82,102,673.01	138,986.41	692,029.64	3,599,652.04	0	659,244,361.20	40,565
Unpriced Carbon Cost/EBIDTA for 2025 (%)	4.13	12.10	0.19	0.72	2.25	0	85.52	40,554
Scope1 Carbon Cost for 2030	33,648,231.20	154,066,093.87	106,879.54	577,861.86	3,488,151.54	46.77	1,224,354,714.00	40,565
Scope2 Carbon Cost for 2030	5,420,117.52	16,250,763.57	163,344.54	661,266.76	2,781,372.94	3,481.53	119,131,164.80	40,565
Total Carbon Cost for 2030	40,392,608.48	168,078,233.31	359,546.51	1,590,472.74	8,019,644.90	7,479.84	1,323,734,561.59	40,565
Unpriced Carbon Cost/EBIDTA for 2030 (%)	8.77	24.98	0.49	1.62	4.86	0.01	176.25	40,554
Scope1 Carbon Cost for 2040	56,863,713.71	261,397,827.50	187,644.43	978,111.04	5,788,201.40	1,807.02	2,090,256,742.00	40,565
Scope2 Carbon Cost for 2040	8,598,157.69	25,696,431.89	268,063.59	1,064,044.90	4,396,847.39	5,485.44	188,413,274.40	40,565
Total Carbon Cost for 2040	67,972,372.91	286,430,294.95	596,456.10	2,607,119.16	13,118,098.85	11,795.29	2,278,939,452.50	40,565
Unpriced Carbon Cost/EBIDTA for 2040 (%)	14.69	42.46	0.82	2.65	7.93	0.02	300.65	40,554
Scope1 Carbon Cost for 2050	115,044,677.81	524,201,946.66	399,730.50	2,067,278.35	12,241,912.86	5,554.73	4,162,020,312.00	40,565
Scope2 Carbon Cost for 2050	17,124,467.17	50,647,575.88	534,513.62	2,161,401.74	8,993,808.92	11,192.72	368,786,154.70	40,565
Total Carbon Cost for 2050	136,336,507.22	566,650,332.99	1,223,792.01	5,426,384.93	27,121,390.19	25,084.40	4,444,079,940.00	40,565
Unpriced Carbon Cost/EBIDTA for 2050 (%)	29.91	85.09	1.68	5.54	16.60	0.04	600.47	40,554

(Continued)

Table 2. Carbon Earnings Risks: Scenario Breakdown *(Continued)*

Variables	Mean	Std. Dev	p25	p50	p75	Min	Max	N
Panel C. High Scenario								
Scope1 Carbon Cost for 2020	4,769,023.12	23,150,943.43	3,752.68	54,770.20	432,319.28	0	189,841,111.70	40,565
Scope2 Carbon Cost for 2020	995,249.02	3,112,099.39	15,773.77	97,978.83	484,579.48	0	23,201,027.93	40,565
Total Carbon Cost for 2020	6,036,401.88	26,086,302.48	33,109.18	207,996.94	1,186,805.04	0	211,317,524.14	40,565
Unpriced Carbon Cost/EBIDTA for 2020 (%)	1.31	3.95	0.04	0.22	0.74	0	28.79	40,554
Scope1 Carbon Cost for 2025	31,201,226.91	143,158,779.48	99,767.85	553,661.83	3,347,317.93	214.42	1,142,774,309.00	40,565
Scope2 Carbon Cost for 2025	5,218,579.62	15,578,273.82	148,512.37	634,702.38	2,681,586.83	3,227.84	113,376,492.00	40,565
Total Carbon Cost for 2025	37,697,510.29	156,642,412.04	328,057.64	1,521,379.71	7,675,935.18	7,049.19	1,237,771,829.36	40,565
Unpriced Carbon Cost/EBIDTA for 2025 (%)	8.29	23.44	0.45	1.56	4.83	0.01	166.85	40,554
Scope1 Carbon Cost for 2030	61,992,696.52	280,801,727.04	214,166.01	1,133,337.06	6,816,692.65	1,613.91	2,221,691,024.00	40,565
Scope2 Carbon Cost for 2030	9,786,820.36	29,065,052.39	295,694.77	1,227,688.65	5,112,993.34	6,373.95	211,774,137.90	40,565
Total Carbon Cost for 2030	74,129,228.17	305,352,499.48	667,374.95	3,021,609.49	15,107,896.96	14,547.01	2,388,631,729.62	40,565
Unpriced Carbon Cost/EBIDTA for 2030 (%)	16.30	45.70	0.92	3.08	9.36	0.02	323.07	40,554
Scope1 Carbon Cost for 2040	99,290,739.41	449,697,943.44	345,889.22	1,798,172.28	10,702,510.39	4,082.29	3,543,553,741.00	40,565
Scope2 Carbon Cost for 2040	15,067,639.03	44,554,619.37	465,749.77	1,896,157.99	7,891,524.60	9,894.51	323,861,745.60	40,565
Total Carbon Cost for 2040	119,007,290.38	494,642,466.25	1,067,279.21	4,749,736.35	23,768,046.45	22,049.75	3,891,695,556.70	40,565
Unpriced Carbon Cost/EBIDTA for 2040 (%)	26.05	73.89	1.47	4.86	14.58	0.03	522.78	40,554
Scope1 Carbon Cost for 2050	135,334,750.14	699,757,577.48	399,730.50	2,067,278.35	12,241,912.86	2,335.28	7,002,060,577.00	40,565
Scope2 Carbon Cost for 2050	19,140,198.73	67,052,869.91	534,513.62	2,161,401.74	8,993,808.92	6,910.15	660,981,582.30	40,565
Total Carbon Cost for 2050	156,364,910.99	737,237,909.46	1,223,792.01	5,426,384.93	27,121,390.19	17,387.88	7,265,197,849.13	40,565
Unpriced Carbon Cost/EBIDTA for 2050 (%)	32.12	101.79	1.68	5.54	16.60	0.02	916.08	40,554

Notes: This table provides the summary statistics on firm-level unpriced carbon cost variables, the proxy for carbon earnings risks, for different scenarios and forecast years for the whole sample. Panel A reports the summary statistics of variables under Low scenario, Panel A reports the summary statistics of variables under Medium scenario, and Panel C reports the summary statistics of variables under High scenario. Our unpriced carbon cost data sample period spans from 2017 to 2020. Statistics are summarized at the firm-year level. All variable definitions are provided in Appendix Table A.1.

Table 3. Industry and Country/Region Representation by Number of Observations

Panel A. Industry Representation

Industry	N	Industry	N	Industry	N
Banks	2,500	Trading Companies & Distributors	621	Biotechnology	248
Real Estate Management & Development	2,004	Food & Staples Retailing	589	Air Freight & Logistics	222
Chemicals	1,892	Health Care Equipment & Supplies	552	Internet & Direct Marketing Retail	220
Machinery	1,640	Entertainment	483	Interactive Media & Services	220
Electronic Equipment, Instruments & Components	1,488	Independent Power & Renewable Electricity Producers	479	Gas Utilities	212
Equity Real Estate Investment Trusts	1,383	Construction Materials	450	Thrifts & Mortgage Finance	211
Food Products	1,367	Professional Services	428	Air Freight & Airlines	210
Metals & Mining	1,365	Building Products	421	Internet & Leisure Products	201
Oil, Gas & Consumable Fuels	1,133	Electric Utilities	398	Automobiles	197
Hotels, Restaurants & Leisure	1,056	Communications Equipment	392	Marine	193
Capital Markets	1,033	Diversified Telecommunication Services	375	Wireless Telecommunication Services	181
Construction & Engineering	1,015	Transportation Infrastructure	369	Life Sciences Tools & Services	162
Semiconductors & Semiconductor Equipment	984	Road & Rail	341	Water Utilities	129
Pharmaceuticals	938	Technology Hardware, Storage & Peripherals	334	Distributors	127
Specialty Retail	869	Energy Equipment & Services	333	Multi-Utilities	120
IT Services	858	Beverages	328	Household Products	107
Auto Components	831	Industrial Conglomerates	327	Health Care Technology	94
Insurance	749	Diversified Consumer Services	318	Mortgage Real Estate Investment Trusts	91
Textiles, Apparel & Luxury Goods	743	Aerospace & Defense	312	Tobacco	71
Software	742	Diversified Financial Services	305		
Household Durables	700	Consumer Finance	300		
Media	671	Containers & Packaging	298		
Electrical Equipment	666	Personal Products	285		
Health Care Providers & Services	650	Multiline Retail	252		
Commercial Services & Supplies	632	Paper & Forest Products	249	Total	40,565

