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Environmental concern, regulations and board diversity

A thesis submitted in fulfilment of the requirements

for the degree of Doctor of Philosophy

by

Quynh Anh Do

SCHOOL OF MANAGEMENT

ACCOUNTING, FINANCE AND LAW DIVISION

March 2023

Certificate

It is certified that the work contained in this thesis entitled **"Environmental concern, regulations and board diversity"** by **Quynh Anh Do** has been carried out under my supervision and that it has not been submitted elsewhere for a degree.

Prof. Dimitrios Gounopoulos

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Prof. David Newton

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Declaration

This is to certify that the thesis titled **"Environmental concern, regulations and board diversity"** has been authored by me. It presents the research conducted by me under the supervision of **Prof. Dimitrios Gounopoulos** and **Prof. David Newton**.

The second study of this thesis (Chapter 3) is a joint work with Dr. Rosie Cao while the third study (Chapter 4) is a joint work with Mr. Tam Nguyen. In all three studies, I perform the standard role of a PhD student by initiating the research projects, cleaning data, conducting empirical analyses, and writing the first complete draft of the working paper for each essay. Inputs from my colleagues are acknowledged in terms of proofreading, giving comments and feedback, improving subsequent versions of the working papers for aforementioned studies. All in all, it is a great experience to work with them.

To the best of my knowledge, it is an original work, both in terms of research content and narrative, and has not been submitted elsewhere, in part or in full, for a degree. Further, due credit has been attributed to the relevant state-of-the-art and collaborations with appropriate citations and acknowledgments, in line with established norms and practices.

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Abstract

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This thesis is comprised of three studies which explore governance and risk management issues of firms. The issues being addressed here are varied but connected to highlight "How uncertainties like geopolitical risk[1], regulation interventions, or governance risk affecting the outcomes of organizations and how to model their impacts?". The following are the brief summaries of three studies:

(i) Proposing that the relationship between board diversity and firm outcomes stems from the theory of social interactions and information cost model, the first study (Chapter 2) examines the non-linear effects of board diversity. As a result, for firms with low information costs, an exogenous increase in the proportion of non-traditional directors should be associated with higher value and improved performance only when the number is greater than the token, whereas, for firms with high information costs, the change should be associated with lower value and worse performance only when the number is low. There is evidence that regulatory actions can alter the structure of these nonlinear effects significantly in small and medium-sized businesses. Further analyses demonstrate that the departure of non-traditional board members in the post-SOX era is associated with fewer patents registered, higher company returns, and reduced stock volatility.

(ii) The second study (Chapter 3) examine the effect of Regional Climate Action Plan Initiative (RAC) and board diversity on environmental Corporate Social Responsibility (CSR) performance. We demonstrate that RAC and SOX can have a substantial impact on environmental performance. Additionally, we uncover evidence supporting the concept that non-shareholder stakeholders are the primary drivers of environmental disclosure.

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[1]also climate risks, but the author decided to not include the side projects into this thesis, see List of publications for more information

Since our analyses are centred on companies with very diverse boards, we emphasise the strategic significance that board diversity plays in regional climate initiatives. In addition, we demonstrate that businesses with less diverse boards are more likely to overinvest in environmental CSR during a financial crisis. This study demonstrates the significance of factors other than market dynamics, such as local climate policy, in determining Environmental, Social, and Corporate Governance (ESG) disclosure.

(iii) The third study (Chapter 4) investigates the mechanism by which geopolitical risk influences firm innovation. Given existing notions that company investment is reduced during uncertain periods, we are inclined to investigate the interaction or moderating effects of abnormal R&D cutbacks during periods of high geopolitical risk to see how they affect in-house innovation. The findings indicate that REM and non-REM cutbacks have distinct patterns of influence on the environment. The results of our research provide credence to the existence of the corporate life-cycle hypothesis. Based on this theory, businesses that engage in profit management in order to reduce their exposure to geopolitical risk are more likely to restrict innovation during the periods of birth and growth. We also find that a greater degree of participation by the US military in global geopolitical risk is connected with a lower level of innovation in businesses.

Abbreviations

2SLS	Two-stage least square
3SLS	Three-stage least square
AEM	Accrual Earning Management
BOE	Bank of England
CSR	Corporate Social Responsibility
DDD	Difference in differences in differences
DID	Difference-in-difference
DFR	Dodd-Frank Act
EB	Entropy Balancing
EPA	Environmental Protection Agency
ESG	Environmental, Social, and Corporate Governance
GHG	Greenhouse Gas
GHGRP	Greenhouse Gas Reporting Program
GPR	Geopolitical risk
HHI	Herfindahl-Hirschman index
KLD	Kinder, Lydenberg, Domini Inc. database

PSM   Propensity Score Matching

RAC   Regional Climate Action Plan Initiative

REM   Real Earning Management

SASB   Sustainability Accounting Standards Board

SEC   Securities and Exchange Commission

SOX   Sarbanes-Oxley Act

SRI   Socially Responsible Investment

TCFD   Task Force on Climate-Related Financial Disclosures

TD   Triple differences

TRI   Toxic Release Inventory

US   United States

USPTO   United States Patent and Trademark Office

UK   United Kingdom

List of Publications

Publications from Thesis

1. Paper 1 *https://sites.google.com/view/review-of-corporate-finance/forthcoming-papers*.

Others

1. Paper 2. *https://doi.org/10.1080/1351847X.2022.2055969*.

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Dedicated to my family, supervisors and friends.

Chapter 1

Introduction

1.1 Background

In the corporate governance literature, agency theory and study on the CEO's motivation prevail due to the CEOs' historical importance in that system of governance. According to the prior study, the board has been seen as having a limited role in corporate governance, with little involvement in decision-making and its members remaining unchanged. This is because the selection of directors was often made to accommodate the preferences of the CEO or chairman, rather than to ensure that they would fulfill their monitoring responsibilities. However, in recent decades, regulatory reforms and external pressures brought on by major scandals within the system have led to significant changes in the structure and makeup of corporate governance. Audit, compensation, and nominating committees have been established to limit the power and influence of the CEO by having external directors serve on them. This has also led to a retirement wave of a significant number of previous directors and a shift in board composition diversity. These changes are aimed at improving the oversight and accountability of the CEO and management, and to increase the effectiveness of the board in fulfilling its role of monitoring and guiding the company's management.

Considering that the CEO, CFO, and Chairman were all key actors in major fraud crimes before to the paradigm shift in governance, it is instructive that the dual role function in the governance structure was heavily criticised subsequently. As a result, today's governance practises must aim to increase oversight, improve board efficiency, and increase transparency. The Dodd-Frank Act of 2010 marked the beginning of a new era for the role of board

committees, which allowed for more room for external whistle-blowers as well as non-traditional directors to play a role in the company's governance. There is a considerable need for monitoring jobs, and board committees play an important role in meeting this demand. The boardroom's flesh and bone are rapidly transforming. Previously, a director could only serve on a small number of boards, but that has changed, allowing people from all walks of life to have a greater voice. To that end, we have been intrigued by the link between diversity and a variety of firm outcomes.

Since the passage of the Sarbanes-Oxley Act and, more recently, the Dodd-Frank Act, an increasing number of studies concerning the diversity of boards of directors have attracted the attention of researchers (ERHARDT ET AL. (2003); CARTER ET AL. (2003); ADAMS AND FERREIRA (2009); ADAMS AND KIRCHMAIER (2015); CHENG ET AL. (2017); GIANNETTI AND ZHAO (2016); BERNILE ET AL. (2018)). Despite the fact that women and members of underrepresented groups were finally allowed in, the contributions of non-traditional directors continued to be questioned. Arguments in favour of board diversity reasoned that it helps raise productivity, enhances innovation through the depth of talent pools, obtains more credits from shareholders, attracts less scrutiny, widens networks, and provides a better grasp of varied markets.

Though being thought as bring in positive impacts such as enhancing more diversity at or below the director level, some prior studies also show that the costs and challenges of regulatory interventions might outweigh the benefits (see FAIRFAX (2005)). Many people argued that more diverse board should make better financial decisions and do better monitor works. For example, female directors tend to follow the less leveraged capital structures than male directors (FACCIO ET AL. (2016)). Or, the non-traditional directors could have better ideas about sale growth and innovation than a locked-in board with homogenous thinking. There are several studies that even went beyond to examine the different financial patterns in female-owned versus male-owned firms (ROBB AND WOLKEN (2002); SARA AND PETER (1998)), or the reputation ranking of those firms who employed female directors (BEAR ET AL. (2010); BRAMMER ET AL. (2009)) while others discovered the role of minor ethnicity directors in facilitating the collaboration between minor ethnicity inventors (MARINO ET AL. (2020); CRESCENZI ET AL. (2016)). However, evidence also shows that a diverse group takes more time to come to the final decision, or not everyone is ready to collaborate with people who do not share the same culture and even different mindsets (MAZNEVSKI (1994)).

Several studies have come to the conclusion that there is no evidence to support claims that enforced quotas for women or ethnic minorities will contribute in any way to the risk or return of a company (ADAMS AND FERREIRA (2009); ANAND AND JOG (2014); SILA ET AL.

(2016)). Research conducted by leading experts shows that non-traditional directors possess many of the same strengths as traditional directors, indicating that there is no significant difference between the two. While there may be some costs and difficulties associated with bringing non-traditional directors onto the board, such as differing perspectives or lack of cohesion, these challenges are outweighed by the benefits of diversity and fresh perspectives in decision-making and policy implementation. (HONG AND PAGE (2004); GAO AND ZHANG (2014)). Previous studies that have assessed the correlation between diversity on corporate boards and business performance have yielded inconsistent findings, as evidenced by the varied data presented.

Traditional theories emphasise two roles: monitoring (agency perspective) and advising (resource view), while ignoring the most crucial part of board function, i.e. policy making, which might be better gauged indirectly in the association with firm performance (see NGUYEN ET AL. (2020); KHATIB ET AL. (2021) for discussion). It thereby might be difficult to describe the implications of board diversity using standard theories, so employing new theoretical lenses might aid in understanding this issue. In particular, there is a scarcity of studies examining how different levels of heterogeneity influence the social interactions that occur within a group. Therefore, the first goal is to integrate theories in psychology and behavior studies into corporate governance literature, tracing back from social identity theory, similarity/attraction perspective (PELLED (1996); WILLIAMS AND O'REILLY III (1998), knowledge-based view (COX AND BLAKE (1991)), group heterogeneity study (BLAU (1977)) and tokenism (KANTER (1977)).

Given that Socially Responsible Investment (SRI) has become a worldwide trend over the past decade, attention to board diversity as well as environmental friendliness and social responsibility, is becoming increasingly prevalent not just among academics but also among practitioners and customers. Despite the fact that investors in the United States (U.S.) and around the world are increasingly demonstrating the need of ESG information in greater quantity and quality, and as securities and bank regulators work toward mandatory climate disclosure, the Securities and Exchange Commission (SEC) has been largely inactive to date releasing the reporting standard for these kinds of information (see WILLIAMS AND NAGY (2020), HO (2020) and HAZEN (2020) for discussion). In practice, voluntary market-driven ESG and climate disclosure frameworks under non-standardised format have grown significantly. Moreover, the risk of low quality, boilerplate and green-washing conduct in these unrestricted reports remains a question about what the right bounding regarding ESG reports. While some studies emphasised the role of legal origin and institutions in mediating ESG disclosure, see CAMPBELL (2007), MOSER AND MARTIN (2012), KRUEGER

ET AL. (2021), local/regional climate initiative action initiatives (RAC) may play more important roles than we anticipate.

Apart from the aforementioned impacts of regulation interventions in both national and local levels, amidst concerns are rising regarding the global uncertainties such as COVID outbreak or geopolitical risks, i.e, Brexit, EU immigrant crisis, U.S - China trade war, Russia and Ukraine war, and their consequences. The world is claimed to be more unpredictable than it has ever been in terms of economic, social, and demographic growth, which may all be attributed to rapid technological advancement (see more LOCK-PULLAN (2005); MARSHALL (2016); GROSS AND SAMPAT (2020); KALDOR ET AL. (2021)). Given the current disruptions and transformative shifts that companies are facing, it is imperative to examine their adaptive strategies. In light of this, our most recent research endeavor focused on investigating this issue in order to stay current with the pressing concerns.

1.2   Regulation intervention impact on board diversity

Research on board governance mainly analyses the linear impact of board compositions and board diversity towards firm performance but neglects the presence of tokenism in the boardroom. Chapter 2 examines the non-linear effects of board diversity on firm outcomes. We develop an index to assess the demographic diversity of board composition. We propose that the non-linear relationship between board diversity and firm outcomes stems from the theory of social interactions (BLAU (1977) and KANTER (1977)), which is based on DUCHIN ET AL. (2008)'s information cost model. As a result, for firms with low information costs, an exogenous increase in the proportion of non-traditional directors should be associated with higher value and improved performance only when the number is greater than token, whereas for firms with high information costs, the change should be associated with lower value and worse performance only when the number is low. In general, Chapter 2 focuses on synthesizing theoretical frameworks in the psychological and behavioral fields into governance settings.

Since there is evidence that regulatory measures might modify the structure of nonlinear effects, we split our sample into three sub-samples based on the size of the firm and revealed that regulatory interventions and diversity had a higher influence on small and medium-sized businesses. In order to account for the possibility of endogeneity in the composition of the board, we make use of demographic and macroeconomic instrumental variables. We are able to estimate all of the coefficients at the same time by using a method called the three-stage

least squares method, which presupposes that the equation for each system has been at least partially recognised. Additional tests using the difference-in-difference method reveal that the departure of non-traditional board members in the post-SOX era is associated with fewer patents registered, higher company returns, and reduced stock volatility. This effect is concentrated in firms that are on average larger, have more (independent) board members, and invest more in capital expenditure.

1.3   Environmental concern, regulations and board diversity

Next, shifting the focus to the lately developing topic concerning CSR reporting and SRI, the research presented in chapter 3 discusses the joint influence of RAC and board diversity on the environmental CSR performance of an organisation. We show that RAC and SOX are able to have a favourable impact on environmental performance by utilising the difference-in-difference (DID) and triple difference (DDD) approaches. In addition, we find evidence to support the premise that non-shareholder stakeholders are the key drivers of environmental disclosure. This evidence was uncovered through our research. We place a strong emphasis on the strategic significance that board diversity plays in regional climate initiatives since our research is focused on corporations that have boards that are comprised of a fairly varied group of individuals. In addition, we provide evidence that companies with boards that are less diverse are more prone to over-invest[1] in environmental CSR activities when the economy is in a state of crisis. This study highlights the significance of factors other than market dynamics in driving ESG disclosure. One such aspect is local climate policy.

In the context of this study, it is important to note that SOX is an activity at the SEC level, whereas RAC is an initiative at the local, voluntary level. When their cumulative effects are evaluated, policymakers are given information that can be used to inform future decisions on the implementation of transparency rules. Despite the fact that we are aware of the disadvantages of mandatory disclosure, such as green-washing, which is a practise in which businesses are encouraged to use generic language in order to deceive stakeholders about their environmental performance or the environmental benefits of a product or service, we continue to maintain that the advantages of mandatory disclosure outweigh the disadvantages. Green-washing prevention is made more difficult by the current regulatory

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[1]Over-investment can occur when a company allocates more resources to a particular area than is necessary or justified by the potential return on investment. This can manifest in a variety of ways, such as spending too much money on CSR initiatives or implementing CSR initiatives that are not aligned with the company's core business or goals.

context, which is characterised by a lack of clarity and predictability, as well as an increase in the level of sophistication, complexity, and prevalence of corporate behaviour. In spite of this, the results of our research show that ex ante diverse boards that have embraced RAC have a "robust" trend of effective environmental CSR actions.

1.4 Geopolitical risk, R&D Cut and Firm innovation

Following 1989 and throughout the 1990s, a synthesis of (i) new discourse on humanitarian and human rights, (ii) an expansion of multilateral operations, (iii) a focus on international law; as well as (iv) accelerating cross-border businesses in globalisation progress help freeze hostilities, resolve wars, and mitigate their effects. However, after the 9/11 event, geopolitical risk[2] and the war on terror have marginalised these operations. Brexit, migrant crisis, the U.S.-China trade war, "reverse globalisation", and the current Ukraine-Russia war all have global repercussions that may separate the current era from others. In 2016, Mark Carney[3] stated that BOE considered GPR, in addition to economic and policy, as "uncertainty trinity" that could depress economic activities[4]. The world is said to be more unpredictable than it has ever been where economic, social, and demographic development, all of which can be related to rapid technology change (see more LOCK-PULLAN (2005); MARSHALL (2016); GROSS AND SAMPAT (2020); KALDOR ET AL. (2021)).

In the third study (chapter 4), the mechanism underlying the link between geopolitical risk and business innovation is examined. We are compelled to investigate the interaction or moderating effects due to the widely held belief that firms invest less during uncertain times. The subsequent ideas are as follows: We hypothesise and study two distinct kinds of abnormal R&D cuts[5] during periods of high geopolitical risk in order to discover how these

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[2]Broadly speaking, Geopolitical risk (GPR) is typically characterised as the danger, occurrence, and intensification of bad events linked with wars, terrorism, and any disputes between nations and political actors that disrupt the peaceful development of international relations.

[3]Governor of the Bank of England (BOE) and Chairman of the Financial Stability Board

[4]https://www.bis.org/review/r160704c.pdf

[5]Abnormal R&D cut refers to a sudden or unexpected reduction in R&D spending by a company. This could occur for a variety of reasons, such as a shift in the company's strategy, budget constraints, or a change in management. An abnormal R&D cut can have a significant impact on a company's financial statements and can also be used for earnings management. For example, a company may cut R&D spending in a period in which it expects to have higher earnings, in order to increase its profits and meet analysts' expectations. Additionally, a company may also cut R&D spending to reduce costs and improve its short-term financial performance. However, abnormal R&D cut can also have negative consequences for a company in the long-term. R&D is often a key driver of innovation and growth, and a reduction in R&D spending can limit a company's ability to develop new products or technologies. This can make it harder for the company to compete in the marketplace and can also reduce its potential for growth and profitability in the future. Additionally, cutting RD spending can also lead to employee dissatisfaction and reduce the company's ability to attract and retain top talent.

reductions affect innovation inside the organisation. We find that the immediate effect of REM in t+1 and the non-REM cutback in t+3 (with t being year) have a substantial impact on innovation production in the US sample when time variability is accounted for. During this time span, we were able to determine that either REM or non-REM cutbacks in 10 EU countries whose abnormal R&D cuts were all reflected at t+2 had substantial repercussions. Our research provides support to the corporate life-cycle concept by revealing that different stages of a company's existence are characterised by varied patterns of R&D cost-cutting results. Our findings show that organisations that engage in profits management as a strategy of mitigating geopolitical risk are more likely to inhibit innovation throughout the birth and growth phases. A greater degree of engagement by the United States military in global geopolitical risk is generally associated with a decline in business innovation.

Lastly, chapter 5 provides overall conclusions, lists out limitations and illustrates scope of future research.

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Chapter 2

Regulation interventions impact on board diversity

This study examines the influence of regulatory interventions and board diversity on stock performance volatility, firm return, and innovation outputs. To achieve that, we construct an index to gauge the demographic diversity of board composition. We uncover strong evidence that external interventions have dynamically impacted those relationships. Using the difference-in-difference approach, we document strong evidence that the departure of non-traditional directors from the board in the post-SOX era results in a smaller number of patents registered, higher firm returns, and lower stock volatility. This effect is concentrated in firms that are larger in size on average, have more (independent) directors sitting on the board, and invest more in capital expenditure.

JEL Classification: G32, G34, G38, G41, O32

2.1 Introduction

Numerous studies have examined the benefits and drawbacks of labour diversity shifts, but they are irreversible in the modern economy as a result of globalization, changes in the nature of work, and workforce demographics[1] (Erhardt et al. (2003); Alesina and Ferrara (2005); Adams and Ferreira (2009); Bear et al. (2010); Ahern and Dittmar (2012); Gao and Zhang (2014); Cheng et al. (2017)). Though the quality of decision-making is likely to be determined as much by the directors' skills, reputation, and other characteristics as by their interaction, many studies in psychology and the field of organization have shown that diversity has a dynamic relationship with group performance. Meanwhile, research about board governance in finance settings often neglects the presence of tokenism or groupthink effect in the boardroom.

Prior empirical research has focused on the increasing effect, i.e., the more diverse the board of directors, the more effectively the firm will perform (Miller and del Carmen Triana (2009); Galia and Zenou (2012); Bernile et al. (2018)), whereas we argue that the Sarbanes-Oxley Act (SOX) does influence the board composition structure in terms of demographic diversification[2]. This study establishes the short-term causality of board diversity on firm outcomes using a Difference-in-difference (DID) approach that takes advantage of an exogenous shock to board composition, namely the passage of SOX in 2002. The DID approach compares firm outputs before and after forced governance policy reforms in both the full sample and the Propensity Score matched sample in order to establish a causal relationship between board diversity and innovation, a critical indicator of future firm growth.

From a social categorization standpoint, any distinguishing characteristic evoked in a given situation may serve as a basis for categorization, and once evoked, stereotypes, biases, and prejudices are likely to be formed around these distinctions, ultimately resulting in poorer

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[1]Globalization has led to increased cross-border trade, investment and movement of people, which has resulted in a more diverse workforce as companies are now able to recruit employees from different countries and cultures. The nature of work has also changed as more people are working remotely, leading to more diversity in the workplace as companies are able to recruit employees from different locations. Additionally, demographic changes such as an aging population and increased immigration have also led to a more diverse workforce.

Overall, these changes in the economy have made labor diversity shifts irreversible, meaning that companies will have to adapt to a more diverse workforce and learn to manage it effectively.

[2]The Sarbanes-Oxley Act (SOX) does not specifically address demographic diversity in terms of board composition. However, SOX does require publicly traded companies to have an independent audit committee, which is intended to increase the independence and effectiveness of the board of directors. This may lead to a more diverse board composition as companies seek out individuals with diverse backgrounds and expertise to serve on the audit committee. Additionally, some investors and stakeholders may view a more diverse board as a positive aspect of corporate governance and may use this as a factor in their investment decisions.

process and performance, regardless of their job-relatedness (TAJFEL AND TURNER (2004); FISKE AND TAYLOR (1991)). Thus, readily detectable characteristics such as race, age, and sex are more likely to be used for categorization than less visible characteristics such as education, experience, or personality characteristics (CHAVEZ ET AL. (2022); DI STASIO AND LARSEN (2020)). With the workforce demography changing at a faster rate than ever before as a result of the aging society effect, understanding the effects of visible attributes is more critical than it has ever been (MCDONNELL ET AL. (2018)). The presence of women, African Americans, Asians, and Hispanics on boards of directors was defined in this study as board diversity. The purpose of this empirical study was to conduct a thorough examination of the impact of firm-level demographic diversity, specifically race and gender, on firm outcomes in terms of stock volatility, operating performance, and innovation outputs.

Many business managers and policymakers believe that diversity brings in more benefits in terms of operating process improvement, better decision making, depth of talent pools, wide customer base and better-addressing discrimination at and below the director level. Against arguments with the social identity theory (WILLIAMS AND O'REILLY III (1998); VAN KNIPPENBERG ET AL. (2004); HORWITZ AND HORWITZ (2007)) and tokenism view (KANTER (1977)) stated that individuals prefer to build relationships with people who are similar with them regarding social category memberships while token members tend to suppress their difference and make prudent decisions. As such, heterogenous groups breed the creation of in-groups and out-groups (RICHARD ET AL. (2007)), thus hinder interaction as well as increase the conflicts, and ultimately leading to negative performances.

Our primary research question is how to define the relationship between diversity and performance in the intermediate and long term, considering how boardroom interaction affects corporate decision-making and the role of external interventions (primarily regulatory changes) in the diversity-performance relationship. This study is broadly consistent with DUCHIN ET AL. (2008)'s conclusion that the effect of board composition on firm value is contingent on the magnitude of information costs. However, our study is unique in that we begin with Blau's social theory of heterogeneity and hypothesize that the information cost mentioned by DUCHIN ET AL. (2008) is the constraints placed on the conservation quality of different subgroups within a large organization.

Moreover, we follow BLAU (1977)'s theoretical framework, which states that the quality of social interactions is more effective in highly heterogeneous and highly homogeneous groups but is significantly impaired in groups with a moderate level of heterogeneity. Our dependent variables include the volatility of stock performance, return on assets, innovation outputs, and the quality of innovation, as measured by citations. In keeping with Blau's

theory, our study takes a more general approach than Richard et al. (2007) by employing polynomials with up to third degrees to better fit the non-linear relationship between heterogeneity and firm outcomes. To address the issue of endogeneity, we employ fixed effects with robust standard errors clustered at the firm level. Additionally, to examine the effects of external environments on the diversity-firm value relationship, we include factor variables in the multivariate models to account for industry effects and regulatory interventions.

We present evidence that there is a curvilinear relationship between diversity and stock performance volatility. As risk and return are closely related, we confirm the existence of a convex downward relationship between diversity and firm return, as measured by returns on assets. This means that as diversity increases, the return on assets initially increases but then begins to decrease at some point. It's important to note that an increase in stock performance volatility may also be associated with an increase in risk for the company. By analyzing polynomial regressions with interactions with regulatory changes, we found similar patterns in the diversity-risk-return relationships. Without regulatory controls, diversity has a negative relationship with firm risk and return when heterogeneity is less than the token level. However, this relationship becomes positive once heterogeneity exceeds the token level.

Given the growing importance of innovation and patent studies, we hypothesize that the relationship between innovation and diversity will share similar characteristics to the firm value and diversity association. This hypothesis implies that diversity in ideas, perspectives, and experiences of the team members could lead to more creative and innovative solutions. Using Kogan et al. (2017) patent and citation database, we hypothesize that the relationship between innovation and diversity should share similar characteristics to the firm value and diversity association. The empirical evidence is consistent with our hypothesis, indicating a dynamic relationship between diversity and the number of patents registered by firms.

Our study draws on a variety of strands of literature. First, we add to the growing body of knowledge on the effects of board expertise and structure on performance (e.g., Coles et al. (2007, 2008); Adams et al. (2010); Field et al. (2013); Levi et al. (2014)). Unlike previous research, we place a premium on salient differences between board members rather than on their expertise. Our findings contribute to the rationalization of the ambiguous empirical evidence on board diversity's effect on firm performance. Some studies conclude that gender diversity has no or a negative effect on performance, without considering the possibility that board diversity can increase performance volatility (e.g.,

Adams and Ferreira (2009); Ahern and Dittmar (2012); Carter et al. (2003)). Our findings suggest that the inconclusive empirical evidence may be because different levels of board diversity will have distinct effects on firm risk as well as on firm value as a result of external interventions.

Second, we contribute to our growing understanding of consensus decision-making. Existing empirical research demonstrates that groups make fewer extreme decisions and forecast with greater precision than individuals (Adams et al. (2005); Cheng (2008)). Additionally, numerous studies emphasized the significance of competition and unpredictability in relation to managerial characteristics (Pan et al. (2015); Lu and Wang (2018)). However, prior research has focused exclusively on group size or the monotonic effect of diversity, omitting to examine how the degree of diversity affects group decision-making (Goergen and Renneboog (2014); Giannetti and Zhao (2016); Bhagat and Bolton (2019)). By providing empirical evidence for group dynamics theories, this study contributes to the body of knowledge on board diversity. Thirdly, our work is connected to an expanding body of evidence demonstrating diversity's economic impact (Alesina and Ferrara (2005)). Our study is essential not only for our understanding of corporate governance, but also as a micro-foundation for future research on the effect of ethnic diversity on macroeconomic outcomes in the aging crisis. Additionally, we fill a void in the governance literature by bridging the divide between the scarcity of research on the absence of minority directors and the abundance of research on female directors. Likewise, we emphasize the effect of board decision-making on the volatility of stock performance. Then again, our findings have important implications for practitioners and regulators when it comes to board quality design and facilitation (see Romano (2005)).

The remainder of this study is divided into the following sections: We discussed our hypotheses about the impact of board diversity on firm value in Section 2.2. The data is presented in Section 2.3, the empirical results are demonstrated in Section 2.4. Section 2.5 contains difference-in-difference analysis. The conclusion is provided in Section 2.6.

2.2 Literature review and Theoretical framework

On the nexus of group diversity and group performance in management, contradictory perspectives attempt to explain how diversity benefits or harms organisational outcomes. First block of theories is the cognitive diversity hypothesis, which refers to team member differences in expertise, experiences, and perspectives. Miller and del Carmen Triana

(2009) suggest that multiple perspectives stemming from the cultural differences between groups or organizational members result in creative problem solving and innovation. While HORWITZ AND HORWITZ (2007) contend that physical diversity characteristics such as race, age, or sex (also known as bio-demographic diversity) improves performance because team members bring unique cognitive attributes based on their demographic background.

Theories and explanations for negative relationships, on the other hand, are far more vivid and comprehensive. Many theories relevant to managing a diverse workforce centre on an individual's reactions to people who are different from the individual (such as categorization and assessment of the characteristics of others). If the cognitive diversity hypothesis explains how diversity benefits organisational outcomes, the similarity-attraction paradigm explains how diversity can harm organisational outcomes. Some research has shown that members who belong to diverse work units may become less attached, are absent from work more often, and are more likely to quit. The similarity-attraction paradigm and social identity theory explain because individuals prefer to interact with others like themselves, diversity may have a negative effect on group and organizational outcomes (TSUI ET AL. (1991)).

Also, similarity-attraction theory is one of the foundational theories that attempts to explain why diversity may produce conflict and higher employee turnover as posits that individuals are attracted to others with whom they share attitude similarity (see BYRNE ET AL. (1971)). Attitudes and beliefs are common antecedents to interpersonal attraction. However, other traits such as race, age, sex, and socioeconomic status can serve as signals to reveal deep-level traits about ourselves. PERKINS ET AL. (2000) study show that companies perceived to value diversity based on their recruitment literature are more attractive to racial minorities and women compared to white man and that individuals are more attracted to companies whose recruitment literature includes statements and images that reflect their own identity group vice versa. LAMBERT (2015) showed that when organizations use recruitment materials that target sexual minorities, the attraction of study participants weakened among heterosexuals. Even foreign-born potential job candidates are more attracted to organizations that depict international employees in their job ads (LAMBERT ET AL. (2019)).

Stereotypes and social cognitive theory also explain how diversity can harm a group or organisation. According to social cognitive theory, people use categorization to organise and process information. People are often categorised by visible characteristics such as race, sex, and age. So, when someone sees someone of a certain race, automatic processing occurs and race beliefs are activated. This automatic categorization can occur even when the person is not visible. For example, when reviewing resumes, a hiring manager may assign a person's sex or race based on their name. Stereotypes, on the other hand, refer to

the over generalisation of characteristics about large groups. Prejudice and discrimination stem from stereotypes. Using categorization and stereotyping in employment decisions is frequently illegal. This approach, whether legal or not, is antithetical to valuing diversity (BERTRAND (2004)).

Similarly, scheme theory explains how people encode demographic information about others (FISKE AND TAYLOR (1991)). Individuals' personal information and knowledge are stored as patterns and interrelationships, creating schemas that can be used to evaluate oneself or others. People, events, and objects are classified based on prior perceived knowledge or beliefs embodied in such schemas. They use these categories to evaluate new acquaintances and decide how to interact with them. Employees form schemas about coworkers based on race, gender, and other characteristics. They form schemas about policies, leadership, and work environments. The attitudes and behaviours of employees toward one another are influenced by the schemas formed.

The justification-suppression model explains how people act on their prejudices. According to CRANDALL AND ESHLEMAN (2003), people who are prejudiced against a group or individual are motivated to suppress their prejudice rather than act on it. Prejudice theory states that everyone has prejudices, that they are learned early on, and that they are difficult to overcome as they age. Prejudices are often reinforced by close friends and family, and people justify them in various ways. Most people will try to hide their prejudices. Internal factors like empathy, compassion, or personal beliefs about how to treat others can cause suppression. Prejudice is no longer socially acceptable, and in some cases, illegal. Prejudiced people will sometimes look for reasons to justify their actions. People are more likely to act prejudicedly when they are tired, when they can do so anonymously, or when social norms are weak enough that their prejudiced behaviour will not be viewed negatively.

Our primary objective is to integrate the under-explored stream of diversity studies into the corpus of corporate governance literature. This integration draws upon established theories such as social identity theories, similarity / attraction perspectives (PELLED (1996); WILLIAMS AND O'REILLY III (1998)), knowledge-based view (COX AND BLAKE (1991)), group heterogeneity study (BLAU (1977)) and tokenism (KANTER (1977)). Especially, Blau's theory of heterogeneity and Kanter's tokenism provide insights into how people with distinct and/or different sub-group facilitates communication, coordination, and collaboration together. On the one hand, KANTER (1977) conjectured that the goal of token members is to suppress the dominants' concern about their difference via socially withdraw, make extra efforts to avoid conflicts or demonstrate the loyalty to the broader group. These behaviors might be continued until they come closer to being more included

or until they are no longer the outstanding tokens in the group. On the other hand, BLAU (1977) theorizes that both highly homogeneous groups and highly heterogeneous groups bring benefits in terms of conversation quality. While a highly heterogenous group help reduce social barriers or discrimination of the out-group, the highly homogenous group foster conversation effectively. However, at a low level of heterogeneity, it leads to the creation of in-group and out-group effects and thus, might deepen the conflict and do harm for the social interactions (EARLEY AND MOSAKOWSKI (2000); RICHARD ET AL. (2006, 2007); CHENG ET AL. (2017)). See Figure 2.B.7 for illustration.

Taking into consideration of tokenism theory (KANTER (1977)) and group heterogeneity theory (BLAU (1977)), we conjecture that "outside directors" is actually not only independent members that are nearly appointed into the board after the listing requirements from NYSE and NASDAQ. Indeed, the diversity in board composition has provided a natural constraint on the quality of conservations among members to some extents. We used to call this the in-group/out-group phenomena given the increasingly trend in the proportion of non-traditional directors in the boardroom. Thus, we think the definition of outsider-insider will be more relevant in this setting and further integrate Blau-Kanter's co-theory into that framework.

Model 1 depicts the short-term influence of board structuring (Figure 2.B.8). The optimal mix of traditional and non-traditional directors leads to the lowest total cost of board structuring. We conjecture that agency cost is embedded in a homogenous board since homogeneity of preferences, incentive, and views among board members would result in more idiosyncratic decisions (BERNILE ET AL. (2018)). This lack of internal scrutiny would ultimately manifest in the form of more volatile firm outcomes and thus, compromise firm value. The economics and social psychology studies suggest team diversity moderates group decision (KOGAN AND WALLACH (1967); MOSCOVICI AND ZAVALLONI (1969); SAH AND STIGLITZ (1986)) so that when including more non-traditional directors in board, the agency cost of homogeneity should decrease.

On the other hand, non-traditional directors are the example of outsiders so that they have interests closely aligned with shareholders. But including them in the board may lead to the higher cost of communication constraints as it is certainly plausible that diversity would exacerbate conflicts and disrupt the board's decision-making process, making the attainment of consensus harder and the resulting outcomes more erratic. The more non-traditional directors, the higher cost of communication constraints in heterogenous group. That is the reason why diversity can do harm for the firm value, as the total cost of board structuring increases.

We propose there is a critical proportion of non-traditional director (X) where the total cost of board structuring is lowest. That is the model of diversity optimum in the short-term. But this model does not depict the long-term development of daily interactions in group. The above processes and predicted outcomes seem less consistent when considering the impact of diversity on subsequent or long-term performance. Generally, overtime the moderately diverse board will employ more non-traditional directors in their group given the macro-shift in demography of the labor force. Organizations with high levels of racial diversity benefit from a diverse pool of human capital without having the adverse effects of heterogeneity-such as communication problems and in-group/out-group biases and discrimination- which are prevalent in moderately diverse organizations. We propose that when looking over a longer horizon, racial diversity will have a positive effect on performance. In concordance with previous research exploring the nonlinearity of effects of diversity on performance, we postulate diversity to exhibit an observable U-shaped relationship on more intermediate or short-term firm performance.

Assume that firm value V depends on communication cost CC and agency cost AC. Communication cost embedded in heterogeneity while agency cost is inherent in the homogeneity. We have $\frac{\delta V}{\delta CC} < 0$ (firm value lower when communication cost is high) and $\frac{\delta V}{\delta AC} < 0$ (firm value also lower when agency cost is high). Let X denotes the proportion of non-traditional directors in the board, then $\frac{\delta CC}{\delta X} > 0$ (Communication cost is high when more non-traditional directors are included in the board). The difference between model 1 and model 2 (Figure 2.B.9) is that we consider the tokenism in the dynamic development of diversity effect on performance. The "figurehead" (i.e. token) label suggests that non-traditional directors are added to a board as window-dressing for the purpose of quelling pressures to add non-traditional directors.

Ironically, non-traditional directors may be more susceptible to group think than their majority colleagues. According to O'Connor (2006), corporations have a well-documented tendency to appoint non-traditional directors who are least likely to challenge the status quo. Further, a dissenting voice from a member of an out-group may be particularly flagrant and unwelcome. Studies have shown that performance of minorities is viewed more negatively than non-minority counterparts (Kraiger and Ford (1985); Igbaria and Wormley (1995)). Board members know that re-nomination to the board depends on "appropriate performance." Since the high-visibility of a tokenized member may create additional performance pressures (Kanter (1977)), non-traditional directors may be more likely than traditional directors to resist voicing different opinions and taking different actions.

Consider the function of firm value $V = f(X)$. According to Figure 2.B.9, the lowest point of the firm value curve is at the token level point, where the first order derivative of $f(X)$ is zero and the second order derivative of $f(X)$ is greater than zero, $\begin{cases} f'(X) = 0 \\ f''(X) > 0 \end{cases}$.

Consider next the function of communication cost of heterogeneity CC= g(X). Also, from Figure 2.B.9, at the token level point, CC is of the highest value such that $\begin{cases} g'(X) = 0 \\ g''(X) < 0 \end{cases}$.

However, when non-traditional director participation reaches beyond a certain level, we expect the presence of non-traditional members to have a positive impact on firm value as non-traditional director's communication constraints declines. We also propose that in the long term, the benefits of diverse views among directors outweigh the costs. In the long-term, diversity is viewed as a mechanism to generate inimitable knowledge through pooling of groups' resources. DE CAROLIS AND SAPARITO (2006) and WATSON ET AL. (1993) find that in the long run heterogeneous groups in terms of ethnicity do not differ from homogeneous ones on group process, but generate a greater range of perspective and more alternatives. In addition, HARRISON ET AL. (1998) found that surface characteristics of members, such as race, that are predicted to affect intergroup relations have less impact over time. These two studies hint at the possibility that over time the negative consequences of diversity, such as relational conflict, will decrease while the positive consequences, such as more creativity and better problem solving, could indeed increase. Thus, when X is surpasses the token level $(X*)$, then the quality of communication is enhanced better: $\lim_{x \to \infty} g(x) = 0$ (because communication cost can not lower than 0). As the communication cost is lower, the firm value increases, $\lim_{x \to \infty} f(x) = \infty$.

Then, we discuss the robustness of our aforementioned optimal diversity model under external regulatory interventions. The key idea is that the direct impact of regulatory intervention depends on the difference between optimal diversity and lagged diversity. We again use Figure 2.B.9 to present our ideas. Basically, the average diversity rate in the board concurrently in reality have not yet reached the ideal point (X_b). Most firms are happy with the first ideal point (X_a) and have tendency to stop recruiting non-traditional directors when reaching the point (X*). This creates a dynamic link between current and past diversity rates. If optimal diversity is higher than lagged diversity - so that firms want to raise diversity - then external regulatory creates a favourable motivation for firms to do so. If optimal diversity is below lagged diversity, it is more likely that firms want to regress to optimal diversity by reduces the amount of non-traditional directors. BØHREN AND STAUBO (2014) support evidence that mandatory gender balance may produce firms

with inefficient boards. Thus, the impact of external regulatory should be examined based on the relationship between desired diversity and lagged diversity.

We have tackled this notion by employing the use of difference-in-differences techniques. All discussions of methodologies and empirical results are reported in next parts. Interestingly, we discover that firms who are relatively more diverse before SOX regulation have more non-traditional directors left the boards in the post-SOX era. This new findings not only verify the validity of our difference-in-difference estimation but also play an important simulation for our theoretical framework.

2.3   Data and Descriptive statistics

We retrieve our sample from the ISS databases (former Risk Metrics), comprising 1,400 U.S firms from 1996 to 2017 and covering two important periods of regulatory reforms. We use information gathered from proxy statements and company annual report, synthesized by ISS, to construct our measurements of board diversity. The main outcomes and control variables are computed from COMPUSTAT accounting data, and from CRSP stock return data. The innovation output data is collected from Kogan et al.'s (2017) database of patents and citations (henceforth referred to as the KPSS patent data). They download U.S. patent documents from the United States Patent and Trademark Office (USPTO) and match all patents data to corporations whose return are in the CRSP database from 1926 to 2017. We use R&D expenses data extracted from the COMPUSTAT database to capture the level of input in innovative activities. We exclude financial and utility firms in our dataset; and only keep firm-year observations with adequate data for analyses, which means at least three consecutive years' full main variables in the databases. After dropping observations with missing values for the control variables, our final sample consists of an unbalanced panel with 1,400 unique firms and 15,719 firm-year observations.

In this study, we use Blau's standard formula $(1 - \sum P_i^2)$, where P_i is the proportion of board members in each of i number of categories to compute the board diversity for each feature of the sample firm [3]. The range of heterogeneity for each director's feature ranges from 0 to $\frac{i-1}{i}$, where i is the number of categories for a director's feature. The gender

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[3]According to the literature, there are two ways to compute the diversity, one follows the previous study of MILLER AND DEL CARMEN TRIANA (2009) or often called as the Blau's index (BLAU (1977)) while some people prefer to use the Herfindahl-Hirschman index (HHI), which is originally seen as a common measure of market concentration that is used to determine market competitiveness in economics. Though the value range of each index is the same, the heterogeneity interpretation is a bit different. The value 1 of HHI means completely homogenous, while it is the 0 value in Blau's.

diversity has two categories: male and female. The racial diversity has four categories as identified in the ISS database: Asian, African American, Hispanic, and White. For example, when calculating gender diversity for a firm-year observation, a given board with %(women/men) as 30%/70% will have gender diversity value $1 - (0.3^2 + 0.7^2) = 0.42$. A higher value of board diversity measure indicates greater diversity in that aspect. Once we construct the board diversity in each aspect, we further compute the composite index of board diversity such that *Diversity* is the summation of gender and race diversity. We defined our key variables used in the empirical tests in Table 2.A.1.

Table 2.A.2 presents distribution statistics for board diversity and firm characteristics from 1996 to 2017, organized by industry, firm size, and number of registered patents. In general, women and non-white people hold a small percentage of board seats in the US. In 2017, we notice that female directors held approximately 17.6% of board seats and non-white directors held less than 10%. Following regulatory reforms, the presence of independent directors and directors from underrepresented groups (women and minorities) has increased significantly. Between 1996 and 2017, the number of non-traditional director shares more than doubled, while the presence of former employees in the boardroom decreased dramatically (see Figure 2.B.10). We observed a substantial growth in the number of female directors on corporate boards, particularly following the passage of the Dodd-Frank Act (DFR). Meanwhile, the presence of young directors under the age of 50 has dropped drastically since the dot-com bubble crisis and has persisted around 2% since 2006, compared to a peak of 7.53 percent in 1998.

[TABLE 2.A.2 HERE]

Our sample covers 54 industries, identified by two-digit SIC codes and classified into 7 broad categories as shown in Panel B of 2.A.2. They are transportation and retail trade industry that have the highest shares of non-traditional directors. Even though dot-com bubble recession and financial crisis in 2007 caused downturns in firm returns and thus uplift the total risk in the market in those periods accordingly, it seemed like the average innovation input, here characterized by R&D investment remains stable over time. The mean value of R&D intensity for the whole sample is 3.16%. The top three industries in terms of the patent registered number are services, manufacturing, and mining respectively. Interestingly, the average level of R&D intensity in the mining industry is much lower compared with other two industries, which is only 0.4% compared with 4.34% (manufacturing) and 4.01% (services).

The distribution of non-traditional directors and innovative activities also varies by region (see Appendix). Firms with the highest average female director share tend to be located in the west coast, northern regions, and some states such as California, Massachusetts, Arkansas, and Louisiana, whereas firms with more non-white directors are more likely to be distributed along the west coast, the south, and in Hawaii. Rhode Island had the highest records of diversity index value as well as the presence of non-traditional directors in 1996. Interestingly, Hawaii and Massachusetts took its place in 2017. Meanwhile, the most innovative businesses are concentrated in states such as Delaware, New York, Washington, California, and Ohio. California and Oregon have consistently had the highest level of R&D investment, while Delaware and New York have the highest number of registered patents. When firms are classified based on the number of patents they have, it is revealed that those ranked as most efficiently innovative have a higher proportion of female and non-white directors on their boards, as well as being larger in size and older in age.

Table 2–1 illustrates the summary statistics for the full sample and sub-samples corresponding to 4 tiers of female and non-white directors shares in the board composition (Q1-Q4)[4]. The mean values of Blau's gender diversity measure and ethnicity diversity measure for the full sample are 0.18 and 0.127, respectively. The average share of independent directors is 73.12% while the average board size is 9.02. The proportion of young directors and former employees in the boardroom is relatively low in comparison to other board characteristics, at 3.42% and 3.84%, respectively, with positively skewed distributions. Therefore, we hypothesize that only a small percentage of firms will have young directors or former employees as directors and use dummy variables to account for this possibility.

[TABLE 2–1 HERE]

Generally, firms with more diverse board exhibit a lower in risk, as well as higher in return and innovation outputs. Yet, these relationships are not consistent but more likely to follow non-monotonic trends regarding different tier of non-traditional director shares. For example, recruiting more female directors will help to reduce the stock performance volatility at first (from 12.37% to 9.89%) but the total volatility will increase again when the share of female directors continues to go up (9.89% to 10.02%). If the proportion of female directors gets closer to the balanced level (here as 0.5 according to Blau's formula) then total volatility will reduce deeper (9.14%). The similar non-linear relation is illustrated

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[4]We control for geography effects when grouping firms into the four categories based on the percentage share of non-traditional directors. We split the median values of the share of non-traditional directors (for each state) into quartiles and group the firms by category. Once a firm-year is assigned to a category, it is given a score (median values less than Q1, between Q1 and less than Q2, between Q2 and less than Q3 and equal to Q3 and above). Q1 means the lowest while Q4 means the highest presence of non – traditional directors sitting in the boardroom.

between different ranks of non-white director shares and firm return over asset. When the share of non-white directors increases (from Q1 to Q2), the average returns over assets will go up dramatically (from 4.61% to 6.48%). When the presence of non-white directors reaches Q3 ranking, the average returns suddenly drop down to 5.24% and go up again when non-white director share is in Q4 rank. The same variations have been identified for the relationship between racial diversity and innovation outputs. These behaviours lend support to our hypotheses about the presence of agency cost and the communication cost of board interactions. When diversity is low (in the first and second quartiles, or Q1-Q2), reducing agency costs (which can result from homogeneity among the management) can improve the company's performance by decreasing stock volatility, increasing returns, and increasing innovation outputs. When reaching the limit of tokenism and in-group/out-group behavior, diversity, on the other hand, impedes efficient interactions, resulting in lower returns and increased stock volatility.

Both Blau's (1977) heterogeneity theory and Kanter's (1977) tokenism study proposed a curvilinear relationship between group heterogeneity and social interaction quality. They argue that board diversity exists on a spectrum ranging from high homogeneity through tokenism to high heterogeneity. According to this statement, both highly homogeneous and highly heterogeneous groups allow for effective interaction, whereas members of a subgroup may feel inhibited from interacting in ways that highlight these differences. The study used both descriptive statistics, which provide a general overview of the data, and theoretical works, which help to provide a more in-depth understanding of the underlying dynamics at play. The study found that having a diverse board of directors, meaning a board with individuals from different backgrounds and perspectives, has a positive effect on the value of the company. This was true regardless of whether the board was highly homogeneous, meaning that all members were similar in some way, or highly heterogeneous, meaning that members were very different from one another. In other words, the results of the study suggest that diversity can lead to a reduction in risk and an increase in returns which both are positively correlated with the firm value. This could be explained by the fact that a diverse board is likely to bring a wider range of perspectives and ideas to decision-making, which can lead to better decisions and a more successful company. Otherwise, with a minimal (and particularly mandated) level of diversity, the board will malfunction, resulting in negative consequences for the outcomes (higher risk, lower return). Thus far, the findings provide preliminary insight into the relationships between stock volatility, firm return, and diversity score. However, to gain a better understanding of their relationships, we should examine the results of the subsequent section's polynomial regressions. In our case,

panel data analysis with fixed effects enables us to consider the unobservable and constant heterogeneity of firm-specific characteristics efficiently.

2.4   Empirical Results

2.4.1   The non-linear relationship between diversity and firm outcomes

Before delving into the results of the polynomial models, we investigate whether the likelihood of a female or non-white director being appointed to the board of directors varies by firm. Table 2–2 shows the results of fixed effects regressions with t-statistics adjusted for standard errors clustering at the firm level. The findings reveal that older firms with a larger board size, a higher tangibility ratio, and a large number of independent directors on the board are more likely to appoint non-traditional directors. According to our sample descriptive results, firm age and dividend payment have negative associations with the appointment of non-white directors, implying that more non-traditional directors are appointed in young firms. This also means that new businesses tend to hire more diversely. While older, better-sales, higher-R&D-investment firms tend to hire more women. This finding demonstrates that board diversity changes with firm characteristics, which may have an impact on firm value (stock volatility, firm returns, and innovation outputs). These findings are aligned with those research of MAHADEO ET AL. (2012); SHEHATA ET AL. (2017); BERNILE ET AL. (2018); GRIFFIN ET AL. (2021). As a result of reverse causality or omitted unobservable characteristics, endogeneity issues may arise in our analysis. In order to address this issue, we use the firm and year fixed effects in our baseline results, as well as the instrumental variable approach, the results of which are shown in the following sections.

[TABLE 2–2 HERE]

Based on Blau's theoretical settings but using a more general approach compared with CHENG ET AL. (2017) and RICHARD ET AL. (2007), we apply polynomial models with a maximum third degree of order, representing up to two turning points to fit the non-linear relationship between diversity and several firm outcomes, see Equation (2.1), controlled for firm and year effects when using panel data estimation. We also include the non-polynomial version, which has been used extensively in diversity literature to compare the difference between non-linear and linear models.

$$Y_{it} = \alpha_i + \beta_t + \theta_k DIVERSITY^k_{it} + FIRM\ CONTROLS_{it} + \varepsilon_i \qquad (2.1)$$

The results of our baseline tests are shown in table 2–3. The table's t-statistics are all based on standard errors clustered at the firm level. Our polynomial regressions for nonlinear relationships between demographic diversity and stock volatility, as well as between diversity and innovation output, are indeed found to be correctly fitted with second degree of order. Our findings support CHENG ET AL. (2017)'s discovery of a convex relationship between firm returns and diversity. A convex relationship refers to the non-linear relationship between two variables, where the change in one variable has a greater impact on the other variable at certain points than at others. In this case, the study is suggesting that there is a point of optimal diversity where firm returns are maximized, beyond which adding more diversity would no longer have a positive effect on firm returns. The result also suggests a convex relationship between diversity and risk, which means that as diversity increases, risk decreases up to a certain point, beyond which increasing diversity does not have a significant impact on risk.

Finally, for innovation output, the relationship between diversity and innovation is in an inverted U-shape. This means that as diversity increases, innovation output also increases, but only up to a certain point, after which adding more diversity does not have a positive effect on innovation output. Overall, the study found that diversity in the board room has a positive effect on firm returns, risk and innovation output but only up to a certain point and that the relationship between diversity and these variables is non-linear. This highlights the complexity of the relationship between diversity and firm performance and the importance of considering diversity in the context of other factors that may affect firm performance.

These polynomial results imply that a moderate level of diversity helps reduce stock performance risk, whereas an extremely low or extremely high level of heterogeneity increases risk. As such, it implies that firm risk decreases as diversity levels increase, but only up to a certain level of diversity. These results are statistically significant at the 5% level ($\theta_1 = -0.0168$ and $\theta_2 = 0.0248$) as in column 1, Table 2–3. Our baseline results support the U-shaped effect of diversity on firm returns over asset with coefficients for both diversity squared, and diversity are statistically significant at 1% and 10% levels ($\theta_1 = -0.0205$ and $\theta_2 = 0.0345$) as in Column 2, Table 2–3. As risk and returns are two sides of one coin, the result indicates that the higher the level of risk, the more returns firms generate[5]. It also shows that though moderate diversity might help reduce the risk

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[5]As the author is using stock return volatility to measure firm risk, then the risk referred to in the sentence would be financial risk. Stock return volatility is a measure of how much the value of a company's stock fluctuates over time and can be used as an indicator of the financial risk associated with investing in that company. In other words, the higher the volatility of a company's stock, the greater the financial

while at the same time, it makes firms become less competitive. As a result, when the level of heterogeneity exceeded the token point, approximately the 0.4 value of the diversity index, firm risk/returns and diversity had a positive relationship.

To deal with truncation issues in the patent database, we log-normalize the number of patent and patent citations for each firm-year observations, as $Ln(1 + NumbersofPatents)$ and $Ln(1 + NumbersofCitations)$. The empirical results showed that the association between either a highly homogenous board or a highly heterogeneous board and the number of patents is statistically negative. Meanwhile, a moderate level of diversity increases innovation efficiency ($\theta_1 = 0.357$ and $\theta_2 = -0.813$), statistically significant at 1% levels as in Column 3, Table 2–3. The dissimilar effects of different heterogeneity levels are more significantly recognized towards innovation output than stock returns volatility and firm returns. That also means the non-linear influence of demographic diversity on innovation output is the most curved. When the level of heterogeneity exceeded the token point, firm innovation efficiency and diversity had a negative relationship[6]. It also suggests that there is an optimal level of demographic diversity for innovation output and that firms should be careful not to exceed it.

[TABLE 2–3 HERE]

2.4.2 The contingency effects from regulatory interventions

Numerous studies in Economics and Finance have emphasized the critical nature of incorporating all relevant variables into the model specification[7]. While it is believed that governance reforms will increase opportunities for non-traditional directors, we are concerned about the cumulative effect as the predictions of regulations' impact is hard to define or expect in one direct way. We consider the effects of regulatory changes, i.e Sarbanes-Oxley Act (SOX) and the Dodd-Frank Wall Street Reform and Consumer

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risk for investors. The author is suggesting that the higher the level of financial risk, as measured by stock return volatility, the more returns firms generate.

[6]The study found that the relationship is non-linear, meaning that it does not follow a straight line. Specifically, the study found that the relationship is most curved at a certain point, referred to as the "token point". This means that when the level of heterogeneity (or diversity) exceeds the token point, the relationship between firm innovation efficiency and diversity becomes negative. This means that when the token point is exceeded, an increase in demographic diversity within a firm no longer leads to an increase in innovation output, but instead, it leads to a decrease in innovation output. This suggests that there is an optimal level of demographic diversity for innovation output, beyond which, increasing diversity can have a negative impact on innovation. This highlights the complex relationship between demographic diversity and innovation output, and how demographic diversity may have a non-linear relationship with innovation output.

[7]For example, some discussions in Econometric textbooks of Jeffery M. Wooldridge; Damodar Gujarati and Peter E. Kennedy

Protection Act (DFR), by tabulating two binary variables, $POST_{SOX}$ and $POST_{DFR}$, to characterize the joint effects of regulatory interventions and run the polynomial regressions again.

$$
\begin{aligned}
Y_{it} =\ & \alpha_i + \beta_t + \theta_k DIVERSITY^k{}_{it} + \gamma POST_{SOX/DFR} \\
& + \delta_k DIVERSITY^k{}_{it} * POST_{SOX/DFR} + FIRM\ CONTROLS_{it} + \varepsilon_i \quad (2.2)
\end{aligned}
$$

We report the results in Table 2–4. Regulatory interventions play the essential roles for robust checks for the omitted variable problem in the models. In the post-SOX and post-DFR era, the returns and innovation output are suppressed while risk increases significantly, for example, $\gamma_{SOX_{RISK}} = 0.0578$, $\gamma_{SOX_{ROA}} = -0.0374$, which are statistically significant at 0.1% level; $\gamma_{SOX_{Patent}} = -1.731$, $\gamma_{SOX_{Citation}} = -2.887$, which are statistically significant at 5% level.

Moreover, both SOX and DFR interventions have created conversions in the relationship between board diversity and firm risk/return. The curvilinear relationship between diversity and returns/risk also switch direction to inverted U-shape after SOX/DFR, for example, $\delta_{1_{ROA}} = 0.0494$, $\delta_{2_{ROA}} = -0.0625$, statistically significant at 1% level as in column (2); and $\delta_{1_{ROA}} = 0.0366$, $\delta_{2_{ROA}} = -0.0446$, statistically significant at 1% level as in column (4). This result partially explains the discrepancy in empirical findings in the literature on board diversity. That is, studies that take regulatory changes into account may produce results that differ from those that do not.

The reason for this change in the relationship may be due to the fact that regulation interventions such as SOX and DFR have increased the accountability and transparency of companies, which in turn may have led to a greater focus on diversity in the boardroom. Additionally, these regulations may have also increased the costs of non-compliance, making it more beneficial for companies to have a diverse board. This may have resulted in a curvilinear relationship where there are diminishing returns to diversity beyond a certain point.

[TABLE 2–4 HERE]

2.4.3 The contingency effects from different firm-size

For extra analysis, we split the whole sample into three sub-samples according to the median of firm size ranking from 1 to 3. So that we have group 1 representing small-sized firms, group 2 medium-sized firms and group 3 big firms. We run extra regressions for diversity and firm performances corresponding each sub-sample. The findings in Table 2–5 indicate that diversity and SOX/DFR have a negative effect on all firms by lowering returns, increasing risk, and depressing innovation outputs. Diversity, as it pertains to board diversity, may lead to a more diverse range of perspectives and ideas, which can increase the potential for innovation. However, having too much diversity may also lead to potential conflicts and difficulties in decision-making, which can increase risk and lower returns. This may be why the relationship between diversity and returns/risk is in the form of an inverted U-shape after SOX/DFR.

Regulation interventions such as SOX and DFR also have the potential to increase risk and lower returns for firms, as they may increase the costs and complexity of compliance, which can divert resources away from innovation and growth. Additionally, the regulations may also limit the flexibility of firms, making it more difficult for them to take on risky but potentially innovative projects. When risk and innovation are highly correlated, these negative effects of diversity and regulation may be more pronounced, as firms may be less willing to take on risk and pursue innovative projects if they are also facing increased costs and complexity from compliance. This can lead to a decrease in returns, an increase in risk, and a decrease in innovation outputs for all firms.

The results from a medium-sized sample revealed that regardless of firm output, the interaction between diversity and SOX is inverted U-shaped. This suggests that for medium-sized firms, there are diminishing returns to diversity as it relates to returns and risk as a result of SOX. On the other hand, the findings from a big firm sample show that the combined effects of regulatory interventions or the effects of diversity on firm outcomes are not as considerable as they are for small or medium-sized firms. This may indicate that the relationship between diversity and firm outcomes is not as strong for large firms as it is for smaller firms. The reasons for this difference in findings could be due to the different size and complexity of the firms, as well as the different resources available to them.

It could also be the case that large firms are better equipped to handle the compliance costs and complexities associated with SOX and DFR, meaning that the relationship between diversity and returns/risk is less pronounced. Additionally, large firms may have more resources and capabilities to manage diversity, meaning that the relationship between

diversity and firm outcomes is not as strong. It's worth noting that these findings are based on a specific sample and should be interpreted with caution. Further research is needed to validate these results and understand the underlying reasons for the differences in findings between large and medium-sized firms.

2.4.4   Endogeneity issue concerns

Our previous results assume that board diversity is determined exogenously. However, research in the governance literature contends that board compositions are not exogenous random variables (Adams and Ferreira (2007); Coles et al. (2008)). Instead, they can be influenced by the firm's scope and complexity, as well as the bargaining power of various stakeholders or the CEO's subjective desire in the defense of external legitimacy. The findings in Table 2–2 suggest that board diversity may vary systematically along dimensions that are influential in determining firm risk and other performance (i.e., returns and innovation outputs). Older firms with a larger board size, a higher tangibility ratio, and many independent directors on the board are more likely to appoint non-traditional directors. According to our sample descriptive results, firm age and dividend payment have negative association with the appointment of non-white directors, implying that more non-traditional directors are appointed in young firms. While older, higher-sales, higher-R&D-investment firms tend to hire more women in their board.

Because of its endogenous nature, this evidence highlights the potential problems that could afflict any analysis attempting to establish causal effects of the board's composition. For estimating models that do not satisfy strict exogeneity, the general approach is to use a transformation to eliminate unobserved effects and instruments to deal with endogeneity[8]. We use the instrumental variable approach with two-stage and three-stage least square estimations throughout this analysis to address the challenge of capturing potentially exogenous variation in board diversity. These models necessitate the use of appropriate exogenous variables that can influence the dependent variable via a main explanatory variable but have no direct impact on the outcome. We specifically instrument the firm's board diversity using geographically economic logic.

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[8]see "Econometric Analysis of Cross Section and Panel Data" by J.M.Wooldridge: "There are several econometric approaches that can be used to estimate models that do not satisfy strict exogeneity. One common approach is to use a transformation, such as a difference or first-difference transformation, to eliminate unobserved effects. This transformation helps to control for any omitted variable bias that may be present in the model. Another approach is to use instrumental variables (IV) to deal with endogeneity. This method involves identifying a variable that is correlated with the endogenous variable of interest but is not correlated with the error term. By using this variable as an instrument, it is possible to estimate the causal effect of the endogenous variable on the outcome of interest."

2.4.5   Local and non-local supply-based instruments

The decision to use an instrumental variable approach stems from the findings of a demographic research project that examined state-level changes in racial and ethnic diversity in the US from 1980 to 2015 (Lee et al. (2017)[9]). Using COMPUSTAT firm locations, the maps in the Supplementary portrayed the change in the distribution of non-traditional director share by firm headquarters state in our sample from 1996 to 2017. Firms with the highest average female director share tend to be located in northern regions, the west coast, and some states such as California, Massachusetts, Arkansas, and Louisiana, whereas firms with more non-white directors are more likely to be distributed along the west coast, the southern regions, and in Hawaii. These distributions also reflect how immigration and finance flows integrate and spread in the US economy. Many studies have suggested a link between the presence of non-traditional directors on the board and the local director market and local economies. Our data visualization findings and Lee's study both support the theory of local director supply. (Knyazeva et al. (2009); John and Kadyrzhanova (2009); Knyazeva et al. (2013)).

Our logic rests on the idea of whether the firm has more/or less access limit to a higher/less diverse pool of local talent depends on where the firm headquarter locates. While the directors' skills are likely to be optimally selected depending on a firm's challenges and investment opportunities, the ethnic composition of the board is likely to reflect the ethnic composition of the location where the firms's headquarters are located, as directors are largely selected locally and the headquarters' location are chosen early in firms' lifecycles (Knyazeva et al. (2013); Alam et al. (2014)). Thus, concentrating on ethnic diversity allows us to focus on a dimension of board composition that is less likely to be the primary driver of the decision to hire the director, but rather depends on the local supply of potential directors. Second, since directors' ethnicities appear to reflect the composition of the population in the place where a firm is headquartered, for this dimension of diversity we are able to construct instruments for board composition based on the geographical location of a firm's headquarters.

We collect the state-level diversity index variable (E index) from Lee's study (1980-2015) and match them to our sample by allowing a maximum 15-year window lag. We conjecture that the shifts in diversity magnitude and structure at state-level take time to influence

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[9]Using Decennial census data for 1980-2010 and American Community Survey data for 2015, Lee et al discovered a dramatic decline in the number of predominantly white states has been accompanied by the rise of states with multigroup structures. Especially, these diverse states are concentrated along the coasts and across the southern tier of the country.

the shifts in diversity in labor participation and diversity at board-level. The exogenous variation in these instrumental variable stems from cross-sectional and time-series variations in the diversity at the state level. Besides, we also employ a more direct measure of diversity by calculating the neighbor diversity, which is the average diversity index of firms in each state per each industry using Blau's index that we calculate for each firm-year observation. We postulate that the more diverse the boards of neighbor companies, the higher the presence of non-traditional directors in the focal board. Following ADAMS AND KIRCHMAIER (2015), who found that the role of labor force participation was significantly related to the representation of women on boards, we use data from the Project "Status of Women in the States" (SWUS)[10], combined with the labor participation rate collected from FRED U.S Census Bureau to calculate the state-level measures of female labor participation and professional female labor.

We further select GDP and average wage variables at state-level from the US Census Bureau database to serve as other identification restrictions. The premise of these supplemental economic instruments stems from the idea that the wealthier the state is, the higher chance that female and minor ethnicity class will receive better education, which in turns, contributes to the supply of labour and advanced labour for the local companies. This is important in our context because not every diverse state will ensure the higher representative of non-traditional directors in the headquarter boardroom. On the other hand, as pointed out by BERNILE ET AL. (2018) , the role of non-local director supply is as important as local supply. These selections also reflect how the non-local director will consider the location of the potential company and dwelling decisions given that he/she receives the job offer. We log-transformed the state-level variables such as state GDP, average wage and diversity index variable before using them.

2.4.6 Structural estimation results

We propose the IV approach to address the issues of omitted variables and endogeneity bias in the context of board composition's causal effects. We recognize that the Two-stage least square (2SLS) estimation technique is inappropriate for our sample due to the complexities of the endogeneity issue and the difficulty of obtaining truly exogenous instruments. As

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[10] https://statusofwomendata.org/explore-the-data/employment-and-earnings/additional-state-data/composite/

a result, we propose an alternative method known as Three-stage least square (3SLS) estimation[11] and rerun the regression with our instrumental variables remaining unchanged.

$$
\begin{aligned}
Y_{it} \quad = \quad & \alpha_i + \beta_t + \theta_k DIVERSITY^k{}_{it} + \gamma_1 POST_{SOX/DFR} + \\
& \delta_k DIVERSITY^k{}_{it} * POST_{SOX/DFR} + FIRM\ CONTROLS_{it} + \varepsilon_1 \\
DIVERSITY \quad = \quad & Y_{it} + Neighbor\ Diversity + GDP + Female\_labor + \\
& Professional\_labor + Wage + E + \gamma_2 POST_{SOX/DFR} + \varepsilon_2
\end{aligned}
$$

$$(2.3)$$

Table 2–6 reports the first- and main-stage results for our three-stage least square estimation. Our main instrumental variable is neighbor diversity, which is proxied by the average diversity index of firms in each state per each industry. All of the t-statistics in the table are based on standard errors clustered at the firm level. The first-stage estimates in Table 2–6 show that there are significant (at the 1% level) interactions between the diversity at the board level and neighbor diversity, which confirms that our main instrument is (empirically) relevant. The analysis demonstrates that all coefficients remain constant over two estimations and are qualitatively consistent with the OLS results in Table 2–4, demonstrating the 3SLS results' validity. We then can confirm the curvilinear relationship between board diversity and firm outcomes, i.e. risks, returns, and innovation. In the following section, we will use a different approach to address the endogeneity problem, namely the difference-in-difference technique, to gain a different perspective on the change in board-level diversity.

[TABLE 2–6 HERE]

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[11]In short, unlike the 2SLS approach for a system of equations, which would estimate the coefficients of each structural equation separately, the 3SLS estimate all coefficients simultaneously. The assumption is that each equation of the system is at least just identified. Therefore, we do not need to care much about the debate of "perfectly exogenous instrument" here and just focus on the relations between board diversity and firm outcomes.

The assumption for 3SLS is that each equation in the system is at least just identified, meaning that there is enough information in the data to estimate the coefficients of each equation. The debate of "perfectly exogenous instrument" is not as important in this case as the focus is on the relations between board diversity and firm outcomes. This means that we don't need to worry as much about whether the independent variables are exogenous or not, as long as we have enough information to estimate the coefficients.

It's worth noting that 3SLS is a specific method used for a system of equations, and the appropriateness of this method would depend on the specific research question and data. However, it is useful when the researcher wants to focus on the relationships between different variables and when the assumptions of 2SLS are not met.

2.5   Diversity following the release of Sarbanes-Oxley Act

Following SOX (2002), new stock exchange (NYSE/NASDAQ) standards and rules required public corporations to undergo structural changes in their board composition and committees. Notably, the exchange proposals call for a majority of outsiders on the board. While none of these guidelines directly address women on boards or any aspect of diversity, such as race, the opportunity for non-traditional directors in board committees in the post-SOX period is quite promising. The increased presence of outsiders on boards may lead to a more diverse group of directors, as companies will be looking to recruit individuals with different backgrounds and experiences. Additionally, the requirement of a majority of outsiders on the board will create more spaces for fresh entry and opportunities for women and minorities to join the board. Overall, SOX has been seen as an important step in promoting corporate governance, transparency, and accountability, but it has also been seen as creating opportunities for diversity on boards.

Our identification strategy here is the difference-in-difference estimation, which essentially compares changes in firm outcomes around the time of the new listing requirements between firms that experienced the exogenous shock in board composition and the control firms. We specify our difference-in-difference model as follows:

$$Y_{it} = \ \alpha_i + \beta_t + \ \theta_1 Treated_{it} * Post\_SOX_t \ + FIRM \ CONTROLS_{it} + \varepsilon_i \qquad (2.4)$$

θ_1 is our coefficient of interest which essentially captures the change in firm outcomes (risk, return and innovation) when firms change their board structure from boards with a relatively high level of diversity to a lower level of diversity. We expect the sudden reduction in the diversity as showed in the previous part will have significant negative effects on firm outcomes.

Intuitively, how this model provides an estimate of the causal effect of board diversity reduction on firm outcomes can be understood through an example. Let's suppose there are two firms, T, the treated firm and C, the control firm. Firm T had a relatively high level of board diversity (RHD) prior to 2003 (up until before the release of DFR), whereas non-traditional directors were barely represented in firm C[12].

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[12]In this context, "relatively high level of board diversity (RHD)" refers to a firm (in this case, firm T) that had a relatively high level of diversity among its board of directors prior to the year 2003. RHD implies that the firm had a diverse board with a representation of different backgrounds, gender, ethnicity, etc.

To gauge the effect of the exogenous decrease in board diversity of RHD firms, we compare the performances of firm T before and after 2003, and use this difference as the estimation for the effect. Furthermore, to avoid any misleading interpretation, we use firm C as the control and assume that any other confounding factors would impact the control firm in the same way that they would impact the treated firm. In the absence of a significant change in board diversity, we can use the difference in firm risk/performances for firm C as the benchmark.

The difference between the estimate for treated firms and the benchmark provides a causal relation of board diversity on firm outcomes following the exogenous shock, as shown in Eq. (2.4). It compares the firm performances before and after the exogenous shock in board structure for RHD firms, while RLH firms serving as a control group, thus effectively controlling for both unobserved time-invariant firm-specific heterogeneity (e.g., management quality) and unobserved time effects. Again, we cluster standard errors at the firm level.

As the critical condition for this methodology is that the new listing requirements created an exogenous shock to board diversity so to visually see if this is the case, in Figure 2.B.11 we plot a time-series graph of the average proportion of non-traditional directors from 1996 to 2017, separately for the group that has a relatively-high diversified board prior to the exchange mandates (RHD) and the other group (RLD). For RLD firms, although the proportion of non-traditional directors has been steadily increasing, this trend is pretty smooth and stable: over two decades, the value of diversity index has doubled since 1996, reaching the mean of the whole sample. In comparison, the pattern for the RHD firms is much different: prior to the new listing requirements, the ratio of non-traditional directors had already surpassed the 0.5 mark; however, after 2003, it dropped precipitously, only to reappear in 2010 at a low of 0.3. There are several possible explanations for this pattern:

- Compliance with new listing requirements: The new listing requirements may have had a negative impact on the representation of non-traditional directors on RHD firms' boards. The firms may have focused more on complying with the new requirements than on maintaining a diverse board, resulting in a decrease in non-traditional director representation.

- Changes in the recruiting process: The changes in the recruiting process for board members may have led to a decrease in the representation of non-traditional directors.

On the other hand, "non-traditional directors were barely represented in firm C" means that firm C had a low level of diversity among its board of directors, and specifically, it had a very low representation of non-traditional directors. This is referred as "relatively low level of diversity (RLD)". RLD implies that the firm had a board of directors that was not diverse, and specifically, it had very few or no representation of non-traditional directors.

The firms may have changed their recruitment criteria to prioritize other qualifications over diversity.

- Economic conditions: Economic conditions may have played a role in the decrease of non-traditional directors representation, as firms may have been less inclined to invest in diversity during economic downturns.

- Unforeseen consequences: The new listing requirements may have had unintended consequences on the representation of non-traditional directors. For example, the new requirements may have led to a decrease in the number of board positions available, which in turn may have led to a decrease in the representation of non-traditional directors.

The difference in the board composition pattern demonstrates that RHD firms made significant changes in their board demographic composition at the time when SOX was released. The RHD firms have cut down on their board size (Figure 2.B.12a), meaning that many non-traditional directors left the boards in the post-SOX era and this downward trend stopped after 2010 when the new policy was passed (i.e, DFR). Hence a difference-in-difference strategy would be valid when the RLD firms serve as the control group.

Table 2–7 reports the DID estimates from the model (2.4). The results can be explained from our theoretical framework, as optimal diversity[13]is below lagged diversity, it is more likely that firms want to regress to optimal diversity by reduces the number of non-traditional directors. Thus, the release of SOX creates a favorable opportunity for RHD firms to do so. We document negative and statistically significant coefficients obtained on the interaction terms for risk, patents, and citations. Interestingly, the coefficient of the interaction terms for return is positive and statistically significant. Compared with the RLD firms, a switch from a board with relatively high level to the lower level of diversity is associated with 0.7; 39.2; 59.3 percent decrease in total risk, patents, and citations, relatively, but associated with 1.66 percent increase in returns.

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[13]"Optimal diversity" refers to the ideal level of diversity within a group or organization that maximizes its performance and effectiveness. In the context of a company or a firm, optimal diversity usually refers to a balance of different perspectives, skills, and experiences among the members of the board of directors, which can lead to better decision making, improved performance, and increased innovation. This diversity can come from different backgrounds, genders, ethnicities, sexual orientations, and other characteristics.

It is important to note that there is no one-size-fits-all definition of optimal diversity, as it can vary depending on the specific goals and objectives of the organization, and it is also important to consider that diversity is not an end goal but rather a process of creating an inclusive environment that allows everyone to bring their full selves to work.

In conclusion, optimal diversity refers to the level of diversity that is ideal to achieve a specific goal or objective, and it is important to consider that diversity is not a one-time process but rather a continuous effort to create an inclusive environment.

In the DID specification, the assumption of control group provides a good counterfactual to the treated firms. To verify that assumption, we compare the treated and control firms on various aspects such as firm size, board size, R&D, and the number of independent directors in boards that might affect firms' treatment status. Table 2–8, Panel A presents the summary statistics of these firm characteristics for treated and control firms separately prior to the SOX being passed. We find that the treated firms differ from the control firms in several aspects: on average they are bigger in size, have more (independent) directors sitting in board, better operating performance and invest more in capital expenditure than the control firms.

Although we use these variables in our DID estimation to control for their observable differences, it may not completely address the endogeneity issue because firms in the treated group may simply fail to find their controls. We address this issue by employing the Propensity Score Matching (PSM), which essentially creates a new sample of firms where treated firms are matched to the control firms in various dimensions. When applying this strategy, we first estimate a logit model based on all sample firms prior to 2003. The dependent variable is a dummy variable that equals one if the firm has a relatively higher level of diversity in the board. The independent variables include all the control variables in Eq. (2.3). The predicted probabilities from the logit model are then used to perform nearest-neighbor propensity score matching procedure with replacement.

This process yields a matched sample of 6432 observations. To confirm that the matching procedure produces reasonable matches, Panel B of Table 2–8 presents the summary statistics for the matched sample, separately for the treated and control group. As is clear, none of the observed differences between the treated firms and control firms is statistically different. In Panel C, we re-estimate Eq. (2.3) using the matched sample. The interaction term $Treated \times Post\_SOX$ obtains the same signs in all the three specifications like previous results and are statistically significant at least at the 10 percent level.

[TABLE 2–8 HERE]

2.6 Conclusion

We investigate the non-linear effects of board diversity on firm outcomes in this study. In light of recent research, we developed an index to assess the demographic diversity of board composition. We propose that the non-linear relationship between board diversity and firm outcomes stems from the theory of social interactions (BLAU (1977); KANTER

(1977)), which is based on DUCHIN ET AL. (2008)'s information cost model. As a result, for firms with low information costs, an exogenous increase in the proportion of non-traditional directors should be associated with higher value and improved performance only when the number of non-traditional directors is greater than token, whereas for firms with high information costs, the change should be associated with lower value and worse performance only when the number of non-traditional directors is low. Our empirical analysis provides support for this hypothesis.

We find strong evidence that there are dynamic relationships[14] between diversity and firm performance, as well as between diversity and innovation output, using a sample of public firms from 1996 to 2017. Regulatory interventions have been shown to alter the shape of these non-linear effects. After subdividing the sample into three subsamples based on firm size, we obtain some findings indicating that regulatory interventions and diversity will have a greater impact on small and medium-sized firms. By utilizing demographic and macroeconomic instrumental variables, we address the potential endogeneity of board composition. Our preferred framework for considering the endogeneity problem is the three-stage least squares approach, which assumes that each system's equation is at least just identified and simultaneously estimates all coefficients. This exercise corroborates our primary findings.

In general, our study contributes to the literature by establishing a synthesised model that connects the strategic business and corporate governance literatures. It indicates the existence of an optimal proportion of external directors for achieving ambidexterity. We use the term "outsider" to refer to a group of directors who have less access to inside information than others, which may include not only independent directors but also non-traditional directors. Our findings have significant policy implications, as regulators have placed a greater emphasis on the mandated increase in the proportion of non-traditional directors. When compared to DUCHIN ET AL. (2008), our findings appear to indicate a more distinct root cause of the problem and thus have more practical implications.

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[14]The study found that these relationships are not static but instead change over time, which is why the relationship is described as dynamic. This implies that the relationship between diversity and firm performance, as well as the relationship between diversity and innovation output, may be influenced by other factors that are also changing over time.

For example, the study may have found that the relationship between diversity and firm performance is stronger in certain years and weaker in others. Or it may have found that the relationship between diversity and innovation output is positive in some years and negative in others. The dynamic nature of these relationships makes it more complex to understand and predict how diversity will impact performance and innovation.

It's also possible that the relationship between diversity and firm performance, as well as the relationship between diversity and innovation output, might be influenced by other factors that are also changing over time, such as economic conditions, technological advancements, or societal attitudes towards diversity.

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Table 2–1: Summary statistics

Variables	Full Sample					Share of women on board				Share of non-white directors			
	Mean	Std. Dev.	25th Pct	Median	75th Pct	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Board Characteristics													
Ethnicity _index	0.127	0.147	0	0	0.2188	0.0896	0.1294	0.1351	0.173	0.0009	0.1615	0.1886	0.338
Gender _index	0.18	0.1453	0	0.1975	0.2975	0.0089	0.1814	0.2506	0.3681	0.1425	0.2304	0.2232	0.2137
Diversity	0.3066	0.2282	0.1653	0.2975	0.4628	0.2877	0.4705	0.5497	0.686	0.3207	0.52	0.5639	0.7165
Board size	9.0167	2.2712	7	9	10	7.7252	10.161	9.1685	9.7643	8.229	11.8124	10.0471	9.4094
% Young directors	3.42%	7.78%	0.00%	0.00%	0.00%	4.77%	2.69%	3.04%	2.44%	4.08%	1.82%	2.44%	3.14%
% independent director	73.12%	15.91%	63.64%	76.92%	85.71%	67.78%	73.35%	74.69%	79.38%	69.95%	75.21%	76.80%	76.15%
% former employee	3.84%	7.13%	0.00%	0.00%	8.33%	4.72%	4.15%	3.51%	2.56%	4.37%	3.40%	3.46%	3.11%
% financial expertise	29.64%	20.98%	12.50%	25.00%	40.00%	34.53%	28.90%	27.27%	25.22%	32.06%	25.93%	26.72%	27.67%
Firm Characteristics													
Firm Age	27.78	16.76	14.00	23.00	41.00	21.58	31.00	28.43	33.50	24.05	37.62	31.87	30.83
Firm Size	7.5893	1.5414	6.4689	7.4333	8.562	6.7911	7.9283	7.7983	8.2776	7.0663	8.6907	8.1231	8.0825
Ln(MtB)	7.7081	1.6121	6.584	7.5265	8.698	6.982	7.9194	7.9191	8.4024	7.1917	8.6673	8.1744	8.2694
Tangibility	0.2558	0.2112	0.0946	0.1928	0.3534	0.252	0.271	0.2614	0.2426	0.263	0.3406	0.2428	0.2436
Ln (1+ Sale)	7.5265	1.5501	6.439	7.422	8.509	6.665	7.9065	7.7361	8.2709	7.0039	8.765	8.0731	7.9907
Ln (1+Leverage)	0.4283	0.479	0.0731	0.3429	0.5972	0.3187	0.4685	0.4506	0.5341	0.3675	0.5917	0.4885	0.4834
Cash holdings	0.1556	0.1617	0.0334	0.0974	0.2264	0.1914	0.116	0.1544	0.1392	0.1603	0.0793	0.135	0.1742
Ln (1+Dividend)	2.3122	2.3734	0	2.1128	4.0897	1.2877	2.6474	2.524	3.3369	1.6383	4.0265	2.9056	3.0084
Financial distress	1.4424	0.66	1.0367	1.3584	1.7664	1.5823	1.3223	1.4212	1.3629	1.4828	1.2724	1.3567	1.4581
Tobin Q	2.0864	1.4615	1.25	1.66	2.39	2.1635	1.9192	2.1316	2.0814	2.0878	1.9679	2.0125	2.1698
R&D intensity	3.16%	5.29%	0.00%	0.51%	4.45%	4.06%	2.44%	3.07%	2.57%	3.11%	1.52%	2.71%	3.90%
Ln (1 + CAPEX)	4.2591	1.7522	3.035	4.1189	5.34	3.513	4.5779	4.4582	4.8971	3.7944	4.4619	4.7189	4.6867
Dependent variable													
Stock return Volatility	10.60%	5.73%	6.98%	9.50%	12.81%	12.37%	9.89%	10.02%	9.14%	11.44%	8.57%	9.60%	9.98%
ROA	4.98%	12.32%	2.44%	5.74%	9.48%	4.13%	5.12%	5.52%	5.61%	4.61%	6.48%	5.24%	5.35%
Ln (1 + N. Patent)	2.5861	1.5742	1.3863	2.3026	3.5553	26.0682	65.9202	97.2648	127.4791	35.3001	80.406	77.6561	112.8145
Ln (1 + N. Citation)	3.9154	2.25	2.1972	3.8712	5.5134	3.6883	4.0606	4.1664	3.9394	3.6088	4.667	4.1773	4.1804
Observation	15719					5429	3293	3335	3662	8016	405	3632	3666
% of full sample	100%					34.50%	20.94%	21.22%	23.30%	51.00%	2.58%	23.11%	23.32%

Notes: This table reports summary statistics for the full sample and sub-samples by the share of female and non-white directors on board. The full sample comprises 15,719 observations (firm-year) from 1400 firms between 1996–2017. We control for geography effects when grouping firms into the four categories based on the percentage share of non-traditional directors. We split the median values of the share of non-traditional directors (for each region) into quartiles and group the firms by category. Once a firm-year is assigned to a category, it is given a score (median values less than Q1 = 1, between Q1 and less than Q2 = 2, between Q2 and less than Q3 = 3 and equal to Q3 and above = 4). We tally the scores for each firm-year and split all observations into quartiles again. Firms are finally categorized into a classification based on the cut-off values of the quartiles. Director characteristics are retrieved from the Institutional Shareholder Services (ISS) database which is available from WRDS. The main outcomes and control variables include accounting data from COMPUSTAT, stock return data from Center for Research in Security Prices, patent data from the Kogan et al.'s (2017) database of innovation. All variables are defined in Table 2.A.1

Table 2–2: Which firms are more likely appoint non-traditional directors?