(Continued)

Table 3. Industry and Country/Region Representation by Number of Observations *(Continued)*

Panel B. Country Representation

Country/Region	N	Country/Region	N	Country/Region	N
United States	6,809	Pakistan	158	Bulgaria	12
Japan	6,807	Denmark	151	Macao SAR	12
China	5,376	Chile	144	Croatia	10
South Korea	2,275	Bermuda	132	Ivory Coast	9
Taiwan, China	1,922	Austria	111	Mongolia	9
India	1,749	Luxembourg	107	Ukraine	91
United Kingdom	1,415	Egypt	97	Lebanon	8
Hong Kong SAR	1,302	Greece	96	Liechtenstein	8
Canada	1,038	United Arab Emirates	87	Estonia	7
Australia	945	Qatar	83	Ghana	7
France	720	Cayman Islands	75	Kazakhstan	7
Germany	677	Vietnam	60	Lithuania	7
Sweden	588	Kuwait	58	Botswana	6
Malaysia	582	Nigeria	58	Mauritius	6
Switzerland	551	Peru	49	Serbia	6
Thailand	548	Colombia	48	Tunisia	6
South Africa	444	Portugal	47	Uganda	6
Brazil	443	Morocco	40	British Virgin Islands	5
Singapore	423	Kenya	34	Jamaica	5
Italy	398	Jersey Channel Islands	31	Uruguay	5
Indonesia	394	Oman	29	Panama	4
Israel	300	Argentina	27	Georgia	3
Turkey	265	Romania	23	Gibraltar	3
Spain	263	Cyprus	21	Papua New Guinea	3
Mexico	247	Czech	21	Senegal	3
Netherlands	239	Guernsey	21	Togo	3
Philippines	229	Bangladesh	17	Zimbabwe	3
Saudi Arabia	222	Jordan	17	Iceland	2
Norway	218	Monaco	17	Malawi	2
Belgium	188	Bahrain	15	Namibia	2
Finland	180	Hungary	15	Trinidad and Tobago	2
Poland	180	Malta	15	Bahamas	1
Russia	175	Slovenia	15	Reunion	1
New Zealand	164	Isle of Man	13	Zambia	1
Ireland	161	Sri Lanka	13	Total	40,565

Notes: The table reports the distribution of firm-year observations in our sample with regard to GIC 6 industry classification and country/region in Panel A and Panel B, respectively. Total represents the total firm-year observations in our unpriced carbon cost data sample.

Table 4. Carbon Earnings Risks: Industry Distribution

Panel A. Scope1 Carbon Cost for 2025				
Industry	Mean	SD	p50	N
Electric Utilities	258,981,697.18	278,697,060.48	112,323,656.00	398
Multi-Utilities	250,830,990.54	243,593,147.29	152,119,272.00	120
Airlines	192,567,239.05	196,770,008.77	119,574,504.00	210
Independent Power & Renewable Electricity Producers	165,281,809.95	242,059,135.12	27,467,688.00	479
Construction Materials	133,289,792.55	193,453,776.15	43,519,904.00	450
Oil, Gas & Consumable Fuels	90,306,002.57	172,364,303.50	14,616,674.00	1,133
Metals & Mining	83,523,429.70	175,048,123.89	6,911,945.50	1,365
Industrial Conglomerates	44,102,521.49	117,722,910.07	3,314,915.00	327
Chemicals	32,127,277.00	90,688,117.72	3,367,494.00	1,643
Paper & Forest Products	31,519,975.95	56,888,934.20	8,239,254.50	249
Panel B. Scope2 Carbon Cost for 2025				
Industry	Mean	SD	p50	N
Multi-Utilities	14,201,860.87	23,147,770.47	2,227,947.63	120
Automobiles	12,894,455.24	21,483,886.19	1,794,887.13	197
Metals & Mining	12,242,904.32	18,888,818.52	3,034,525.00	1,365
Wireless Telecommunication Services	9,867,776.42	16,280,007.73	1,898,739.38	181
Industrial Conglomerates	9,047,150.40	15,314,433.10	1,926,443.50	327
Construction Materials	8,982,683.93	15,457,004.09	2,212,687.00	450
Food & Staples Retailing	8,611,120.56	15,998,084.18	2,610,716.00	589
Electric Utilities	8,291,345.90	16,941,978.05	306,295.80	398
Oil, Gas & Consumable Fuels	7,624,037.86	15,274,572.06	1,484,008.25	1,133
Containers & Packaging	7,583,523.63	13,713,066.55	1,318,028.63	298

(Continued)

Table 4. Carbon Earnings Risks: Industry Distribution *(Continued)*

Panel C. Total Carbon Cost for 2025

Industry	Mean	SD	p50	N
Electric Utilities	278,814,540.74	297,866,624.46	121,630,468.00	398
Multi-Utilities	269,856,510.25	259,354,105.58	184,688,952.00	120
Airlines	197,986,491.99	208,318,010.19	120,070,976.00	210
Independent Power and Renewable Electricity Producers	174,148,694.88	259,357,770.86	27,673,066.00	479
Construction Materials	142,823,906.17	207,297,333.79	47,446,918.00	450
Oil, Gas & Consumable Fuels	99,113,138.29	185,964,036.15	17,751,604.00	1,133
Metals & Mining	98,964,785.48	192,775,975.50	12,317,633.00	1,365
Industrial Conglomerates	53,692,204.73	127,172,511.66	5,973,909.00	327
Chemicals	41,680,854.91	109,452,452.44	5,638,749.00	1,643
Paper & Forest Products	37,550,120.56	63,040,940.65	13,215,180.00	249

Panel D. Unpriced Carbon Cost/EBITDA for 2025 (%)

Industry	Mean	SD	p50	N
Construction Materials	46.44	35.08	42.92	450
Independent Power and Renewable Electricity Producers	31.98	38.34	10.19	479
Electric Utilities	29.16	31.18	17.55	398
Airlines	23.27	16.75	19.54	210
Multi-Utilities	21.58	23.30	14.70	120
Metals & Mining	20.85	28.05	6.86	1,365
Paper & Forest Products	12.70	12.51	8.52	249
Oil, Gas & Consumable Fuels	12.43	18.79	5.07	1,133
Chemicals	9.63	14.48	4.79	1,643
Marine	9.42	14.08	4.82	193

Notes: This table reports the industry distribution of our unpriced carbon cost variables, the proxy for carbon earnings risks. Panel A reports the top 10 of GIC 6 industries in terms of unpriced carbon cost for Scope 1 emissions for year 2025. Panel B reports the top 10 of GIC 6 industries in terms of unpriced carbon cost for Scope 2 emissions for year 2025. Panel C reports the top 10 of GIC 6 industries in terms of unpriced carbon cost for total GHG emissions for year 2025. Panel D reports the top 10 of GIC 6 industries in terms of the ratio of total unpriced carbon cost over EBITDA for year 2025. All variable definitions are provided in Appendix Table A.1.

Table 5. Carbon Earnings Risks: Country/Region Distribution

Panel A. Scope1 Carbon Cost for 2025				
Country/Region	Mean	SD	p50	N
Russia	196,284,733.93	269,751,723.51	31,503,330.00	175
Czech	94,977,088.79	220,594,358.62	257,638.98	21
Panama	61,157,968.00	26,578,534.38	73,893,208.00	4
Colombia	61,097,442.22	112,975,378.81	3,089,123.25	48
Portugal	58,482,361.81	145,973,903.54	1,848,263.50	47
Argentina	54,182,765.64	82,558,911.27	489,087.03	27
Morocco	50,682,361.40	118,055,824.48	675,684.38	40
Poland	49,118,918.89	138,507,381.23	314,504.11	180
Chile	48,590,076.43	111,071,693.98	1,309,949.19	144
Luxembourg	46,065,706.33	154,360,395.19	773,606.13	107
Panel B. Scope2 Carbon Cost for 2025				
Country/Region	Mean	SD	p50	N
Russia	13,361,768.30	20,465,797.63	3,908,818.75	175
Mexico	8,816,046.93	16,447,401.56	1,473,012.00	247
Luxembourg	7,258,634.50	16,121,021.77	873,400.44	107
South Africa	6,815,811.24	12,826,667.90	1,494,474.38	444
Germany	5,772,051.95	14,036,124.79	685,521.88	677
Macao SAR	5,616,347.87	5,072,252.44	4,164,488.38	12
Portugal	5,141,037.06	7,192,963.73	1,656,733.00	47
Hungary	5,117,109.18	8,928,522.62	636,360.13	15
Spain	4,793,296.83	10,918,059.85	579,479.75	263
Netherlands	4,738,818.92	11,925,089.37	424,485.66	239

(Continued)

Table 5. Carbon Earnings Risks: Country/Region Distribution *(Continued)*

Panel C. Total Carbon Cost for 2025

Country/Region	Mean	SD	p50	N
Russia	215,291,079.89	290,047,782.08	37,488,372.00	175
Czech	103,683,042.89	239,373,752.43	681,000.13	21
Portugal	64,591,203.69	154,536,512.52	5,951,238.50	47
Colombia	64,171,380.85	118,698,332.66	3,622,507.38	48
Panama	61,317,432.50	26,644,352.96	74,106,404.00	4
Argentina	56,917,595.83	85,611,070.65	845,941.69	27
Poland	54,116,534.69	145,779,142.34	878,848.44	180
Luxembourg	53,143,853.54	167,720,038.57	1,934,161.25	107
Morocco	52,574,762.80	120,590,447.45	1,528,829.38	40
Chile	52,411,051.87	112,417,806.50	3,036,324.38	144

Panel D. Unpriced Carbon Cost/EBITDA for 2025 (%)

Country/Region	Mean	SD	p50	N
Russia	19.536	30.271	4.13	175
Morocco	19.099	30.655	1.213	40
Pakistan	17.997	28.109	2.594	158
Turkey	17.641	29.465	2.857	265
Oman	14.625	30.41	0.027	29
Egypt	14.314	30.467	0.943	97
Mongolia	13.607	31.382	3.178	9
Panama	12.189	4.338	13.54	4
Argentina	10.439	18.259	1.533	27
Saudi Arabia	10.196	19.997	1.314	222

Notes: This table reports the country/region distribution of our unpriced carbon cost variables, the proxy for carbon earnings risks. Panel A reports the top 10 of countries/regions in terms of unpriced carbon cost for Scope 1 emissions for year 2025. Panel B reports the top 10 of countries/regions in terms of unpriced carbon cost for Scope 2 emissions for year 2025. Panel C reports the top 10 of countries/regions in terms of unpriced carbon cost for total GHG emissions for year 2025. Panel D reports the top 10 of countries/regions in terms of the ratio of total unpriced carbon cost over EBITDA for year 2025. All variable definitions are provided in Appendix Table A.1.

Table 6. Variance Decomposition of Carbon Earnings Risks

	Scope1 Carbon Cost for 2025	Scope2 Carbon Cost for 2025	Total Carbon Cost for 2025	Unpriced Carbon Cost/EBIDTA for 2025
Panel A. Averaged Carbon Earnings Risks across scenarios				
Year Fixed Effects	0.37%	0.50%	0.43%	0.65%
Industry Fixed Effects	27.79%	11.67%	26.50%	35.00%
Industry * Year Fixed Effects	0.84%	1.46%	0.81%	1.31%
Country Fixed Effects	2.04%	0.39%	2.13%	1.65%
Firm Fixed Effects	68.95%	85.98%	70.13%	61.39%
Total	100%	100%	100%	100%
Panel B. Low scenario				
Year Fixed Effects	0.46%	0.73%	0.54%	1.03%
Industry Fixed Effects	26.42%	10.83%	24.97%	30.60%
Industry * Year Fixed Effects	1.65%	0.68%	1.56%	2.81%
Country Fixed Effects	2.55%	3.77%	2.70%	2.31%
Firm Fixed Effects	68.92%	83.98%	70.24%	63.25%
Total	100%	100%	100%	100%
Panel C. Medium scenario				
Year Fixed Effects	0.39%	0.64%	0.46%	0.74%
Industry Fixed Effects	27.59%	11.82%	26.44%	35.50%
Industry * Year Fixed Effects	1.13%	0.56%	1.10%	1.59%
Country Fixed Effects	2.04%	3.35%	2.12%	1.58%
Firm Fixed Effects	68.85%	83.63%	69.89%	60.59%
Total	100%	100%	100%	100%
Panel D. High scenario				
Year Fixed Effects	0.34%	0.39%	0.38%	0.52%
Industry Fixed Effects	27.69%	11.69%	26.39%	34.83%
Industry * Year Fixed Effects	0.62%	0.38%	0.60%	0.99%
Country Fixed Effects	1.97%	2.98%	2.05%	1.74%
Firm Fixed Effects	69.38%	84.57%	70.58%	61.92%
Total	100%	100%	100%	100%

Notes: This table provides a variance decomposition of our unpriced carbon cost variables, the proxy for carbon earnings risks. Panel A reports the variance decomposition of our carbon earnings risks measures average across three scenarios for year 2025. Panel B report the variance decomposition of our carbon earnings risks measures under the "Low" scenario for year 2025. Panel C report the variance decomposition of our carbon earnings risks measures under the "Medium" scenario for year 2025. Panel D report the variance decomposition of our carbon earnings risks measures under the "High" scenario for year 2025. All variable definitions are provided in Appendix Table A.1.

Table 7. Determinants of Carbon Earnings Risks

	log(Scope1 Carbon Cost for 2025)	log(Scope2 Carbon Cost for 2025)	log(total Carbon Cost for 2025)	Unpriced Carbon Cost/EBIDTA for 2025
	(1)	(2)	(3)	(4)
Size	0.906***	0.954***	0.951***	-0.070
	(89.80)	(129.77)	(122.08)	(-1.11)
Leverage	0.005***	0.004***	0.005***	0.036***
	(6.28)	(6.39)	(6.86)	(6.37)
ROA	1.011***	0.977***	0.963***	2.325***
	(30.82)	(38.64)	(37.48)	(10.36)
M/B	-0.575***	-0.127**	-0.391***	-5.323***
	(89.80)	(129.77)	(122.08)	(-1.11)
Strategic Active Institutional Ownership	-0.003*	-0.000	-0.001	-0.016
	(-7.82)	(-2.52)	(-7.37)	(-13.74)
Foreign Held Shares %	-0.004***	0.000	-0.001	0.006
	(-3.68)	(0.11)	(-1.00)	(0.78)
Government Held Shares %	-0.000	0.000	0.000	-0.009
	(-0.12)	(0.23)	(0.14)	(-0.48)
Employees Held Shares %	0.001	-0.000	0.000	0.004
	(0.73)	(-0.26)	(0.11)	(0.39)
Pension Fund Held Shares %	-0.009	-0.001	-0.007	-0.105***
	(-1.28)	(-0.21)	(-1.13)	(-2.64)
Log(GDP per capita)	0.030	0.100***	0.030	0.018
	(1.09)	(5.31)	(1.44)	(0.11)
Hofstede Power Distance	0.011***	0.006***	0.008***	0.032**
	(6.24)	(4.25)	(5.44)	(2.23)
Hofstede Individualism	0.003**	-0.003***	-0.001	-0.000
	(2.22)	(-2.81)	(-0.51)	(-0.02)
Hofstede Masculinity	0.001	0.007***	0.005***	0.011
	(0.54)	(8.66)	(5.44)	(1.56)
Hofstede Uncertainty Avoidance	0.006***	0.008***	0.007***	-0.002
	(7.13)	(14.50)	(11.59)	(-0.37)

(Continued)

Table 7. Determinants of Carbon Earnings Risks *(Continued)*

	log(Scope1 Carbon Cost for 2025)	log(Scope2 Carbon Cost for 2025)	log(total Carbon Cost for 2025)	Unpriced Carbon Cost/EBIDTA for 2025
	(1)	(2)	(3)	(4)
Hofstede Long-Term Orientation	-0.013***	-0.016***	-0.013***	-0.034***
	(-8.73)	(-14.17)	(-11.81)	(-2.97)
Hofstede Indulgence	0.006***	-0.001	0.002	-0.032***
	(3.66)	(-0.45)	(1.47)	(-2.83)
Scandinavian Civil Origin	-1.076***	-0.215**	-0.411***	0.152
	(-8.31)	(-2.57)	(-4.94)	(0.29)
French Civil Origin	0.104	-0.095**	-0.027	0.537
	(1.62)	(-2.09)	(-0.56)	(1.10)
German Civil Origin	0.383***	0.254***	0.172***	0.673
	(4.63)	(4.27)	(2.72)	(1.15)
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
Observations	32,439	32,439	32,439	32,430
R^2	0.704	0.724	0.768	0.346