Dependent Variables	Fixed effects logistic regressions		Fixed - effects panel regression
	Female director Appointment	Non − white director Appointment	Demographic diversity
	(1)	(2)	(3)
Board size	0.743***	0.397***	0.00505**
	(17.78)	(14.93)	(2.83)
Firm age	2.260***	-0.795**	-0.0196
	(5.40)	(-3.11)	(-1.01)
% independent directors	2.061***	0.364	0.106***
	(4.60)	(1.01)	(4.44)
% former directors	0.215	0.340	0.0229
	(0.30)	(0.58)	(0.65)
% financial expertise	-0.778+	0.0962	-0.0221
	(-1.95)	(0.34)	(-1.07)
Firm Size	-0.138	0.165	0.0174+
	(-0.56)	(1.05)	(1.73)
Sale	5.042**	1.251	0.0319
	(3.27)	(1.33)	(0.56)
Market - to -Book ratio	0.124	0.122	-0.00532
	(1.02)	(1.26)	(-0.99)
ROA	-0.339	-0.361	-0.0106
	(-0.61)	(-0.88)	(-0.54)
Total Volatility	-0.843	0.00843	-0.0193
	(-0.78)	(0.01)	(-0.39)
Altman's Z-score	-0.0267	-0.0354	0.00581
	(-0.17)	(-0.27)	(0.92)
Leverage	0.206	-0.0828	0.00669
	(1.27)	(-0.74)	(1.18)
Tangibility	2.283*	1.327*	0.0433
	(2.47)	(2.03)	(1.01)
CAPEX	-0.206*	-0.0315	-0.00385
	(-2.33)	(-0.49)	(-1.16)
Cash holdings / Total Assets	0.845	0.499	0.0139
	(1.51)	(1.20)	(0.59)
Dividend	0.0253	-0.0776*	0.00268
	(0.51)	(-2.54)	(1.37)
R&D / Total Assets	6.752**	-3.378+	-0.112
	(2.76)	(-1.94)	(-1.24)
Intercept			-0.0399
			(-0.45)
Fixed effects	Yes	Yes	Yes
Std. Error clustered by firms	Yes	Yes	Yes
N	7589	7969	15652
R squared			0.254
Chi squared	2586.5	1059.8	

Notes: This table reports fixed-effect logistics regression with dependent variables are dummies variables taking value as 1 when non-traditional directors are appointed in the boardroom and zero otherwise. For example, column 1 reports result with female appointment as dependent variables, while column 2 reports result with non-white director appointment. Column 3 reports the fixed-effect panel regression with Diversity Index Value as dependent variable. All variable descriptions are in Table 2.A.1. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 2–3: Non-linear relationship between firm outputs and racial – gender diversity

Dependent variable	Stock return volatility	ROA	Patents	Citations
	(1)	(2)	(3)	(4)
Diversity	-0.0168+	-0.0205+	0.357*	0.356+
	(-2.44)	(-1.94)	(2.08)	(1.85)
$Diversity^2$	0.0248**	0.0345**	-0.813*	-0.614*
	(4.02)	(2.99)	(-2.34)	(-2.14)
Boardsize	-0.00123*	0.000116	-0.00367	-0.00965
	(-3.19)	(0.18)	(-0.29)	(-0.75)
Firm age	-0.00498**	-0.00507	0.968***	0.639***
	(-4.53)	(-0.73)	(6.02)	(3.75)
% Young directors	0.0421**	0.0135	0.0412	-0.0679
	(4.45)	(1.06)	(0.24)	(-0.29)
% Independent directors	0.00769*	-0.000764	0.505***	0.287
	(2.49)	(-0.09)	(3.42)	(1.58)
% Former directors	0.00438	-0.0305+	-0.0381	-0.320
	(1.29)	(-1.95)	(-0.17)	(-1.19)
% Financial experts	0.0124+	0.00820	-0.221+	-0.201
	(2.44)	(1.20)	(-1.68)	(-1.34)
Firm size	0.0124***	-0.0709***	0.137+	0.336***
	(6.61)	(-12.06)	(1.84)	(4.28)
Sale	-0.0299**	0.492***	0.0527	0.197
	(-4.64)	(12.11)	(0.14)	(0.38)
Market-to-book ratio	-0.0158***	0.0296***	-0.00572	-0.0442
	(-6.22)	(8.43)	(-0.13)	(-1.01)
Tobin_Q	0.00585***	-0.00631***	0.0346*	0.0279
	(19.18)	(-3.59)	(2.53)	(1.25)
Altman's Z-score	-0.0129***	0.0726***	-0.0360	-0.0751
	(-7.74)	(10.18)	(-0.78)	(-1.41)
Leverage	-0.000431	0.00316	-0.0318	-0.00778
	(-0.54)	(0.90)	(-0.65)	(-0.15)
Tangibility	0.00223	-0.0746***	0.833**	1.304***
	(0.24)	(-4.38)	(2.67)	(3.73)
CAPEX	0.00309**	-0.000343	0.00496	-0.00774
	(4.12)	(-0.21)	(0.21)	(-0.33)
Cash holding	0.0564***	-0.00853	0.220	0.382+
	(10.35)	(-0.56)	(1.28)	(1.86)
Cash Dividend	-0.00415**	0.000661	-0.0643**	0.0108
	(-4.22)	(0.84)	(-3.10)	(0.60)
R&D intensity	0.0943***	-0.774***	2.093**	0.541
	(17.00)	(-11.47)	(2.69)	(0.73)
Intercept	0.114***	-0.639***	-2.896***	-1.861*
	(6.62)	(-11.54)	(-4.03)	(-2.15)
Firm-year Fixed effects	Y	Y	Y	Y
Std. Err clustered by industry	Y	Y	Y	Y
N	15642	15642	15642	15642
adj. R-sq	0.472	0.302	0.327	0.110

Notes: This table reports polynomial panel regression with fixed effects. The model is simply a panel linear regression model with k order/degree polynomial[15]. *DIVERSITY* is the composite index of gender and race diversity measures, which are calculated by Blau's formula $(1 - \sum P_i^2)$, where P_i is the proportion of board members in each of i number of categories. We recruit total stock return volatility in the last 24 months as our first dependent variable, employing CAPM market model to define the excess returns. Then, we use return over assets as the second dependent variable and log normalized patent/citation count as third/fourth dependent variable. We control for industry, geography and time effects with standard errors clustered by firms. All variable descriptions are in Table 2.A.1. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 2–4: Interactions between board diversity and regulatory interventions

	Stock return volatility (1)	ROA (2)	Stock return volatility (3)	ROA (4)	Patents (5)	Citations (6)	Patents (7)	Citations (8)
Diversity	-0.0309*	-0.0559**	-0.0222*	-0.0341**	0.774*	0.609	0.682*	0.550
	(-3.11)	(-3.25)	(-3.09)	(-2.60)	(2.91)	(1.14)	(3.42)	(1.90)
$Diversity^2$	0.0578**	0.0798*	0.0302*	0.0517**	-0.308	-1.743+	-0.140	-1.144+
	(4.82)	(2.47)	(3.51)	(2.62)	(-1.00)	(-2.21)	(-0.32)	(-2.04)
postSOX	0.0776***	-0.0374***			-1.731*	-2.887*		
	(11.49)	(-4.30)			(-3.55)	(-3.62)		
Diversity post SOX	0.0174+	0.0494**			-0.764*	-0.252		
	(2.09)	(3.18)			(-2.86)	(-0.65)		
$Diversity^2$ post SOX	-0.0385*	-0.0625*			-0.103	0.819		
	(-3.46)	(-1.98)			(-0.23)	(0.95)		
postDFR			0.0769***	-0.0352***			-1.503*	-2.812*
			(10.37)	(-3.87)			(-3.45)	(-3.36)
Diversity post DFR			0.0135	0.0366**			-1.352*	-0.404
			(1.75)	(2.59)			(-2.99)	(-1.03)
$Diversity^2$ post DFR			-0.0139	-0.0446*			0.0757	0.385
			(-1.30)	(-2.04)			(0.21)	(0.75)
Intercept	0.116***	-0.647***	0.115***	-0.646***	-1.772**	-3.156**	-1.750**	-3.174**
	(6.71)	(-11.60)	(6.60)	(-11.57)	(-4.08)	(-5.69)	(-4.16)	(-5.72)
Firm-year Fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Std. Err clustered by industry	Y	Y	Y	Y	Y	Y	Y	Y
N	15642	15642	15642	15642	15642	15642	15642	15642
adj. R-sq	0.472	0.303	0.472	0.302	0.432	0.514	0.439	0.514

Notes: This table reports polynomial regressions using factor variables to capture regulatory interventions, controlled for fixed effects with standard errors clustered by firms. All variable descriptions are in Table 2.A.1. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by +, *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively. Full results will be provided when required.

Table 2–5: Sub-sample regressions

Dependent variable	Small				Medium				Large			
	Stock return vol	ROA	Patents	Citations	Stock return vol	ROA	Patents	Citations	Stock return vol	ROA	Patents	Citations
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
						Panel A: Sarbanes − Oxley Act (2003)						
Diversity	-0.0557*	-0.0371	0.647**	1.390+	-0.0296+	-0.0692**	-0.953+	-1.556+	-0.0160	-0.0176	1.627+	1.599
	(-3.14)	(-0.97)	(4.53)	(2.30)	(-2.18)	(-2.76)	(-2.27)	(-2.31)	(-1.75)	(-0.38)	(2.19)	(1.60)
$Diversity^2$	0.120	0.0133	-1.678**	-4.207*	0.0687+	0.122*	0.924	0.589	0.00753	0.0202	-1.289+	-3.239*
	(1.70)	(0.14)	(-5.36)	(-3.39)	(2.09)	(2.35)	(1.55)	(0.66)	(0.22)	(0.33)	(-2.04)	(-3.36)
postSOX	0.0922***	-0.0551**	-0.854*	-2.052*	0.0694***	-0.0443**	-1.647*	-2.977*	0.0586**	-0.0284*	-2.719**	-3.811**
	(9.91)	(-2.83)	(-2.56)	(-2.88)	(10.11)	(-2.96)	(-3.39)	(-3.36)	(5.82)	(-2.35)	(-5.13)	(-4.64)
Diversity post SOX	0.0294*	0.0307	-0.513*	-0.790+	0.0306+	0.0485*	1.194*	2.275*	0.0209+	-0.00382	-1.611+	-0.748
	(3.29)	(0.85)	(-2.84)	(-2.09)	(2.85)	(2.00)	(3.38)	(3.05)	(2.06)	(-0.08)	(-1.96)	(-0.66)
$Diversity^2$ post SOX	-0.0810	-0.0299	1.065*	2.595+	-0.0701	-0.0988+	-1.552+	-2.707+	-0.00640	-0.0111	1.237	2.452+
	(-1.49)	(-0.30)	(3.68)	(2.23)	(-1.77)	(-1.92)	(-2.01)	(-2.04)	(-0.16)	(-0.18)	(1.34)	(2.43)
Intercept	0.111**	-0.656***	-0.291	0.274	0.158***	-0.725***	1.093	1.702	0.0823+	-1.067***	-3.543*	-6.064*
	(4.82)	(-7.36)	(-0.89)	(0.88)	(12.77)	(-7.08)	(1.79)	(1.21)	(2.23)	(-5.10)	(-3.35)	(-3.53)
N	5215	5215	5215	5215	5223	5223	5223	5223	5204	5204	5204	5204
adj. R-sq	0.424	0.306	0.339	0.339	0.448	0.249	0.396	0.476	0.492	0.325	0.550	0.628
						Panel B: Dodd − Frank Act (2010)						
Diversity	-0.0473*	-0.0259	0.468*	1.109	-0.0100	-0.0404*	0.0857	0.154	-0.00530	-0.0268	1.284+	1.015
	(-3.01)	(-0.83)	(2.53)	(1.93)	(-1.41)	(-2.13)	(0.43)	(0.50)	(-0.59)	(-1.25)	(2.07)	(1.55)
$Diversity^2$	0.0936+	0.0164	-1.514**	-3.680**	0.0178	0.0401	-0.736*	-1.915*	-0.000277	0.0247	-0.536	-0.889
	(2.08)	(0.25)	(-4.43)	(-3.92)	(1.91)	(1.05)	(-2.69)	(-2.77)	(-0.02)	(1.01)	(-0.64)	(-0.71)
postDFR	0.0909***	-0.0538**	-0.873*	-2.103*	0.0714***	-0.0453**	-1.436*	-2.672*	0.0595**	-0.0334*	-2.439***	-3.751**
	(8.74)	(-2.69)	(-2.51)	(-2.77)	(9.53)	(-2.89)	(-3.02)	(-3.05)	(5.80)	(-2.40)	(-6.46)	(-5.19)
Diversity post DFR	0.0334*	0.0275	-0.431	-0.594	0.0120+	0.0298	-0.154	0.275	0.0147	0.0126	-2.136*	-0.349
	(2.65)	(0.72)	(-1.70)	(-0.96)	(1.98)	(1.27)	(-0.64)	(0.68)	(1.79)	(0.60)	(-2.65)	(-0.45)
$Diversity^2$ post DFR	-0.0786+	-0.0563	1.258*	2.735+	-0.0181	-0.0153	0.662+	0.410	0.00125	-0.0255	0.980	0.0996
	(-1.99)	(-0.72)	(2.47)	(2.31)	(-1.08)	(-0.31)	(2.44)	(0.98)	(0.06)	(-0.99)	(1.33)	(0.07)
Intercept	0.110**	-0.656***	-0.254	0.331	0.155***	-0.730***	0.966	1.429	0.0790+	-1.068***	-3.487*	-6.135*
	(4.68)	(-7.38)	(-0.85)	(1.04)	(11.88)	(-7.13)	(1.55)	(1.04)	(2.12)	(-5.11)	(-3.22)	(-3.30)
N	5215	5215	5215	5215	5223	5223	5223	5223	5204	5204	5204	5204
adj. R-sq	0.424	0.305	0.339	0.340	0.448	0.249	0.394	0.474	0.493	0.325	0.555	0.628
Other controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm-year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
S.E clustered	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: This table reports sub-sample regressions corresponding to firm sizes. The dependent variable Risk is characterized as total volatility in the last 24 months. To deal with truncation issues in the patent database, we log − normalize the number of patent and patent citations for each firm-year observations, as Ln $(1 + Numbers\ of\ Patents)$ and Ln $(1 + Numbers\ of\ Citations)$. Further, we take into account the 2-year gap since firms apply for patent registration to the point they receive that patent by using 2-year leaded log − normalized patent counts. Our last dependent variable is log − normalized patent citations. Diversity is the composite index, calculated from Blau's formula and used to measure the level of heterogeneity in boardroom. All variable descriptions are in Table 2.A.1. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by +, *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively. Full results will be provided when required.

Table 2–6: Instrumental variable approach: 3SLS tests

Dependent variable	Stock return volatility	ROA	Patents	Citations
	(1)	(2)	(3)	(4)
Main stage				
Diversity	-0.0576***	-0.0592***	0.367**	0.880**
	(-6.38)	(-3.30)	(2.58)	(3.29)
$Diversity^2$	0.0584***	0.0789**	-0.438+	-1.074*
	(4.08)	(2.77)	(-1.94)	(-2.53)
postSOX	0.141***	-0.0325***	-0.0943*	-1.202***
	(46.46)	(-5.39)	(-1.98)	(-13.37)
Diversity post SOX	0.0234*	0.0461*	-0.107	0.0950
	(2.26)	(2.25)	(-0.66)	(0.31)
$Diversity^2$ post SOX	-0.0456**	-0.0414	0.243	0.232
	(-2.83)	(-1.30)	(0.96)	(0.49)
postDFR	-0.0449***	-0.0130**	-0.127**	-1.208***
	(-18.38)	(-2.69)	(-3.28)	(-16.67)
Diversity post DFR	0.0215*	0.0352*	0.369**	-0.00565
	(2.47)	(2.04)	(2.69)	(-0.02)
$Diversity^2$ post DFR	-0.0233*	-0.0348	-0.136	0.0460
	(-1.98)	(-1.49)	(-0.73)	(0.13)
Intercept	0.259***	-0.664***	-2.776***	-3.247***
	(15.36)	(-19.78)	(-10.43)	(-6.48)
First stage				
Avg_diversity_state_industry	0.932***	0.995***	0.983***	1.002***
	(50.27)	(53.58)	(54.01)	(54.69)
GDP	0.215***	0.0232	-0.0178	-0.0105
	(6.05)	(0.66)	(-0.52)	(-0.30)
Female labour	0.168	-0.0142	-0.0567	-0.0603
	(1.47)	(-0.12)	(-0.50)	(-0.53)
Professional female labour	0.000356	0.0208	-0.0879	-0.0666
	(0.00)	(0.19)	(-0.81)	(-0.61)
Wage	-0.198***	-0.0213	0.0172	0.0107
	(-6.02)	(-0.66)	(0.54)	(0.34)
Ln(E+1)	-0.0134	-0.000440	-0.00214	-0.00135
	(-1.31)	(-0.04)	(-0.21)	(-0.13)
postSOX	-0.0180***	-0.000818	0.00351	0.00622
	(-3.45)	(-0.16)	(0.69)	(1.21)
postDFR	-0.0158***	-0.00198	-0.000460	0.00856*
	(-3.64)	(-0.46)	(-0.11)	(1.99)
Stock return volatility	-0.935***			
	(-24.74)			
ROA		0.187***		
		(8.22)		
Patents			0.0252***	
			(27.23)	
Citations				0.0140***
				(22.74)
Intercept	1.068***	0.0992	-0.0458	-0.0382
	(5.60)	(0.53)	(-0.25)	(-0.21)
N	15642	15642	15642	15642
R-sq	0.662	0.555	0.919	0.883

Notes: This table reports 3SLS regression estimates obtained when the board diversity is instrumented with geographical economic-based variable. The dependent variable are the annualized standard deviation of the firm's daily stock returns, ROA, log normalized patents and citations counts. All variable descriptions are in Table 2.A.1. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively. Full results will be provided when required.

Table 2–7: Difference in difference estimation for the effect of board diversity

Dependent variable	Stock return volatility	ROA	Patents	Citations
	(1)	(2)	(3)	(4)
Treated*post_SOX	-0.00738+	0.0166**	-0.392***	-0.593**
	(-1.93)	(2.97)	(-3.44)	(-2.90)
Boardsize	-0.00136***	-0.00000940	-0.00134	-0.00941
	(-3.52)	(-0.01)	(-0.11)	(-0.48)
Firm age	-0.0172***	-0.00493	0.966***	1.071***
	(-3.55)	(-0.71)	(6.14)	(4.17)
% Young directors	0.0323***	0.0141	0.0234	-0.131
	(3.38)	(1.11)	(0.14)	(-0.41)
% Independent directors	-0.00197	0.000469	0.463**	0.992***
	(-0.36)	(0.05)	(3.15)	(3.81)
% Former directors	0.00247	-0.0320*	-0.00502	0.403
	(0.29)	(-2.03)	(-0.02)	(1.09)
% Financial experts	0.00782	0.00867	-0.229+	-0.439+
	(1.60)	(1.28)	(-1.75)	(-1.88)
Firm size	0.00906**	-0.0709***	0.133+	0.294*
	(2.98)	(-12.08)	(1.80)	(2.38)
Sale	-0.0784***	0.492***	0.0506	-0.782
	(-4.75)	(12.11)	(0.13)	(-1.21)
Market-to-book ratio	-0.0123***	0.0297***	-0.00834	-0.0130
	(-5.95)	(8.48)	(-0.20)	(-0.18)
Tobin_Q	0.00449***	-0.00623***	0.0327*	0.102***
	(5.17)	(-3.58)	(2.45)	(4.28)
Altman's Z-score	-0.00509*	0.0726***	-0.0379	-0.0308
	(-2.17)	(10.22)	(-0.83)	(-0.40)
Leverage	0.00759***	0.00314	-0.0320	-0.0292
	(4.76)	(0.90)	(-0.66)	(-0.39)
Tangibility	0.0381***	-0.0746***	0.828**	1.778***
	(3.41)	(-4.36)	(2.69)	(3.53)
CAPEX	-0.00230*	-0.000378	0.00629	0.0220
	(-2.28)	(-0.23)	(0.28)	(0.58)
Cash holding	0.0139*	-0.00877	0.224	0.497+
	(1.97)	(-0.58)	(1.30)	(1.68)
Cash Dividend	-0.00323***	0.000718	-0.0659**	-0.0790*
	(-5.82)	(0.90)	(-3.16)	(-2.42)
R&D intensity	-0.0640*	-0.775***	2.121**	3.266**
	(-2.23)	(-11.47)	(2.72)	(2.65)
Intercept	0.257***	-0.647***	-2.692***	-1.689
	(10.16)	(-11.52)	(-3.83)	(-1.47)
Firm-year Fixed effects	Y	Y	Y	Y
Std. Err clustered by industry	Y	Y	Y	Y
N	15642	15642	15642	15642
adj. R-sq	0.429	0.302	0.329	0.367

Notes: This table reports the difference-in-difference estimate of the effect of board diversity on firm outcomes. The sample period is 1996-2017. Innovation is measured by the number of patents that are granted to the firm (Patents) and the total number of citations received on the firm's patents (Citations), all these measures have been adjusted for time effects; Treated is a dummy variable which equals one if a firm have a relatively high-diversified board compositions before 2002, i.e DIV (diversity index value) higher than preSOX sample median, zero otherwise; PostSOX is an indicator for years after 2002; All variable descriptions are in Table 2.A.1. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 2–8: Propensity Score matching

Panel A: Mean differences between treatment and control group before matching			
	Treatment	Control	Difference (p-value)
% Share of Female directors	0.1446	0.0610	0.000
% Share of non-white directors	0.1746	0.0373	0.000
Boardsize	10.208	8.6708	0.000
% independent directors	0.6659	0.5912	0.000
Firm Size	8.1372	6.9707	0.000
Sale	2.0725	1.9209	0.000
Tobin_Q	2.7217	2.2357	0.000
CAPEX	4.9865	3.9141	0.000
R&D intensity	0.0329	0.0341	0.628
Panel B: Mean differences between treatment and control group of PSM sample (N=6432)			
	Treatment	Control	Difference (p-value)
% Share of Female directors	0.1446	0.1499	0.248
% Share of non-white directors	0.1746	0.1695	0.524
Boardsize	10.208	10.2820	0.645
% independent directors	0.6659	0.6764	0.257
Firm Size	8.1372	8.0136	0.162
Sale	2.0725	2.0705	0.866
Tobin_Q	2.7217	2.7882	0.662
CAPEX	4.9865	4.9680	0.859
R&D intensity	0.0329	0.0345	0.56

Panel C: DID with matched firms	Tot_Vol	ROA	Patents	Citations
Treated*post-SOX	-0.0101*	0.0116+	-0.274*	-0.353
	(-2.54)	(1.86)	(-2.32)	(-1.64)
Board size	-0.00107*	0.00126	-0.0119	-0.0302
	(-2.01)	(1.47)	(-0.59)	(-0.98)
Firm age	-0.0338***	-0.000228	1.095***	1.483***
	(-4.19)	(-0.02)	(4.20)	(3.38)
% independent directors	0.00749	-0.00330	0.613*	1.370**
	(1.02)	(-0.24)	(2.50)	(3.22)
Firm size	0.00421	-0.0709***	0.238+	0.427*
	(0.94)	(-7.57)	(1.87)	(1.99)
Sale	-0.0545*	0.531***	-0.0885	-1.402
	(-2.00)	(7.58)	(-0.12)	(-1.09)
R&D intensity	-0.0685+	-0.760***	3.610**	5.763*
	(-1.96)	(-7.60)	(2.74)	(2.57)
Intercept	0.290***	-0.722***	-4.078**	-3.464
	(6.97)	(-6.88)	(-3.20)	(-1.60)
Firm-year Fixed effects	Y	Y	Y	Y
Std. Err clustered by industry	Y	Y	Y	Y
N	6432	6432	6432	6432
adj. R-sq	0.486	0.312	0.404	0.445

Notes: This table reports summary statistics (Panels A and B) and the results of a difference-in-differences model (Panel C), using a sample matched on propensity scores. We match the treated firms with the control firms using one-to-one nearest neighbor propensity score matching, with replacement. The propensity scores are estimated from a logit model that uses the averages over 1996–2001. Treated is a dummy variable which equals one if a firm have a relatively high-diversified board compositions before 2002, i.e DIV (diversity index value) higher than pre-SOX sample median, zero otherwise; PostSOX is an indicator for years after 2002; All variable descriptions are in Table 2.A.1. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Appendix

2.A   Appendix A

Table 2.A.1: Description of variables used

Feature	Description	Source
	Panel A: Board composition Measurements	
Female share	Percentage of directors who female	ISS
Non-white share	Percentage of directors who are Asian, African American, and Hispanic	ISS
U50 share	Percentage of directors who are above 50 years old	ISS
Ethnicity diversity index	Ethnicity is the index for ethnic diversity. The ethnicity diversity has four categories as identified in the Risk Metrics database: Asian, African American, Hispanic, and White. We use Blau's (1977) index of heterogeneity to measure diversity of board's ethnic diversity. Blau's index is calculated as $(1 - \sum P_i^2)$, where P_i is the proportion of board members in each of i number of categories.	ISS
Gender diversity index	Gender is the index of diversity for gender with two categories: male and female. We use Blau's (1977) index of heterogeneity to measure diversity of board's gender. Blau's index is calculated as $(1 - \sum P_i^2)$, where P_i is the proportion of board members in each of i number of categories.	ISS
Young directors share	Percentage of directors who are under 50 years old	ISS
Financial expertise share	Percentage of directors who have past financial experience in either a banking or investment firm, in a large auditing firm (e.g., Pricewaterhouse, Deloitte, Ernst & Young, KPMG, Arthur Andersen, Coopers, Touche Ross), or in a finance-related role (e.g., accountant, treasurer, VP of finance, CFO)	ISS
Former employee share	Percentage of directors who used to be former employee.	ISS
Independent directors share	Percentage of directors who are independent directors in the current year.	ISS
Diversity or (Total) Diversity Index Value	For each firm-year, this index is computed as Ethnicity_index + Gender _index	ISS
	Panel B: Firm Characteristics	
Board size	Number of directors in a board for a firm in the current year.	Compustat
Firm age	Logarithm of one plus firm age, which is the number of years since the firm's initial public offering (IPO).	Compustat
Firm size	Natural log of book assets.	Compustat
Tangibility	Sum of investments and net Property, Plant, and Equipment (PP&E) divided by book assets.	Compustat
Sale	Nature log of net sales	Compustat
MB	Nature logarithm of Market value of stock divided by Book value per share	Compustat
ROA	Ratio of earnings before interest and taxes over total assets.	Compustat
Patents	Nature logarithm of one plus total number of patent applications in a given year of a firm. Total number of patent applications in a given year is extracted from Kogan et al.'s (2017) patent database.	Compustat
Citations	Nature logarithm of one plus total number of citations in a given firm-year observation.	Compustat
Leverage	Logarithm of one plus the ratio of total long-term debt plus total current liabilities over total assets.	Compustat
CAPEX	Logarithm of one plus Capital Expenditure	Compustat
Cash Holdings	Cash and short-term equivalents divided by book assets.	Compustat
Dividend	Logarithm of one plus total dividend in a current year.	Compustat
R&D	Ratio of research and development expense to book value of assets	Compustat

Table 2.A.1: Description of variables used - continued

Feature	Description	Source
Total Volatility	Total stock return volatility in the last 24 months, which is square root of 24 multiplied by the standard deviation of monthly excess stock returns. Excess return is defined using a CAPM market model estimated over the prior year.	Compustat
Financial distress	Logarithm of one plus Altman Z-score. The Altman Z-score is calculated based on five financial ratios: profitability, leverage, liquidity, solvency and activity to predict whether a company has high probability of being insolvent. A score below 1.8 means it's likely the company is headed for bankruptcy, while companies with scores above 3 are not likely to go bankrupt.	Compustat
Avg_diversity_state_industry	The average diversity index of firms in each state per each industry using Blau's index that we calculate for each firm-year observation	
GDP	The comprehensive measure of the economic growth of each state which estimates the value of the goods and services produced in a state over time. Data is collected from US census bureau	FRED
Female_Labor	The section of working population in the age group of 16-64 in the state currently employed or seeking employment. Data is collected from US census bureau	FRED
Professional_female_labor	The proportion of professional workers among female labor in the state currently employed or seeking employment	FRED & SWUS
E	Entropy index calculated by Lee's t al., 2017 to characterize the racial and ethnic diversity magnitude based on five panethnic populations. The entropy index reaches maximum value when all ethnoracial categories are the same size	Lee's t al., 2017
Wage	Annual wage is calculated by summing all the annual salaries of all persons in work and dividing the total by the number of workers in the state. This measure can help gaining some understanding of the relative worth of a job or workplace compared with others	FRED
Panel C: Other control variables		
Treated (T)	Dummy variable indicating those firms owned a relatively high level of board diversity (RHD) before 2003 than control firms (C)	
Post SOX	Dummy variable that equals 1 since Sarbanes Oxley Act was released	
Post DFR	Dummy variable that equals 1 since Dodd-Frank Act was released	

Table 2.A.2: Distribution statistics

Panel B: Distribution of firms, demographic diversity, firm performance, and innovation activities by industry

Industry	N. of firms	Female share	Non-white share	Independent share	Total Volatility	ROA	R&D	Patents
Constructions (15 − 17)	26	8.94%	6.68%	72.32%	10.68%	3.91%	0.01%	2
Manufacturing (20 − 39)	754	11.16%	8.01%	74.25%	10.44%	5.13%	4.34%	56
Mining (10 − 14)	65	7.34%	4.35%	74.85%	11.86%	1.88%	0.40%	45
Retail trade (52 − 59)	129	15.43%	8.38%	70.01%	10.89%	7.00%	0.11%	3
Services (70 − 87)	274	10.89%	8.12%	72.57%	11.24%	4.20%	4.01%	165
Transportation (40 − 48)	90	11.73%	9.72%	68.59%	9.25%	5.20%	0.18%	27
Wholesale trade (50, 51)	62	11.36%	7.71%	71.61%	9.86%	5.42%	0.05%	2

Panel C: Distribution of firms, demographic diversity, firm performance, and innovation activities by level of patents registered

Level of patent acquired - (Median patent counts)	N. of Obs	Female share	Non-white share	Independent share	Total Volatility	ROA	R&D	Firm Age
1 − 1-(1.42)	1156	7.99%	6.78%	69.19%	12.10%	4.25%	4.15%	23.7
2 − 2-(4.91)	743	6.91%	7.66%	71.11%	11.99%	4.72%	5.73%	25.7
3 − 3-(12.95)	833	8.54%	7.10%	73.16%	11.81%	4.01%	6.10%	28.5
4 − 4-(36.94)	839	10.26%	8.51%	73.15%	11.69%	3.42%	6.04%	31.4
5 − 4-(280.08)	863	13.15%	10.91%	74.88%	10.56%	6.23%	6.71%	36.9

Panel D: Distribution of demographic diversity, stock volatility, firm return, and R&D investment by firm size

Firm Size	N. of Obs	Female share	Non-white share	Independent share	Total volatility	ROA	R&D	Ln(1+Patents)
Small	5258	7.66%	5.71%	68.68%	12.55%	4.05%	4.02%	1.7063
Medium	5240	11.16%	7.26%	73.12%	10.42%	5.04%	2.75%	2.3145
Big	5221	15.17%	10.84%	77.57%	8.82%	5.85%	2.71%	3.5285

Notes: This table presents distributional statistics for a sample of 15,719 firm-year observations from 1996-201. The sample is described by industry in Panel B while Panel C reports different patent-level distribution of firm characteristics and panel D reports the summary statistics by firm size. Director characteristics are retrieved from the Institutional Shareholder Services (ISS) database which is available from WRDS. The main outcomes and control variables include accounting data from COMPUSTAT, stock return data from Center for Research in Security Prices, patent data from the Kogan et al.'s (2017) database of innovation. All variables are defined in Table 2.A.1. DIV means Diversity Index Value

Table 2.A.3: Univariate Regression Model

	Linear Form				Quadractic form				Cubic form			
	ROA	Stock Vol	Patents	Citations	ROA	Stock Vol	Patents	Citations	ROA	Stock Vol	Patents	Citations
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
diversity	0.00575	-0.00451	0.276+	0.257	-0.0292	-0.0283**	0.986***	1.062**	-0.0638	-0.0667***	0.540	-0.141
	(0.38)	(-0.96)	(1.93)	(1.47)	(-0.95)	(-3.05)	(3.58)	(2.77)	(-1.33)	(-4.08)	(1.08)	(-0.21)
$Diversity^2$					0.0499+	0.0340**	-1.067**	-1.211*	0.173	0.170***	0.538	3.125+
					(1.86)	(3.26)	(-3.04)	(-2.43)	(1.58)	(3.90)	(0.37)	(1.68)
$Diversity^3$									-0.106	-0.117***	-1.393	-3.764**
									(-1.31)	(-3.53)	(-1.20)	(-2.58)
Intercept	0.0634***	0.0310***	2.162***	4.838***	0.0667***	0.0333***	2.095***	4.762***	0.0678***	0.0346***	2.109***	4.801***
	(12.92)	(12.03)	(29.56)	(50.02)	(11.82)	(12.16)	(27.71)	(47.00)	(11.52)	(12.33)	(28.20)	(46.84)
Fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Std. Err												
clustered by firms	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	15709	15709	4429	4429	15709	15709	4429	4429	15709	15709	4429	4429
adj. R-sq	0.027	0.373	0.046	0.570	0.027	0.374	0.051	0.571	0.027	0.375	0.052	0.572

t statistics in parentheses

$+ \ p<0.10, \ * \ p<0.05, \ ** \ p<0.01, \ *** \ p<0.001$

Notes: This table reports univariate regression with fixed effects. We control for industry, geography and time effects with standard errors clustered by firms. The dependent variable Risk is characterized as total volatility in the last 24 months. We also recruit returns over asset, discretionary accruals, patents and citations as other dependent variables. To deal with truncation issues in the patent database, we $log - normalize$ the number of patent and patent citations for each firm-year observations, as Ln ($1 + Numbers$ of *Patents*) and Ln ($1 + Numbers$ of *Citations*). Further, we take into account the 2-year gap since firms apply for patent registration to the point they receive that patent by using 2-year leaded $log - normalized$ patent counts. Our last dependent variable is $log - normalized$ patent citations. Diversity is the composite index, calculated from Blau's formula and used to measure the level of heterogeneity in boardroom. Our main independent variables are diversity and polynomial forms of diversity. Diversity is the composite index, calculated from Blau's formula and used to measure the level of heterogeneity in boardroom. All variable descriptions are in Table 2.A.1. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by $+$, $*$, $**$ and $***$ and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

2.B   Appendix B

This part contains visually distribution statistics for the panel dataset including U.S public firms during 1996-2017 period. We retrieved our sample from the ISS databases (former Risk Metrics), comprising 1,400 U.S firms from 1996 to 2017 and covering two important periods of regulatory reforms. We used information gathered from proxy statements and company annual report, synthesized by ISS, to construct our measurements of board diversity. The innovation output data is collected from the Kogan et al.'s (2017) database of patents and citations (henceforth referred to as the KPSS patent data). They download U.S. patent documents from the USPTO and match all patents data to corporations whose return are in the CRSP database from 1926 to 2010. We excluded financial and utility firms in our dataset; and only keep firm-year observations with adequate data for analyses, which means at least three consecutive years' full main variables in the databases. After dropping observations with missing values for the control variables, our final sample consists of an unbalanced panel with 1,400 unique firms and up to 15,719 firm-year observations.
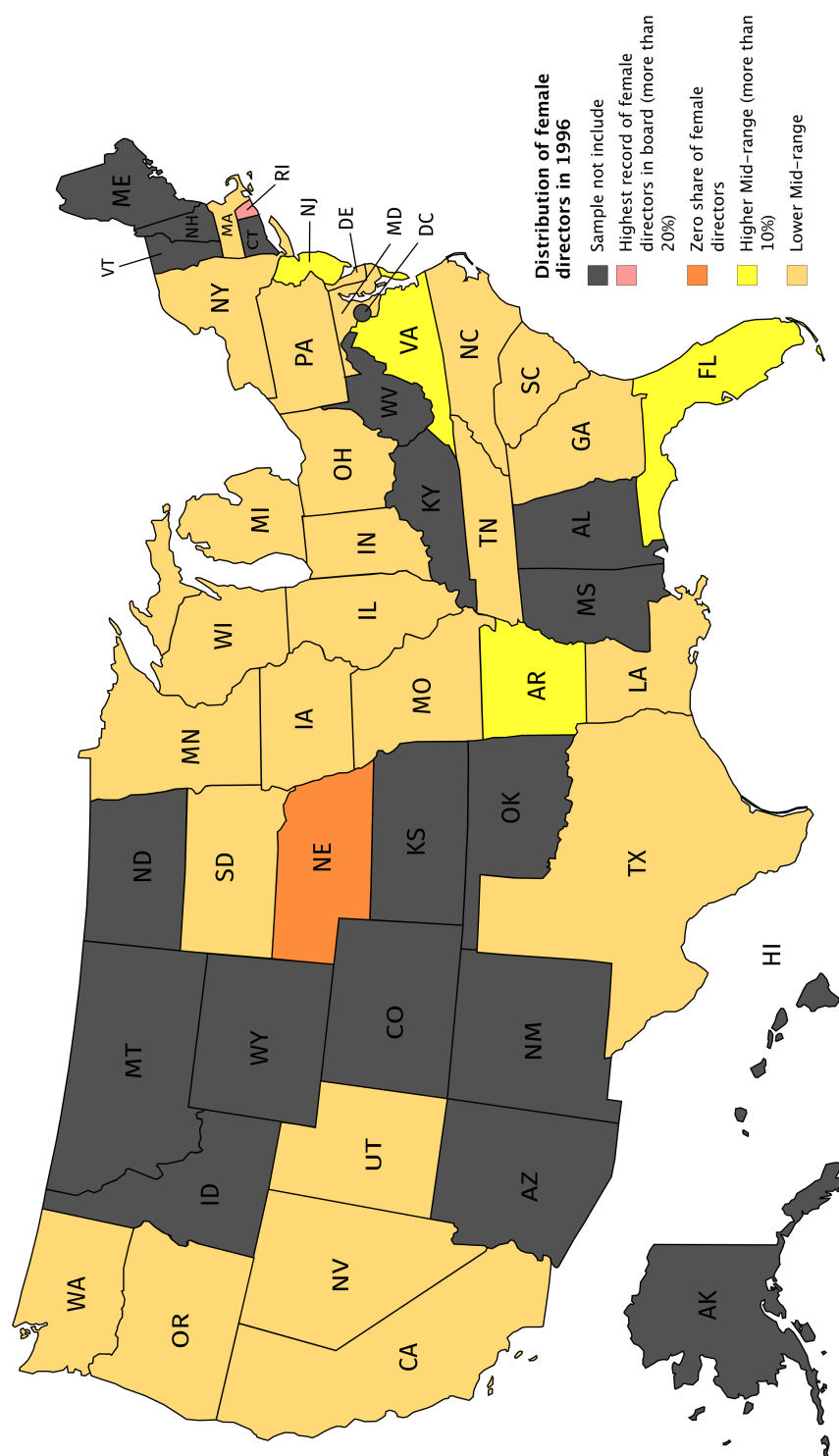
Figure 2.B.1: Distribution of female directors in 1996
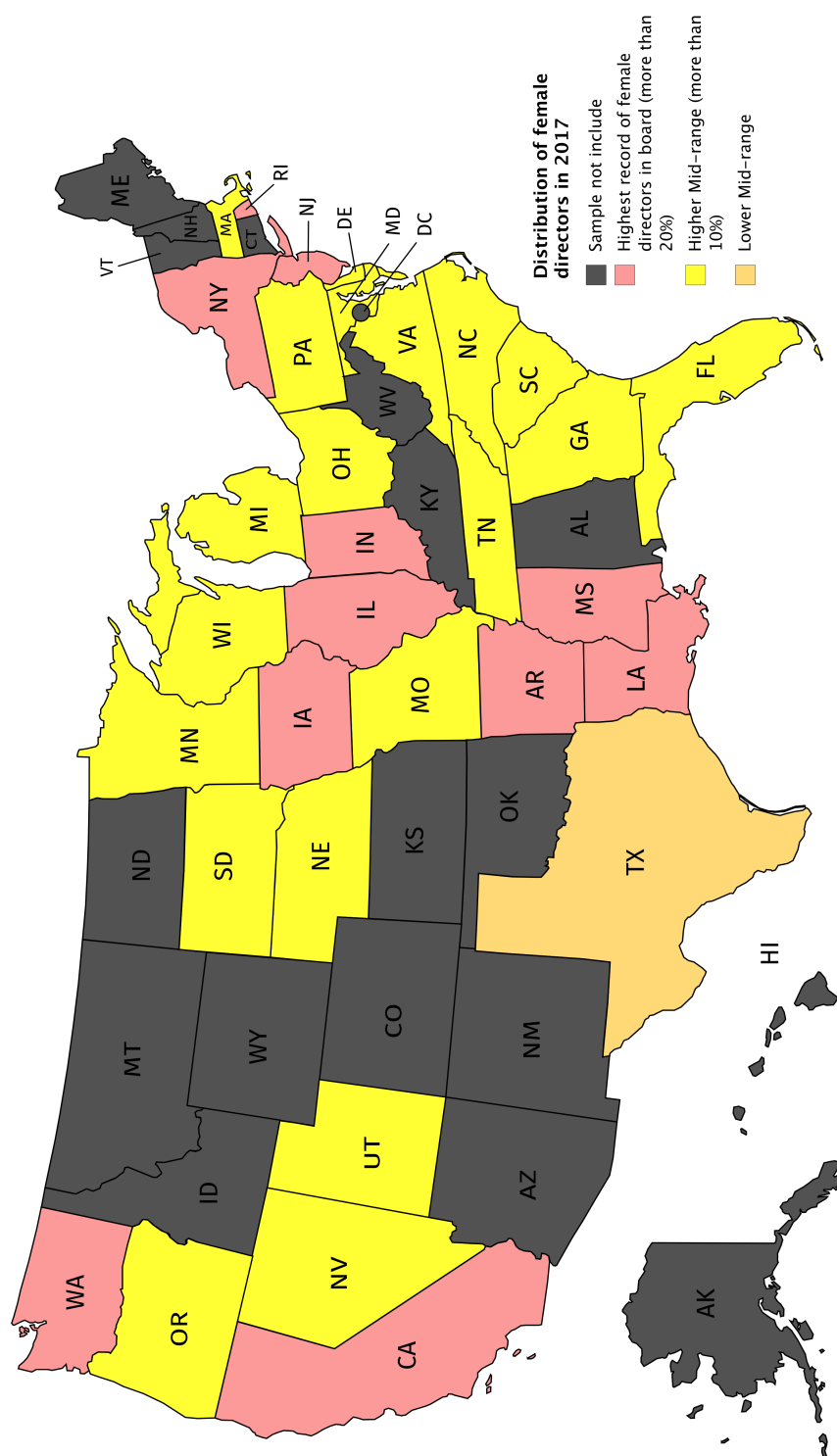
Figure 2.B.2: Distribution of female directors in 2017
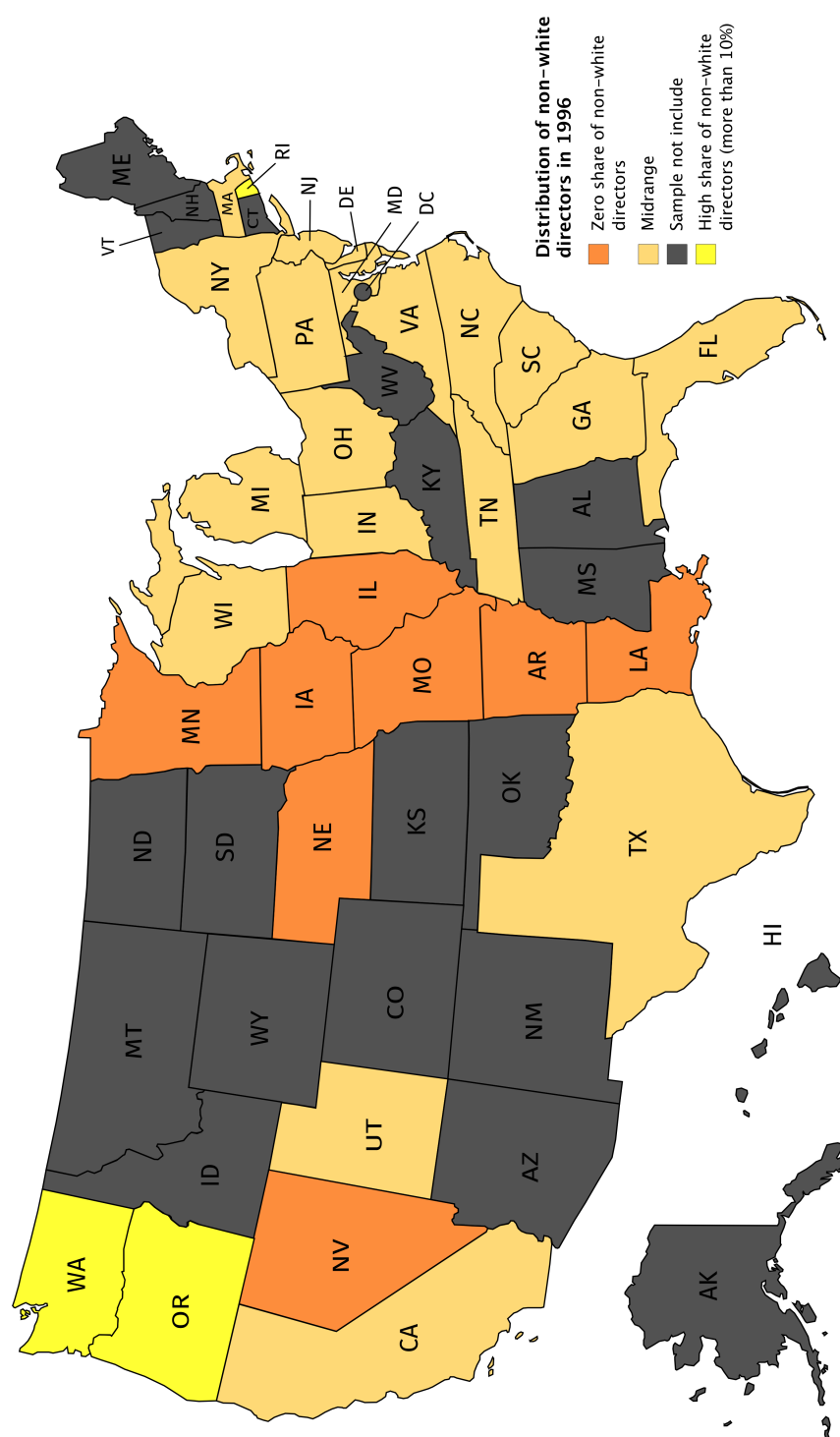
Figure 2.B.3: Distribution of non-white directors in 1996
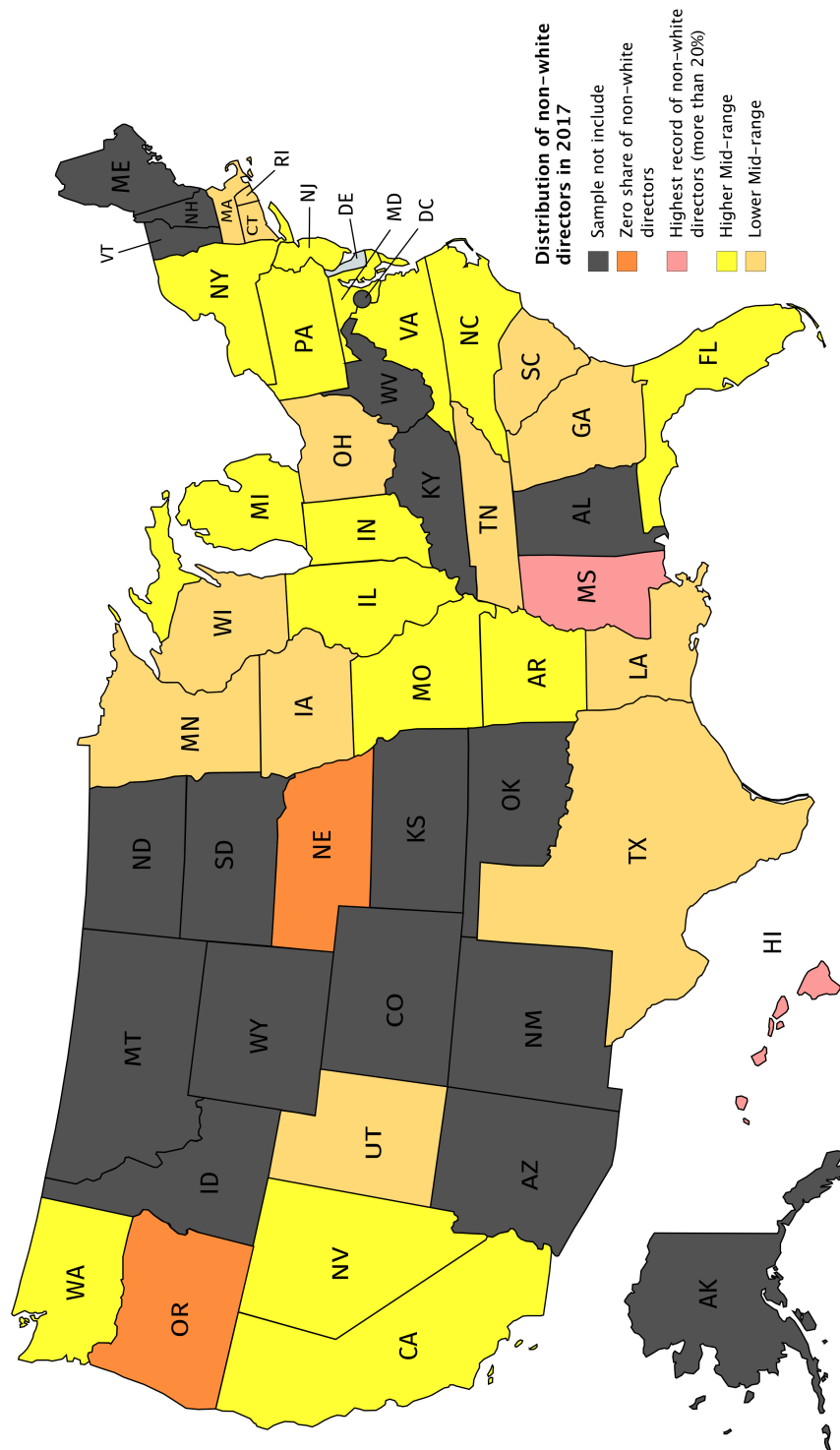
Figure 2.B.4: Distribution of non-white directors in 2017
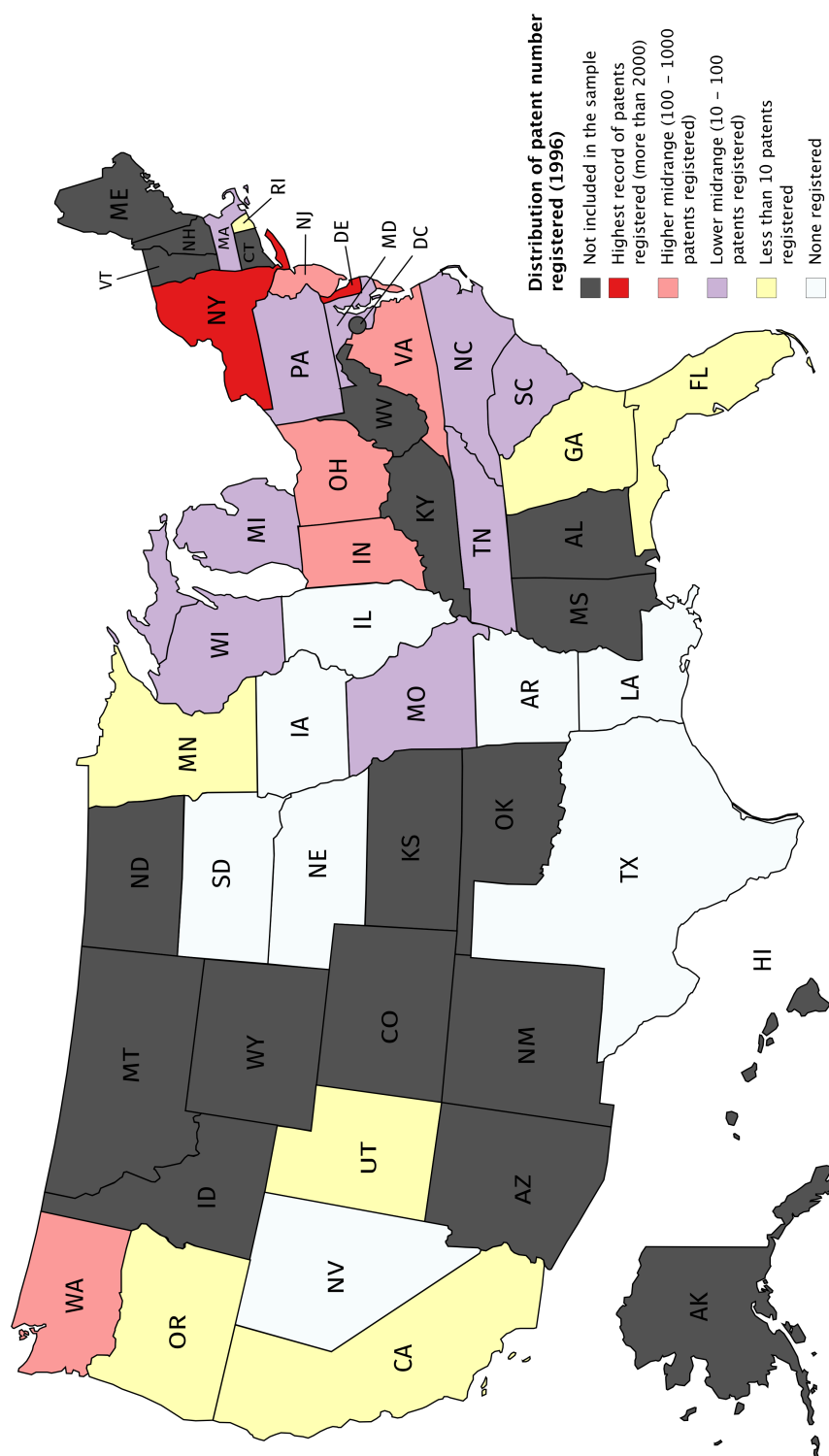
Figure 2.B.5: Distribution of patents registered in 1996
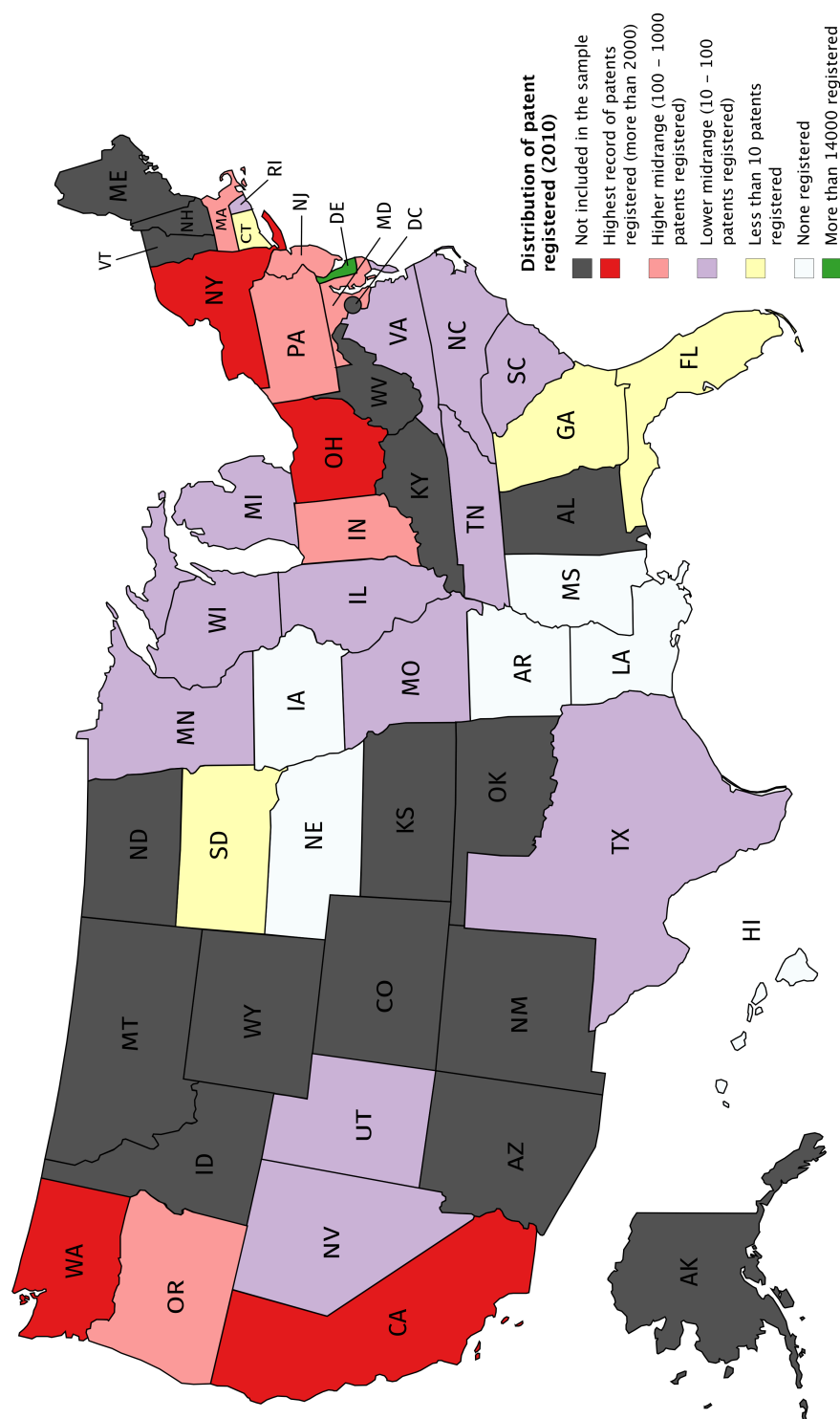
Figure 2.B.6: Distribution of patents registered in 2010
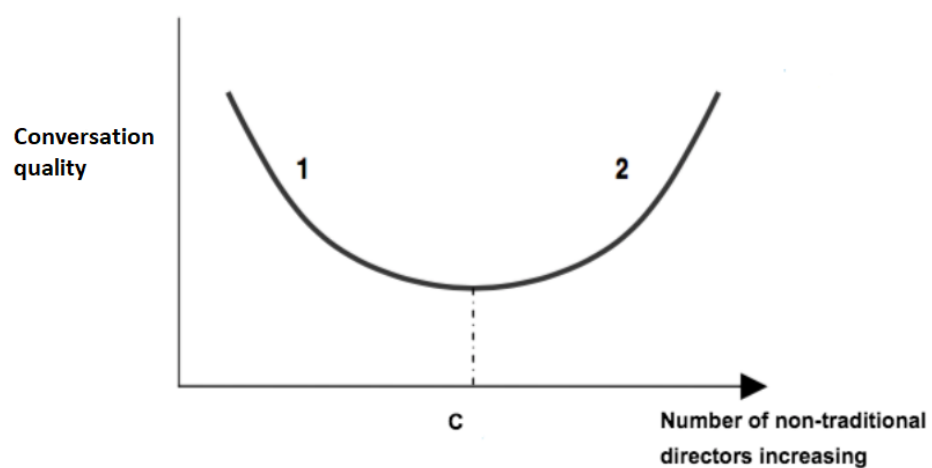
Figure 2.B.7: Blau's theory of heterogeneity
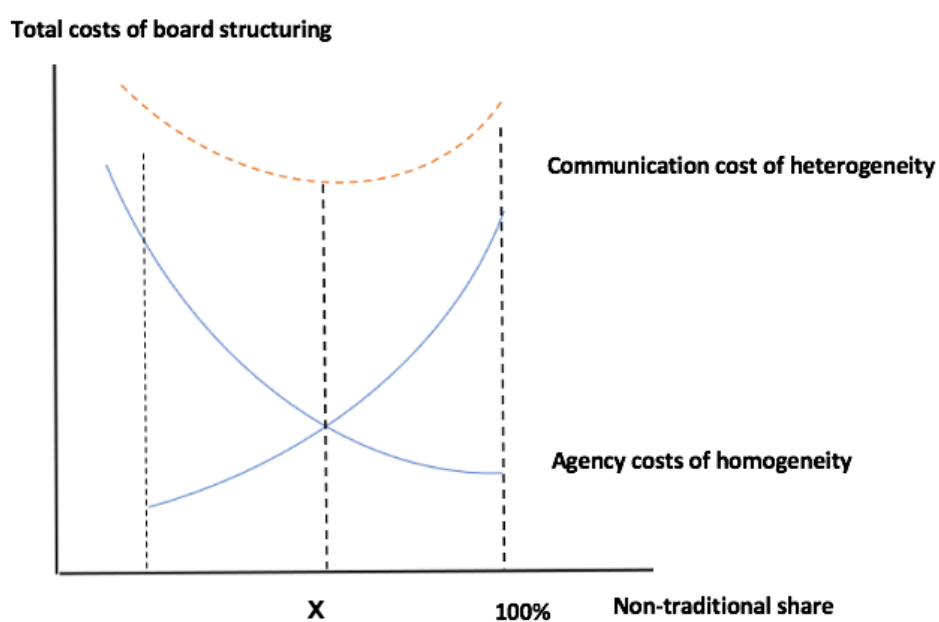
Figure 2.B.8: The optimal model of board diversity (Model 1)
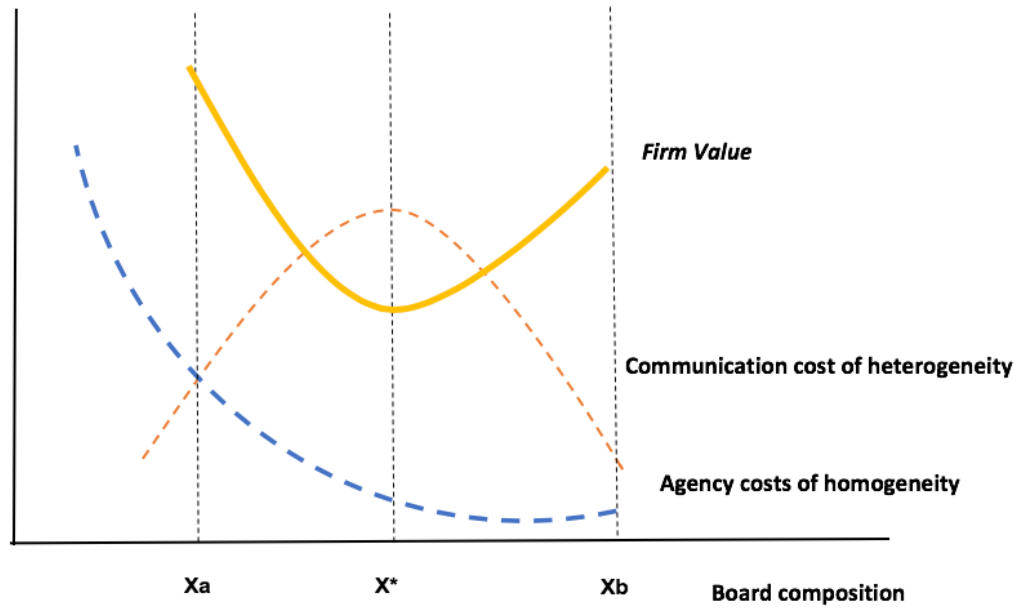
Figure 2.B.9: The alternative model for board diversity and firm value (Model 2)
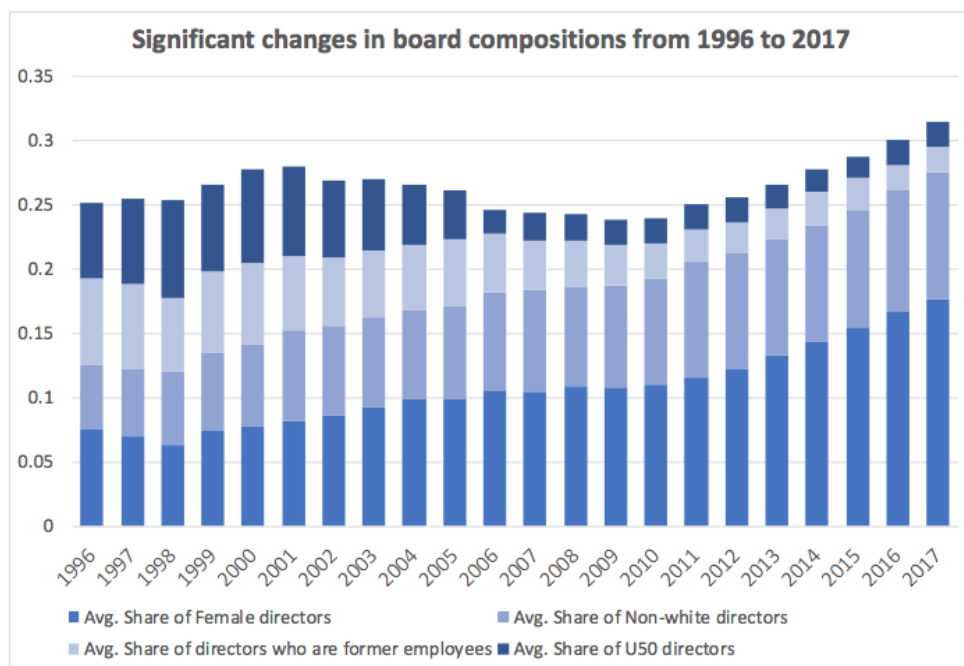
Figure 2.B.10: Board composition statistics whole sample

Diversity Index Value (DIV)
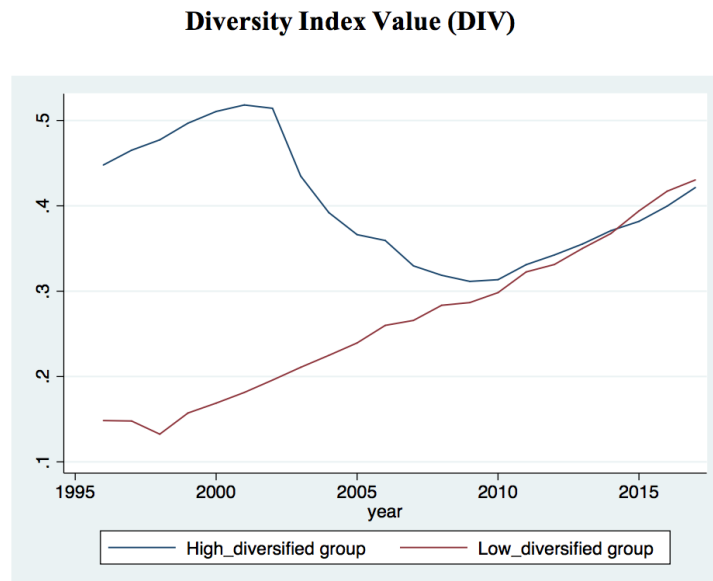
Figure 2.B.11: A sudden reduction in the diversity after 2003
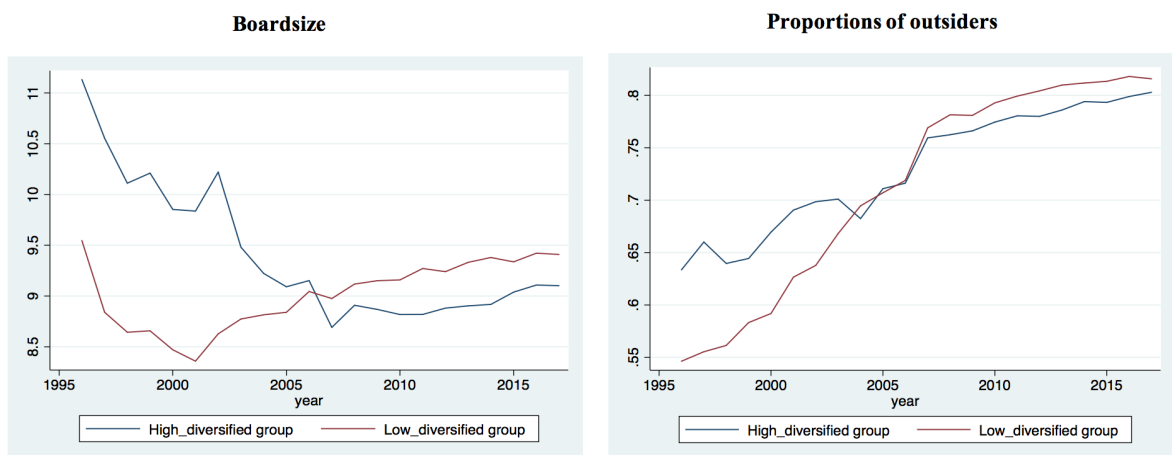
(a) Changes of board size

(b) Changes of independence

Figure 2.B.12: Changes in board structures over time

Chapter 3

Environmental concern, regulations and board diversity

Despite an increasing need for trustworthy ESG data and pressure from worldwide authorities to mandate climate disclosure, the SEC has been sluggish to respond to the demand of investors for a more holistic approach. Our study demonstrates a unique research setting in the context of local state implementation of the RAC. The empirical analysis reveals a positive correlation between RAC and environmental CSR for enterprises with a diverse board of directors, as defined by the Blau index. It indicates that a high-diversified board triggers an improvement in a firm's environmental performance on average in the period following RAC. Additionally, we demonstrate that firms with a less diverse board of directors were more prone to over-invest in environmental CSR during the 2007-2010 financial crisis. In general, this study illustrates the importance of factors other than market forces in determining ESG disclosure, such as local climate policy

JEL Classification: M14; G34; G39

3.1   Introduction

> Companies are "no longer expected to be mere contributors to the global economy, but rather to reconcile the skill-fully balance multiple bottom lines and manage the interests of multiple stakeholders"
>
> *Jamali et al., 2008*
> *pp.443*

Climate risk and environmental concern have become subjects of discussion in recent years, both among practitioners and in the academic literature. Hence, the environmental aspect of CSR is increasingly becoming integrated into CSR and is playing a larger role in the corporate landscape. A growing literature has studied the reason why companies engage in environmental CSR and how it relates to corporate performance (see Flammer (2013); Ferrell et al. (2016); Ben-Amar et al. (2017); Buchanan et al. (2018); Davidson et al. (2019); Krueger et al. (2021)). As a result, there is a global demand for both quantity and quality in terms of ESG information.

To narrow the gap between the investor demand for ESG information and business supply, numerous countries have enacted mandatory ESG disclosure legislation requiring corporations to include ESG information in their standard financial disclosures or in specialized standalone reports. Additionally, in 2015, the Task Force on Climate-Related Financial Disclosures (TCFD) was formed with the goal of developing a voluntary set of climate-related financial risk disclosures.

Even though the financial value of ESG information has drastically increased in the eyes of investors in the US and around the world, and as securities and bank regulators work toward mandatory climate disclosure, the SEC has been largely inactive to date (see Williams and Nagy (2020); Ho (2020); Hazen (2020)). However, the climate change regulatory body in the US is well-known for being modelled after regional experiments.

Prior literature in ESG/ CSR revise the traditional corporation model focusing on the profit maximization target for shareholders to determine the relationship between CSR investment and financial performance. Companies may operate in ways that are detrimental to society because they are required to maximise the "money-making" process to satisfy the wealth-maximization interests of their shareholders. Indeed, these assumptions underpin

entire fields of economic research, such as economic regulations and transaction cost analysis. Particularly, it is not uncommon to find an example of corporations that commit unethical acts to fulfil their financial goals, such as customer deceptions, abusive employment practices, tax avoidance, and environmentally damaging activities. Nevertheless, this does not rule out the existence of many businesses that devote efforts to 'socially friendly' behaviors, including charity donation, community supporting activities, fair and responsible employment and customer practices, and legitimacy (see ORLITZKY ET AL. (2003);CALLADO-MUÑOZ AND UTRERO-GONZÁLEZ (2011); SOANA (2011)).

The academic community, thus, questions why firms invest in CSR or environment-friendly activities to help the community (MALIK (2015); LIANG AND RENNEBOOG (2020)). There is also a growing strand of literature attempting to provide answers to this, and interestingly, it is reaching the consensus that externality-driven factors beyond the market like institutional investors, legal origin, regulations, etc. may play significant roles (HEINKEL ET AL. (2001); CAMPBELL (2007); LIANG AND RENNEBOOG (2017); BUCHANAN ET AL. (2018); DYCK ET AL. (2019); KRUEGER ET AL. (2021)).

Due to the high levels of Greenhouse Gas (GHG) emissions in many states, regional actions can have more effective impacts on emission reductions in comparison to federal actions. This is particularly true in the case of environmental regulation, where the majority of federal environmental laws are modelled after state laws[1]. In this study, the focus is on the RAC, a voluntary climate practice initiated within a particular state. Despite its non-mandatory nature, we conjecture that RAC created economic and social pressures for firms, motivating them to review their environmental strategic plans. This triggers a better environmental performance, assisting the firm's stakeholder relationship harmonization objective. Therefore, we conjecture that firm's environmental performance increases with the existence of RAC. We, therefore, set our study in the context of the adoption of the RAC. We explore how RAC impacts the environmental performance by applying a Triple differences (TD) analysis, also named Difference in differences in differences (DDD) to identify the influence of RAC on environmental performance.

Following that, we illustrate one mechanism for RAC in relation to the board's governance role. Particularly, some researchers showed an their interests in board diversity and documented a sophisticated relationship between board diversity and CSR performance, see MALLIN AND MICHELON (2011); ZHANG ET AL. (2013); and HARJOTO ET AL. (2015). Especially, ZHANG ET AL. (2013) emphasizes that SOX has an important impact on the

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[1]"States and municipalities often function as policy laboratories, developing initiatives that serve as models for federal actions", according to a 2007 brief by the PEW Center on Global Climate Change.

representation of women directors on boards. Moreover, while studying the corporate response to sustainability initiatives in a Canadian setting, BEN-AMAR ET AL. (2017) report that the likelihood of voluntary disclosure of climate change information increases with women presence on boards. In this study, we show how the interaction of board diversity and RAC in the post-SOX era affects a firm's environmental performance. We believe that this is because a more diverse board is more likely to make commitments in accordance with regional state law. We treat the recent regional climate action plan as an exogenous agent to firms and use it to disentangle the recursive relationship between environmental performance and board diversity. We hypothesize that the separating effects of SOX and RAC are in the same directions, and jointly to become the ultimate effect of regulation interventions at different levels of government[2]. Firms led by highly diversified boards are more like to possess a wide range of views, opinions and perspectives enhancing the chance that RAC is perceived as an external pressure. With this pressure, firms tend to modify and adjust their environmental practices leading to better performance. In other words, we predict that firms with highly diverse boards have more tendency to react to the RAC, especially during the post-SOX period. As a result, the environmental performance of those firms is relatively higher than their other counterparts.

We only use the environmental score in ESG KLD, because the components in ESG are proved to be correlated with each other (see, e.g., HARJOTO ET AL. (2015); TAMIMI AND SEBASTIANELLI (2017)). Additionally, we are interested to know more about the environmental activities (alone) that a firm engages in and their underlying drivers. The results indicate that public regulation and board diversity play mediating roles in explaining the higher commitment of firms to pro-environmental practices. Supporting our hypotheses, we find that firms based in RAC states have higher environmental performance. This effect is stronger for firms led by highly diversified boards. Furthermore, in the post-SOX era, firms with highly diversified boards (identified by a treated indicator) have an environmental performance that is approximately 28% better than their counterparts. We also find that the low-diversified firms have a higher environmental net score than high diversified firm before 2003 and environmental CSR investment surged around the financial crisis (see

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[2]The author is hypothesizing that the effects of two different regulations, SOX and RAC, are both in the same direction and that when they are applied together, they have an even stronger effect on regulation interventions at different levels of government. This suggests that the two regulations work together to effectively regulate the government and that their combined effect is greater than the sum of their individual effects.

It is possible that the effects of the Regional Climate Action Plan Initiative (RAC) and the Sarbanes-Oxley Act (SOX) are similar because both are intended to regulate and improve various aspects of government and business operations. For example, SOX is intended to improve financial reporting and corporate governance, while RAC aims to reduce greenhouse gas emissions and promote sustainable development. Both regulations may have similar effects on the overall transparency and accountability of government and business operations.

how Fig.3.B.1 illustrates the trends for both groups). Our study suggests the relevance of the conflict-resolution effect and over-investment effect which vary with regulation intervention: the relative importance of the environmental achievement increases following the implementation of RAC. Further, highly diversified boards boost firms' environmental achievement following RAC enactment (during the 2003-2009 period) and (may) maintain more robust investment in environmental CSR projects compared to the low diversified group. These results are also consistent with the strand of literature studying the determinants of firm disclosure, especially regarding environmental CSR disclosure, see MOSER AND MARTIN (2012); DHALIWAL ET AL. (2012); HUANG ET AL. (2022); and KRUEGER ET AL. (2021).

To alleviate the concern of the existence of systematic differences between the treated and control firms, we further use propensity score matching and entropy balancing to define the control group. Our treated and control samples are well balanced on multiple firm characteristics, and the baseline results persist when using those matched samples. We additionally perform analyses on different sub-samples and provide evidence on how economic mechanisms drive our findings (i.e., historical financial performance, CEO and governance factors and financial crisis). Furthermore, to gain a better understanding of RAC's effect on other corporate decisions and outcomes, we extend our analysis by examining how highly environmental CSR firms react following RAC implementation. Overall, our findings are consistent with the arguments that CSR is motivated by a broader group of stakeholders and that the significance of their stakeholders' claims relies on the legislative environment in which they operate.

Our study's contributions to the literature are two-fold. First, we examine the effect of RAC, a voluntary environmental regional initiative, on corporate environmental performance. Distinct from the literature, our focus targets the transition effect of climate change law at the regional level, where SEC have not released any mandatory rules about environmental disclosures (e.g., carbon emission or recycling procedure, and more). Second, the significance of board diversity in the post-SOX era is incorporated into the RAC-environmental performance association. Particularly, we propose board diversity as a condition for RAC to act as an intrinsic pressure on firms. This study helps to fill the theoretical and empirical void by exploring the regulatory effect under which a firm engages in environmental behavior, thereby providing a meaningful implication for regulators at the federal and regional levels.

The rest of the study is organized as follows: Section 3.2 provides a background on regulation body regarding environmental and climate change concerns; section 3.3 presents the methodology. While section 3.4 contains the variable definition and sample construction;

section 3.5 reports the baseline and main results; Section 3.6 depicts additional analyses, and section 3.7 concludes and provides some notes on the study.

3.2   Environment concern and regulations

3.2.1   Overview about disclosure mandates

Interest in SRI, also known as ethical investing or sustainable investing, has exploded in popularity during the last two decades. SRI is a concept that refers to the incorporation of non-financial factors into the investment selection process, such as ESG considerations. According to the Global Sustainable Investment Review, over \$30 trillion was managed responsibly in 2018. Moreover, while ESG investing is more common in Europe, it has grown rapidly in recent years in the US. According to the recent report of Edelman Trust Barometer 2020, 98% of the top 100 US institutional investors consider ESG factors[3].

Not only has the topic gained attention in the business press and among corporate and political leaders, but it has also spawned a corpus of scholarly work (see SPARKES (2003), SPARKES AND COWTON (2004), SANDBERG ET AL. (2009), GALEMA ET AL. (2008), CAPELLE-BLANCARD AND MONJON (2012), WIDYAWATI (2020), LIANG AND RENNEBOOG (2020)). Whereas ESG ratings supplied by specialist rating agencies are critical for the decision-making process of socially responsible managers and investors, as well as for academic research, WIDYAWATI (2020) reaffirms two critical issues with ESG metrics (a lack of convergence and transparency)

Over the last two decades, voluntary and market-driven climate disclosure frameworks have grown significantly, demonstrating both a market and inventive supply. However, reporting in accordance with those numerous frameworks has not resulted in the consistent provision of reliable, comparable data. Institutional investors frequently express dissatisfaction with the scarcity and low quality of firm-level ESG disclosures, which impairs their ability to make informed investment decisions. Indeed, issuers have the legal right - and frequently exercise it - to remain silent about information, regardless of its importance to shareholders and potential investors [4].

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[3]https://www.edelman.com/sites/g/files/aatuss191/files/2021-11/2020%20Investor%20Trust%20Report_FINAL.pdf

[4]Also cited by Ho (2020): The Sustainability Accounting Standards Board (SASB) conducted an analysis of the 10-Ks climate disclosure of the ten biggest firms in the US (by revenue) in each industry category and discovered that almost a third of these firms do not report any climate risks. Over 40% have boilerplate disclosures on the subject. The SASB's analysis also indicates that climate change poses intrinsic financial risks to companies in 72 out of 79 industries, accounting for \$27.5 trillion, or 93% of the US equity market.

Some research has highlighted the role of legal origin and institutions' mediating role in ESG disclosure. Institutionalists acknowledge the necessity of external forces in ensuring that corporations are responsive to the interest of social actors, particularly in today's contemporary business environment, see CAMPBELL (2007), MOSER AND MARTIN (2012), KRUEGER ET AL. (2021).