Notes: This table reports the firm- and country-level determinants of our unpriced carbon cost variables, the proxy for carbon earnings risks. Scope1 Carbon Cost in 2025 denotes the unpriced carbon cost for Scope 1 emission averaged across three scenarios for year 2025. Scope2 Carbon Cost in 2025 denotes the unpriced carbon cost for Scope 2 emission averaged across three scenarios for year 2025. Total Carbon Cost in 2025 denotes the unpriced carbon cost for total GHG emission (Scope 1 emissions and Scope 2 emissions) averaged across three scenarios for year 2025. Unpriced Carbon Cost/EBIDTA in 2025 represents the ratio of a firm's total unpriced carbon cost over EBITDA averaged across three scenarios for year 2025. All variable definitions are provided in Appendix Table A.1. We report the results of the pooled regression with standard errors clustered at the firm level and year. t-statistics are reported in parentheses. All regressions include year fixed effects and industry fixed effects. 1% significance; ** 5% significance; * 10% significance.

Table 8. Validation with Other Climate Change Measure

	log(Scope1 Carbon Cost for 2025)	log(Scope2 Carbon Cost for 2025)	log(total Carbon Cost for 2025)	Unpriced Carbon Cost/EBIDTA for 2025
	(1)	(2)	(3)	(4)
Panel A. Using Regulatory Shock Measure of Sautner et al. (2022)				
Regulatory shock exposure	0.886***	0.657***	0.853***	7.245***
	(6.62)	(5.58)	(7.10)	(6.25)
Regulatory shock risk	2.364***	1.492**	1.994***	11.919*
	(3.61)	(2.36)	(3.37)	(1.90)
Regulatory shock negative sentiment	0.515*	0.403	0.475*	2.700
	(1.83)	(1.47)	(1.90)	(1.10)
Regulatory shock positive sentiment	-0.180	-0.071	-0.178	-4.385***
	(-0.99)	(-0.44)	(-1.10)	(-3.37)
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
Country FEs	Yes	Yes	Yes	Yes
Observations	14,639	14,639	14,639	14,638
R^2	0.519	0.301	0.471	0.331
Panel B. Using Emission data				
log(Total emissions + 1)	0.921***	0.480***	0.840***	4.694***
	(21.26)	(11.69)	(20.67)	(12.93)
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
Country FEs	Yes	Yes	Yes	Yes
Observations	3,713	3,713	3,713	3,713
R^2	0.737	0.555	0.690	0.502

Notes: This table reports results of regressions that relate firm-level regulatory shock variable and carbon emissions to our carbon earnings risks variables, proxied by unpriced carbon cost variables. Regressions are estimated at the firm-year level. Scope1 Carbon Cost for 2025 denotes the unpriced carbon cost for Scope 1 emission averaged across three scenarios for year 2025. Scope2 Carbon Cost for 2025 denotes the unpriced carbon cost for Scope 2 emission averaged across three scenarios for the year of 2025. Total Carbon Cost for 2025 denotes the unpriced carbon cost for total GHG emission averaged across three scenarios for the year of 2025. Unpriced Carbon Cost/EBIDTA for 2025 represents the ratio of a firm's total unpriced carbon cost over EBITDA. In Panel A, data for regulatory shock measure are extracted from Sautner et al. (2022), and the coefficients are divided by 10^3. In Panel B, only observation for US firms between 2017 and 2018 are included in the regression, due to data availability. US firms' emission data are extracted from Trucost. All variable definitions are provided in Appendix Table A.1. We report the results of the pooled regression with standard errors clustered at the firm level and year. t-statistics are reported in parentheses. All regressions include year fixed effects and industry fixed effects. 1% significance; ** 5% significance; * 10% significance.

Table 9. Variance across Scenarios and Years

Panel A.Variance across three scenarios

	Average Variance across Scenarios	Average variance/Mean Value		Average Variance across Scenarios	Average variance/Mean Value
Scope1 Carbon Cost for 2020	2,127,784.33	85.61%	Scope1 Carbon Cost for 2040	37,695,979.85	62.45%
Scope2 Carbon Cost for 2020	416,828.67	75.97%	Scope2 Carbon Cost for 2040	5,544,984.38	59.78%
Total Carbon Cost for 2020	2,657,150.25	83.54%	Total Carbon Cost for 2040	45,109,443.28	62.34%
Unpriced Carbon Cost/EBITDA for 2020 (%)	0.58	85.01%	Unpriced Carbon Cost/EBITDA for 2040 (%)	9.88	62.54%
Scope1 Carbon Cost for 2025	12,641,282.50	70.97%	Scope1 Carbon Cost for 2050	49,360,044.33	57.03%
Scope2 Carbon Cost for 2025	2,020,833.16	65.94%	Scope2 Carbon Cost for 2050	7,106,201.88	54.57%
Total Carbon Cost for 2025	15,155,530.94	70.06%	Total Carbon Cost for 2050	58,167,938.35	56.61%
Unpriced Carbon Cost/EBITDA for 2025 (%)	3.36	71.00%	Unpriced Carbon Cost/EBITDA for 2050 (%)	12.72	56.38%
Scope1 Carbon Cost for 2030	24,258,863.30	66.23%			
Scope2 Carbon Cost for 2030	3,687,451.67	62.36%			
Total Carbon Cost for 2030	28,842,597.81	65.60%			
Unpriced Carbon Cost/EBITDA for 2030 (%)	6.36	66.03%			

(Continued)

Table 9. Variance across Scenarios and Years*(Continued)*

Panel B. Variance across forecast years

	Average Variance for Low Scenario	Average variance/Mean Value	Average Variance for Medium Scenario	Average variance/Mean Value	Average Variance for High Scenario	Average variance/Mean Value
Scope1 Carbon Cost	12,228,459.36	80.57%	44,576,920.37	99.80%	46,011,741.05	73.67%
Scope2 Carbon Cost	1,943,798.59	75.03%	6,517,239.59	94.94%	6,713,516.50	69.65%
Total Carbon Cost	14,649,409.09	79.60%	52,709,561.05	98.91%	54,543,826.01	73.07%
Unpriced Carbon Cost/EBITDA (%)	3.25	80.08%	11.58	99.72%	11.96	73.05%

Notes: This Table reports the variations in unpriced carbon cost, the proxy for carbon earnings risks, at the firm-level across three scenarios. Panel A presents the average standard deviation across three scenarios by firms. Panel B presents the average standard deviation across forecast years by firms. Scope1 Carbon Cost for 2025 denotes the unpriced carbon cost for Scope 1 emission averaged across three scenarios for the year of 2025. Scope2 Carbon Cost for 2025 denotes the unpriced carbon cost for Scope 2 emission averaged across three scenarios for year 2025. Total Carbon Cost for 2025 denotes the unpriced carbon cost for total GHG emission averaged across three scenarios for the year of 2025. Unpriced Carbon Cost/EBIDTA for 2025 represents the ratio of a firm's total unpriced carbon cost over EBITDA for the year of 2025. All variable definitions are provided in Appendix Table A.1.