Although the US is the second-largest emitter of GHG emissions (per capita) in the world, and yet, the SEC has been, to date, failed to act. HAZEN (2020), WILLIAMS AND NAGY (2020) and HO (2020) illustrate the SEC's blinding spot toward ESG significance. Although the SEC enacts very limited social disclosure regulations, some mandates in the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 are highlighted. The SEC issued guidance for companies in 2010 to clarify corporate disclosure obligations regarding climate risks5[5]. In other words, the 2010 climate guidance provided issuers with a refresher course on materiality, while also tipping the scales in the direction of disclosure. Nonetheless, more than a decade later, the findings demonstrate that principles on materiality per se have not resulted in high-quality, decision-useful climate disclosure.

Despite the fact that U.S being the second largest emitter of greenhouse gas emissions per person in the world, and yet, the SEC has been, to date, failing to act. HAZEN (2020), WILLIAMS AND NAGY (2020) and HO (2020) illustrate the SEC's blinding spot toward ESG significance. Although Congress directed the SEC to enact very few social disclosure regulations, several mandates in the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 stand out. The Securities and Exchange Commission (SEC) issued guidance to companies in 2010 to clarify their disclosure obligations regarding climate risks[6]. In other words, the 2010 climate guidance provided issuers with a refresher course on materiality, while also tipping the scales in the direction of disclosure. Nonetheless, more than a decade later, the findings demonstrate that materiality principles alone have not resulted in high-quality, decision-useful climate disclosure.

Still, investors possess insufficient information on firms' self-assessment and management relating to the material climate risks, at least from the companies' required filings. Sustainability

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[5]The reluctance of SEC to mandate ESG and climate disclosure stems in part from its belief that enforcing meaningful disclosure requirements in these areas would be exceedingly difficult in terms of standard setting, materiality of disclosures, boilerplate language use, and enforcement. `https://corpgov.law.harvard.edu/2021/05/28/sec-regulation-of-esg-disclosures/`

[6]The SEC's reluctance to require ESG and climate disclosure stems in part from its belief that enforcing meaningful disclosure requirements in these areas would be exceedingly difficult in terms of standard setting, materiality of disclosures, boilerplate language use, and enforcement. `https://corpgov.law.harvard.edu/2021/05/28/sec-regulation-of-esg-disclosures/`

(ESG) disclosure has concluded that materiality mandate remains unsatisfied in meeting investors' perceived needs.

3.2.2 Regional Climate Action Plan Initiative (RAC)

The US climate change policy has major impacts on global climate mitigation since the country is the second largest emitter of GHG emissions per capita in the world. The body of the climate change and GHG emission legislation framework, in fact, has long been established in the US dating back to 1960s, including the Clean Air Act in 1963, the Clean Air Act Extension in 1970, and the Clean Air Act Amendments in 1977 and 1990. However, many federal and international law bills failed to pass the Congress committee, such as the Kyoto Protocol (1997); the Climate Protection Act and Sustainable Energy Act (2013) and the Paris Agreement (2018).

Municipal and state governments have made significant investments in climate change policies[7]. Regional efforts can be more efficient than Federal programs because they cover a larger geographic area, reduce the duplication of effort, and establish more uniform regulatory regimes. In addition, regional cooperation help avoid the duplication of effort that frequently happens when various governments focus on comparable problems. According to a study by the National Center for Atmospheric Research (NCAR), regional efforts can result in the coordination of policies and programmes across multiple states, thereby reducing the administrative burden on individual states and increasing the overall effectiveness of climate change mitigation and adaptation efforts (KIEHL ET AL. (1998)) .

Several regional efforts have begun in recent years to establish mechanisms to lessen carbon dioxide emissions, improve renewable energy output, track renewable energy credits, and conduct research and set baselines for carbon sequestration. Certain states are extremely engaged in climate change action policy and frequently serve as the catalyst for neighboring states to join the regional legislative plan (see Appendix for more information on Connecticut,

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[7]Some examples include: According to a research from the Center for Local Climate Action and Adaptation (LOCA) and the Georgetown Climate Center, over 1,700 localities in the United States have adopted measures to cut greenhouse gas emissions and promote sustainable energy (see `https://www.georgetownclimate.org/clean-energy/index.html`). According to a research by the National League of Cities, cities are in the forefront of developing and implementing climate change laws and programmes, with 89% of questioned cities reporting that they have taken steps to decrease their carbon footprint (see `https://www.nlc.org/`). According to a research by the Environmental Defense Fund, governments are also taking action against climate change, with 29 states and the District of Columbia establishing greenhouse gas reduction targets and 18 states adopting sustainable energy standards (see Appendix).

New York, and California). We define any regional initiative actions as Regional Action toward Climate Change (RAC)

3.2.3 Impacts of RAC on Corporation Environmental Performance

Stemming from the legitimacy and stakeholder theories, a firm's commitment to CSR activities (comprising environmental-related participation) is perceived by its stakeholders as moral legitimacy, and this helps corporations satisfy and build harmonising relationships with all stakeholders, instead of the conventional sole focus on shareholders (Cornell and Shapiro (1987); Freeman et al. (2004); Scherer and Palazzo (2007); Freeman (2010)). A great number of prior studies employed CSR performance to assess firms' stakeholder management performance (see, for example, Hillman and Keim (2001); Benson and Davidson (2010); Benson et al. (2011); Harjoto et al. (2015); Lopatta et al. (2017)). That is to say, CSR-related behaviours are deemed to be an effective stakeholder management tool in today's business environment, which contributes to the maximisation of corporate value, reputation and market standing (Harjoto et al. (2015)). The extant literature has empirically provided evidence supporting the financial benefits brought by CSR participation, such as, greater firm value, lower costs of capital (both equity and debt), and reduced firm market risk (Benson et al. (2011); Dhaliwal et al. (2011); El Ghoul et al. (2011); Oikonomou et al. (2012)).

Given the ongoing and increasing environmental interest, more pressure has been exerted by different stakeholders on firms' behaviors and attitudes towards pro-environmental practices. Novo Nordisk (1997)[8] has foreseen that corporate stakeholder management in the area surrounding environmental matters will become a daily task in most firms, and not necessarily just for environmentally pioneering firms. Although corporations are aware of the benefits as well as detrimental consequences of their environmental performances, they remain selective in responding to stakeholder claims due to limited resources (Madsen and Ulhøi (2001)). Capturing the loophole, regulations are claimed to be the key controlling factors encouraging more environment-friendly corporate practices (Madsen and Ulhøi (1996)). Corporations, especially those operating in the industrial sector, have been exposed to regulations for a significant period of time, yielding a positive environmental effect. Nevertheless, such a legitimate factor is far from sufficient owing to the claimed overly complex corporate regulatory system. Alternatively, many regional initiatives have been put into place with most of which are voluntary. It is argued that the presence of environmental

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[8]Novo Nordisk. 1997. Environmental Report.
http://www.novonordisk.com/Reports/press/environmental/er97/index.html

issues would trigger corresponding corporate responses on such matter. These pressures can be internally borne, such as firm size, industry, corporate structure (González-Benito and González-Benito (2010); Clemens et al. (2008)); or externally borne, including stakeholder pressure, uncertainties, and regulations (González-Benito and González-Benito (2006); Sprengel and Busch (2011); Thornton et al. (2003)).

According to the theory of corporate control of Fligstein (1990),top managers in large corporations exhibit managerial control of both internal as well as external environments. Such controls allow the management team to tackle issues related to firm growth, profitability, and relationships with stakeholders. Generally, the theory conceptualizes the view that firms experience the pressures that drive them to exercise the identification process for their subsequent goals and the means by which they should adopt. Budros (2002) supports the theory by reporting that corporations adopt involuntary strategic action when facing "economic pressures and when social processes define these acts as natural". In the current study, we conjecture that although regional initiatives are not mandatory, they still act as an important source of influence on stakeholders' perceptions on the environmental area proposed in the initiatives, and hence, there is more pressure on firms to put effort into achieving a better environmental performance. With the heightened perceptions through RAC, more external pressure is placed on firms. This triggers their control to obtain, maintain, and/or improve the relationships with stakeholders as part of their stakeholder management objective. Overall, the following hypothesis will be tested:

- *H1. RAC is positively associated with firm's environmental performance*

3.2.4 How board diversity in the post Sarbanes-Oxley (SOX) era and RAC jointly impact firm's environmental performance

While RAC potentially serves as an external pressure for firms to exercise their environmental strategy, the top management team is the key decision-maker of the corporate internal control, identification, and implementation of corporate goals, including the maintenance of a harmonizing relationship with green stakeholders. Therefore, the likelihood that firms perceive the pressure from RAC depends on their leaders. The urge in changing the corporate board composition represents a global demand attracting media attention, stakeholder calls, and regulatory changes. Subsequent to the enactment of SOX in 2002, an increasing body of research has focused on the role of governance in CSR, and particularly, the board diversity. The board of director is the major decision-maker being accountable for

the success of firms' CSR, primarily due to its responsibility to a wide range of stakeholders (Coffey and Wang (1998); Williams (2003a); Mackenzie (2007); Bear et al. (2010); Larcker and Tayan (2015); Krüger (2015); Rao and Tilt (2016)). The enactment of SOX in 2002 places an extensive focus on the compositions of corporate board (Linck et al. (2009); Zhang et al. (2013)). After the act's passing, noticeably, an increase in representation of female directors on board has also been captured, although the gender component was not directly addressed within the SOX guidelines (Dalton and Dalton (2010); Valenti (2008)). Overall, after 2002, the boards of directors of publicly listed firms comprised substantially higher fraction of independent directors and female directors. These post-SOX observations raise an awareness of market participants in a new era of corporate governance being officially regulated by external forces, leading to more thoughts on the importance of corporate board structure that relates to its diversity level.

The literature consistently reports the impacts of boards with different diversity levels on CSR performance, whilst views on the associations are claimed to remain a "double-edged sword" (Hambrick et al. (1996), pp. 668). Particularly, board diversity is said to positively influence the CSR based on the resource dependence theory (Hillman et al. (2009)). Boards comprising directors of different backgrounds, cultures, ages, and genders have a tendency to magnify those resources, bringing more diverse perspectives and viewpoints to the board discussion tables, and hence, fostering more comprehensive board decisions (Harjoto et al. (2015)). From the stakeholder management perspective, a more diversified board is likely to cover more stakeholders due to the diverse perception on the priority of various stakeholders in terms of their power and the urgency and legitimacy of the claims (Mitchell et al. (1997)). For example, female board members are more sensitive to social issues, e.g. charity donations, and the environment (Boeker and Goodstein (1991); Williams (2003b); Zhang et al. (2013)). Furthermore, female directors tend to be more sympathetic, nurturing, affectionate, compassionate, and kind (Eagly et al. (2003); Nielsen and Huse (2010)). Owing to their heightened attention to others' needs, the salience of non-investor stakeholders' claims is likely to be fostered. Since CSR performance is a strategic tool for stakeholder management, board diversity can enhance CSR performance.

Regarding the negative effect of board diversity, a wide range of opinions and perspectives in the boardroom can create conflicts and team-work dissatisfaction, given corporate resource constraints. Conflicts on a highly diverse board can be fierce, which lengthens the time until consensus is reached and thus, challenges the whole decision-making process (Harjoto et al. (2015); Rao and Tilt (2016)). Furthermore, it has been suggested that diversity

can be inferior to the group working process if the members do not trust/believe their group (VAN KNIPPENBERG AND SCHIPPERS (2007)). This view entails a potential negative impact of board diversity on firm CSR. However, the overall net effect remains on the positive side of board diversity because according to the literature on work group diversity, conflict arises from board 'surface' diversity, i.e., the observable attributes such as age, ethnicity, and gender, which can be resolved over time (HARRISON ET AL. (1998); VAN KNIPPENBERG AND SCHIPPERS (2007)). HAMBRICK ET AL. (1996) indicates that the advantageous aspects of diversity (various perspectives, in-depth discussions, decision creativity, more efficient problem-solving process) far outweigh its major drawbacks (delays in the decision-making process, in-group/outgroup bias, conflicts). Consequently, the literature supports the positive associations between board diversity and CSR performance.

As explained above, diverse boards are more likely to integrate non-financial interests and the pressures of stakeholders, including pro-environmental matters, into the corporate goals and objectives. With the existence of RAC, the imposed social pressure on corporate environmental performance becomes more salient for firms with a greater level of diversity. With similar arguments, when members of the boards are greatly heterogenous from each other, their views, opinions, and attention to issues are different. This enhances the chance that RAC, and the involuntary environmental initiatives, can be perceived as external pressures on firms and hence become more intrinsic. Consequently, we propose that firms led by highly diversified boards in the post-SOX era are more likely to commit to regional environmental regulation initiatives, and as a result, achieve better environmental performance. As such, we form our second hypothesis as follows:

- *H2. In RAC states, firms led by high diversified board in post SOX era exhibit greater environmental performance.*

3.3   Identification strategy

To test H1, which predicts a rise in environmental awareness following RAC, we study a firm's environmental activity around the passing of RAC by considering aggregated environmental performance score, as well as environmental strength score and environmental concern score. We estimate the following model:

$$ENV\_score_{i,t} = \alpha_{i,t} + \beta_1 RAC_{s,t} + \beta_2 High\_diversified\_board_{i,t} +$$
$$\beta_3 High\_diversified\_board_{i,t} \times RAC_{s,t} + \nu_{i,t} + \omega_{s,t} + \epsilon_{i,t} \quad (3.1)$$

where i, s and t index firms, firm's state of incorporation, and years, respectively.

In the baseline model, the dependent variable, $ENV\_score_{i,t}$, which is the environmental performance of firm i in year t. $RAC_{s,t}$ is a (0,1) indicator variable denoting that a climate risk initiative action program is effective in state of incorporation s at time t at the end of the fiscal year. $High\_diversified\_board_{i,t}$ is an indicator to divide our full sample into high and low board diversity groups regardless of SOX release. Equation 3.1 controls for unobserved firm heterogeneity $\nu_{i,t}$, time-varying differences across states $\omega_{s,t}$, and $\epsilon_{i,t}$, the error term. The regression model also includes fixed effects for firm i , operating in state s at time t.

To capture the difference-in-difference of the environmental performance, the key variables of interest are the slope coefficients for $RAC_{s,t}$, and the interaction term, $High\_diversified\_board_{i,t} \times RAC_{s,t}$.

In the setting of the US, where there is no prior mandatory requirement before regarding environmental concerns, RAC provides an interesting opportunity to focus on the relationship between local initiative actions regarding climate change and firms' environmental responsibility. We conjecture that one channel for the effective enactment of RAC is due to the board diversity.

As proposed in literature, high diversified board are more likely to comply with disclosure voluntary (Harjoto et al. (2015); Ben-Amar et al. (2017)). Moreover, many prior studies indicate the substantial presence of outside and women directors on boards in the post SOX era (Linck et al. (2009); Dalton and Dalton (2010); Zhang et al. (2013)). Researchers show that the role of women and non-white directors in the boardroom become more evident as public firms generally have added outside directors to their boards to meet the independence requirements of SOX.

We thus estimate the following triple difference regression model to examine the joint effect of SOX and RAC on environmental performance. We use an indicator Treated to divide our sample into high and low diversified board at the beginning of 2002.

$$ENV\_score_{i,t} = \alpha_{i,t} + \beta Treated_{i,t} \times Post\_SOX_t \times RAC_{s,t} + \gamma X_{i,t} + \nu_{i,t} + \omega_{s,t} + \epsilon_{i,t} \quad (3.2)$$

The key coefficient of interest is the triple interaction term $Treated \times Post\_SOX \times RAC$, which measures the different response of environmental performance to regulation interventions between high diversified firms and low diversified firms. Due to the benefits of government interventions, we should expect positive and significant coefficient for these interaction terms. In contrast, if interventions pose any opposite effect or unexpected outcome (i.e it is costly for firms[9]), the coefficient for those interaction terms should be negative and significant.

A key condition of difference-in-difference models is the parallel trend as shown by the time-series plots of environmental scores for two types of boards, the highly diversified one and the lower diversified using the $Treated$ indicator to split them (Fig.3.B.1 and Fig.3.B.4). We draw a dotted orange line to indicate when the two groups (treated and control) begin to disperse separately, roughly around 2002-2003. Another dotted orange line on the right-hand side sets the boundary for the period 2009-2010 period (financial crisis peak). It is interesting to consider the grey areas where the dynamic changes happen between two groups. While Fig.3.B.1 demonstrates that the net environmental score of the highly diversified board is just slightly higher than the other group. Fig.3.B.4 gives the explanation for this change. In particular, the lower diversified group pursues a strategy of increasing total strength rather than decreasing concern, as opposed to the highly diversified group. It's worth debating the underlying mechanism of that disparity in strategy pursuit. This phenomenon will be discussed further in the following analyses.

(Insert Figures 3.B.1, Figure 3.B.4 about here)

3.4 Data and Summary statistics

In this section, we describe our data sources and clarify constructions for the sample of firms used as well as some measurements in our analysis.

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[9]GREWAL ET AL. (2019) show that after the passage of EU Directive mandating increase non-financial disclosure, the equity market reacts negatively. Also, see CHEN ET AL. (2018) for research of mandatory disclosure in China market.

3.4.1 Sample construction

We obtain data on firm environmental performance from Kinder, Lydenberg, Domini Inc. database (KLD). We employ ISS, IBES and BoardEx to derive those necessary governance variables. Finally, we obtain accounting information and stock market valuation data from CRSP and COMPUSTAT. Our final sample consists of 6,674 firm-year observations and cover 1,972 firms from the U.S. during the period 1995-2013. The Panel A of Table 3–1 presents preliminary interactive effects of SOX and RAC. Notably, the correlation between $Post\_SOX$ and RAC is 0.2877. We code the SOX as S and RAC as R. Across four distribution groups, we see that groups 2 and 4 (where R = 1) perform better than groups 1 and 3 regarding the environmental net scores as well as two components: total strengths and total concerns scores.

Table 3–1, Panel B presents the summary statistics of the variables used in our analysis, including the additional dependent variables used in extra analyses (financial distress, cash flow volatility and earning smoothing, for more detail please check Appendix). All financial variables, except for dummies are winsorized at the 1st and 99th percentiles to alleviate the potential impact of outliers.

(Insert Table 3–1 about here)

3.4.1.1 ESG-KLD

Since the early 1990s, KLD data has been considered the de facto standard in CSR research. Regarding our main dependent variable, the environmental performance[10], we only employ the environmental net score (one component of corporate social responsibility (CSR)) from KLD database. The main reasons are because we only fond of environmental investment performance of firms over time and due to the fact that components of CSR are proved in previous research to be correlated and may have an impact on each other, e.g., the governance score toward the environmental score (see TAMIMI AND SEBASTIANELLI (2017)).

When KLD data was initially utilised in CSR research in 1991, it classified around 650 publicly listed corporations in the United States according to a variety of socially responsible traits, dubbed concerns or strengths. KLD, a manager of socially responsible investment funds, recruited an independent, trained research staff to mine public business papers (e.g.,

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[10]The aggregations of KLD "strengths and concerns" rankings, in which "concerns" refers to environmental threats and "strengths" to commitments made that promise to ameliorate such threats.

annual reports, company websites, and corporations' CSP reporting) and other data sources and to analyse, examine, and assess the data. Recently, the number of businesses insured in the United States increased to almost 3,000. At the conclusion of each calendar year, KLD assigns around 80 ratings of 0 or 1 to each firm it monitors as concern and strength criteria. A value of 0 indicates that no specific strength or worry was seen; a value of 1 indicates that these were observed.

To develop two measures of environmental performance, we included the values of the items of strengths and concerns. However, this is problematic because the combined measure balances strengths and concerns, which may result in insignificant or erroneous results. More crucially, current research indicates that the KLD strengths and weakness measures are conceptually and empirically separate and reflect two independent variables, despite the fact that they may correlate with one another (MATTINGLY AND BERMAN (2006); STRIKE ET AL. (2006)). For example, pollution levels are fairly well captured by environmental concerns, but environmental strengths do not properly forecast future pollution or compliance failures (CHATTERJI ET AL. (2009)). Environmental strengths, on the other hand, represent the underlying strategic competencies that businesses acquire in order to improve their environmental performance (WALLS ET AL. (2012)). As a result, we applied the two measurements independently to ensure the integrity of both components of environmental performance.

3.4.1.2 Board diversity and treated indicator

We use Blau formula to calculate board diversity based on two aspects: gender and race[11]. There are two types of gender diversity: male and female. According to the ISS database, there are four distinct racial groups: Asian, African American, Hispanic, and White. A higher number for the board diversity metric suggests that there is more variety in that area. After constructing the diversity of the board in each aspect, we compute the composite index of board diversity, where *Diversity* equals the total of gender and race diversity. *High diversified* is a dummy variable taking value as 1 if firm has a score of *Diversity* higher than the mean value of the whole sample in year t. While *Treated* indicator is a dummy variable with a value of 1 if the company had a highly diverse board of directors prior to SOX and 0 otherwise.

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[11]Blau's standard formula $(1 - \sum P_i^2)$, where P_i is the proportion of board members in each of i number of categories to compute the board diversity for each feature of the sample firm.

3.5   Empirical results

3.5.1   Baseline results

Table 3–2 presents the baseline regression estimates of the SOX and RAC impact on U.S. firms' environmental performance. We use three sub-scores: a strength score, a concern score and a net score (the difference between the total strength and the total concern scores) to proxy for environmental achievement. Panel A shows the results for net score of environmental performance while Panel B illustrates the results further when using two components of environmental performance score, i.e, environmental total strengths (TS) score and total concern (TC) score.

Using Eq. 3.1, we estimate difference-in-difference (DID) and triple difference (DDD) regressions of environmental net score on board diversity, RAC, and control variables in columns (1) and (2), respectively. We should expect positive and significant coefficients for the slope coefficient of RAC as well as the interaction term due to the benefits of local government initiative programs. In contrast, if legislative interventions have negative or unexpected effects (i.e., they are costly for firms), the coefficients for the interaction term should be negative and significant.

Here, our results indicate a significant positive association between RAC and the firm's net environmental score, see column (1). That is, firms based in those states that employ RAC tend to have better environmental performance. This supports the hypothesis (H1) which proposes that firms operating in RAC states tend to perceive greater environmental pressures and hence exercise their strategic control and implementation on environmental issues. Consequently, the corporate environmental performances are improved as a result. However, column (2) results show that the coefficient on the dummy variable *High_diversified* is negative and significant, contradicting with what we expect. Although the majority of the literature has supported the positive effect of highly diverse boards, the opposing viewpoints are widely acknowledged. Particularly, conflicts and dissatisfactions exist in diverse boards can bring about negative impacts. Also, decisions on the consumption of corporate resources on non-financial environmental practices can be exceedingly debatable. Therefore, the negative sides of having a diverse board are inflated.

Notably, the interaction term *High_diversified* $\times RAC$ is positive and significant. The estimated coefficient is 0.168, with t-statistic of 2.49. In other words, the *High_diversified* variable is positively moderated by RAC to the extent that its effect is modified from negatively significant to positively significant (i.e., -0.0985 to +0.0695). In economic terms,

the findings indicate that firms led by high-diversified boards exhibit an environmental performance that is around 10% points lower than their low-diversified counterparts. However, in RAC states, the environmental performance of those high-diversified led firms become higher by roughly 7% points. This result is as we expected such that in a corporate environment with higher social pressures brought about by RAC, the decisions to improve firms' environmental performance become more prominent, especially in diversified boards with wider viewpoints and perspectives. As a result of the heightened environmental concerns, the conflicts in firms with high-diversified boards are more likely to be surpassed and resolved. This triggers out the positive aspects of having a diverse board. We note that the indicator *High_diversified* is merely a dummy variable calculated by taking the median of board diversity index as boundary to split the whole sample into two groups, comparing with *Treated* indicator, a tracking dummy tracing those firms which have high diversified board even before SOX.

We test the Eq. 3.2 for the hypothesis 2 and report them in columns (3) and (4) of Table 3–2. Consistent with existing studies (see ZHANG ET AL. (2013); HARJOTO ET AL. (2015)), the results suggest that on average, the treated group exhibit higher achievement in environmental score following SOX enactment, the interaction term $Treated \times Post\_SOX$ is positive and significant with value of 0.276. This indicates that firms with high-diversified boards tend to perform better environmentally by 27.6% points in the post-SOX era in comparison to the pre-SOX period. The results from the last model specification (column (4)) consistently show significant and positive coefficients on RAC, suggesting a positive impact of the RAC's implementation on environmental performance. Particularly, the coefficient in column (4) are consistent with our expectation, positive and significant with value of 0.427. This result once again support the hypothesis that RAC's adoption induces firms to take more steps to increase their environmental performance because the coefficient in column (4) (i.e., the triple difference model) is higher than the coefficient in column (2) (i.e., the difference-in-difference model).

In Panel B of the Table 3–2, the same regressions are performed with the adoption of environmental total strength (ENV_STR) and environmental total concern (ENV_CON) scores of firms as response variables. WALLS ET AL. (2012) and GLASS ET AL. (2016) suggested researchers to examine these notions independently due to their distinct concepts both theoretically and empirically. The concept of environmental strength captures the environmental awareness and response of firms on environmental matters. The strength score is reflected on a number of aspects, such as, pollution treatment, clean energy, pro-environmental products/services, management systems strength, product carbon footprint,

and many other strengths. On the other hand, the environmental concern score captures through corporate environmental violations and pollution levels: hazardous waste, emissions, climate change, non-carbon releases, and other concerns.

In brief, the ENV_STR and ENV_CON depict a firm's 'good acts' and 'bad acts' on environment, respectively. Consequently, these scores can capture the firm's response to the green stakeholders' pressures imposed by RAC. The findings in show that firms in RAC states tend to expose to lower environmental concerns (Eq.3.1, $\beta_1 = -0.0987, p - value = 0.01$, column (6)), and the effect remains relatively similar across firms led by high-diversified boards and low-diversified boards (insignificant β_3, Eq. 3.1, column (6)). On the other hand, the RAC variable does not show its statistical significance for the environmental strength, yet a positively significant interaction is obtained for the interaction between $High\_diversified$ and RAC (Eq. 3.1, $\beta_3 = 0.191, p - value = 0.01$, column (2)). This indicates that firms led by high-diversified board in the RAC states achieve a better score in their environmental strength during 2003-2007. This supports our prediction that the social pressures on environmental issues borne by RAC are heightened in high-diversified board firms.

Although our results for both ENV_STR and EV_CON support the two hypotheses for before and after the SOX period, they reveal that the voluntary RAC (2003-2007) seems to act strongly as pressures to firms in terms of their environmental 'good acts', at least, stronger than corporate 'bad acts' (significant β in columns (3) - (4), also see more in Fig. 3.B.1, Fig. 3.B.2). Additionally, RAC encourages treated firms to focus on improving their environmental performance through lowering their environmental concern score (see more in Fig. 3.B.3).

The coefficient signs for the control variables are consistent with existing empirical evidence on environmental performance. In particular, note that environmental performance is negatively related to Tobin Q, firm age, firm size, R&D intensity and stock return volatility while it is positive related to leverage. It is understandable that older and larger firms, due to economies of scale, have more available resources to effectively manage the requirements of stakeholders and achieve legitimacy and credibility than smaller and younger firms. However, there may be compelling reasons for small and emerging businesses to invest in environmentally friendly activities, such as capitalising on the appeal of CSR to key market segments. Response to the growth importance of CSR attributes to customers today, businesses are becoming increasingly concerned with CSR investment, see FLAMMER (2013).

Cheng et al. (2014) provide robust evidence that firms with better CSR performance face lower capital constraints. However, it can be owing to the characteristics of CSR firms, i.e., low idiosyncratic risk and systematic risk due to their higher social capital with stakeholders (see Cheung (2016) for discussion). The negative association between stock return volatility and environmental performance in our models confirm this notion, such that less volatile stock return implies a higher environmental performance.

Academic researchers are often interested in the benefits of environmental investment to a company's financial performance, see also Kim et al. (2014), Buchanan et al. (2018), Dumitrescu and Zakriya (2021). However, there are arguments about the reasons why firms invest in CSR and strong belief that investing in CSR activities are likely to be undertaken at the expense of shareholders, see Moser and Martin (2012). Examples of costs that must be less than benefits include lower fuel costs, improved customer reputation, increased employee satisfaction and retention, and less regulation. Because the potential benefits of green technology are limited, managers who only seek to maximise shareholder value would not overspend on it. Managers whose goals included meeting social or environmental demands may overspend on such technology. The significant and negative sign of Tobin's Q coefficient in our model show agreement for the latter.

On the other hand, McWilliams and Siegel (2000) illustrates that the inclusion of R&D is important in modelling CSR investment, in that they are positively correlated, and that omitting R&D in the relationship between financial performance and CSR is prone to model inaccuracy. Here, in our models, we realize that R&D intensity is negatively linked with environmental achievement. There are two possible reasons for this, 1) firms do not necessarily invest in R&D to aim for higher ESG or they do not devote resource to ESG in reality; 2) under-investment also (regardless of signalling to ethical investors or not) might be the case. The coefficients of R&D and Tobin's Q indeed are building up a fact about the environmental-friendly investment here in our study.

Additionally, there are numerous plausible explanations for the positive relationship between leverage and environmental performance, e.g., financially constrained firms owning fearfulness of missing out on the CSR investment trend (the case for small and young firms), or long-lived established firms investing excessively in CSR, resulting in an aggressive capital structure with high debt. Other results of R&D intensity and Tobin's Q as control variables in our model provide support for this.

As demonstrated in the literature, we believe that the demand for CSR information is triggered by non-shareholder constituents and the related disclosure may therefore serve

broader purposes than other traditional corporate financial disclosure. In sum, the evidence in Table 3–2 suggests that a diversified board invests more in environmental issues, especially with the implementation of RAC as (locally) external institutions force.

(Insert Table 3–2 about here)

3.5.2   Financial performance and the SOX/RAC enactment

Customers, suppliers, employees, governments, community groups, and some shareholders have all recently pressed companies to increase their CSR spending. Some businesses have responded by increasing their corporate social responsibility budgets. Other CEOs have objected, claiming that CSR and profit maximization are incompatible. The ensuing debate has prompted researchers to investigate the relationship between CSR and financial performance in order to determine whether the concerns about a CSR-profit trade-off are valid (MCWILLIAMS AND SIEGEL (2000); ORLITZKY ET AL. (2003); HONG AND ANDERSEN (2011); SOANA (2011); BARNETT AND SALOMON (2012); KORSCHUN ET AL. (2014); NIE ET AL. (2019); AHLUWALIA (2022)).

There are two contrasting views on this relationship: (1) companies often invest in CSR because it increases profitability and firm value, a relationship referred to as "doing well by doing good." or (2) other research examines whether only high-performing firms can afford to invest in CSR.

This section provides an extended discussion of the relationship between financial performance environmental performance and intervention from external regulations. We use the interaction terms with those lags of Tobin's Q, Tangibility, NCSKEW (stock crash risk) and Advertising Expenditure. We present the results in Table 3–3.

The results in columns (1) and (2) in Table 3–3 support the second view, as higher (interaction of legislative interventions with) first lags of Tobin's Q and tangibility show positive signs. The magnitude of institution factors (SOX and RAC) reduce, from 0.427 (as reported in Table 3–2) to 0.0654 and to 0.0804, see column (1), possibly due to the negative association of Tobin's Q with environmental performance alone; however, the magnitude of institution factors increase when interacting with the first lag of tangibility (from 0.427 to 0.566 and to 0.762, see column (2)), implying that firms with higher tangible assets are easier to divert parts of their projects to environmental activities.

This finding supports MOSER AND MARTIN (2012)'s argument that certain CSR or environmentally friendly investments may continue to detract from shareholder value for two reasons: (1) managers may continue to direct resources toward investments that would earn a higher rate of return, rather than towards CSR or environmentally friendly investments. This is consistent with the agency theory, which argues that managers may not always act in the best interests of shareholders and may prioritize their own interests over those of shareholders; and (2) while the aggregate influence of all CSR activities may be profitable, some individual CSR projects may remain unprofitable because the motivation is to enhance company's reputation and image (see IOANNOU AND SERAFEIM (2010)).

Recently, studies on stock crash risk, especially the relationship between CSR investment and stock valuation (as well as investor awareness), have gained its popularity within academic research. FLAMMER (2013) states that environmentally responsible companies see a significant increase in stock price, whereas firms behaving irresponsibly see a significant decrease. However, the negative (positive) stock market reaction to environmentally harmful behavior has increased (decreased) over time. KIM ET AL. (2014) confirm that future crash risk decreases with CSR performance after controlling for other predictors, such as engagement in CSR helping to prevent from bad news hoarding behavior, thus, reducing crash risk.

Nevertheless, DUMITRESCU AND ZAKRIYA (2021) report that firms' environmental practices and governance mechanisms may have trivial effects on stock crashes. However, studying ESG mandatory disclosure around the world, KRUEGER ET AL. (2021) show that the enactment of mandatory ESG disclosure mitigates ESG incidents and stock price crash risk. Interestingly, SERVAES AND TAMAYO (2013) point out a positive association between CSR and firm value for firms with high customer awareness, as measured by advertising expenditures. For low customer-aware firms, the relation is either negative or insignificant, thus, the ones with a poor reputation are unlikely to reap any immediate benefits from CSR engagement.

Hence, we are curious to see how crash risk and advertising expenditure interact with the impact of local legislative factors since firms could be ready to join the CSR-rating game in order to gain access to the increasingly available resources under industry entry or competitiveness factors (industry barrier effect). We acknowledge the discrepancy in Panel A and Panel B of Table 3–3 as there are positive and significant signs for the interactions of SOX and first lags of crash risk/ advertising expenditure towards environmental performance, but we do not find the same results for RAC. In other words, the jointly effect of SOX and RAC cancel out the industry effect of environmental achievement.

(Insert Table 3–3 about here)

3.5.3 Sub-sample analyses

We now include in our study a further analysis about Toxic Release Inventory (TRI)[12], a mandatory programme mandated by Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) to address public concerns about local chemical emergency preparedness and the availability of hazardous substance information. To monitor the management of certain toxic chemicals that may endanger human health and the environment, the TRI requires the US facilities in various industries to provide annual report on chemical-released level into environment and/or managed through energy recovery, recycling, and treatments. The TRI Program currently covers 770 individually listed chemicals and 33 chemical categories. The results in Panel A: Non-subject to TRI industries versus TRI industries reported in Table 3–4 show that while SOX only affects TRI industries, RAC has a consistent effect on both groups.

Following HUANG ET AL. (2022), who find that firms in disaster-affected counties increased their ESG disclosure transparency after the disaster, we report consistent results for the impact of SOX and RAC for both group of firms (those who are more likely to be exposed to natural disasters and the others[13]). However, there is a higher probability of increasing environmental performance for those firms that are less likely to be exposed to catastrophes when interacting with the record of disasters (the significance level is higher and the absolute value of the coefficient is larger).

We next split the whole sample by quality of air and report the results in Panel C. We create a categorical variable based on the ranking of state air quality, whose data is from the US Environmental Protection Agency's AirNow. There are five levels of clean/poor air quality in total[14]. Interestingly, according to the results presented in panel C, only the first and the second groups have significant results under the impact of SOX and RAC. This may imply that the environmental performance in other groups (3, 4 and 5) may not be affected by SOX or RAC.

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[12]https://www.epa.gov/toxics-release-inventory-tri-program/what-toxics-release-inventory

[13]We derive a dummy variable based on the record of a hazard that occurs in that specific state. The dummy variable takes a value of 1 if the total record of natural hazard is higher than the median of the sample, and 0 otherwise.

[14]The U.S. Environmental Protection Agency's AirNow data metrics reveals that the total number of 'unhealthy' to 'hazardous' days has declined from 2000 to 2018. Within the 35 metropolitan areas that were monitored for ozone pollution, a drop in the total number of poor air days from 1562 days in 2000 to 671 days in 2018 was observed. For more detail, see `https://www.airfiltersdelivered.com/c/cleanest-air-by-state`

(Insert Table 3–4 about here)

3.5.4 Robustness with Propensity score matching and entropy balancing samples

To allay concerns that systematic differences in the characteristics of the control and treated firms may explain their disparate environmental performance, we identify the control sample using propensity score matching (PSM) and entropy balancing (EB)[15].

We use a logit model to estimate the propensity score of being a treated firm, that is, we regress the treatment indicator (highly diversified before SOX) on relevant firm-level covariates (i.e., board size, firm age, tangibility, cash holding, R&D intensity, Tobin's Q, firm size, leverage and dividend). Under both matching schemes, the treated and control firms exhibit no significant difference in their covariates.

Consistent with the baseline result, we continue to observe that SOX and RAC have a significant and positive effect on environmental performance; see Table 3–5. The adjusted R-square in EB is higher compared to PSM, showing the superior power of EB in performing better with respect to the balancing treatment and control group at the baseline for the first three moments of several predictors, resulting in the least biased estimates of the treatment effect. Overall, we conclude that our main finding continues to hold after controlling for different matching/weighting techniques, namely, PSM and EB.

(Insert Table 3–5 about here)

3.6 Additional analyses

3.6.1 The impact of SOX/RAC with varying CEO and other governance characteristics

As CEOs are key decision-makers and are in charge with the corporate strategies, including environmental-friendly projects and directions, they are responsible for the firms' sound profitability, sustainable operation, and harmonious stakeholder relationships (WEI ET AL. (2018)). Academic researchers have long reached a consensus about the critical influences

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[15]Further discussions about the comparison of matching and weighting methods for causal inference, please refer to MATSCHINGER ET AL. (2020).

of CEOs in corporate strategic decisions (WALDMAN ET AL. (2004)), including the environmental management (WALDMAN ET AL. (2006); HOUSE AND ADITYA (1997)). For instance, DAVIDSON ET AL. (2019) shows that CEO fixed-effects, particularly materialism CEO[16] explain 63% of variation in CSR score. LEWIS ET AL. (2014) reported that CEOs' tenure and education are associated with voluntarily environmental disclosure. They document that firms run by CEOs with shorter tenure and MBA-holders produce better quality carbon-related information

Using the interaction of SOX/RAC with CEO characteristics, we report the result in Panel A, Table 3–6. We find no evidence that CEO gender, ethnic origin or longer tenure has an effect on the company's environmental performance. Meanwhile we realize that CEO departure is positively related to the environmental responsibility score, as shown in column (2), Panel A. One possible implication is that newly appointed CEOs are more likely than their predecessors to engage in environmentally friendly projects to bolster their image (also see LEWIS ET AL. (2014)). Similarly, COLAK ET AL. (2020) presents interesting research evidence showing that when CEOs' risk exposure to ESG issues reaches extreme levels, they are significantly more likely to be fired.

To extend the measure of board diversity, we employ two dimensions: the difference in the educational qualification of board directors and their age distribution, i.e., $STDEVNoQuals$ and $STDEVAge$. We find that the interaction term with $STDEVAge$ is negative and significant at the 5% level, see column (4) in Panel B, but there are no significant results for $STDEVNoQuals$ or board busyness. Regarding the number of analysts following, while DHALIWAL ET AL. (2012) show that a stand-alone CSR report can lower analyst forecast errors, BARKO ET AL. (2021) demonstrates that firms engaged in ESG activism typically have lower ex ante ESG ratings yet are the most visible, i.e., followed by more analysts than their peers. Here, we reveal that the amount of analyst coverage interacting with RAC enactment is strongly related to the environmental responsibility score (column (1), Panel B), wherein the effect of regulations (stand-alone) is cancelled out. This result is consistent with studies of FLAMMER (2013) and SERVAES AND TAMAYO (2013), implying that more reputable firms are more likely to engage in CSR investment (characterized by either the number of analysts following or the advertising expenditure). Moreover, there are some explanations regarding the green-washing motivation, (for more discussion about green-washing, see LAUFER (2003), PARGUEL ET AL. (2011), and DELMAS AND BURBANO (2011)).

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[16]Materialism is gauged by high luxury and asset ownership of CEOs

(Insert Table 3–6 about here)

3.6.2 The impact of SOX/RAC with institutional investors

Institutional investors, such as pension funds, typically have large amounts of money under management and can exert significant influence on the companies in which they invest. By assessing the impact of institutional investors on ESG and CSR, researchers aim to understand how these investors can use their financial power to promote more sustainable and responsible business practices, which can ultimately benefit society as a whole. Additionally, there is a growing interest on the part of investors to understand the potential financial benefits of investing in companies with strong ESG and CSR practices, which could potentially lead to better returns on investment. It is undeniable that the role of green/ethical investors play an essential role in diverting the resources to social responsible firms, see HEINKEL ET AL. (2001), DYCK ET AL. (2019), BUCHANAN ET AL. (2018) for example. HEINKEL ET AL. (2001) explores the effect of exclusionary ethical investing on polluting firms while DYCK ET AL. (2019) confirm that institutional ownership is positively associated with environmental and social performance across 41 countries. BUCHANAN ET AL. (2018) shows that the relationship between CSR and firm value is influenced by institutional ownership. Before the crisis, CSR increases the value of firms with low institutional ownership, but not those with high IOR. A positive CSR-firm value relation during a crisis suggests that over-investment concerns dominate.

The results in Table 3–7 tell an interesting story regarding co-founding impact from institutional investors and regulation enactments. We employ three measures of institutional investors' holdings, i.e., *Institutional Concentration* (IOC_HHI), *Institutional Breadth* ($\Delta BREADTH$), and *Institutional Ownership* (IOR), also see Appendix for more detail. We show that the involvement of ethical institutional investors (IOR) does help mitigate the environmental concern score, the coefficient value is -0.223 and significant at 1% level (as reported column (9) in Table 3–7). Meanwhile, the net increase in the amount of institutional holding (proxied by $\Delta BREADTH$) negatively impacts not only the firm's environmental concern score but also its environmental strength score; see columns (5) and (8) in Table 3–7. Additionally, we also find that the change in institutional holding when interacting with regulation interventions has a negative impact on environmental strength score. Although institutional concentration (IOC_HHI) does not show any significant impact on environmental performance, its interaction terms with legislative release results in a negative effect for both aggregate environmental achievement and environmental strength score, see columns (1) and (4) in Table 3–7.

We doubt that although the inclusion of institutional investors does play a role in a firm's environmental performance, the change in its holding and the diverse types of institutional investors represent a new path in ESG/CSR research that is worth exploring in the near future. We have come to a new social-friendly era in which green investors have become more perceptible and critical. However, their influential force has not yet surpassed the traditional profit maximization target. For instance, the estimates on SRI funds or sustainable mutual funds are quite modest, typically lower than \$1 trillion[17]), also cited by LIANG AND RENNEBOOG (2020).

(Insert Table 3–7 about here)

3.6.3 After SOX and RAC enactment: transitional risks or opportunities

This extra section further investigates the impact of SOX/RAC on high environmental performance firms (or green firms) towards financial distress, cash flow volatility and earning management. This section is likely motivated by the desire to understand how these regulations, which were implemented to improve financial reporting and corporate governance, may impact firms that have a strong focus on environmental performance. SOX and RAC require firms to disclose more information about their financial and operational performance, which can increase transparency and reduce the risk of financial fraud. However, these regulations may also impose additional costs and compliance burdens on firms, particularly those that have a strong focus on environmental performance. We use a dummy taking the value of 1 if the net environmental score is larger than zero, and otherwise taking the value of 0. Table 3–8 presents our results with dependent variables as financial distress, cash flow volatility and earning management in Panel A - C, respectively. Simply put, for green firms after RAC implementation, financial distress and cash flow volatility reduce in the following years (the strongest effect in year t+1) but earning smoothing increases.

Although it has previously been argued that CSR may impose unnecessary costs on a firm, limiting its ability to access capital, CHENG ET AL. (2014) find that firms with higher CSR performance face significantly lower capital constraints as a result of increased stakeholder engagement and transparency about CSR performance. Following the social capital with stakeholders, CHEUNG (2016) finds the positive effect of CSR on cash holding via the systemic risk channel. The author postulates that CSR firms with lower systematic risk

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[17] The Global Sustainable Investment Review (2018

have a shorter debt maturity structure and, as a result, a higher refinancing risk, so they will increase cash to mitigate that risk.

Here in our study, we realise that the coefficient on the RAC indicator in column (2), Panel A is significant and negative, at 5%. This result implies that after SOX and RAC enactments, green firms with diverse boards experienced lower possibility of financial distress, which is consistent with findings of Cheng et al. (2014). However, we find that after RAC enactment, green firms show less volatile cash flow (the coefficient in column (6) of Panel B, negative and significant, at 0.1%). It's possible that these companies were better prepared for the increased disclosure obligations and had stronger systems and procedures in place to monitor their environmental performance. Furthermore, RAC may have had a favourable influence on the reputation and market perception of green enterprises, leading to higher investor confidence and lower cash flow volatility. It's also likely that the RAC restrictions led to higher investment in renewable energy and sustainable practises, which might have resulted in a more steady cash flow for those companies because they aren't as vulnerable to the volatility and price changes of fossil fuels. Furthermore, RAC legislation may have increased awareness of enterprises' environmental performance, leading to more deliberate investment decisions and a more consistent income flow for green firms.

While Kim et al. (2012) report a negative association between CSR performance and each of their three measures of earnings management measures, namely discretionary accruals, real earnings manipulation and Accounting and Auditing Enforcement Releases; Gao and Zhang (2015) point out those income-smoothing firms with higher CSR experience a higher contemporaneous earnings-return relationship, greater Tobin's Q and stronger current return-future earnings relationship. Nevertheless, the positive and significant result, as presented in Panel C, column (10), shows that after SOX/RAC, green firms are more likely to engage in earning management. there are several possible explanations for this observed phenomenon: (1) Compliance costs: SOX and RAC regulations may impose additional costs and compliance burdens on firms, particularly those that have a strong focus on environmental performance. In order to meet these regulations, firms may engage in earning management practices to meet earnings targets and improve their financial performance. (2) Reputation management: Green firms may be more likely to engage in earning management in order to maintain a positive reputation and market perception as environmentally-friendly companies. (3) Pressure to meet financial targets: SOX and RAC regulations may lead to increased scrutiny of firms' financial performance, which may put pressure on green firms to meet earnings targets and maintain financial performance. (4) Lack of comparability: The regulations may have led to a lack of comparability in terms

of environmental performance among firms, which could have led some firms to engage in earning management to improve their relative performance.

(Insert Table 3–8 about here)

3.6.4 More visibly external forces during and after financial crisis (2009 - 2010)

BUCHANAN ET AL. (2018) emphasizes some notions about ESG performance during financial crisis and find that firms tend to over-invest in CSR around financial crisis time. We revisit those analyses using Fig.3.B.1, where the environmental performance surge around the financial crisis time, particularly the low diversified firms tend to boost higher environmental investment compared with the other group. In fact, there is another parallel event happening around that time which may strengthen the 'obligations' of firm environmental performance,i.e, the release of Greenhouse Gas Reporting Program (GHGRP)[18].

GHGRP was set up in 2010 under the Clean Air Act. It requires big emitters of GHG and suppliers of certain products to send EPA annual greenhouse gas reports. Emissions of GHG cause more of these gases to be in the air, which changes the Earth's radiative balance, in turn causing climate change. These high levels are likely to put the public health and the public welfare of both current and future generations at risk. By collecting timely industry-specific data, the GHGRP assists us better understand the source of emissions and make better climate policy. Some may feel that TRI (as mentioned in the sub-sample analyses) and GHGRP overlapping. However, according to a 2017 report by EPA[19], the reporting coverage of TRI and GHGRP is aimed at different top-emitting sectors; thus, together they draw up a comprehensive picture of emission at the sector and facility levels.

As seen in Fig. 3.B.4, and as briefly mentioned above, there is a transitional period after 2009, where both groups consistently inflate their environmental performance, especially in terms of total strength (TS) score. On the other hand, the highly diversified board group places more efforts into reducing the total concern scores in comparison to their peers. We now report the results excluding the financial crisis period to mitigate the joint effect of the financial crisis in Table 3–9. Notably, the results in Table 3–9, columns (1)

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[18]On December 26, 2007, President George W. Bush signed into law the Consolidated Appropriations Act of 2008, providing funds for Environmental Protection Agency (EPA) to develop a mandatory greenhouse gas reporting rule, for more detail of greenhouse gas reporting program, see TOMAR (2021).

[19]see `https://19january2017snapshot.epa.gov/sites/production/files/documents/2011_tri_na_overview_greenhouse_gas.pdf`

and (2): when excluding the crisis time, the baseline effect still holds and even has higher magnitude compared to when including crisis time. The impact fades in the crisis time (2007-2009), which implies that board diversity helps to mitigate the over-investment effect. The results reported in columns (3)-(8) illustrate how the financial crisis is driving out our previous findings of the impact of high environmental performance. As can be seen from columns (4) and (8), investment in environmental projects during the financial crisis cause firms to become more financially distressed, which may induce them to engage in earning management

(Insert Table 3–9 about here)

3.7 Conclusion, limitation and remarks

In this study, we question how RAC and board diversity, jointly affect firm environmental CSR performance. By applying DID and TD approaches, we document that despite the voluntary nature of RAC, it still acts as a social pressure on firms and influences their environmental practices thereby enhancing their environmental performance. Nevertheless, such perceived pressure imposed by RAC can change with the level of board diversity. Specifically, firms led by highly diversified boards are likely to be more aware of the heightened pressure of stakeholders owing to the existence of RAC. Consequently, those firms devote greater efforts to addressing the stakeholders' environmental concerns through their improved environmental performance. Additionally, we find supporting evidence for the notion that the motive for environmental disclosure is mostly driven by non-shareholder constituents. Since our analysis focuses on firms with highly diversified boards, we highlight that board diversity plays a strategic role in commitment to regional climate initiatives.

Again, we emphasize in our study that SOX is a SEC-level effort while RAC is local and voluntary. Studying their joint effects provides policymakers with some implications for the implementation of mandatory disclosure in the future. Specifically, the downsides of mandatory disclosure have been widely reported and are known by academic researchers and practitioners, e.g. the notion of green-washing. With mandatory disclosure, firms can publicize their pro-environmental actions through disclosure, which can divert stakeholders' focus from the negative ones. In other words, firms are induced to use language to mislead stakeholders about their 'true' environmental performance and strength. Mitigating green-washing is especially challenging in an environment of limited and uncertain regulation as firms' behaviors are becoming increasingly sophisticated, complex and prevalent. Nevertheless,

our study shows a "robust" trend of effective environmental CSR initiatives in those ex-ante diverse boards under RAC adoption.

Despite our efforts in trying to provide a comprehensive picture of how RAC may play a model role in the implementation of semi-mandated ESG disclosure, we derive our results solely from the data taken from KLD, neglecting the criticism around the usage of different sources of ESG metrics (Bloomberg, Thomson Reuters, etc.,)[20]. In the future, once we can obtain post-2013 data from KLD or we can access other sources of ESG databases, we will re-update our study and extend it further.

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[20]see more discussions from DORFLEITNER ET AL. (2015)

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Table 3–1: Summary Statistics

Panel A : Summary statistics for environmental performance following SOX/ RAC implementations							
S = SOX; R = RAC.	mean	sd	min	max	p25	p50	p75
Group 1: S = 0; R = 0							
ENV_score	-0.082	0.780	-5	5	0	0	0
ENV_str_num	0.194	0.538	0	5	0	0	0
ENV_con_num	0.275	0.707	0	6	0	0	0
Group 2: S = 0; R = 1							
ENV_score	0.105	0.659	-4	4	0	0	0
ENV_str_num	0.207	0.609	0	5	0	0	0
ENV_con_num	0.102	0.450	0	5	0	0	0
Group 3: S = 1; R = 0							
ENV_score	-0.078	1.405	-5	5	-1	0	0
ENV_str_num	0.698	1.091	0	5	0	0	1
ENV_con_num	0.776	1.166	0	5	0	0	1
Group 4: S = 1; R = 1							
ENV_score	0.521	1.240	-4	5	0	0	1
ENV_str_num	0.877	1.234	0	5	0	0	1
ENV_con_num	0.356	0.809	0	5	0	0	0

Panel B: Descriptive statistics of key variables							
	Full sample				Female dominated industry		Male domiated industry	
Variables	Mean	S.D	Min	Max	Mean	S.D	Mean	S.D
Environmental concerns								
ENV_score	0.023	0.889	-5	5	0.084	0.523	-0.017	1.063
ENV_str_num	0.301	0.741	0	5	0.138	0.515	0.409	0.842
ENV_con_num	0.278	0.736	0	6	0.054	0.317	0.427	0.881
Board characteristics								
Boardsize	9.724	2.679	3	34	2.355	0.263	2.335	0.228
Board Diversity	0.325	0.215	0	1.037	0.338	0.221	0.314	0.217
Turnover ratio	0.183	0.26	0	2.5	0.187	0.284	0.179	0.270
Board interlock	0.011	0.102	0	1	0.012	0.111	0.020	0.139
CEO change	0.115	0.319	0	1	0.139	0.346	0.123	0.329
Analyst coverage	16.038	9.958	1	57	15.059	8.801	14.383	9.626
Busyness	0.395	0.175	0	0.929	0.416	0.190	0.405	0.192
STDEVNoQuals	1.028	0.39	0	3.3	1.013	0.393	1.013	0.381
STDEVAge	7.264	2.151	2.6	15.3	7.566	2.258	7.209	2.206
Female CEO	0.085	0.279	0	1	0.089	0.284	0.082	0.275
Non-white CEO	0.109	0.311	0	1	0.117	0.322	0.103	0.304
Firm characteristics								
Firm Age	27.084	16.897	0	64	2.897	0.654	3.267	0.692
Tangibility	0.244	0.172	0.008	0.878	0.166	0.207	0.300	0.226
Cash holding	0.156	0.161	0	0.905	0.152	0.166	0.152	0.169
R&D intensity	0.041	0.053	0	0.68	0.035	0.061	0.057	0.068
Tobin_Q	2.242	1.527	0.59	24.55	1.938	1.456	1.941	1.399
Firm Size	7.962	1.599	4.016	13.59	8.113	1.913	7.799	1.594
CAPEX intensity	0.047	0.038	0.002	0.372	0.036	0.045	0.054	0.054
Stock return volatility	2.377	0.413	1.2	4.004	2.362	0.429	2.364	0.439
Leverage	0.421	0.495	0	8.038	0.503	0.559	0.482	0.503
Dividend payment	0.015	0.023	0	0.306	0.011	0.038	0.016	0.036
NCSKEW	0.405	0.839	-1.992	6.384	0.363	0.889	0.388	0.834
Financial Distressed	0.37	0.483	0	1	0.428	0.495	0.332	0.471
Cash flow volatility	0.035	0.062	0	1.502	0.027	0.060	0.039	0.063
Earning Smoothing	0.0106	0.0892	-1.1844	0.6867	0.011	0.088	0.010	0.090

Notes: This table reports the summary statistics of all the variables used in our main empirical analysis. The sample consists of U.S firms reporting to KLD from 1997 to 2013. Panel A shows data on different sub-samples following SOX/RAC implementations. We code the SOX as S, RAC as R. Panel B reports summary statistics on environmental performance scores and firm's characteristics. For the definitions of all the variables and the details of their construction, see Appendix.

Table 3–2: Board diversity, SOX/RAC and environmental performance

Panel A: Environmental Net Score				
	Dependent variable: Environmental Performance Score (ENV_score)			
	(1)	(2)	(3)	(4)
RAC	0.163*	0.0671		
	(2.52)	(1.02)		
High_diversified		-0.0985*		
		(-2.00)		
High_diversified × RAC		0.168*		
		(2.49)		
Treated × PostSOX			0.276**	
			(3.22)	
Treated × PostSOX × RAC				0.427***
				(4.44)
Board size	0.163	0.165	0.194	0.176
	(1.34)	(1.35)	(1.59)	(1.45)
Firm Age	-0.932***	-0.902***	-0.881***	-0.870***
	(-4.61)	(-4.55)	(-4.59)	(-4.39)
Tangibility	-0.640	-0.646	-0.609	-0.607
	(-1.54)	(-1.57)	(-1.48)	(-1.48)
Cash holding	0.245	0.253+	0.239	0.212
	(1.60)	(1.67)	(1.59)	(1.41)
R&D intensity	-1.044*	-0.978*	-0.984*	-0.941*
	(-2.36)	(-2.24)	(-2.27)	(-2.24)
Tobin_Q	-0.0441***	-0.0434***	-0.0442***	-0.0383**
	(-3.45)	(-3.50)	(-3.51)	(-3.19)
Firm size	-0.148*	-0.144*	-0.130*	-0.134*
	(-2.51)	(-2.48)	(-2.27)	(-2.31)
CAPEX intensity	0.689	0.699	0.705	0.674
	(1.47)	(1.50)	(1.51)	(1.43)
Stock return volatility	-0.113+	-0.110+	-0.120*	-0.108+
	(-1.92)	(-1.86)	(-2.06)	(-1.85)
Leverage	0.123*	0.122*	0.112*	0.111+
	(2.19)	(2.18)	(2.01)	(1.93)
Dividend	0.292	0.287	0.365	0.277
	(0.65)	(0.64)	(0.81)	(0.63)
Intercept	3.408***	3.324***	3.193***	3.157***
	(4.74)	(4.66)	(4.56)	(4.46)
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observations	6604	6604	6604	6604
adj. R-squared	0.229	0.231	0.230	0.237

Panel B: Environmental component scores								
Dependent variable:	ENV_str_num				ENV_con_num			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RAC	0.0784	-0.0316			-0.0851*	-0.0987**		
	(1.39)	(-0.57)			(-2.50)	(-2.75)		
High_diversified		-0.121**				-0.0221		
		(-2.91)				(-0.77)		
High_diversified × RAC		0.191**				0.0234		
		(3.16)				(0.66)		
Treated × PostSOX			0.346***				0.0692	
			(4.35)				(1.34)	
Treated × PostSOX × RAC				0.321***				-0.105+
				(3.74)				(-1.87)
Intercept	2.762***	2.660***	2.515***	2.580***	-0.647+	-0.664+	-0.677+	-0.576+
	(4.55)	(4.43)	(4.31)	(4.26)	(-1.83)	(-1.87)	(-1.92)	(-1.66)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6604	6604	6604	6604	6604	6604	6604	6604
adj. R-squared	0.280	0.283	0.287	0.287	0.062	0.062	0.060	0.062

Notes: This table presents the results from difference-in-difference and triple difference analyses relating environmental performance score with board diversity, SOX implementation and RAC enactment for U.S firms reporting to KLD from 1997 to 2013. The dependent variables are ENV_Score (Panel A), and components of ENV_Score, i.e, ENV_str_num and ENV_con_num (Panel B). PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. Treated is an indicator variable set to one if that firm had high diversified board before SOX, and zero otherwise. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3–3: The impact of SOX/RAC, financial performance and environmental achievement

Dependent variable: Environmental Performance Score (ENV_score)				
	Panel A: PostSOX			
	(1)	(2)	(3)	(4)
$Treated \times PostSOX \times Tobin\_Q$	0.065***			
	(3.63)			
$Treated \times PostSOX \times Tangibility$		0.566*		
		(2.03)		
$Treated \times PostSOX \times NCSKEW$			0.033*	
			(2.12)	
$Treated \times PostSOX \times Advertising\_Expense$				0.096+
				(1.94)
Intercept	3.366***	3.363***	3.537***	3.627***
	(4.72)	(4.73)	(4.01)	(2.33)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observations	6604	6604	4752	1196
adj. R-squared	0.228	0.234	0.253	0.339
	Panel B: SOX and RAC			
	(1)	(2)	(3)	(4)
$Treated \times PostSOX \times RAC \times Tobin\_Q$	0.080*			
	(2.58)			
$Treated \times PostSOX \times RAC \times Tangibility$		0.762*		
		(1.99)		
$Treated \times PostSOX \times RAC \times NCSKEW$			0.082	
			(1.54)	
$Treated \times PostSOX \times RAC \times Advertising\_Expense$				0.035
				(0.84)
Intercept	3.481***	3.456***	3.642***	3.577*
	(4.36)	(4.30)	(3.72)	(2.13)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observations	6118	6118	4489	1196
adj. R-squared	0.235	0.234	0.261	0.335

Notes: This table illustrates the results from the difference-in-difference and triple difference (without matching) regressions estimating the effect of regulation on environmental performance with varying financial characteristics for high-diversified boards from 1997 to 2013. The dependent variable is environmental performance, i.e. ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. Treated is an indicator variable set to one if that firm had relatively low diversified board before SOX, and zero otherwise. Tobin_Q, Tangibility, NCSKEW and Advertising Expense are one-year lagged measures of respective controls. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3–4: The impact of SOX/RAC by industry, possibility of exposure with natural hazard and air quality ranking (by state)

	Panel A: Sub-sample by industry			
	Non-subject to TRI industries		Subject to TRI industries	
	(1)	(2)	(3)	(4)
$Treated \times PostSOX$	0.133		0.371***	
	(1.08)		(3.50)	
$Treated \times PostSOX \times RAC$		0.437**		0.447***
		(2.76)		(3.75)
Intercept	1.970*	1.777+	3.310***	3.423***
	(2.05)	(1.82)	(3.62)	(3.70)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes
Observations	2354	2354	4250	4250
adj. R-squared	0.151	0.165	0.263	0.267

	Panel B: Sub-sample by possibility of exposure with natural disasters (state cluster level)					
	More likely to be exposed group			Other group		
	(1)	(2)	(3)	(4)	(5)	(6)
$Treated \times PostSOX$	0.280*			0.257*		
	(2.57)			(2.28)		
$Treated \times PostSOX \times RAC$		0.454**			0.458***	
		(3.27)			(3.82)	
$Treated \times PostSOX \times RAC \times Record\_hazard$			0.056*			0.093***
			(2.07)			(4.02)
Intercept	4.892***	0.586	1.838	2.425**	3.766***	4.539***
	(5.00)	(0.60)	(1.49)	(2.70)	(4.03)	(4.16)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3150	2081	1929	3454	4523	4034
adj. R-squared	0.210	0.179	0.190	0.228	0.261	0.259

	Panel C: Sub-sample by air-quality (state cluster level)									
	1st rank		2nd rank		3rd rank		4rd rank		5th rank	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$Treated \times PostSOX$	0.685**		0.044		0.143		0.244		0.182	
	(2.96)		(0.25)		(0.48)		(1.53)		(1.38)	
$Treated \times PostSOX \times RAC$		0.484**		0.339+		0.662		0.413		0.140
		(3.32)		(1.78)		(1.24)		(1.53)		(1.08)
Intercept	4.124*	3.919*	2.427+	2.527+	5.035*	5.161*	5.273**	5.108**	1.857+	1.819+
	(2.44)	(2.35)	(1.77)	(1.80)	(2.07)	(2.07)	(2.83)	(2.73)	(1.78)	(1.70)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1168	1168	851	851	733	733	1439	1439	2262	2262
adj. R-squared	0.353	0.351	0.199	0.207	0.262	0.275	0.193	0.197	0.236	0.235

Notes: This table illustrates the results for sub-sample analyses. The dependent variable is ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. Treated is an indicator variable set to one if that firm had relatively low diversified board before SOX, and zero otherwise. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3–5: The impact of SOX/RAC and environmental achievement using Propensity score matched and Entropy balanced samples

	Propensity score matching		Entropy balancing	
Dependent variable: Environmental Performance Score (ENV_score)				
	(1)	(2)	(1)	(2)
$Treated \times PostSOX$	0.292**		0.327***	
	(3.15)		(4.31)	
$Treated \times PostSOX \times RAC$		0.375***		0.372***
		(3.91)		(6.21)
Intercept	2.944***	2.915***	1.450***	1.312***
	(4.12)	(4.10)	(3.31)	(3.03)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observations	5416	5416	6674	6674
adj. R-squared	0.228	0.232	0.731	0.732

Notes: This table illustrates the results from the difference-in-difference and triple difference (with matching/weighting samples) regressions estimating the effect of regulations on environmental performance for high-diversified boards from 1997 to 2013. The dependent variable is ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3–6: The impact of SOX/RAC with varying CEO and governance characteristics

	Dependent variable: Environmental Performance Score (ENV_score)			
	Panel A: CEO characteristics			
	(1)	(2)	(3)	(4)
$Treated \times PostSOX \times RAC$	0.388+	0.403***	0.408***	0.445***
	(1.80)	(4.26)	(4.00)	(4.28)
$Treated \times PostSOX \times RAC \times CEO\_tenure$	0.0350			
	(0.38)			
$Treated \times PostSOX \times RAC \times CEO\_change$		0.185+		
		(1.72)		
$Treated \times PostSOX \times RAC \times Female\_CEO$			0.156	
			(0.82)	
$Treated \times PostSOX \times RAC \times Non-white\_CEO$				-0.073
				(-0.56)
Intercept	3.002***	3.160***	3.184***	3.158***
	(3.84)	(4.47)	(4.49)	(4.47)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observation	4923	6604	6584	6584
adj. R-squared	0.232	0.238	0.238	0.238
	Panel B: Board characteristics			
	(1)	(2)	(3)	(4)
$Treated \times PostSOX \times RAC$	-0.050	0.296	0.058	1.160***
	(-0.30)	(1.31)	(0.19)	(4.30)
$Treated \times PostSOX \times RAC \times Analyst\_coverage$	0.022***			
	(3.78)			
$Treated \times PostSOX \times RAC \times Busyness$		0.342		
		(0.77)		
$Treated \times PostSOX \times RAC \times STDEV NoQuals$			0.383	
			(1.33)	
$Treated \times PostSOX \times RAC \times STDEV Age$				-0.100**
				(-3.27)
Intercept	3.364***	3.801***	3.871***	3.580***
	(4.81)	(4.60)	(4.66)	(4.34)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observation	6566	5849	5849	5849
adj. R-squared	0.242	0.246	0.247	0.250

Notes: This table presents the baseline results from the OLS regressions relating environmental performance score with varying CEO and board governance characteristics for U.S firms reporting to KLD from 1997 to 2013. The dependent variable is ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3–7: The impact of SOX/RAC with institutional investors

	ENV_score			ENV_str_num			ENV_con_num		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Treated \times PostSOX \times RAC$	0.620***	0.427***	0.517	0.574***	0.319***	0.599*	-0.046	-0.108+	0.082
	(4.18)	(4.45)	(1.57)	(3.76)	(3.76)	(2.09)	(-0.51)	(-1.94)	(0.42)
IOC_HHI	-0.352						0.187		
	(-1.13)						(1.44)		
$Treated \times PostSOX \times RAC \times IOC\_HHI$	-5.150+			-6.770*			-1.620		
	(-1.71)			(-2.26)			(-0.97)		
$\Delta BREADTH$		-0.350			-2.342*			-1.991*	
		(-0.24)			(-2.14)			(-1.96)	
$Treated \times PostSOX \times RAC \times \Delta BREADTH$		-7.582			-15.40+			-7.819	
		(-0.77)			(-1.70)			(-1.49)	
IOR			0.052			-0.170			-0.223**
			(0.40)			(-1.45)			(-3.02)
$Treated \times PostSOX \times RAC \times IOR$			-0.121			-0.374			-0.253
			(-0.29)			(-1.05)			(-1.11)
Intercept	3.200***	3.165***	3.126***	2.611***	2.648***	2.624***	-0.589+	-0.518	-0.501
	(4.54)	(4.44)	(4.42)	(4.34)	(4.37)	(4.37)	(-1.71)	(-1.48)	(-1.45)
Observations	6600	6600	6604	6600	6600	6604	6600	6600	6604
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
adj. R-squared	0.238	0.237	0.237	0.289	0.289	0.288	0.062	0.064	0.065

Notes: This table presents the impact of SOX/RAC with institutional investors towards environmental performance score of firms (total score, strength score, concern score, respectively). For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by $+$, $*$, $**$ and $***$ and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3–8: The impact of SOX/RAC and high environment performance on financial distress, cash flow volatility and earning management

	Panel A: Financial distress			
	Financial distress (1)	F.Financial distress (2)	F2.Financial distress (3)	F3.Financial distress (4)
$Treated \times PostSOX \times RAC \times High\_ENV$	-0.034	-0.052*	-0.053	-0.046
	(-1.42)	(-2.03)	(-1.44)	(-1.12)
Intercept	-0.807***	-0.736**	-0.771*	-0.444
	(-3.40)	(-2.88)	(-2.53)	(-1.37)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observations	6604	5821	5147	4517
adj. R-sq	0.142	0.074	0.052	0.051
	Panel B: Cash flow volatility			
	Cash flow volatility (5)	F.Cash flow volatility (6)	F2.Cash flow volatility (7)	F3.Cash flow volatility (8)
$Treated \times PostSOX \times RAC \times High\_ENV$	-0.009*	-0.012***	-0.010**	-0.010**
	(-2.56)	(-3.66)	(-3.19)	(-2.99)
Intercept	0.071	-0.012	0.028	0.087
	(1.57)	(-0.21)	(0.47)	(1.38)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observations	5519	5423	5117	4490
adj. R-squared	0.076	0.114	0.072	0.057
	Panel C: Earning management			
	DA_Jones (9)	F.DA_Jones (10)	F2.DA_Jones (11)	F3.DA_Jones (12)
$Treated \times PostSOX \times RAC \times High\_ENV$	0.011+	0.015**	0.005	0.008
	(1.77)	(2.63)	(0.71)	(0.84)
Intercept	0.071	-0.116+	0.022	0.056
	(0.80)	(-1.87)	(0.32)	(0.71)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observation	6496	5721	5058	4435
adj. R-squared	0.080	0.023	0.018	0.017

Notes: This table illustrates the results from the OLS regressions estimating the effect of climate risk regulations on financial distress probability, cash flow volatility and earning management of green firms from 1997 to 2013. The dependent variable is ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. Treated is an indicator variable set to one if that firm had relatively low diversified board before SOX, and zero otherwise. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3–9: The impact of SOX/RAC and financial crisis

	ENV_score		F.Financial distress		F.Cash flow volatility		F.DA_Jones	
	Exclude crisis time	2007-2009	Exclude crisis time	2007-2009	Exclude crisis time	2007-2009	Exclude crisis time	2007-2009
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Treated \times PostSOX \times RAC$	0.463***							
	(4.16)							
$Treated \times PostSOX \times RAC \times High\_ENV$		0.036	-0.055*	0.059*	-0.013***	0.006	0.007	0.041+
		(0.45)	(-2.07)	(2.34)	(-3.70)	(0.28)	(1.23)	(1.74)
Intercept	3.333***	-0.633	-0.835**	-0.199	-0.031	0.746**	-0.061	-0.271
	(4.03)	(-0.93)	(-3.08)	(-0.23)	(-0.55)	(2.81)	(-0.91)	(-0.59)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	5216	1388	4470	1351	4101	1322	4390	1331
adj. R-squared	0.276	0.028	0.072	0.093	0.089	0.344	0.028	0.076

Notes: This table cross-checks the results for the impact of SOX/RAC during and without financial crisis. The dependent variable is ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. Treated is an indicator variable set to one if that firm had relatively low diversified board before SOX, and zero otherwise. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by $+$, $*$, $**$ and $***$ and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Appendix

3.A Appendix A

Table 3.A.1: Description of variables used

Feature	Description	Source
	Panel A: Environment concerns	
ENV_score	The net score of environmental performance from MSCI ESG data, measured as total strength score minus total concern score	KLD
ENV_str_num	Total strength score for environmental performance of firm i in year t	KLD
ENV_con_num	Total concern score for environmental performance of firm i in year t	KLD
CO2 emission	Natural logarithm of total CO_2 emissions at state level during year t	S&P_Intelligence
SO2 emission	Natural logarithm of total SO_2 emissions at state level during year t	S&P_Intelligence
NOX emission	Natural logarithm of total NOX emissions at state level during year t	S&P_Intelligence
Totaldmg	Natural logarithm of total damage to property and crop in U.S. dollars at state level during year t	SHELDUS
Natural disaster records	Count of the natural disasters at state level during year t	SHELDUS
	Panel B: Board characteristics	
Race diversity index	The race diversity has four categories as identified in the Risk Metrics database: Asian, African American, Hispanic, and White. We use Blau's (1977) index of heterogeneity to measure diversity of board's racial diversity. Blau's index is calculated as $(1 - \sum P_i^2)$, where P_i is the proportion of board members in each of i number of categories.	ISS
Gender diversity index	The index of diversity for gender has two categories: male and female. We use Blau's (1977) index of heterogeneity to measure diversity of board's gender. Blau's index is calculated as $(1 - \sum P_i^2)$, where P_i is the proportion of board members in each of i number of categories.	ISS
Board Diversity	For each firm-year, this index is computed as Race diversity index + Gender diversity index	
Diversity change	Dummy variable that equals 1 if diversity index year t is different from year t-1	
CEO change	Dummy variable that equals 1 if CEO is also the founder	
CEO tenure	The total tenure of CEO serving in a firm	
Nonwhite-CEO	Dummy variable that equals 1 if CEO is not categorized as White in Ethnicity classification	ISS
Female CEO	Dummy variable that equals 1 if CEO is female	Execu & ISS
Busyness	Proportion of busy directors on the board. Busy directors are referred to those who are siting at least 3 boards	BoardEx & ISS
Analyst coverage	The number of analysts following the firm during year t	IBES
Turnover ratio	Turnover ratio is calculated as if any members of board in a year t is different with those in year t-1	
Institutional ownership (IO)	This is calculated taking all institutional shares divided by Total Shares Outstanding. This measure is scaled by 100.	TR-13F
Institutional concentration (IC)	This is captured by the Herfindahl-Hirschman Index that uses all institutional holdings of a particular security and conveys information about institutional ownership distribution. This measure is scaled by 100.	TR-13F
Institutional Breadth (IB)	This simply represents the number of institutions owning the stock during the quarter, and the change in IB reflects the net increase or decrease in the number of institutions. This measure is scaled by 100.	TR-13F
	Panel C: Firm Characteristics	

Table 3.A.1: Description of variables used - continued

Feature	Description	Source
Board size	Number of directors in a board for a firm in the current year.	Compustat
Firm age	Logarithm of one plus firm age, which is the number of years since the firm's initial public offering (IPO).	Compustat
Firm size	Natural log of book assets.	Compustat
Tangibility	Sum of investments and net Property, Plant, and Equipment (PP&E) divided by book assets.	Compustat
Leverage	Logarithm of one plus the ratio of total long-term debt plus total current liabilities over total assets.	Compustat
CAPEX intensity	Calculated as Capital Expenditure divided by total assets	Compustat
Cash Holdings	Cash and short-term equivalents divided by book assets.	Compustat
Dividend	Logarithm of one plus total dividend in a current year.	Compustat
R&D	Ratio of research and development expense to book value of assets	Compustat
Stock return volatility	Total stock return volatility in the last 24 months, which is square root of 24 multiplied by the standard deviation of monthly excess stock returns. Excess return is defined using a CAPM market model estimated over the prior year.	Compustat
Altman Z (Z)	Logarithm of one plus Altman Z-score. The Altman Z-score is calculated based on five financial ratios: profitability, leverage, liquidity, solvency and activity to predict whether a company has high probability of being insolvent. A score below 1.8 means it's likely the company is headed for bankruptcy, while companies with scores above 3 are not likely to go bankrupt.	Compustat
Financial distress	To capture the probability of financial distress, we use Altman's Z-score. Financial distress is a dummy varaible, taking value of 1 if Altman Z-score is lower than 1.8, and 0 otherwise. Common interpretation of Z Score:> 3.0 - safe based on these financial figures only;2.7 to 2.99 - On Alert; 1.8 to 2.7 - Good chances of going bankrupt within 2 years; < 1.80 - Probability of Financial distress is very high.	Compustat
Advertising Expense	Natural log of total advertising expense reported in year t	Compustat
NCSKEW	The negative coefficient of skewness of firm-specific daily returns over the fiscal year. See more details in the Complicated variable calculation section.	Compustat
Cash flow volatility	The rolling standard deviation of cash flow item over last three financial years. Cash flow = (Income Before Extraordinary Items (Cash Flow) + Depreciations)/Total Assets	Compustat
Earning smoothing	Discretionary accruals computed through the cross-sectional Jones (1991) model	Compustat
	Panel D: Other variables	
Treated (T)	Dummy variable indicating those firms owned a relatively high level of board diversity (RHD) before 2003 than control firms (C)	
SOX	Dummy variable that equals 1 since Sarbanes Oxley Act was released	
RAC	Dummy variable that equals 1 since Regional Climate Action Plan was enacted	

Table 3.A.2: State adoption of Regional Climate Action Plan

State	Regional Climate Action Plan	Timeline
Connecticut	First state global warming law to require specific actions for reducing CO2	1990
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont	Climate Change Action Plan (NEG_ECP), including short and long-term GHG emission reduction goals.	2001
North Dakota, South Dakota, Iowa, Wisconsin, Minnesota	Powering the Plains Initiative (PPI)	2002
California	AB 1493 and SB 812	2002
Delaware, Maine, New Hampshire, New Jersey, New York and Vermont	Regional Greenhouse Gas Inititative (RGGI)	2003
Arizona and New Mexico	Southwest Climate Change Initiative	2006
Washington, Oregon, Maryland	Western Coast Governors' Global Warming Initiative	2006
Amazon, New Mexico, Washington, Oregon, Maryland	Western Regional Climate Action Initiative	2007
Pennsylvania, Rhode Island, Massachusetts + RGGI states	Eastern Climate Registry	2008

Notes: This table presents the dates that Regional Climate Action Plan(RAC) was adopted. In 2001, at the same year when the George W. Bush administration announced about the Kyoto Protocol withdrawal, six New England states (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont) committed to the New England Governors and Eastern Canadian Premiers (NEG-ECP) Climate Action Plan with the goal of reducing GHG emission. In 2002, Powering the Plains Initiative (PPI) (Participating states: Iowa, Minnesota, Wisconsin, North Dakota, South Dakota, Canadian Province of Manitoba), a regional effort aims to develop strategies, policies, and demonstration projects for alternative energy sources and technology and climate-friendly agricultural development. In 2003, New York proposed and attained commitments from 9 Northeast states (Participating states: Maine, New Hampshire, Vermont, Connecticut, New York, New Jersey, Delaware, Massachusetts, Maryland, Rhode Island. Observer states and regions: Pennsylvania, District of Columbia, Quebec, New Brunswick, Ontario) to form the Regional Greenhouse Gas Initiative (RGGI), a cap and trade carbon dioxide emissions program for power generators. It is believed that the state-level program will apply pressure on the federal government to support Kyoto Protocol. Since February 2007, seven U.S. states and and four Canadian provinces have joined to create the Western Climate Initiatives (WCI), a regional greenhouse gas emissions trading system. The initiative was created when the West Coast Global Warming Initiative(California, Oregon, Washington) and the Southwest Climate Change Initiative (Arizona and New Mexico) joined efforts with Utah and Montana, along with British Columbia, Manitoba, Ontario, and Quebec.

Table 3.A.3: U.S President's attitude regarding climate change action (only author viewpoint)

President with tenure	(+)/(-)	Proof.
Bush (1989-1993)	(+)	Declared that the US fully intends to be the world's pre-eminent leader in protecting the global environment; Renewable energy production tax credit added to 1992 Energy Policy Act.
Clinton (1993 - 2001)	(+)	Climate Change Action Plan announced (1993); British Thermal Tax proposed (1993); Kyoto Protocol negotiated to sign in 1997; Clean Air Partnership Fund; Climate Change Technology Initiative
Bush (2001-2009)	(-)	Declared that U.S. won't implement Kyoto Protocol; Alternative plan for Kyoto Protocol; Suppressed discussion of global warming and pressured to under-report global warming; Consolidated Appropriation Act signed into law in 2007; several lawsuit filed over global warming, i.e, Massachusetts v. Environmental Protection Agency (EPA); California v. General Motors.
Obama (2009-2017)	(+)	Cap-and-trade legislation pass the House; US House of Representatives passed the American Clean Energy and Security Act of 2009 (but failed to pass the Senate); Climate Change Science Program; Clean Energy Standard (CES); Renewable Portfolio Standards (RPS); Congress passed National Flood Insurance Program Extension Act; Sunnylands summit (2013)
Trump (2017- 2021)	(-)	Announced withdrawal from Paris climate agreement; Ordered the EPA to remove references to climate change from its website, suppressed government publication of scientific reports showing the threat of climate change and the effectiveness of renewable energy and politicized decisions made at the EPA[21].
Biden (2021-now)	(+)	Since taking office, the Biden Administration has paused construction of the Keystone XL Pipeline (considered as very dangerous for climate) in addition to other actions on climate change, such as creating a National Climate Task Force and pausing oil and gas leases on public land.