Table 10. Physical Risk : Industry and Country/Region Distribution

Panel A. Industry Distribution					*Panel B. Country/Region Distribution*				
Coldwave Score for 2020					Coldwave Score for 2020				
Industry	Mean	SD	p50	N	Country/Region	Mean	SD	p50	N
Aerospace & Defense	39.01	3.85	39.00	121	Lithuania	43.75	1.25	44.00	4
Life Sciences Tools & Services	37.85	3.75	39.00	62	Kazakhstan	43.00	0	43.00	4
Electrical Equipment	37.24	4.26	38.00	355	Poland	42.90	1.42	43.00	126
Biotechnology	37.19	5.37	38.00	247	Ukraine	42.71	0.48	43.00	7
Communications Equipment	37.05	4.282	38.00	191	Georgia	42.50	0.70	42.50	2
Multi-Utilities	36.59	8.62	40.00	41	Mongolia	42.25	2.49	42.50	8
Pharmaceuticals	36.58	5.13	38.00	522	Czech	42.21	1.31	43.00	14
Automobiles	36.56	6.87	39.00	120	Bulgaria	42.00	1.77	41.00	8
Technology Hardware, Storage & Peripherals	36.34	3.956	37.00	190	Croatia	42.00	0	42.00	6
Building Products	36.22	5.91	38.00	178	Germany	41.92	2.66	42.00	496
Flood Score for 2020					Flood Score for 2020				
Air Freight & Logistics	4.25	8.87	2.00	103	Bangladesh	13.20	4.82	13.00	10
Tobacco	4.23	4.18	3.00	30	Panama	13.00	14.14	13.00	2
Construction Materials	3.85	8.63	2.00	241	Ghana	11.00	11.66	10.00	4
Thrifts & Mortgage Finance	3.84	4.37	2.00	32	Hungary	8.54	23.70	1.00	11
Electric Utilities	3.81	6.22	2.00	182	Norway	7.15	8.97	5.00	170
Airlines	3.78	5.37	2.50	100	Tunisia	6.50	0.57	6.50	4
Banks	3.77	7.34	3.00	874	Sweden	6.46	7.59	5.00	414
Equity Real Estate Investment Trusts	3.75	8.08	2.00	470	Bulgaria	5.62	9.92	2.00	8
Health Care Technology	3.70	7.77	2.00	34	Nigeria	5.42	8.30	3.00	42
Food Products	3.65	7.14	2.00	691	India	5.23	7.98	5.00	1,090

(Continued)

Table 10. Physical Risk : Industry and Country/Region Distribution *(Continued)*

Panel A. Industry Distribution					*Panel B. Country/Region Distribution*				
Heatwave Score for 2020					Heatwave Score for 2020				
Industry	Mean	SD	p50	N	Country/Region	Mean	SD	p50	N
Semiconductors & Semiconductor Equipment	9.97	3.41	9.17	548	Colombia	22.63	7.17	22.00	33
Household Products	9.86	4.89	8.33	44	Indonesia	22.59	6.32	22.00	268
Industrial Conglomerates	9.84	5.22	8.83	196	Kenya	18.64	4.25	17.83	22
Water Utilities	9.80	4.41	8.83	60	Uganda	18.33	4.46	18.33	4
Multiline Retail	9.77	5.17	8.00	120	Cote d'Ivoire	16.44	5.01	16.50	6
Banks	9.67	4.96	8.33	874	Malaysia	16.43	5.08	16.00	379
Real Estate Management & Development	9.66	5.16	8.00	1,043	Philippines	16.30	4.39	15.00	151
Energy Equipment & Services	9.65	4.97	8.33	129	Panama	15.66	5.18	15.66	2
Gas Utilities	9.53	4.70	8.00	95	Sri Lanka	15.23	5.69	16.00	10
Food Products	9.50	4.86	8.00	691	Mauritius	15.06	4.60	13.33	5
Sea Level Rise Score for 2020					Sea Level Rise Score for 2020				
Real Estate Management & Development	6.75	11.23	1.00	1,043	Macao SAR	20.25	8.69	20.00	8
Multi-Utilities	6.39	11.51	3.00	41	Netherlands	12.87	13.05	9.00	181
Banks	4.74	6.87	1.00	874	United Arab Emirates	11.72	18.17	1.00	87
Gas Utilities	3.99	10.83	1.00	95	Thailand	9.97	13.27	1.00	374
Independent Power & Renewable Electricity Producers	3.85	7.91	1.00	271	Vietnam	9.00	14.27	1.00	40
Transportation Infrastructure	3.78	10.74	1.00	205	Guernsey	8.23	10.55	4.00	17
Industrial Conglomerates	3.69	11.92	1.00	196	Nigeria	7.00	12.52	1.00	42
Construction & Engineering	3.61	10.01	1.00	507	India	6.89	15.58	1.00	1,090
Real Estate Investment Trusts	3.58	4.93	1.00	470	Belgium	6.37	13.08	1.00	135
Household Products	3.54	8.56	1.00	44	Bahrain	5.60	0 7.64	1.00	10

(Continued)

Table 10. Physical Risk : Industry and Country/Region Distribution *(Continued)*

Panel A. Industry Distribution					*Panel B. Country/Region Distribution*				
Water Stress Score for 2020					Water Stress Score for 2020				
Industry	Mean	SD	p50	N	Country/Region	Mean	SD	p50	N
Mortgage Real Estate Investment Trusts	93.00	0.00	93.00	2	Pakistan	94.96	8.19	100.00	115
Communications Equipment	69.30	21.65	73.00	191	Saudi Arabia	94.36	11.08	100.00	69
Automobiles	65.53	27.30	67.00	120	Jordan	93.91	9.10	98.50	12
Gas Utilities	64.21	29.92	73.00	95	Kazakhstan	89.75	11.84	90.00	4
Transportation Infrastructure	64.14	31.45	80.00	205	Morocco	87.71	15.472	98.00	28
Aerospace & Defense	63.14	26.61	59.00	121	Qatar	86.31	21.34	100.00	57
Pharmaceuticals	62.30	27.00	60.00	522	China	85.85	20.28	94.00	3,410
Electrical Equipment	62.26	26.91	59.00	355	United Arab Emirates	85.72	19.192	98.000	87
Diversified Financial Services	62.03	29.46	62.00	167	India	84.96	19.315	92.00	1,090
Containers & Packaging	61.46	27.89	57.00	114	Israel	84.47	19.61	93.00	209
Wildfire Score for 2020					Wildfire Score for 2020				
Insurance	9.93	10.55	6.00	292	Chile	31.42	7.92	33.00	93
Air Freight & Logistics	9.68	8.10	9.00	103	Australia	28.24	9.68	29.00	784
Tobacco	9.60	9.11	6.50	30	Uruguay	26.00	26.87	26.00	2
Diversified Telecommunication Services	9.59	8.85	6.00	192	India	24.30	7.85	25.00	1,090
Health Care Technology	9.41	7.69	9.50	34	United States	23.38	12.03	23.00	5,884
Equity Real Estate Investment Trusts	9.26	9.27	6.00	470	Panama	22.50	0.70	22.50	2
Energy Equipment & Services	8.86	6.89	8.00	129	Canada	22.46	11.88	22.00	834
Wireless Telecommunication Services	8.39	9.15	5.00	99	South Korea	22.25	4.93	22.00	1,759
Real Estate Management & Development	7.68	6.41	6.00	1,043	Mexico	22.10	6.56	22.00	170
Banks	7.58	8.00	5.00	874	Brazil	21.20	15.37	29.00	322

(Continued)

Table 10. Physical Risk : Industry and Country/Region Distribution *(Continued)*

Panel A. Industry Distribution					*Panel B. Country/Region Distribution*				
Equal Weighted Composite Score for 2020					Equal Weighted Composite Score for 2020				
Industry	Mean	SD	p50	N	Country/Region	Mean	SD	p50	N
Mortgage Real Estate Investment Trusts	70.50	0.70	70.50	2	Philippines	69.88	6.17	72.00	151
Semiconductors & Semiconductor Equipment	64.35	6.89	65.50	548	Taiwan, China	69.81	4.04	70.00	1,340
Communications Equipment	63.48	6.87	65.00	191	India	68.46	6.09	70.00	1,090
Technology Hardware, Storage & Peripherals	63.40	7.27	65.00	190	Pakistan	67.09	2.34	68.00	115
Electronic Equipment, Instruments & Components	63.23	7.66	65.00	757	Hong Kong SAR	66.78	6.18	68.00	1,086
Textiles, Apparel & Luxury Goods	61.65	8.44	63.00	380	China	66.63	5.55	68.00	3,410
Automobiles	61.36	9.62	64.00	120	Chile	65.84	6.48	67.00	93
Leisure Products	61.36	7.12	62.00	83	Bahamas	65.66	7.50	66.00	3
Electrical Equipment	61.24	8.87	64.00	355	Kazakhstan	65.50	3.00	66.00	4
Pharmaceuticals	60.82	8.80	63.00	522	Mexico	65.49	5.68	67.00	170
Sensitivity Weighted Composite Physical Risk Score for 2020					Sensitivity Weighted Composite Physical Risk Score for 2020				
Multiline Retail	58.72	15.18	60.66	120	Malawi	59.00	.	59.00	1
Thrifts & Mortgage Finance	58.59	7.65	5.00	32	Ukraine	55.16	26.947	59.00	6
Water Utilities	58.21	21.86	63.50	52	Philippines	52.19	20.98	59.00	125
Paper & Forest Products	57.14	17.81	58.00	114	Taiwan, China	50.51	17.60	51.00	1,321
Independent Power & Renewable Electricity Producers	52.69	22.54	53.50	228	Chile	48.19	23.88	49.66	79
Metals & Mining	50.77	18.32	48.00	629	Uruguay	46.33	20.74	46.33	2
Chemicals	50.06	15.51	50.00	723	India	45.66	21.51	47.00	977
Hotels, Restaurants & Leisure	49.72	20.92	57.33	182	Pakistan	44.61	25.06	42.00	95
Pharmaceuticals	46.65	16.84	49.00	485	Cayman Islands	43.22	14.75	45.00	53
Containers & Packaging	49.45	18.24	46.50	108	Bulgaria	42.66	16.55	35.333	7

Notes: This table provides industry and country distributions of this physical risk measure averaged across three scenarios for year 2020. Specifically, Trucost assigns each firm with scores that reflect its expected sensitivities to six key climate hazards, including cold wave, flood, heatwave, sea level rise, water stress and wildfire. The key climate hazards include cold wave, flood, heat wave, sea level rise, water stress, and wildfire. This measure also includes three future climate change scenarios: Low, Medium and High. In particular, the "High" scenario represents aggressive mitigation actions to halve emissions by 2050, which is likely to result in warming of less than 2 degree Celsius by 2100. The "Medium" scenario denotes strong mitigation actions to reduce emissions to half of current levels by 2080. The "Low" scenario represents continuation of business as usual with emissions at current rates, which is expected to result in an increase of global temperature by more than 4 degrees Celsius by 2100.

Table 11. Real Effect of Carbon Earnings Risks

Panel A. Baseline Results			
	Environmental Innovation Score	Discretionary Accruals	CO_2 Emissions from Foreign Supplier
	(1)	(2)	(3)
Unpriced Carbon Cost/EBITDA for 2025	0.207**	0.001***	0.020**
	(2.16)	(2.90)	(2.17)
Size	7.443***	0.002***	0.842***
	(23.19)	(5.12)	(9.47)
Leverage	-0.061***	-0.000***	0.000
	(-3.82)	(-13.53)	(0.04)
ROA	3.230***	-0.006***	0.825***
	(4.69)	(-3.44)	(2.96)
M/B	413.441***	1.490***	-101.028***
	(3.16)	(3.72)	(-2.68)
Capex/Sales	-0.034**	0.000	-0.042***
	(-1.99)	(0.79)	(-3.27)
Strategic Active Institutional Ownership	0.036	-0.000***	-0.008
	(1.41)	(-3.20)	(-0.59)
Foreign Held Shares %	-0.017	-0.000	-0.005
	(-1.04)	(-1.20)	(-0.38)
Government Held Shares %	-0.050*	0.000	-0.108***
	(-1.83)	(1.13)	(-3.65)
Employees Held Shares %	-0.077***	0.000***	-0.002
	(-2.65)	(3.42)	(-0.18)
Pension Fund Held Shares %	0.108	0.000	0.090
	(1.03)	(0.76)	(1.17)
Log(GDP per capita)	0.253	0.068***	17.528
	(0.03)	(2.62)	(1.19)
Year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
Country FEs	Yes	Yes	Yes
Observations	13,975	20,543	2,331
R^2	0.333	0.084	0.434

(Continued)

Table 11. Real Effect of Carbon Earnings Risks *(Continued)*

Panel B. Alternative Measure			
	Environmental R&D expenses	Discretionary Accruals	Scope 3 CO_2 Emissions growth
	(1)	(2)	(3)
Unpriced Carbon Cost/EBITDA for 2025	0.007**	0.001***	0.012**
	(2.11)	(2.93)	(2.17)
Controls	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
Country FEs	Yes	Yes	Yes
Observations	2,713	20,543	3,227
R^2	0.590	0.083	0.037

Notes: This table reports how firms respond to carbon earnings risks. In Panel A, the dependent variable are environmental innovation score (the proxy for green innovation), discretionary accruals estimated by modified Jones model (the proxy for earnings management), and the aggregated amount of estimated GHG emission imported from suppliers overseas (the proxy for outsourcing activity). Unpriced Carbon Cost/EBIDTA for 2025, the independent variable, represents the ratio of a firm's total unpriced carbon cost over EBITDA averaged across three scenarios for the year of 2025. In Panel B, we employ alternative measures as dependent variables. Specifically, dependent variables are environmental R&D expenses, discretionary accruals estimated by another specificaiton of modified Jones model, and Scope 3 CO_2 emission growth in Column (1), (2), and (3) respectively. We include the year, country, and industry fixed effects in both panels. All standard errors are clustered at the industry-by-year level. All variable definitions are provided in Appendix Table A.1. *** 1% significance; ** 5% significance; * 10% significance.

Table 12. Real Effect of Carbon Earnings Risks: IV Results

	Unpriced Carbon Cost/EBITDA for 2025	Unpriced Carbon Cost/EBITDA for 2025	Environmental Innovation Score	Discretionary Accruals	CO_2 Emissions from Foreign Supplier
	(1)	(2)	(3)	(4)	(5)
The adoption of carbon tax or ETS	1.685***				
	(7.35)				
Number of climate-related disasters		1.467***			
		(8.27)			
Unpriced Carbon Cost/EBITDA for 2025			0.215**	0.002*	0.022**
			(2.53)	(1.72)	(2.01)
Controls	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes
Observations	20,531	2,028	13,753	20,531	2,028
R^2	0.564	0.314	0.329	0.062	0.041

Notes: This table reports the IV regression results. The instrumental variable is whether the country has implemented emission trading scheme or adopted a carbon tax as IV when testing the relation between carbon earnings risks and environmental innovation and earnings management and outsourcing activity and the number of disasters associated with climate change, such as drought and flood, at the state where the firm headquarters back to 3 to 10 years ago when testing the relation between carbon earnings risks and outsourcing activity. In order to mitigate the concerns that climate-related disasters would impact firms' operation directly, we exclude those observations of firms which experience climate-related disasters during the recent past three years. The independent variable is Unpriced Carbon Cost/EBIDTA for 2025, the ratio of a firm's total unpriced carbon cost over EBITDA averaged across three scenarios for the year of 2025. The dependent variable are environmental innovation score (proxy for green innovation), discretionary accruals estimated by modified Jones model (proxy for earnings management), and the aggregated amount of estimated GHG emission imported from suppliers overseas (proxy for outsourcing activity). Column (1) and (2) report the first-stage results, and Column (3)-(5) reports the second-stage results. We include the same set of control variables, year, country, and industry fixed effects in this regression as in Table 11. All standard errors are clustered at the industry-by-year level. All variable definitions are provided in Appendix Table A.1. *** 1% significance; ** 5% significance; * 10% significance

Table 13. Cross-sectional Analysis

	Environmental Innovation Score (1)		Discretionary Accruals (2)		CO_2 Emissions from Foreign Supplier (3)	
Panel A. Governance Score	High	Low	High	Low	High	Low
Unpriced Carbon Cost/EBITDA for 2025	0.282**	0.025	0.001**	0.001*	0.020*	0.018
	(2.06)	(0.21)	(2.24)	(1.74)	(1.71)	(1.16)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,884	7,091	9,587	10,704	1,011	1,320
R^2	0.351	0.317	0.085	0.115	0.474	0.463
Panel B. Market Concentration	High	Low	High	Low	High	Low
Unpriced Carbon Cost/EBITDA for 2025	0.203*	0.141	0.000	0.001***	0.124***	0.006
	(2.06)	(0.21)	(2.24)	(1.74)	(1.71)	(1.16)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,009	8,966	9,395	11,148	997	1,334
R^2	0.380	0.322	0.115	0.075	0.787	0.423