Table 3.A.4: T-test statistics

	Female-dominated industries N = 7157				Male-dominated industries N= 10835				Difference	
	mean	sd	min	max	mean	sd	min	max	(t-test)	
ENV_score	0.085	0.625	-4	5	0.161	1.059	-5	5	0.101***	(7.47)
Gender diversity	0.194	0.134	0	0.497	0.179	0.137	0	0.500	0.0155***	(6.25)
Racial diversity	0.144	0.149	0	0.667	0.135	0.144	0	0.722	0.00841**	(3.16)
Diversity	0.336	0.228	0.000	1.086	0.312	0.217	0.000	1.037	0.0239***	(6.00)
Ln(Firm age)	2.910	0.587	1.386	4.174	3.270	0.643	1.386	4.159	-0.370***	(-35.37)
Tangibility	0.247	0.220	0.006	0.878	0.204	0.136	0.003	0.788	-0.134***	(-39.08)
R&D intensity	0.032	0.054	0.000	0.58813	0.053	0.057	0.00	0.680	-0.0223***	(-15.27)
Firm size	7.514	1.588	4.016	13.590	7.689	1.548	4.231	12.757	0.314***	(11.75)
Financial distress	0.428	0.495	0.000	1.000	0.332	0.471	0.000	1.000	0.0964***	(13.17)
Cash flow volatility	0.027	0.060	0.000	1.502	0.039	0.063	0.000	0.996	-0.0114***	(-10.34)

Notes: This table presents t-test statistics for two sub-samples, i.e, female dominated industries versus male-dominated industries. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

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[21]Sabine Center for Climate Change Law, Columbia Law School, Columbia University Earth Initiative, "DOE Reports Cancelled", "Release of Solar Energy Studies Blocked by DOE", "Scientific Research Subject to Political Interference at EPA", "EPA Science Advisors Excluded from Decision-Making"

Table 3.A.5: The impact of SOX/RAC by female-dominated versus male-dominated industries

	Female dominated industries		Male-dominated industries	
	(1)	(2)	(3)	(4)
$Treated \times PostSOX$	0.119		0.352***	
	(0.91)		(3.48)	
$Treated \times PostSOX \times RAC$		0.454***		0.458***
		(3.27)		(3.82)
Intercept	0.855	0.586	3.706***	3.766***
	(0.83)	(0.60)	(4.02)	(4.03)
Control variables	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Observations	2081	2081	4523	4523
adj. R-squared	0.159	0.179	0.256	0.261

Notes: This table illustrates the results from the difference-in-difference and triple difference regressions estimating the effect of regulations on environmental performance for high-diversified boards from 1997 to 2013. The dependent variable is ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. Treated is an indicator variable set to one if that firm had relatively low diversified board before SOX, and zero otherwise. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3.A.6: The impact of SOX/RAC on environmental concerns with greenhouse emission

	Dependent variable: Environmental Concern Score (ENV_con_num)		
	(1)	(2)	(3)
$Treated \times PostSOX \times RAC \times CO2\_emission$	-0.0114*		
	(-1.97)		
CO2_emission	0.0680+		
	(1.75)		
$Treated \times PostSOX \times RAC \times SO2\_emission$		-0.00628+	
		(-1.66)	
SO2_emission		0.0286+	
		(1.88)	
$Treated \times PostSOX \times RAC \times NOX\_emission$			-0.00663+
			(-1.89)
NOX_emission			0.0637*
			(2.18)
Intercept	-1.244*	-1.116**	-1.742**
	(-2.49)	(-2.59)	(-2.84)
Control variables	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes
Observations	6472	6472	6472
adj. R-squared	0.063	0.063	0.064

Notes: This table presents the baseline results from the OLS regressions relating environmental performance score with director turnover, diversity change and SOX/RAC implementation for U.S firms reporting to KLD from 1997 to 2013. The dependent variable is ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 3.A.7: Director turnover, SOX/RAC and environmental performance

|	Dependent variable: Environmental Performance Score (ENV_score)					
	(1)	(2)	(3)	(4)	(5)	(6)
$Turnover\_ratio \times PostSOX$	0.102*					
	(2.35)					
$Diversity\_change \times PostSOX$		0.0810**				
		(3.01)				
$Diversity\_change \times Turnover\_ratio \times PostSOX$			0.153*			
			(2.52)			
$Turnover\_ratio \times RAC$				0.205***		
				(3.77)		
$Diversity\_change \times RAC$					0.176***	
					(5.58)	
$Diversity\_change \times Turnover\_ratio \times RAC$						0.230**
						(3.10)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6596	5704	5703	6596	5704	5703
adj. R-squared	0.147	0.154	0.153	0.148	0.157	0.154

Notes: This table presents the baseline results from the OLS regressions relating environmental performance score with director turnover, diversity change and SOX/RAC implementation for U.S firms reporting to KLD from 1997 to 2013. The dependent variable is ENV_Score. PostSOX is an indicator variable set to one for 2002 and later, and zero otherwise. RAC is an indicator variable set to one for Regional Climate Action Plan adoption, and zero otherwise. The variable turnover ratio is calculated as if any members of board in a year t is different with those in year $t-1$. Diversity change is an indicator variable set to one if diversity index year t is different from year $t-1$. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

3.B   Appendix B
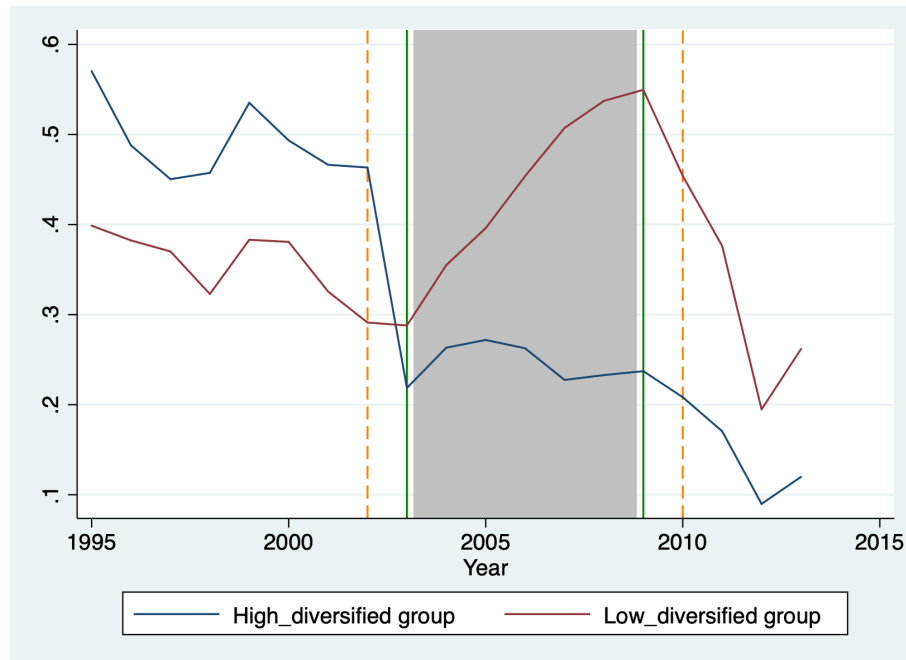
Figure 3.B.1: Board diversity and aggregated environmental performance over time
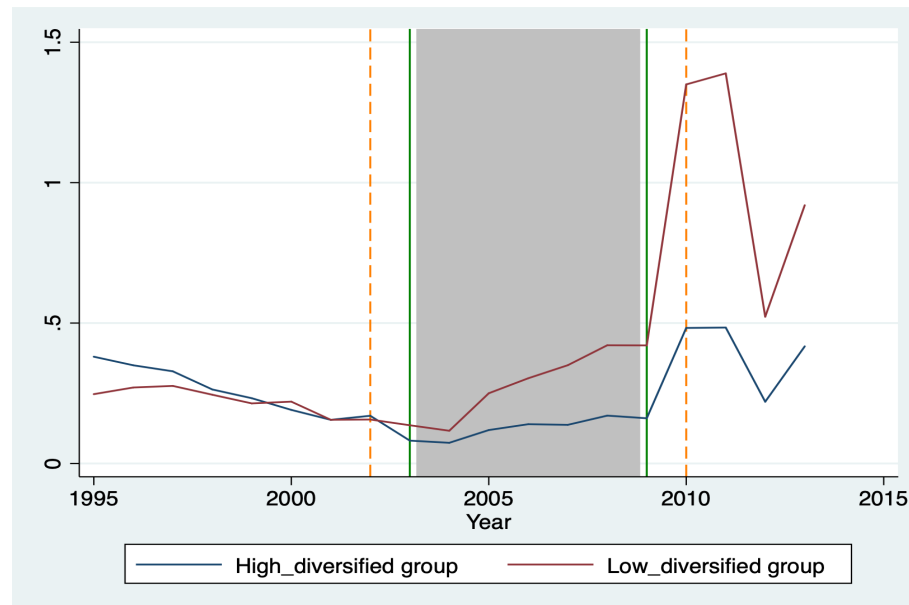
Figure 3.B.2: Environmental total strength (TS) score
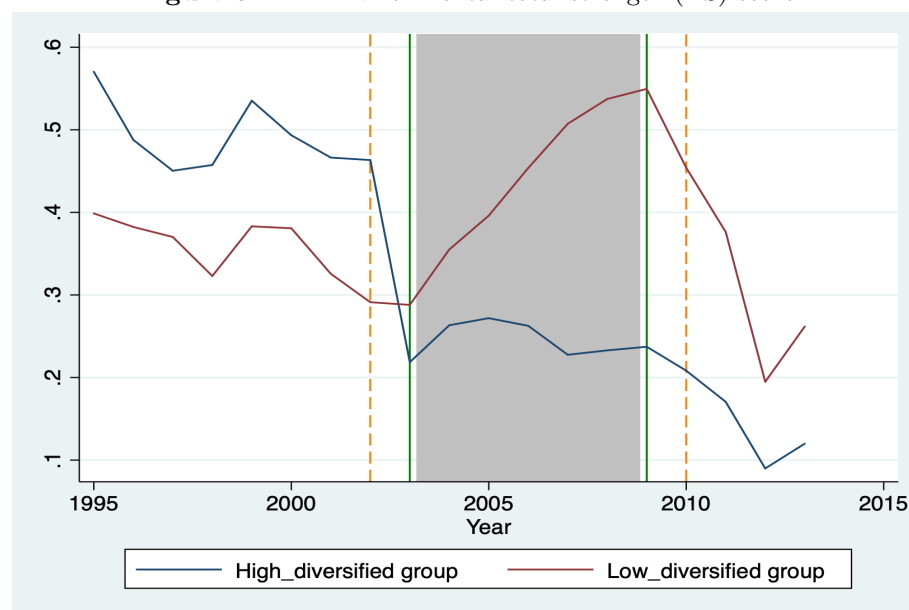
Figure 3.B.3: Environmental total concern (TC) score

Figure 3.B.4: Board diversity and environmental performance (TS-TC breakdown) over time

3.B.1   Regional Climate Action Plan (RAC)

The climate change policy of the United States (U.S.) has major impacts on global climate change and on global climate mitigation. This is because the United States is the second largest emitter of greenhouse gas (GHG) emissions per person in the world.

The body of climate change and greenhouse gas (GHG) emission legislation framework, in fact, have long been established in U.S. dating back to 1960s, to name a few, Clean Air Act in 1963, Clean Air Act Extension in 1970, and Clean Air Act Amendments in 1977 and 1990. Besides, many law bills failed to pass committee too, such as the Climate Protection Act and Sustainable Energy Act, proposed February 14, 2013.

Since the meddling time between Goerge H.W. Bush and Bill Clinton administration tenures (in the early 1990s), the U.S. have experienced many turns (often contrasting views) in its concerns and actions regarding climate change policy. Interestingly, each U.S's president marked their impacts on the national climate change regulations. For example, as observing from their different reactions for Kyoto Protocol (Bill Clinton and Goerge W. Bush) and Paris Agreements emission target (Obama and Trump) [22].

On the other hand, municipal and state governments have invested heavily in climate change policies. Rather than that, regional efforts can be more efficient than state-level programmes because they span a larger geographic area, minimise duplication of effort, and establish more uniform regulatory regimes. Several regional efforts have begun establishing mechanisms to minimise carbon dioxide emissions from power plants, improve renewable energy output, track renewable energy credits, and conduct research and set baselines for carbon sequestration during the last several years.

Particularly, in 2001, at the same time when the George W. Bush announced about the Kyoto Protocol withdrawal, six New England states[23] committed to the New England Governors and Eastern Canadian Premiers (NEG-ECP) Climate Action Plan with the goal of reducing GHG emission. In 2002, Powering the Plains Initiative (PPI)[24], a regional effort aims to develop strategies, policies, and demonstration projects for alternative energy sources and technology and climate-friendly agricultural development.

There are certain states that are extremely engaged in climate change action policy and frequently serve as the catalyst for adjacent states to join the regional legislative plan.

Connecticut was the first states in the U.S. to pass a number of bills in the early to mid 1990s, on global warming as well as state law to require specific actions for reducing CO2 emission. It then joined Climate Change Action Plan in 2001 with Maine, Vermont, New Hampshire, Massachusetts, and Rhode Island; and later participated in Regional Greenhouse Gas Initiative.

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[22]See detail in table 3.A.3

[23]Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont

[24]Participating states: Iowa, Minnesota, Wisconsin, North Dakota, South Dakota, Canadian Province of Manitoba

In 2003, New York state proposed and attained commitments from nine Northeast states to form a cap and trade carbon dioxide emissions program for power generators, called Regional Greenhouse Gas Initiative (RGGI). The successful implementation of RGGI model will set the stage for other states to join or form their own regional cap and trade systems and may encourage the program to expand to other GHG and other sectors. RGGI states, along with Pennsylvania, Massachusetts and Rhode Island are also developing a GHG registry called Eastern Climate Registry.

California is another active state with efforts to address global warming, independently of federal government. In July, 2002, Governor Gray Davis approved AB 1493, a bill directing the California Air Resources Board to develop standards to achieve the maximum feasible cost-effective reduction of GHG. Later on September 7th, 2002, California Climate Action Registry was approved. Also, the California Global Warming Solutions Act (commonly known as AB 32) was signed into law in September, 2006, mandating a reduction in GHG emissions to 1990 levels by 2020.

In 2006, Arizona and New Mexico states signed an agreement to create the Southwest climate Change Initiative while the West Coast states - Washington, Oregon, and California cooperated on a strategy to reduce GHG emissions, known as the Western Coast Governors' Global Warming initiative. In 2007, these five Western states (Washington, Oregon, California, Arizona, and New Mexico) agreed to combine their efforts to develop regional targets for reducing greenhouse emissions, creating Western Regional Climate Action Initiative.

As described in a 2007 brief by the PEW Center on global climate change, "States and municipalities often function as policy laboratories, developing initiatives that serve as models for federal actions. This has been especially true with environmental regulation-most federal environmental laws have been based on state models. In addition, state actions can have a significant impact on emissions, because may individual states emit high levels of GHG.

3.B.2   Complicated variable calculation

3.B.2.1   Institutional investors (IOC_HHI, $\Delta BREADTH$, IOR)

Following Chen et al. (2002), Sias et al. (2006), Lehavy and Sloan (2008) and Agarwal et al. (2009), we calculate different measures for institutional investor ownership. *Institutional Ownership, Concentration,* and *Breadth Ratios* are usually computed using

equity holdings by institutions which file 13F reports. *Institutional Ownership (IOR) Level* is calculated by adding up all shares for each security for each quarter, and IO Ratio is simply the IO Level divided by Total Shares Outstanding at quarter end.

Institutional Concentration (IOC_HHI) is captured by the Herfindahl-Hirschman Index that uses all institutional holdings of a particular security and conveys information about institutional ownership distribution.

Institutional Breadth (ΔBREADTH) simply represents the number of institutions owning the stock during the quarter, and the change in $\Delta BREADTH$ reflects the net increase or decrease in the number of institutions holding this specific security, possibly, because of informational motivations. In the computation of changes in Breadth of Institutional Ownership, we rely on the Lehavy and Sloan (2008) algorithm:

$$\Delta BREADTH_{i,t} = \frac{No.\_institutions_{i,t} - No.\_institutions_{i,t-1}}{No.\_institutions_{i,t-1}} \tag{3.3}$$

3.B.2.2   Stock price crash risk (NCSKEW)

Number of research publications, centred around the concept of crash risk in the financial market, has increased considerably nowadays.

Following prior literature (Kim et al. (2011), Kim et al. (2014), Kim and Zhang (2016)), we first estimate a time-series model for each firm and year using weekly stock returns, as shown below,

$$r_{i,t} = \alpha_i + \beta_1 r_{m,t-2} + \beta_2 r_{m,t-1} + \beta_3 r_{m,t} + \beta_4 r_{m,t+1} + \beta_5 r_{m,t+2} + \varepsilon_{i,t} \tag{3.4}$$

where $r_{i,t}$ is the return on stock i in week t and $r_{m,t}$ is the value-weighted market return in week t. Next, we calculate the natural log of one plus residue, $W_{i,t} = ln(1 + \varepsilon_{i,t})$.

We then estimate the negative conditional skewness of firm-specific weekly returns over a fiscal year (NCSKEW) via the following equation

$$NCSKEW = \frac{[n(n-1)^{(3/2)} \sum W_{j\tau}^3]}{[(n-1)(n-2)(_{j\tau}^2)^{(3/2)}]} \tag{3.5}$$

3.B.2.3   Financial distress (FD)

To capture the probability of financial distress, we use Altman's Z-score. Altman Z (Z) Logarithm of one plus Altman Z-score. The Altman Z-score is calculated based on five

financial ratios: profitability, leverage, liquidity, solvency and activity to predict whether a company has high probability of being insolvent.

$$AltmanZ - Score = 1.2A + 1.4B + 3.3C + 0.6D + 1.0E \tag{3.6}$$

Where:

- A = working capital / total assets

- B = retained earnings / total assets

- C = earnings before interest and tax / total assets

- D = market value of equity / total liabilities

- E = sales / total assets

A score below 1.8 means it's likely the company is headed for bankruptcy, while companies with scores above 3 are not likely to go bankrupt. *Financial distress* is a dummy variable, taking value of 1 if Altman Z-score is lower than 1.8, and 0 otherwise.

Common interpretation of Z Score:

- \> 3.0 - safe based on these financial figures only;

- 2.7 to 2.99 - On Alert;

- 1.8 to 2.7 - Good chances of going bankrupt within 2 years;

- \< 1.80 - Probability of Financial distress is very high.

3.B.2.4 Earning smoothing (DA_Jones)

Discretionary accruals computed through the cross-sectional Jones (1991) model (DA_Jones) through three steps below:

Step 1: Total accruals (TA) as follows:

$$TA_t = \frac{\Delta CA_t - \Delta CL_t - \Delta Cash_t + \Delta STD_t - Dep_t}{A_{t-1}} \tag{3.7}$$

where CA is current assets, CL is current liabilities, STD is the portion of long-term debt in current liabilities, Dep is depreciation and amortization expense, and A is total assets.

Step 2: The Jones Model for non-discretionary accruals NDA_t in the event year is estimated by running the following regression:

$$NDA_t = a_1(1/A_{t-1}) + a_2(\Delta REV_t/A_{t-1}) + a_3(PPE_t)/A_{t-1} + \varepsilon_t \qquad (3.8)$$

where: NDA_t is non-discretionary accruals in year t scaled by lagged total assets; REV_t is revenues in year t less revenues in year t - 1; PPE_t is gross property plant and equipment at the end of year t; A_{t-1} is total assets at the end of year t - 1; and a_1, a_2, a_3 are firm-specific parameters.

Step 3: The difference between the predicted and actual values of total accruals is the discretionary accruals (DA_t) arising from managers' choice of accounting rules and procedures.

$$DA_t = TA_t - NDA_t \qquad (3.9)$$

3.B.3 Female dominated versus male dominated industries

According to Industry Canada (2003), there is below-rate participation by female majority owners in the manufacturing and knowledge-based industries and the agriculture, forestry, and energy sectors in Canada. While survey also show that women are under-presented in the manufacturing, construction, transportation and agricultural sectors in the U.K. (CUMMING ET AL. (2015)), similar patterns are found in the U.S.[25] Consistently, we use a dummy variable to categorize two group of sectors, female dominated versus male dominated. We then split the whole sample based on that dummy and report the results for each sub-sample. We present summary statistics for two sub-sample, i.e., those firms in female-dominated industry versus male-dominated industry in Table 3.A.4. On average, firms categorized in female industries have higher environmental scores, younger, bigger in size, hold less tangible assets, have less cash flow volatile and invest less in R&D comparing with male-dominated peers. The results in Table 3.A.5 show that while SOX only affect male dominated sample, RAC have a consistent effect on both groups.

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[25]https://www.bls.gov/opub/reports/womens-databook/2020/home.htm (By industry, women accounted for more than half of all workers within several sectors in 2019: education and health services (74.8 percent), other services (53.9 percent), financial activities (52.6 percent), and leisure and hospitality (51.2 percent). (Other services include repair and maintenance industries, personal and laundry services, membership associations and organizations, and private households.) However, women were substantially underrepresented (relative to their share of total employment) in manufacturing (29.4 percent), agriculture (26.2 percent), transportation and utilities (24.1 percent), mining (15.8 percent), and construction (10.3 percent)). (See Table 14).

3.B.4 The impact of SOX/RAC and GHG emission

Table 3.A.6 present the implication of RAC enactment and GHG emission. If a business is located in a state with high emissions, particularly if there are numerous heavy or dirty factories in the area, or if the business is classified in those sectors, an environmental concern score is a better direction to follow. We find that those local action plans play important role in mitigating the environmental concern score. As such, the coefficients of interaction terms are all negative and significant at least at 10% level.

3.B.5 The impact on environmental performance following board turnover and diversity change

Additionally, we cross-check (our baseline results) to determine whether the structural changes in board diversity contributed to the improvement in environmental performance following SOX and RAC implementations. Results are demonstrated in Table 3.A.7. In general, these results confirm that board structural changes (proxied by director turnover or diversity change) jointly with regulation interventions are driven factors to increase in environmental performance.

Chapter 4

Geopolitical risk, R&D Cut and Firm innovation

This study investigates the mechanism by which geopolitical risk influences firm innovation. Given existing notions that company investment is reduced during uncertain periods, we are inclined to investigate the interaction or moderating effects. We discover that the immediate effect of REM in t+1 and non-REM cutback in t+3 under uncertain time have significant impacts on innovation output in the US sample. Meanwhile, we document indifferent effects from REM and non-REM cutbacks in 10 EU countries where abnormal R&D cut all reflect in the t+2. Our findings support the presence of corporate life-cycle theory: there are divergence of outcomes from R&D cut strategies in different stages under effects of geopolitical risk. We reveal that companies engaging earnings management to mitigate geopolitical risk are more likely to stifle innovation during the birth and growth phases. We also discover that a higher degree of U.S military involvement in global geopolitical risk is associated with lower firm innovation. Our results are robust to endogeneity concerns.

JEL Classification: D81, G32, O32

4.1 Introduction

Interest in innovation has been growing since the early of 1980s. It has been shown that technological innovation is vital for a country's economic growth and a firm's long-term competitive advantage (Schumpeter (1911); Solow (1957); Romer (1986); Porter (1992); Klette and Kortum (2004); He and Tian (2018); Akcigit and Kerr (2018); Acemoglu et al. (2018)). Chang et al. (2016) document that a one-standard deviation increase in patent stock per capital is associated with a 0.85% increase in GDP growth. Given the importance of innovation for economic growth, there is a large literature that focuses on the differences in incentives of innovative firms and their characteristics, such as the development of financial markets (Hsu et al. (2014)), access to stock markets (Acharya and Xu (2017)), firm strategy (Hoskisson and Hitt (1988); Baysinger and Hoskisson (1989); Baysinger et al. (1991)), internal and external finance (Himmelberg and Petersen (1994); Brown et al. (2009); Hall and Lerner (2010); Brown and Petersen (2011)), anti-takeover provisions (Atanassov (2013)), the choice of financing (Atanassov (2016)), corporate income taxes (Atanassov and Liu (2016)), and corporate tax credits (Bloom and Van Reenen (2002); Rao (2016)); credit supply (Chava et al. (2013); and Cornaggia et al. (2015)), and law and legal systems (Acharya et al. (2013); Francis et al. (2018)).

Though finance or optimal R&D investment has been seen as vital part of innovation process, yet it is not always clear that innovative firms are able to access the finance they need, as well as optimally invest their limited resources in R&D. Therefore, identifying optimal R&D investment has been one of the main research subjects. Generally, R&D investment can be influenced by both internal and external factors, such as firm size, cash flows, management strategy or market competition, economic situation or investment opportunities. Although under real options theorysee Trigeorgis et al. (1996), uncertainty can reduce investment owing to asymmetric adjustment costs, convex return theory[1] suggests uncertainty can raise investment via a convexity channel if the product market is competitive and production returns to scale are non-decreasing. Recent disputes, geopolitical events and economic downturns whose consequences have not yet measured raise concerns about the impact on firm innovation and performance overall. Using the same measurement for GPR, Hao et al. (2020) uncover negative relation between geopolitical risk and acquisition activity while Pan (2019); Wang et al. (2019) ; Le and Tran (2021) all agree that GPR impacts firm investment in R&D.

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[1] "Convexity of Production Sets" theory and it was developed by economists Joseph Stiglitz and Martin Weitzman in the 1970s

It is also necessary to consider R&D investment in conjunction with the motivation of managers engaged in earning management, because managers are incentivised to change financial reporting in order to meet/exceed shareholder expectations, issue more debt/equity, and earn higher compensation. For example, BABER ET AL. (1991) find that US managers cut R&D in order that their firms report positive and increasing earnings. DECHOW AND SLOAN (1991) indicate that R&D development is negatively associated with the horizon problem, measured as the CEO's final years in office. BUSHEE (1998) shows that institutional ownership mitigates managers' myopic investing behaviour to some extent but if transient institutional investors possess a high proportion of shares, their monitoring role is weakened. OSMA AND YOUNG (2009) discuss whether short-term earnings pressure is the reason why UK managers are pressed to cut R&D spending and how the market reacts to such behaviour. Unlike Accrual Earning Management (AEM), which involves changing how transactions are presented in financial accounts, Real Earning Management (REM) modifies the underlying business operations, such as selling assets or reducing discretionary expenses. Therefore, REM is more difficult to detect (by external auditors) than AEM. In addition, it becomes a challenge in research to identify and differentiate REM, especially in the case of R&D expenditures. Thus, abnormal R&D cut backs and their repercussions have become a hot topic in recent years, see MUDAMBI ET AL. (2015); PAPPAS (2016); PETACCHI AND PETACCHI (2016); VORST (2016); BERESKIN ET AL. (2018); CHOUAIBI ET AL. (2019).

Simultaneously, there are contrasting views about the impacts of R&D cuts. While some researchers argue that REM-related R&D cuts is negatively associated with firm innovation, see BERESKIN ET AL. (2018), VORST (2016) reports about the reversal characteristic of REM-related R&D cuts, and illustrates that firms revert R&D cutbacks in the next financial year to mitigate the long-run economic costs. Discussing exploitation and exploratory types of innovation, MUDAMBI ET AL. (2015) conclude that sometimes cutting R&D spending can yield more innovation. According to the research conducted by CURTIS ET AL. (2020), there exists diminishing marginal returns to R&D investments, which aligns with the growing competition within the realm of innovation. Given the inherent uncertainty of R&D, a portion of R&D expenditures may not be productive, and may not yield valuable patent output. To address this, managers may opt to eliminate these wasteful expenses in order to address short-term pressures from external stakeholders, while not compromising the future prospects of the organization. The same rationale applies for CEO's "pet" projects to promote her/himself career prospects (see ALMEIDA ET AL. (2013)).

This study investigates the mechanism via which firms' response to geopolitical risk might impact companies' ability to produce patents. We use patents and accounting/ financial data

for US and 10 EU countries in our study ranging from year 1985 up to 2020. We employ difference-in-difference approach to evaluate how the interaction between country-level geopolitical risks and abnormal R&D Cut curtail in-house innovation output. We begin by adopting the country-specific geopolitical risk (GPR) indices introduced by Caldara and Iacoviello (2022). GPR reflects large effects on the economy, allowing us to observe different phases (when the index indicates high or low risk), but the GPR index is a continuous news-based index[2]. Therefore, we derive the country-specific geopolitical risk measure as developed by Caldara and Iacoviello to compute for "extreme-event" risks. We construct abnormal R&D Cut based on previous studies[3].

We find that greater geopolitical risk and higher abnormal R&D cutbacks result on lower firm innovation output. The absolute value of REM-related cutbacks are higher than non-REM. Besides, the former has immediate effects since t+1, while the latter starts impede in-house innovation output in t+3. Additionally, we see that firm size positively impacts on the number of patents issue while firm age is negatively associated with the number of patents issued. These results imply that while large firms keep spending more on R&D and generating more innovation in absolute terms; small firms, well-known to involve deeper in explorative innovation through R&D investments, are hit worse when shocks occur and less effective in receiving financial aid.

Similarly, Paunov (2012); Lee et al. (2015); Schmitz (2016); Acemoglu et al. (2018); Akcigit and Kerr (2018) illustrate that smaller firms are, on average, more susceptible to financial shocks despite being more inventive than their larger counterparts. Also, limited collateral value and asymmetrical information between firms and investors can make it very hard for businesses to get external funding in the beginning phases. That heterogeneous effect exacerbates the consequences of a shock and explains its broader crisis response, which adds to the subsequent sluggish growth. Xu (2020) provides novel evidence that higher uncertainty hinders innovation not only through the traditional investment irreversibility channel, but also through the cost-of-capital channel, particularly for high-tech firms and small firms. Acemoglu et al. (2018) take the view that firms are heterogeneous in their innovative capacities. They assume that firms change over time and, in particular, highly innovative firms can drop to low innovation, accommodating the possibility that firms that have grown large over time may have ceased to be innovative. This notion is similar

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[2]We argue that when using quarterly aggregated GPR, the endogeneity issues should be considered. We also report in Appendix: Another approach section the results of IV-GMM analysis where the endogeneity test confirm that data fact.

[3]see e.g. Bereskin et al. (2018); Gunny (2010).

to the long-established firm/industry life cycle theory in organization and the strategic management literature.

Small firms (those that survive) are presumably relatively more innovative during the early life-cycle stages. The distribution of innovations between new and incumbent firms changes over the life cycle with consequences for entry barriers and the probability of survival for new firms. While large firms can have the innovative advantage in markets characterized by imperfect competition, small firms can gain advantage in highly innovative industries. Innovation is a vehicle for new firms to enter the market successfully and undermine established firms. Meanwhile, the latter also needs to innovate to maintain their positions. Moreover, instead of conducting R&D in-house, large firms can outsource R&D investment to small firms and then acquire those that successfully innovate (PHILLIPS AND ZHDANOV (2013)). What is more, they are also more effective at obtaining subsidies during times of economic slowdown (SCHMITZ (2016); ACEMOGLU ET AL. (2018); AKCIGIT AND KERR (2018); STOFFMAN ET AL. (2020)).

In addition, it has been shown that small innovating firms generate more innovations per dollar of R&D than large ones (COHEN AND KLEPPER (1996b)), have higher ratios of R&D to sales and patents to employees and their patents are, on average, more cited and more likely to represent major breakthroughs (AKCIGIT AND KERR (2018)). BONAIME ET AL. (2018) and NGUYEN AND PHAN (2017) present evidence that, during periods of high uncertainty, wealth transfers from the financially constrained targets to acquirers. SCHMITZ (2016) indicates that financing constraints during a crisis cause misallocation of innovation investment and lead to a persistent rightward shift in the size distribution of innovating firms, which continues to depress innovation in the aftermath of a crisis. STOFFMAN ET AL. (2020) argue that an innovation premium exists among small firms, but not large firms, because small innovators focus more on risky product innovation and rely more on organization capital, which amplifies their systematic risk. In addition, small innovators contribute significantly to the size premium. The higher cost of equity for small innovators has implications for their investment, growth and capital structure decisions.

Our study contributes to growing body of knowledge about the impact of geopolitical risk on firm innovation. We also add to the stream of literature that examines the effects of uncertainty on firm growth (NGUYEN AND PHAN (2017); PAN (2019); XU (2020); HAO ET AL. (2020)). Our research is close to the work of XU (2020) who investigate the effect of economic uncertainty on corporate innovation, as well as NGUYEN AND PHAN (2017) and BONAIME ET AL. (2018) who investigate the relationship between uncertainty and M&A activities. However, we note that the variable of interest in our research is geopolitical

risk uncertainty proxied by the GPR index, whereas Nguyen and Xu's variables of interest are EPU/ BBD indices (Baker et al. (2016)), which are different in measurement, time frame, and implications.

Next, this study contributes to the literature that explores the real effect of abnormal R&D Cut and earning management literature. Not only focusing on a different type of uncertainty - geopolitical risks, which are typically wide and observable, we also examine the implications of abnormal R&D cutbacks, which suggests a channel affecting innovation output. As the literature of AEM/REM is developing, particularly the measurements/detection of REM is still controversial, the findings from our study expand and support for studies of Roychowdhury (2006); Gunny (2010); Vorst (2016) and Bereskin et al. (2018).

Third, our findings also add to the several different literatures of FLC theory. By exploiting the firm life-cycle theory in organization and management sciences, we complement the literature strand of Schmitz (2016) and Acemoglu et al. (2018), and show how our work connects this unifying framework to the growing body of literature on endogenous growth.

Finally, given the significance of current geopolitical disputes[4] as well as an attempt to extend our study, we decide to apply the aforementioned empirical analyses into the EU context after combining data from PATSTAT and COMPUSTAT (EU). Contrary to its counterpart (the United States), geopolitical risks in the European region are influenced not only by local geopolitical risks, but also by regional events that have indirect regional repercussions on neighbouring EU nations due to their high interconnectedness.

Despite having addressed these factors, our study remains limited in certain aspects. First, given that the majority of the newspapers from which Caldara and Iacoviello collect keywords are from English-speaking countries (the United States and the United Kingdom), there is a high likelihood of bias in using GPR measurements. Nevertheless, the difference-in-difference design and derived measurements of country-specific GPR can mitigate this drawback[5]. Next, there is an obvious limitation in the company name matching ML algorithm that we use when matching COMPUSTAT (EU) companies and the PATSTAT database. We

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[4]Being viewed via geographical perspectives, US has reaped the benefits of its fortunate geographical location and natural resource endowment for more than two centuries, it also was the world's biggest economic and military post-war power while Europe was drained and in ruins. Many people thought Western Europe was 'post-conflict' after two world wars, seven decades of peace, and the fall of the Soviet Union. This may still be true in the future, but potential sources of conflict bubble under the surface, and Europeans and Russians may clash (Ukraine-Russia war is an example). The 2008 economic downturn decreased European nations' capabilities and widened the Eurozone's ideological rift.

[5]Before following DID, we attempted IV-GMM identifications and we shall discuss this in the Extra tests and reports IV-GMM results in Appendix sections.

describe in detail the matching algorithm in the Appendix and welcome any external contributions to improve it. Additionally, the limitation of available data or empirical setting for the EU can be the case. Therefore, unlike US analyses, we cannot detect the difference between R&D cuts related to REM and non-REM cutbacks in terms of time lag. In another word, the main findings of the US sample are not applicable in any other countries, which opens room for international researchers with their better knowledge about patent data to explore in the future. This could be because the EU and US have different accounting rules or managers engage in REM/AEM differently between the EU and US. Additionally, the limitation of available data or empirical setting for the EU can be the case.

The rest of the paper is organized as follows: Section 4.2 provides background and a comprehensive review of related literature; Section 4.3 contains variable definition and shows descriptive statistics; Section 4.4 discusses methodology; Section 4.5 reports the baseline results, difference-in-difference (DID) analysis and firm-life cycle analyses; Section 4.6 reports extra analyses; Section 4.7 concludes.

4.2 Literature Review and Hypotheses Development

4.2.1 How R&D cuts affect Firm innovation under Geopolitical risk?

Exogenous shocks, such as war or terrorist attacks, cause economic instability through a variety of channels, including death toll, physical capital destruction, defense spending, or increased precautionary behaviour. On the global scale, Kaldor et al. (2021) describes the contrast between "new war" and traditional Clausewitzean war and concludes that geopolitical competition nowadays is more likely to take the form of imaginary war, in which participants have a stake in continued violence and conflicts tend to persist "forever". Geopolitical risks or threats therefore can hamper post–crisis economic recovery in productivity, leading to sluggish growth in its aftermath as higher geopolitical risk is associated with higher probability of economic disasters and with larger downside risks to the global economy. (Julio and Yook (2012); Gulen and Ion (2016); Schmitz (2016); Nguyen and Phan (2017)).

On the national or regional scale, previous research has discovered a statistically significant and unfavourable relationship between a risky or unstable political environment and foreign direct investment (FDI), as such politically unstable countries tend to be less capable of attracting investment, developing human capital, and supporting enterprises. Long-term

collaborative partnerships between government, industry, and universities—the ecology of innovation—cannot emerge in the midst of large-scale social upheaval, civil conflict, and violence, which discourages investment (Nigh (1985); Agarwal and Ramaswami (1992); Leydesdorff and Meyer (2006); Allard et al. (2012)).

With industry- and firm- level analysis, Wang et al. (2019); Pan (2019); Le and Tran (2021); Caldara and Iacoviello (2022) show that high level of GPR lowers investment. Thus, those confounding uncertainty can exacerbate firms' financial constraints and increase the cost of external financing (Greenwald and Stiglitz (1990); Pástor and Veronesi (2013); Gilchrist et al. (2014); and Brogaard and Detzel (2015)) and increase managerial risk aversion (Panousi and Papanikolaou (2012)). Therefore, GPR might induce favorable conditions for outcomes of brand-new inventions, new products or substitute the manufacturing line/productivity in post-war/ post-crisis time. On the other hand, geopolitical risk is believed to suppress and curtail innovation by aggravating the economic uncertainty affecting firms near the attacks and by worsening the uncertainty about personal security faced by their inventors (see also Lock-Pullan (2005); Kopytov et al. (2018);Argente et al. (2018);Fich et al. (2019); Gross and Sampat (2020)).

Pointing to changes in risk-taking ability and inventors' mobility, Habiba (2020) documents a negative impact of GPR on corporate innovation. Using the same measures of innovation outcome (i.e. number of patents and number of citation), Dissanayake and Wu (2021) construct a measure for GPR using both narrative-based and newspaper frequency-based measures, finding that GPR are more pronounced in firms whose income are foreign-derived. The relationship between GPR and innovation is robust using different measures of innovation outcome (i.e. the financial value of patents granted to the company)[6]. As such, among sources of uncertainty, GPR has eventually gained attention in decision-making process of both managers and investors by manifesting its effect on firms' outcome. A survey by Giambona et al. (2018) shows that the common strategy to hedge against GRP is to not invest in areas having higher level of geopolitical uncertainty. The divestment strategy might subject a branch located in foreign territory to lack of financial and human capital to achieve breakthrough investment, which aggravates the detrimental effect of geopolitical uncertainty.

As it is widely assumed that R&D supports innovation and productivity growth, the number of research topics for R&D investment and firm patents has increased since the early 1980s. Specifically, R&D is generally viewed by many innovation researchers as an input for internal innovation, from which results are typically measured by the number of patents

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[6]https://hbr.org/2022/03/research-when-geopolitical-risk-rises-innovation-stalls

granted or the number of citations. Scholars in the field of innovation have grounded some characteristics of R&D investment (1) R&D is financed mostly by internal capital (cash is preferred) due to asymmetric information problems (such as adverse selection or moral hazard) and expensive external sources (as no bankable collateral) (2) long opened time lags (3) uncertainties (from both internal progress and external factors) (4) under-investment problem: due to financing difficulties, R&D investment is kept well below the socially optimal level (see BAKKER (2013); KANG ET AL. (2017); BROWN ET AL. (2017) for discussion).

On the other perspective, R&D expense manipulation due to managers' subjective will is widespread in accounting literature. COHEN AND ZAROWIN (2007); RAJGOPAL ET AL. (2007) show that firms tend to manage earnings to meet investors' earning benchmarks by manipulating either accruals or real transactions, in which economic state is *a priori* condition shaping market participants' expectation of earnings. While accrual earning management (AEM) relates to the exercise of accounting discretion allowed by GAAP to purposefully intervene reported earnings; real earning management (REM) involves transactions adjusting timing and scale of underlying activities within the course of business (see XU ET AL. (2007)). Due to its characteristics, REM is less visible than AEM, which causes it more difficult for auditors or regulators to scrutinise.

In addition to its desirability of reporting over- or under-stated real reported earnings, REM is linked with lower future performance (COHEN AND ZAROWIN (2010), increasing cost of capital (KIM AND SOHN (2013)), and higher future stock price crash risk (FRANCIS ET AL. (2016)). Scholars have been disentangling the effect of earnings management on the outcome of innovation as cutting expenditure on R&D is one of the discretionary choices that managers can exercise to beat earnings benchmarks. BUSHEE (1998), mentioned in ROYCHOWDHURY ET AL. (2019), provides evidence pointing to managers' readiness to trade off future R&D advantages in order to avoid short-term revenue reductions. In addition to R&D, managers can engage to other business activities, such as price discounts, overproduction, or reduction of discretionary expenses - selling, general, and administrative expenses) to not report losses (ROYCHOWDHURY (2006)).

The decision of engaging REM by sacrificing future benefits of innovation to beat the short-term earnings benchmark has attracted efforts to investigate the effect on innovation outcome. BERESKIN ET AL. (2018) document a reduction of patent output and innovative efficiency relating to R&D cuts in earnings management. Classifying R&D cuts into earnings management driven and other abnormal reasons, the authors find that the former has a more severe impact on innovation output and efficiency relatively to the latter. Two

explanations are offered to explain for the results (i) when cuts are motivated by meeting earnings benchmark, the results are by definition more costly than operational purpose; and (ii) managers might create "pet" project to meet short-term investment goals, which might have unnecessary and wasteful outcome. Zhu (2021) finds a similar result in the context of state-owned and non-state owned enterprises in China setting.

Despite the established impact of GPR and R&D cuts on innovation outcome separately, there has been no attempt to look into the interplay of R&D cuts when geopolitical risk intensifies. We intend to fill this void in particular by investigating how managers engage to R&D cuts driven by earnings management motive as a channel to affect innovation output during the period of heightening geopolitical uncertainty. As geopolitical uncertainty lies beyond the control of firms, its exogeneity has offered a unique setting to cleanly deduce the causal effect on the reduction of patent numbers and citations. Our effort fits into the literature by pointing out that R&D cuts arisen from real earning management motivation is a channel hurting innovation outcome when GPR heightens.

- *H1: Under geopolitical effects, abnormal cutting R&D yield less innovation*

4.2.2 Effects of R&D cutbacks in different life stages: revisited

Geopolitical risk is a key element that can have a detrimental influence on economic activity, causing the business and financial cycles to weaken. This can result in financial and labor-supply shocks disrupting a firm's cash flow and a lasting drop in aggregate innovation following a crisis. Furthermore, the magnitude of these shocks might differ based on the stage of the firm's life cycle (see Sharif et al. (2020); Mansour-Ichrakieh and Zeaiter (2019)).

Firm life-cycle (FLC) theory is long-established even dating back to the 1950s. Since then, the literature concentrating on firm's life-cycle has been developed extensively. Miller and Friesen (1984) systematise a cycle consisting of five distinct stages[7] through which a firm would eventually evolve throughout its life. Jawahar and McLaughlin (2001) link stakeholder theory to firm life-cycle by pointing out the cruciality of identifying the importance of one stakeholder group relative to another in each stage. Building on the same theory, Moores and Yuen (2001) show the complementary role of management accounting systems to organizational characteristics matters in all within- and across life-cycle stages. Activity-based costing proved to differ among firms in different stages (Kallunki and

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[7]i.e. birth, growth, maturity, revival, and decline

Silvola (2008)). Understanding the current position of a firm's maturity not only aids managers to create competitive advantage, but also enhances performance (Lester et al. (2003)).

Firms in the birth stage are typically small, with low profits, dominated by their owners (entrepreneurs), simple, informal in structure, undifferentiated and with highly centralized power systems and considerable focus on innovation, with the purpose of identifying a feasible market segmentation so as to maintain the on-going status (Miller and Friesen (1984); Kallunki and Silvola (2008)).