Notes: This table reports the cross-sectional analysis results of firms' response to carbon earnings risks. In Panel A, we partition our sample into those above and below the median of the governance score from Refinitive database, and run the regression on these two subsamples separately. In Panel B, we partition our sample into two groups based on the median value of country-level Herfindahl-Hirschman Index (HHI) from World Integrated Trade Solution of World Bank in 2017 and industry-level CR4 ratio in 2012 from Davis and zgür Orhangazi (2021), and rerun the regression on these two subsamples separately. The dependent variable are environmental innovation score (proxy for green innovation), discretionary accruals estimated by modified Jones model (proxy for earnings management), and the aggregated amount of estimated GHG emission imported from suppliers overseas (proxy for outsourcing activity). Unpriced Carbon Cost/EBIDTA for 2025 represents the ratio of a firm's total unpriced carbon cost over EBITDA averaged across three scenarios for the year of 2025. We include the same set of control variables, year, country, and industry fixed effects in both panels as in Table 11. All standard errors are clustered at the industry-by-year level. All variable definitions are provided in Appendix Table A.1. *** 1% significance; ** 5% significance; * 10% significance

Appendix 1: Definitions of Variables

Table A1. Variable Definition

Variable	Source	Description
Scope1 Carbon Cost	S&P Trucost	The estimated unpriced carbon cost for scope 1 emission. It is estimated by multiplying the carbon price risk premium and Scope 1 emission across different regions. There are three scenarios, High, Meidum, and Low, for analyzing the price risk premiums of several forecast years, 2020, 2025, 2030, 2040, 2050.
Scope2 Carbon Cost	S&P Trucost	The estimated unpriced carbon cost for scope 1 emission. It is estimated by multiplying the carbon price risk premium and Scope 2 emission across different regions. There are three scenarios, High, Meidum, and Low, for analyzing the price risk premiums for several forecast years, 2020, 2025, 2030, 2040, 2050.
Total Carbon Cost	S&P Trucost	The estimated unpriced carbon cost for total emission (Scope 1 + Scope 2 emissions). It is estimated by multiplying the carbon price risk premium and Scope 1 emission across different regions. There are three scenarios, High, Meidum, and Low, for analyzing the price risk premiums for several forecast years, 2020, 2025, 2030, 2040, 2050.
Unpriced Carbon Cost/EBITDA	S&P Trucost	The ratio of total unpriced carbon cost for total emission over a firm's EBITDA.
Environmental Innovation Score	Datastream	This score reflects a company's ability to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes, or eco-designed products. It includes a company's product innovation, as well as its green revenues, research and development (R&D) and capital expenditures (CapEx).
Discretionary Accruals	Self-Constructed	We first run the following modified Jones model (Dechow et al., 1995) within each fiscal year and Fama-French 48 industry and get the estimated coefficients: $\frac{TA_{i,t}}{ASSET_{i,t-1}} = \beta_0 + \beta_1 \frac{1}{ASSET_{i,t-1}} + \beta_2 \frac{\Delta REV_{i,t}}{ASSET_{i,t-1}} + \beta_3 \frac{PPE_{i,t}}{ASSET_{i,t-1}} + \varepsilon$, where i denotes firms and t denotes fiscal years. Total accruals $TA_{i,t}$ are defined as earnings before extraordinary items and discontinued operations minus operating cash flows for fiscal year t; $ASSET_{i,t-1}$ is total assets at the end of year $t-1$; $\Delta REV_{i,t}$ is the change in sales revenue from year $t-1$ to t. We then use the following model and the estimated coefficients from the equation above to compute the fitted value of normal accruals, $NA_{i,t}$: $\frac{NA_{i,t}}{ASSET_{i,t-1}} = \hat{\beta}_0 + \hat{\beta}_1 \frac{1}{ASSET_{i,t-1}} + \hat{\beta}_2 \frac{\Delta REV_{i,t} - \Delta AR_{i,t}}{ASSET_{i,t-1}} + \hat{\beta}_3 \frac{PPE_{i,t}}{ASSET_{i,t-1}}$, where $\Delta AR_{i,t}$ is the change in accounts receivable from year $t-1$ to t. Following Dechow et al. (1995), we subtract the change in accounts receivable from the change in sales revenue, since credit sales might also provide a potential opportunity for accounting distortion. After obtaining the fitted normal accruals $NA_{i,t}$ from the model above, we calculate firm-year-specific discretionary accruals as: $DA_{i,t} = (TA_{i,t}/ASSET_{i,t-1}) - NA_{i,t}$.

(Continued)

Appendix 1: Definitions of Variables

Table A1. Variable Definition *(Continued)*

Variable	Source	Description
CO_2 Emissions from Foreign Supplier	Panjiva	We estimate the aggregated metric tons of CO2 equivalent into the air from the production of all imported goods based on a $1 million worth of output over all shipment containers (in the unit of TEU) each year. We adopt the EIO-LCA GHG emission model from Carnegie Mellon to approximate the outsourced CO2 emission intensity at shipment level. The imported good's industry is based on the six-digit HS Code from Panjiva and the HS to NAICS table from Peter K. Schott Website, and the importer's primary industry NAICS code is from Compustat.
Size	WorldScope, Compustat	The natural logarithm of a firm's total assets plus one.
Leverage	WorldScope, Compustat	The ratio of debt to total assets of a firm.
ROA	WorldScope, Compustat	The ratio of a firm's net profit to total assets.
M/B ratio	WorldScope, Compustat	Market-to-Book ratio, Market Capitalization / Net Book Value
Strategic Active Institutional Ownership	Datastream	The percentage of total shares held strategically and not available to ordinary investors if these holdings amount to 5% or more of the company's total shares. Holdings of 5% or more held by the hedge fund owner type or the investment advisor/hedge fund owner type are regarded as active, and not counted as strategic. Total strategic holdings represent the sum of all the above categories (government, corporations, pension fund, investment company, employees, other holdings, foreign held, etc.).
Foreign Held Shares %	Datastream	The percentage of total shares held by a shareholder domiciled in a country other than that of the issuer if these holdings amount to 5% or more of the company's total shares.
Government Held Shares %	Datastream	The percentage of total shares held by a government or government institution if these holdings amount to 5% or more of the company's total shares.
Pension Fund Held Shares %	Datastream	The percentage of total shares held by pension funds or endowment funds if these holdings amount to 5% or more of the company's total shares.
Employees Held Shares %	Datastream	The percentage of total shares held by employees, or by those with a substantial position in a company that provides significant voting power at an annual general meeting (typically family members) if these holdings amount to 5% or more of the company's total shares.
GDP per Capita	World Bank	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of the gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for the depreciation of fabricated assets or for the depletion and degradation of natural resources. Data are in current U.S. dollars. Source: World Bank.

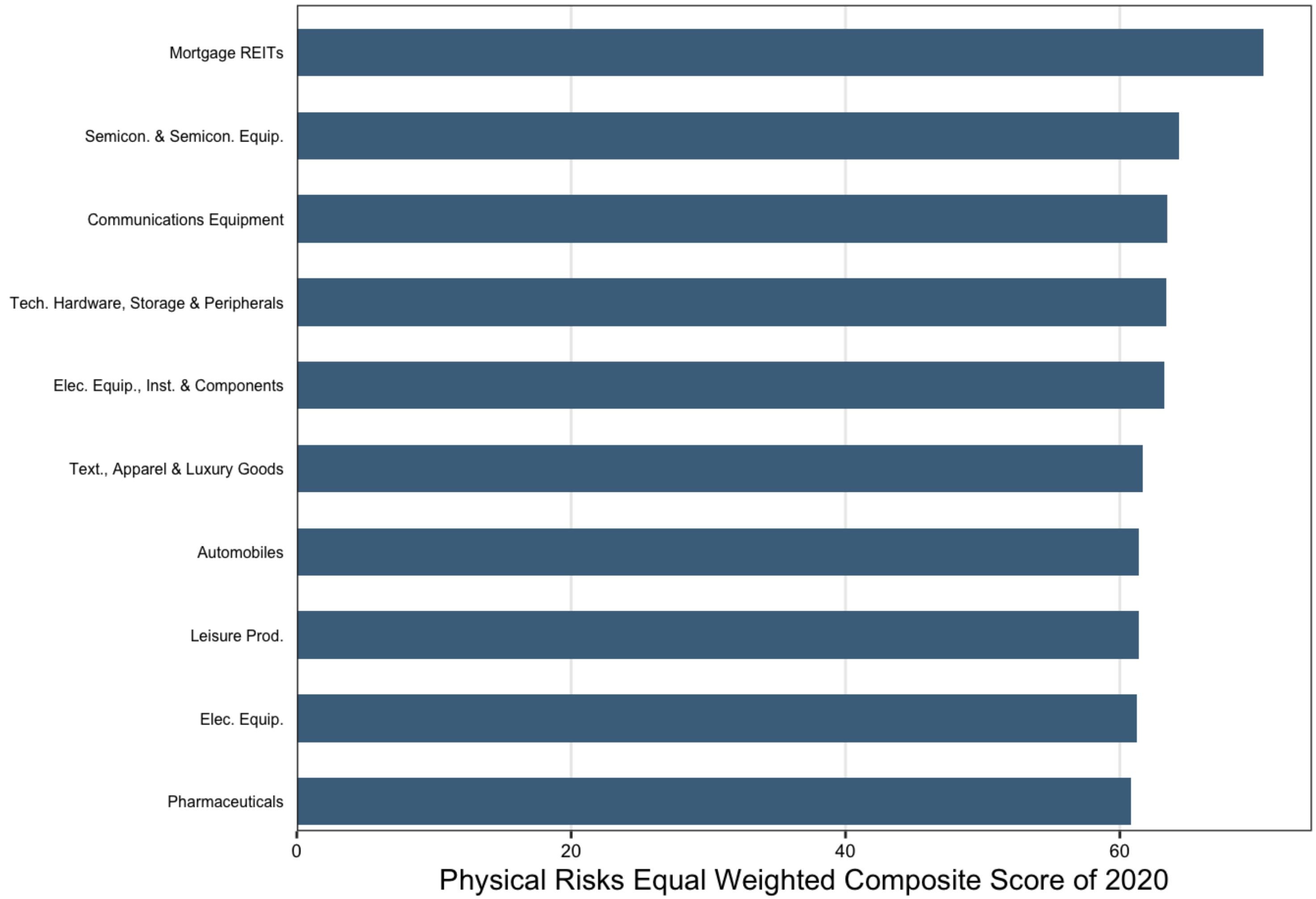
(Continued)

Appendix 1: Definitions of Variables

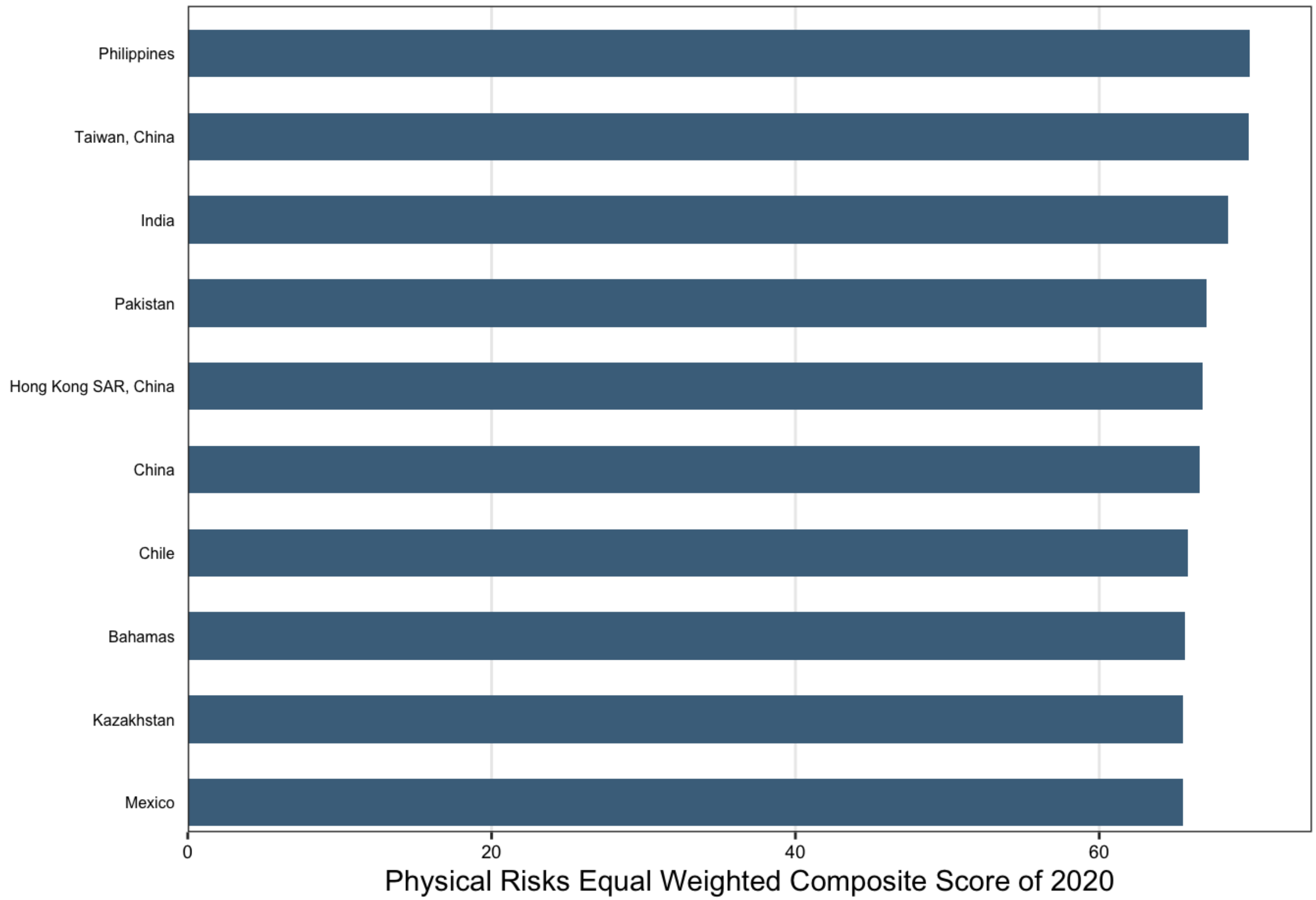
Table A1. Variable Definition *(Continued)*

Variable	Source	Description
Power Distance	Hofstede website	"Power distance" is defined as the extent to which the less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally. A higher score indicates a large power distance between individuals.
Individualism	Hofstede website	"Individualism" refers to the degree of interdependence among members of a group and defines people's self-image in terms of "I" or "We." In individualist societies, people focus on themselves and their immediate family whereas in collectivist societies people belong to "in-groups" that take care of them in exchange for loyalty. A higher score indicates more individualism.
Masculinity	Hofstede website	A high score on the "Masculinity/femininity" dimension indicates that a masculine society is driven by competition, achievement, and success, with success being defined by the "winner" or "best-in-field." A low score means that the dominant values in the feminine society consist of caring for others and quality of life. A feminine society is one where quality of life is the sign of success and standing out from the crowd is not admirable.
Uncertainty Avoidance	Hofstede website	"Uncertainty avoidance" captures how a society deals with the fact that the future is uncertain and the extent to which the members of a culture feel threatened by ambiguous or unknown situations and have created beliefs and institutions that try to avoid uncertainty. A higher score implies a higher level of uncertainty avoidance.
Long-term Orientation	Hofstede website	This index describes how society reconcile some links with its past while responding to the challenges of the present and future. Normative societies who score low, prefer to maintain time-honored traditions while viewing societal change with suspicion. Societies with a high score encourage thrift and efforts in modern education as a way to prepare for the future.
Indulgence	Hofstede website	This dimension captures the extent to which people try to control their desires and impulses, based on the way they were raised. Relatively weak control scores high on "Indulgence" and relatively strong control scores high on "Restraint."
Law Origins	LLSV (1998), Djankov et al. (2008), La Porta et al. (2008)	The legal origin of the company law or commercial code of each country in which the focal firm is headquartered. We distinguish five major legal origins: English common law, French commercial code (civil law), German commercial code (civil law), Scandinavian civil law, and socialist (former or current) law.

Appendix 2: Physical Risks Equal Weighted Composite Score of 2020: Distribution



Physical Risks Equal Weighted Composite Score of 2020: Industry Distribution



Physical Risks Equal Weighted Composite Score of 2020: Country Distribution