Firms at the growth stage are typically medium sized with multiple shareholders, and achieving rapid growth. In addition, characterising with insufficient capital but having promising potentiality to develop, firms establish their brand identity and market share in the growth stage, invest strongly in expansion projects (Hasan and Habib (2017); Hasan et al. (2018); Dickinson (2011)). Due to product differentiation, firms will undergo a period of higher revenue and profit margin (Selling and Stickney (1989). Managers are given more decision-making responsibility, and a separation of ownership and control begins to emerge (Mueller (1972); Miller and Friesen (1984)). As a result, firms experiencing growth attract more attention from both analysts and different stakeholders to reduce information asymmetry (Barth et al. (2001)).

Mature and declining firms are less likely to take on innovative or risky strategies than in their birth and growth stages. In these later stages, Mueller (1972) argues, internal fund flows exceed investment opportunities, and the cost of capital declines as uncertainty diminishes, notwithstanding lower returns when compared to prior stages. Mature firms aim for the smooth functioning of the business in a well-defined market. Despite reduced returns, these corporations generate positive cash flows and over-invest in core business (which might take on inefficient M&A) (Jensen (1986)).

Firms in decline are encroaching stagnation and suffer from low profitability and predominantly adopt a 'harvest' strategy where the main aim is the collection of as much cash from existing operations as possible (Thietart and Vivas (1984)).

After revising the life-cycle theory, we are curious about how to position the life-cycle theory in the context of geopolitical risk and abnormal R&D Cut? Geopolitical risk is a key element that can have a detrimental influence on economic activity, causing the business and financial cycles to weaken. This can result in financial and labor-supply shocks disrupting a firm's cash flow and a lasting drop in aggregate innovation following a crisis. Furthermore, the magnitude of these shocks might differ based on the stage of the firm's life cycle.

Classifying innovation into two types: *internal* and *external*, Akcigit and Kerr (2018) attribute the former to make improvements on current products, while the latter to create new products and capture new market share. The heterogeneity in innovation types links with firm size, at which large firms tend to focus on generating internal improvements; whilst entering entrepreneurs make exploratory innovation as they do not have products to improve. The results are in line with Cohen and Klepper (1996a), which furthers that proportion of R&D rises with firm size. In addition, large firms, with abundance of capital, might increase their share of patented invention by acquiring smaller firms. In addition to providing a theoretical model, Phillips and Zhdanov (2013) empirically confirm the findings that large firms outsource innovation process to small firms, and subsequently acquire those with successful outcome. Such course of action has altered the landscape of entrepreneurial market by stimulating competition amongst small firms to seek opportunities for exit strategy. Prior technological linkage to targets positively determines the incidence of transaction (Bena and Li (2014)), and firms potentially for being acquirers are less innovative and have a declining innovation output within the last three years (Zhao (2009)). Nevertheless, Valentini (2012) documents an increase in the number of patent output, but a reduction in patent impact, originality, and generality via M&A transactions.

As sizes of firms are gradually evolving during stages of a life life-cycle, there has been recent attempt to reconcile innovation behaviour throughout different stages of firm life-cycle. Subject to liquidity constraints, idiosyncratic risk, and cash flow risk, Shahzad et al. (2022) find that firms tend to make more innovation input regardless of any stages; whilst generate more innovation output during growth and mature stages. Despite cost of capital is higher during introduction and decline, and lower in growth and mature stages (Hasan et al. (2015)), firms would thrive to achieve first-mover in market to secure its entering position as suggested by Wernerfelt (1985) and Acs and Audretsch (1987). On the other hand, firms in the mature stage with abundance of free cash flow might be reluctant in investing to innovation-oriented goals but rather maintaining its assets (Richardson (2006)). Using U.S. publicly traded firms from the early 1980s to the mid-1990s, McGahan and Silverman (2001) find contrary evidence suggesting that innovation activities in mature and emerging industries are comparable. Last, firms entering decline might face capital constraints and inefficiencies, which prompts management team to pursue additional innovation activities, thus generating more innovation output to gather their hold back in the market (Dickinson (2011), Shahzad et al. (2022)).

The above-mentioned background has accentuated the need to disentangle the effect of GPR on innovation output in the framework of firm life-cycle. Evolving through stages with distinctive characteristics, firm's risk profile will be either aggravated or attenuated during different periods of geopolitical uncertainty, which translate into the number of patents/citation and innovation efficiency via real earnings management pathway. In the next section, we develop empirical analyses which answer those questions.

4.3 Data and Descriptive Statistics

In this section, we discuss our data sources, constructions of used variables and report descriptive results. We form the panel samples for our investigation of the relationship between geopolitical risk and firm innovation output, also known as patent stocks, using a universe of firms included in the COMPUSTAT databases (North American and European). Using PERMCO as identifying variable, we then merge COMPUSTAT data with GPR data developed by Caldara and Iacoviello (since 2018), extended patent database published by Kogan et al. (2017) and Stoffman et al. (2020) and updated by Winston Xu and Siqi Xue until 2020 (for US firms' patents) and PATSTAT (for 10 European countries' firm-level patents).

The final sample consists of all firms with available financial data from COMPUSTAT covering yearly from 1985 to 2020. Firms in the financial industry (SIC 6000 - 7000) and utility industry (SIC 4400 - 5000) are excluded because they operate in highly regulated industries with accounting rules that differ from other industries.

4.3.1 Geopolitical risk measurements

Our main explanatory variable is GPR_{jt}, which is denoted as the average value of GPR index for country j in year t. GPR index and country specific GPR indexes are created and developed by Caldara and Iacoviello since 2018, for more detail, see more in the Appendix. While GPR index ($GPR_{world,t}$) is based on 11 leading newspapers (most of them are from U.S and U.K), country specific GPR indexes (GPR_{jt}) are derived from 3 U.S newspapers. Therefore, all GPR indexes capture the U.S perspective on geopolitical risks (or at least from U.S systematic bias in views amongst the population of reporters and commentators).

Caldara and Iacoviello have been creating and developing GPR (world) index and country specific indexes since 2018. They argue that, though the GPR index is primarily relevant

from a North American and British perspective, their validation analysis reveals that the index can be further subdivided into separate country-specific components, presumably reflecting the different geographic imprint of major geopolitical events.

GPR_{jt} is a relatively common measure to use in time series econometric settings[8], for example see Baur and Smales (2018); Liu et al. (2019); Baur and Smales (2020); Al Mamun et al. (2020). As we continue to study more about the relationship of R&D and firm innovation in finance and accounting perspectives, we realize GPR is not directly informative for our models with firm-level panel settings. Lag effect, localised effect and confounding effect are examples of inherent problems that may arise. We provide explanations as below:

Lag effects: Bakker (2013); Wang and Hagedoorn (2014); Kang et al. (2017) revise the lag relationship of R&D and innovation. Also, it is logical to conjecture that GPR indeed have lag impact on firms' R&D. This implies that the impact of GPR on a firm's R&D and innovation may not be immediately observable and may take some time to materialize. This suggests that the influence of GPR on a company's R&D and innovation may not be immediately apparent and may take time to manifest. In order to fully comprehend the link between GPR and R&D/innovation, the proposed research topic focuses on finding the appropriate time lag in the empirical data. This can assist companies and politicians in determining ways to offset the detrimental impacts of GPR on R&D and innovation.

Localised effects: Given the approach used to construct GPR indexes, some may argue that not all GPR index values matter in the empirical environment since business innovation may be only susceptible to events with direct consequences, while events from afar may not pose any risks. However, we shall explore the diffused effects of connectedness, as in the case of EU zone, in the Extra Analyses section.

Confounding effects from economic downturn: It is well-known that higher geopolitical risk is related with a higher possibility of economic disasters and larger downside risks to the global economy (e.g, Ukraine - Russia war and the current economic stagnancy in EU zone). These entangled impacts make it more difficult to isolate the effect of geopolitical risk in empirical setting; instead, we postulate a holistic overview where the main challenge is trimmed down on how to define effective timeline in the model.

After considering all of above issues, we decide to use difference-in-difference with scaled GPR_{jt} as the robust identification, complementing to our baseline analysis. We choose

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[8] In the previous version of this study, we used to attempt another approach to employ quarterly GPR measure in studying direct effect of geopolitical risk and firm innovation output, see Appendix A3 for more detail.

the 99% percentile value in country specific GPR_{jt} distribution as the standard threshold to formulate the dummy GPR_99jt, dissecting the effect of tail risk. We use graphs to rationalize for this transformation. As observed from the Figure 4.B.2, which is made from data of US, the aggregated level of R&D investment intensity shows a shock after 2001 and not reverting to its previous level until recently. Though threshold cutoff point is a matter of subjectivity, major events, such as 11/09, can be considered as tail risk ones. We thus only focus on the incidents that yield the most destructive aftermath, which is the ones belonging to 99% percentile.

4.3.2   Internal innovation performance

We define patents as innovation output while R&D investment as innovation input measures, following innovation literature.

4.3.2.1   R&D investment and Abnormal R&D Cut

The R&D investment covers all costs incurred including salaries and departmental expenses that relate to the development of new products or services during the financial year. Previous papers primarily use the ratio of R&D expense to total assets (R&D/Assets) to measure R&D intensity. While some academics contend that R&D investment is independent, the degree of R&D investment is determined by the organization's status (i.e, capital, firm size, strategic diversification) as well as external factors (i.e, market competition and technical opportunities).

BAKKER (2013); KANG ET AL. (2017) and BROWN ET AL. (2017) have summarised some characteristics of R&D investment: (1) Due to asymmetric information difficulties (such as adverse selection or moral hazard) and expensive external sources, R&D is generally funded by internal capital (cash is preferred) (as no bankable collateral), (2) lengthy open time lags, (3) uncertainty (from both internal progress and external factors), (4) Under-investment: also owing to funding constraints, R&D investment is often kept substantially below the socially desirable level, and (5) volatile or unstable [9].

Indeed, because of these endogenous characteristics, R&D intensity may not represent an adequate indicator for the underlying mechanism in the geopolitical risk and firm innovation.

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[9]According to DITR (2007), R&D investment at the national and industry level shows little year-on-year change but it is unstable at the firm level.

To mitigate those concerns and focus on the moderating effects, we decide to use abnormal R&D cut in our main empirical setting.

Following ROYCHOWDHURY (2006); GUNNY (2010) and BERESKIN ET AL. (2018), we calculate abnormal R&D as the residual ($\varepsilon_{i,t}^{R\&D}$) estimated from following regression:

$$\frac{R\&D_{i,t}}{A_{i,t-1}} = \alpha_0 + \alpha_1 \frac{1}{A_{i,t-1}} + \beta_1 MV_{i,t} + \beta_2 Q_{i,t} + \beta_3 \frac{INT_{i,t}}{A_{i,t-1}} + \beta_4 \frac{R\&D_{i,t-1}}{A_{i,t-1}} + \varepsilon_{i,t}^{R\&D} \quad (1)$$

where $R\&D_{i,t}$ is the R&D expense of focal firm i in year t; $A_{i,t-1}$ is the total assets of focal firm i in year $t-1$; $MV_{i,t}$ is the natural log of focal firm i's market value in year t; $Q_{i,t}$ is focal firm i's Tobin's Q in year t; and $INT_{i,t}$ is the internal funds of focal firm i in year t. Equation (1) is estimated for each year and industry (defined by SIC 2 digit codes), where there are at least 10 firms in the industry-year group.

The lower value of $\varepsilon_{i,t}^{R\&D}$ indicates a deeper, unexpected cut in firm i's R&D expense in year t. As we focus on abnormal cuts to R&D, where $\varepsilon_{i,t}^{R\&D}$ is negative, so we define:

$$R\&DCut_{i,t} = -1 \times \varepsilon_{i,t}^{R\&D} \times Indicator(\varepsilon_{i,t}^{R\&D} < 0)$$

where $Indicator(\varepsilon_{i,t}^{R\&D} < 0)$ is an indiator function that equals one if $\varepsilon_{i,t}^{R\&D} < 0$ and zero otherwise. A higher value of $R\&DCut_{i,t}$ reflects a deeper, unexpected cut in firm i's R&D expenditure in year t.

Following BERESKIN ET AL. (2018), we then categorize R&D decline into those associates with real earning management (REM) and those associated with all other R&D cuts, such as reduced innovation opportunities as below:

$$R\&DCut_{i,t} = \begin{cases} R\&DCut\_REM_{i,t} & \text{if } Benchmark = 1 \\ R\&DCut\_Other_{i,t} & \text{if } Benchmark = 0 \end{cases}$$

where $Benchmark$ is defined as the value of ROA being in the range of [0; 0.01].

4.3.2.2 Patents, citations and efficiency

We use patent and citation data from extended versions of KPSS data orginally created by KOGAN ET AL. (2017) and STOFFMAN ET AL. (2020), then developed by Winston Xu and Siqi Xue . The granted patent data for U.S. firms are available up to 2020. Additionally, we take the natural logarithm to lessen the skewed distribution of patent application fillings, i.e. $Ln(No.ofFillings + 1)$ following HALL ET AL. (2000); HALL ET AL. (2005). We also measure the quality of patents on the basis of the citation count that each patent receives in

the subsequent years. Last, we define innovation efficiency by taking log-linearized number of patent counts divided by R&D expenditure, see COHEN ET AL. (2013), BERESKIN ET AL. (2018).

4.3.3   Other control variables

In order to mitigate the potentiality confounding factors, we account for firms' characteristics by including a wide array of time-varying variables. *Firm size*, which is estimated by taking natural logarithm of total book assets, is expected to positively correlate with innovation output. Large firms not only have more potential resources to invest in R&D (KIMBERLY AND EVANISKO (1981); but also are tolerant towards unsuccessful innovative effort (DAMANPOUR (1996)), which generate more innovation outcome in forms of patents , (ETTLIE AND RUBENSTEIN (1987)). *Firm age* also influences innovation type and productivity (RONG ET AL. (2017),XIE ET AL. (2020)). *Firm profitability*, which is captured by return-on-assets, shares a complex relationship with innovation process, attributing to competing landscape (KOELLINGER (2008)). *Asset tangibility*, measured by a ratio of investment and net PP&E to total assets, is expected to relate positively with firms' innovation. Representing a larger amount of pledgeability, a high proportion of asset tangibility reduce the likelihood of financial constraints, which allows firms to make more investments in innovative procedures (ALMEIDA AND CAMPELLO (2007), CHEN ET AL. (2021)).

Contrary to asset tangibility, an additional unit of capital spent on capital expenditure translates to a lesser resources invested in innovation. Hence, we predict a trade-off effect between innovation outcome and CAPEX. HE AND WINTOKI (2016) find that 20% of incremental cash holding is due to the changing characteristics of R&D investment during 1980-2012. In addition, LYANDRES AND PALAZZO (2016) attribute a surplus of cash among innovative firms to the inability of to access capital from external markets. Thus, firms characterised with high innovation outcome will hold a large amount of cash. Using a sample of listed Chinese firms during 2007-2015, YANG ET AL. (2020) find that in order to gain access to external equity markets, innovative firms strategically pay high dividends. Thus, we define *Cash dividend* as one plus total paid dividend. Last, we account for market participants' expectation by including market-to-book ratio. The definitions of the variables used and details of data sources are summarised in the Appendix.

We also employ some macroeconomic controls such as population, GDP per capita and GDP growth for EU sample analyses.

4.3.4 Summary Statistics

Table 4–1 presents descriptive statistics for the key variables used in the study. Results indicate that on average, one firm within a year applies for an approximate 40 patents, and receives average 500 forward citation,[10] of which standard deviations are 1.5 and 2.2 (in natural log-linearized value), respectively. The mean value of innovation efficiency, which is calculated by the ratio of number of patents to total R&D expenditure, is 4.8 (natural log-linearized value), whose lowest and highest value stands at 0 and 12, accordingly.

Our main independent variables of interest, $R\&DCut_{i,t}$, has a mean of 0.022 and standard deviation of 0.074. Classifying the independent into two sub categories, we see that $R\&DCut_{i,t}$ relating to real earning management has smaller mean value (i.e. 0.01) comparing to that of *Other* purpose (i.e. 0.022). Next, while the period with the lowest geopolitical tension stands at 0.053, the highest value of $GPR_{i,t}$ can jumps up to 1.5, whose mean is 0.77. The average value of an indicator variable shows that only 10 percentage of major events leading to highly geopolitical uncertainty period in the U.S.

In terms of control variables, firms including in the sample on average have a size of 3.3 million dollars[11] of which total debts account for 50% of total assets. Spanning from -19% to 22%, firm's profitability is highly volatile with a mean and standard deviation of -0.06%, and 0.379. Making an annual investment of 545 thousand dollars,[12] firms has 22% of its assets are tangible. Consistent with the literature, firms in our sample hold a large amount of cash surplus (25% of total assets), highly-valued by market participants ($\overline{MTB} = 3.3$); and pays large amount of dividend ($\overline{dividend} = 1.4$)

Panel B of Table 4–1 reports a matrix of correlations. The coefficients show that none of the variables share a high correlation with another. The highest value of coefficient is capital expenditure and asset tangibility, 0.572; while the lowest value of -0.496 is between cash holding and asset tangibility. Other than that, we find that our results will not be subject to multi-collinearity problem.

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[10]$10 \times (e^{2.029} - 1) = 60$, $10 \times (e^{3.911} - 1) = 500$

[11]$10 \times e^{5.81} - 1 = 330$

[12]$(10 \times e^{0.051} - 1) * 1,000 = 545$

4.4 Methodology Discussion

4.4.1 Pre-modified model

Our goal is to link geopolitical risk to firm innovation outcomes. The most straight-forward approach is to estimate whether direct impact of geopolitical risk has increased in recent years. We present here the basic models:

$$PAT_{ijt} = \alpha_0 + \alpha_1 GPR_{jt} + \alpha_2 R\&D\_Cut_{it} + \alpha_3 GPR_{jt} \times R\&D\_Cut_{it} + \beta X_{ijt} + \varepsilon_{ijt} \quad (4.1)$$

$$
\begin{aligned}
PAT_{ijt} = {} & \alpha_0 + \alpha_1 GPR_{jt} + \alpha_2 R\&D\_Cut\_Other_{it} + \alpha_3 R\&D\_Cut\_REM_{it} \\
& + \alpha_4 GPR_{jt} \times R\&D\_Cut\_Other_{it} + \alpha_5 GPR_{jt} \times R\&D\_Cut\_REM_{it} + \beta X_{ijt} + \varepsilon_{ijt}
\end{aligned}
$$
$$(4.2)$$

4.4.2 Difference-in-difference with time windows

Political instability, war, terrorism, and economic sanctions can cause global commercial uncertainty and volatility. Due to risk and uncertainty, corporations may reduce or stop R&D. In a politically unstable country, a corporation may curtail R&D investment to focus on preserving its assets and personnel. If it expects economic sanctions or a geopolitical-induced global economic slowdown to hurt sales, a corporation may slash R&D expenditure. Geopolitical issues can make it harder for corporations to obtain R&D resources and people. For instance, if a country is at war, corporations may struggle to hire and keep highly experienced R&D professionals and obtain the essential raw materials, equipment, and technology.

When evaluating impact of geopolitical extreme tension events on internal innovation performance, the timing of effects is of particular importance. Besides, the increasing reaction in R&D Cut after a direct hit by extreme geopolitical events reflects both the increase in uncertainties, as well as a potential learning about increased similar kind of risk in the future.

To address the concern of effective timing of tail risk events, we derive the dummy measure GPR_99_{jt} from GPR_{jt} as it can be argued that GPR_{jt} index is a good measure to track

the effective time windows for an event m at country j in a year t. Specifically, we test whether there is a significant change in R&D Cut in specific years surrounding the events, and whether those R&D Cut decisions may affect the innovation output (i.e., patents) or not.

The econometric setup in most complete form can be described by equation below

$$PAT_{ijt} = \alpha_0 + \alpha_1 GPR\_99_{jt} \times High\_R\&D\_Cut_{it} + \beta X_{ijt} + \varepsilon_{ijt} \qquad (4.3)$$

where PAT_{ijt} refers to patent output of firm i in country j in year t; GPR_99_{jt} is a dummy for the effective time of geopolitical risk.

We include $Firm \times Industry \times Year$ fixed effects in our regression.

We design a staggered difference-in-difference analysis (DiD)The "staggered" aspect of this method refers to the timing of the intervention. Instead of implementing the intervention all at once for all units in the treatment group, the intervention is implemented at different times for different units. This allows for a more nuanced analysis, as it allows for the examination of the effect of the intervention over time, rather than just looking at the overall effect of the intervention.

The "difference-in-difference" aspect of this method refers to the comparison of changes in the outcome variable between the treatment and control groups. The treatment group is the group that is exposed to the intervention, while the control group is a group that is similar to the treatment group but is not exposed to the intervention. By comparing the changes in the outcome variable between these two groups, the DD analysis can estimate the causal effect of the intervention.

Staggered DD analysis is particularly useful in observational studies where randomization of the treatment is not possible, and it can help to control for potential confounding variables that might affect the outcome. It can be applied in various fields such as economics, political science, and public health. for our study that captures the effect of geopolitical risks occurring at different time points. To disentangle the effect of geopolitical risks on R&D Cut and internal innovation performance, we transformed the GPR_{jt} index into GPR_99_{jt} dummy variable, clarify the clearest effective timeline.

In this context, we hypothesise that only geopolitical events classified as extreme tail risk are genuine exogenous shocks, filtering out the noise in the geopolitical risk index. Furthermore,

we divided the entire sample based on R&D Cut mean value, tracing back those firms with higher or lower R&D Cut levels compared to that mean value.

Using Figure 4.B.4 and Figure 4.B.5 as specification, we discovered that parallel trend condition is satisfied between any pairs: high and low R&D Cut; high and low R&D Cut Other and high and low R&D Cut REM. Therefore, it is logical to assign the treatment for high R&D Cut group under impact of geopolitical and the low R&D Cut group as control group.

4.5 Empirical Results

4.5.1 Geopolitical risk, R&D Cut and technological performance

Table 4–2 presents the results from estimating Equations 4.1 and 4.2. Because innovation activities vary across industries, in this specification, we include industry, firm and year fixed effects, while error is clustered at the firm level, controlling for unobservable, industry-level heterogeneity in firm innovation. The first two specifications examine the number of patent application filings by a sample firm; the next two specifications examine the sample firm's patent citations; and the last two specifications examine the sample firm's innovation efficiency.

As shown in Table 4–2, the key coefficient is α_3, the effect the interaction of our time varying measure of R&D Cut of firm i under impact of geopolitical risks GPR_{jt} in country j in year t. In column (1), the coefficient estimate of $GPR_{US,t} \times R\&D\_Cut_{it}$ is negative 0.561 basis points, and statistically significant at the 1% level. This result suggests that when a company is exposed to geopolitical risk, an increase in R&D Cut will have a negative effect on its internal innovation output, which is measured by number of patent application fillings. The economic impact of this interaction is comparable to a decline in technological performance.

In column (2), the coefficients of $GPR_{US,t} \times R\&D\_Cut\_Other_{it}$ and $GPR_{US,t} \times R\&D\_Cut\_REM_{it}$ are both significantly negative at 5% level and 1% level, respectively. Interestingly, the absolute value of $GPR_{US,t} \times R\&D\_Cut\_REM_{it}$ is much larger than $GPR_{US,t} \times R\&D\_Cut\_Other_{it}$, implying that REM related cutback is more stressful upon innovation output than Other cut. However, noticeably, the stand-alone coefficients of abnormal R&D Cut, regardless of REM related or not, carry positive signs (see columns (1) and (2)). The

results are consistent across three different dependent variables: Number of (patent) fillings, Number of cites and Efficiency.

Our findings have various implications: (1) In the absence of external shocks, abnormal R&D cuts may benefit firms in terms of efficient R&D expenditure by reducing wasteful amounts; (2) In certain conditions (such as serious geopolitical events), abnormal R&D cutbacks are negatively associated with firm innovation [13]. In this study, we successfully indicate one underlying mechanism of how geopolitical risks increase managerial risk aversion at firm-level operations and ultimately impact the innovation output.

Looking at the control variables in the models, we recognise that firm size, firm age, cash holding and leverage are the most statistically significant across the empirical analyses. These findings are in line with prior literature. There is a higher chance that patents will be filed by larger companies because bigger, more established companies often confront less financial constraints than their smaller competitors. Leverage is negatively significant, implying higher leveraged, more unstable finance will lead to less patents released whereas cash holding is positively significant with the number of patents filling or firms with higher cash capacity face less financial constraints. Firm age is thought to be a critical determinant of innovation due to the revealed capacity of the US economy to generate an increasing flow of young innovative firms that manage to survive and introduce new products, taking their place at the core of emerging sectors (see HANSEN (1992); BALASUBRAMANIAN AND LEE (2008); OUIMET AND ZARUTSKIE (2014); COAD ET AL. (2016)). While large firms still spend more on R&D and generate more innovation in absolute terms, small firms are well-known to be more innovative, tend to invest in exploration innovation through R&D investments, but they are hit harder in any shocks and less effective in receiving financial aid, i.e, firm age is indeed significantly negative in the result[14].

Furthermore, we have significantly positive predictors from Tangibility, Cash dividend, and MTB, and significantly negative determinants from ROA and capital expenditures about the possibility of filing a patent application. We explain that organisations with more physical assets, which means more bankable collateral when seeking outside financing, are more likely to receive the funds required to continue investing in internal patents. The same logic applies to greater MTB, where better current market value relative to book value or higher investor expectations about future prospects imply lesser financial limitations.

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[13]Moreover, the aggregated cutbacks are almost non-reversal, see Figure 4.B.2a to notice that the aggregated R&D intensity reduced significantly after 2001 and have just bounced back recently. The bigger standard deviation gap after geopolitical risk also characterize for the difference of R&D intensity between firms, also see Figure 4.B.2b

[14]HAO ET AL. (2020) showed that small firms' R&D investments are negatively associated with GPR in a more significant degree compared with large firms.

A positive relationship between cash dividend and business innovation output can be validated because firms with large cash reserves can finance R&D projects while also paying large cash dividends to shareholders. We may also employ the FLC framework to comprehend the metrics of Cash dividend, ROA, and capital expenditures[15]. More mature firms have bigger cash reserves, higher ROA, and prefer to invest more, but their activities have diminishing returns, thus they are more inclined to use exploitation strategy or engage in M&A instead.

Overall, the baseline results confirm which what we expect from literature.

[TABLE 4–2 HERE]

4.5.2 More severe geopolitical risk events and stronger R&D Cut

To isolate the moderating effects of severe geopolitical risk events and significantly abnormal R&D Cut, we then design the difference-in-difference (DID) settings, and presents the results in Table 4–3. As observed from column (1), (2) and (3), the coefficients on $GPR\_99_{US,t} \times High\_R\&D\_Cut_{it}$, $GPR\_99_{US,t} \times High\_R\&D\_Cut\_Other_{it}$ and $GPR\_99_{US,t} \times High\_R\&D\_Cut\_REM_{it}$ are all negatively significant, indicating that under effect of geopolitical shocks, innovation output decreases in those firms that strongly reduce R&D investment.

There are lag effects, in particular, that must be addressed here. We thus run several tests with different time lags and graph the coefficients in Figure 4.B.6.

While $R\&D\_Cut\_REM$ has the earliest effect from t+1, $R\&D\_Cut\_Other$ shows the greatest impact on innovation output at t+3[16]. This result is intriguing because it demonstrates the immediate effect of REM, namely how a fraction of R&D investment is manipulated to reflect managers' subjective incentive to adjust the yearly income figure in financial reports.

Our finding is also in line with VORST (2016), who found that reversing an abnormal cut in discretionary investments in the year following the cut is indicative of REM. Overall, findings from this DID setting provide strong evidence on the negative relation between geopolitical risk and firm innovation, which strengthens our baseline results.

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[15]FLC is constructed based on these variables an firm age

[16]However, we can not document the same pattern for the EU sample, which can be explained by the discrepancy in accounting regulations or REM behaviours in different nations. This can be a potential research idea to delve into in the future when there is better data availability.

[TABLE 4–3 HERE]

4.5.3 The impact of R&D cuts under geopolitical uncertainties in different life-cycle stages

In this section, we conduct further analysis investigating how firms in different life-cycle stages respond to geopolitical risks in terms of R&D expenditure and innovation output. We began by categorising firm-year observations into birth, growth, maturity, and decline stages.

We situate our analysis within the context of the firm life-cycle framework, drawing on theoretical works as described from the extensive discussion in literature section.

Due to the advent of momentum, we anticipate that firms in earlier stages, such as birth and growth, will have a greater capacity to release more patents from internal R&D and will continue to invest in "exploratory" projects. On the other hand, firms in mature and decline stages tend to allocate a greater proportion of their R&D budget to "exploitation" projects, and some will even use mergers and acquisitions or outsource R&D to maximise output confidence.

Possible explanations include the escalation of shareholder and external analyst pressures on firms as they grow, as well as differences in financial structure, capital budget, and management vision at each stage. Companies that have reached maturity stage have fewer financial constraints but are subject to a higher level of scrutiny from external stakeholders. As a result, investors will have a greater desire for and expectation of superior performance from any significant R&D projects. Therefore, we anticipate that more mature companies will engage in REM. In contrast, a firm in its early life does not subject to these pressures and this subjects to less scrutiny from external stakeholders. However, they are often susceptible to higher financial risks and frequently encounter less acceptance from outside lenders for their R&D project sponsorships.

Results from Table 4–4 support our expectations and clarify how firms at various life-cycle stages effectuate R&D cuts in response to geopolitical risk, and how this hinders innovation output.

When we look at absolute values across those columns in Table 4–4, we see that under the influence of geopolitical risk, the R&D cutback strategy of firms in the growth stage has the greatest impact on the number of patents and citations.

Moreover by comparing results from columns (2) and (3), we spot out how different R&D cut down strategies impact firm innovation in different life stages. On the one hand, the significance of the coefficients $GPR\_99_{US,t} \times High\_R\&D\_Cut\_Other_{it} \times Growth\_stage$ and $GPR\_99_{US,t} \times High\_R\&D\_Cut\_Other_{it} \times Mature\_stage$ at 1% and 5% levels, respectively, in column (2) indicates that innovation performance in the growth or mature stages is more likely to be affected by R&D cutbacks due to reduced investment opportunities under geopolitical risks rather than by REM motivation. On the other hand, the significant coefficients $GPR\_99_{US,t} \times High\_R\&D\_Cut\_REM_{it} \times Birth\_stage$ and $GPR\_99_{US,t} \times High\_R\&D\_Cut\_REM_{it} \times Growth\_stage$ at 5% and 10% levels, respectively, in column (3) provide empirical evidence that in the birth and growth stages, firms that are more inclined to implement R&D Cut REM will generate fewer in-house patents (during the following fiscal year) or even less radical innovation, and will ultimately lose innovative momentum.

Interestingly, HASAN ET AL. (2018) point out that high (low) organization capital is more likely to be in the introduction and decline (growth and maturity) stage, which fits the simple growth model of ATKESON AND KEHOE (2005) where the life cycle of a firm's profit (or organization rent), is expressed as a function of firm-specific knowledge (or organization capital) in equilibrium.

[TABLE 4–4 HERE]

4.6 Extra analyses

4.6.1 Alternative economic explanation: Attention to US political position

Due to its fortunate geographical location, US was protected during both World Wars, and this situation persists to this day. Regarding global geopolitical challenges, the US only intervenes if it serves American interests. Under this section, we expect that the higher of U.S military involvement in global geopolitical risk, the higher the impacts of those risks on U.S innovation process. From the International crisis Behavior Database, we employ a factor variable, called U.S involvement[17]. By each year, we sum up the total involvement of U.S military and then merge with our working dataset.

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[17]The original value of this indicator is from 1 to 9, the higher the score the higher the level of involvement: (1) U.S. not involved in the crisis being coded (2) U.S. non-intervention or neutrality (3) U.S. political involvement - including statements of approval or disapproval by authorized and senior government officials (4) U.S. economic involvement - e.g., financial aid, or the withholding of aid from an actor (5) U.S. propaganda involvement - increase in Voice of America broadcasts beamed at a particular country (6) U.S. covert involvement - (7) U.S. semi-military involvement - military aid or advisors, without participation

Regression results in Table 4–5 show that the coefficient of interaction $GPR_{world,t} \times US\_military\_involvement$ is -0.085 (Volumn (1)), statistically significant at 1% level. Caldara and Iacoviello (2018) divide their GPR index into indexes for Geopolitical Threats (GPT) and Geopolitical Acts (GPA). GPT encompasses geopolitical threats that are not contemporaneously associated with geopolitical activities (at the time of classification), such as tensions escalating before wars. The GPA reflects the actual occurrence of bad geopolitical events. The significance of positive interaction term $GPT_{world,t} \times US\_military\_involvement$ strike an interesting results, implying that higher (global) geopolitical threats instead stimulate higher innovation in U.S. Further analysis with citations per patent and innovation efficiency as dependent variable confirm the same patterns. We also report extra results in Appendix A.3, Table 4.A.3 where we use IV-GMM identification as another approach methodology.

[TABLE 4–5 HERE]

4.6.2 Geopolitical risk in EU zone

As an attempt to extend our study, we decide to apply the similar analyses for a group of 10 European countries including Belgium (BEL), Switzerland (CHE), Germany (DEU), Denmark (DNK), Finland (FIN), France (FRA), United Kingdom (GBR), Italy (ITA), Netherland (NLD) and Sweden (SWE)[18]. There are many reasons why we use a group of European countries as comparison in the study: (1) data availability of patents (PATSTAT) and financial/accounting (COMPUSTAT), matching algorithm between company names and patent databases works best with Latin alphabetical names[19]; (2) juxtaposition of EU and US in terms of economic and political dynamics, the main difference lies at the geography and regional connectedness; (3) as mentioned from Methodology section, GPR measurements show the highly reflections of political views from US-UK and their allies.

Under the scope of country-specific geopolitical risk, the GPR_99_{jt} scale measure can quantitatively capture the local risk. However, the EU should perceive geopolitical risk considerably differently from the US. In contrast to its counterparts (US), geopolitical risks in the European region are influenced not just by local geopolitical risks, but also by regional events that have indirect repercussions on neighbouring EU nations at regional

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in actual fighting (8) U.S. direct military intervention - dispatch of troops to Vietnam, aerial bombing of targets or naval assistance to a party in a war (9) U.S. crisis actor.

[18]Unfortunately, we were unable to include Russia and Ukraine in the present study since fuzzy matching algorithm only works efficiently with English based companies name.

[19]Please see Appendix for detail about matching algorithm

level because their connectedness is high. The increasing reaction in R&D Cut after a direct hit by extreme geopolitical events reflects both the increase in uncertainties, as well as a potential learning effect about increased similar kind of risk in the future. We create two variables that capture whether geopolitical events have recently occurred at the regional and local levels in the EU zone. Local events are those that emerge only in one country j during the year t, whereas regional events are those events that impact not only that specific country j during the year t but also have diffused effects on neighbouring countries.

We then update our DID model, using interaction term $GPR\_99_{EU,t} \times GPR\_99_{j,t}$ to characterise for both the indirect and direct impact of geopolitical risk among European countries. Table 4–6 and Figure 4.B.6 illustrate some results for EU sample with our empirical identification. The presence of significantly negative coefficients from interactions terms, as expected, demonstrates that both regional and local geopolitical extreme risk events have jointly impacts on firm innovation output in the EU zone. Specifically, the moderating effects are strongest in the second lags and diluted gradually.

However, we can not detect the time-lag differences of REM-related and non-REM related R&D cutbacks as in US analyses. This could be because different accounting rules or how REM/AEM are used in EU comparing with US.

[TABLE 4–6 HERE]

4.7 Conclusion and Remark

Acting as economic development backbone, innovation and its determinants have received enumerating effort among scholars and practitioners. In addition to its endogenous characteristics, innovation activities have been influenced by increasing geopolitical, in a combination with economic and policy, uncertainty. In general, the effects of geopolitical risks can be summarised as follows: (1) terrorist attacks or wars are destructive events that cause severe physical asset damage and put human life at risk, and there are lag effects that can last for a long time afterwards. (2) Politically unstable countries and regions are less capable of attracting investment and promoting human capital development and free trade, which can lead to human capital flight and a decrease in growth; and (3) indirect effects from neighbouring countries, which can lead to regional/global crises (in terms of economic and politic) to some extent.

We provide evidence of aggravating GPR will reduce innovation output, measured by number of patents, citation, and innovation efficiency, via R&D cuts. Particularly, segregating

the amount of abnormal R&D cuts into real earning-management and other purposes, we document that the former generates a more severe effect on innovation outcome revealing in a shorter time period than the latter. The result is robust when taking into account the involvement of U.S. military into geopolitical events on a global scale.

The current literature attributes reduction of innovation activities among firms in mature stage in the framework of firm life-cycle. We extend the body of knowledge by documenting that the effect of reduction in innovation outcome by cutting back R&D spending is most visible among firms in mature stage when exposing to heightening level of geopolitical uncertainty. In addition, the behavior of R&D cuts attributing to various purposes (i.e. REM or others) shall have differential effect on firms in differing stages. While abnormal reduction in R&D spending does not yield any definitive results, R&D cuts relating to REM is non-trivial for firms in birth and growth stage as it might impact the competitive advantage of firms entering market.

We provide a brief additional analysis of impact of geopolitical uncertainty in European context. The result using data from PATSTAT reveals the same picture, in which GPR reduces not only number of registered patents and number of citation, but also innovation efficiency. In the same line of analysis, the segregation of abnormal R&D reduction nevertheless, shows a quite contradictory results where R&D cuts for other purposes dominates the effect of R&D cuts relating to REM. We attribute this divergence to the difference in institutional background as well as monitoring efforts of financial regulators in the two regions.

Though Ukraine and Russia can be a potential future direction for research taking into recent dispute, but due to the limit of current data and matching algorithm, we decided not to continue to take them into consideration of this study. Moreover, it is better to study about the current war effect in the future because there are many hidden effects we may not know about. Last but not least, including the current Ukraine war to our current sample may bias the results.

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Table 4–1: Summary statistics

Panel A: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
$Number of fillings_{it}$	44,800	2.029	1.451	0.693	9.094
$Number of cites_{it}$	44,800	3.911	2.204	0.000	11.973
$Efficiency_{it}$	38,460	4.761	2.154	0.121	14.554
$Firmsize_{it}$	54,596	5.811	2.320	0.032	13.241
$Leverage_{it}$	54,380	0.512	0.657	0.000	2.496
$Firmage_{it}$	52,866	2.110	0.903	0.000	3.664
ROA_{it}	54,527	-0.066	0.379	-19.451	21.789
$Tangibility_{it}$	54,564	0.221	0.172	0.000	1.000
$Capital expenditure_{it}$	53,956	0.053	0.053	-0.021	1.457
$Cashholding_{it}$	54,566	0.254	0.258	-0.010	1.000
MTB_{it}	49,315	3.249	2.873	0.668	11.734
$Cashdividend_{it}$	53,861	1.345	2.109	0.000	10.494
$R\&D\_cut_{it}$	41,863	0.022	0.074	0.000	4.443
$R\&D\_cut\_REM_{it}$	41,863	0.001	0.008	0.000	0.571
$R\&D\_cut\_Other_{it}$	41,863	0.022	0.074	0.000	4.443
$GPR_{US,t}$	51,808	0.770	0.346	0.053	1.470
$GPR\_99_{US,t}$	51,808	0.096	0.294	0.000	1.000

Panel B: Matrix of correlation among control variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
$GPR_{US,t}$ (1)	1.000										
$R\&D\_cut_{it}$ (2)	-0.048	1.000									
Firm size (3)	0.010	-0.131	1.000								
Leverage (4)	0.018	-0.058	0.299	1.000							
Firm age (5)	-0.028	-0.084	0.411	0.129	1.000						
ROA (6)	-0.035	-0.179	0.334	0.010	0.163	1.000					
Tangibility (7)	0.024	-0.128	0.224	0.228	0.009	0.120	1.000				
Capital expenditure (8)	-0.051	-0.053	0.018	0.009	-0.180	0.032	0.572	1.000			
Cash holding (9)	-0.010	0.200	-0.342	-0.353	-0.245	-0.291	-0.496	-0.212	1.000		
Cash dividend (10)	0.003	-0.113	0.731	0.242	0.325	0.225	0.307	0.053	-0.359	1.000	
MTB (11)	-0.068	0.145	-0.081	0.106	-0.063	-0.164	-0.182	0.003	0.289	-0.026	1.000

Notes: This table reports the summary statistics of variables used in our study. All variables are defined in Table ??.

Table 4–2: Geopolitical Risk, R&D Cut and Technological Performance

	Number of fillings		Number of cites		Efficiency	
	(1)	(2)	(3)	(4)	(5)	(6)
$GPR_{US,t}$	-0.011	-0.011	-0.601***	-0.601***	0.042**	0.042**
	(0.508)	(0.505)	(0.000)	(0.000)	(0.008)	(0.008)
R&D_Cut	0.544***		0.494		1.123+	
	(0.000)		(0.115)		(0.059)	
$GPR_{US,t} \times R\&D\_Cut$	-0.561**		-0.697**		-0.273	
	(0.008)		(0.006)		(0.157)	
R&D Cut_REM		0.670		-0.930		2.595**
		(0.193)		(0.472)		(0.001)
$GPR_{US,t} \times R\&D\_Cut\_REM$		-1.636**		-1.091		-2.621***
		(0.006)		(0.744)		(0.000)
R&D Cut_Other		0.543***		0.500		1.115+
		(0.000)		(0.112)		(0.062)
$GPR_{US,t} \times R\&D\_Cut\_Other$		-0.550*		-0.686**		-0.256
		(0.010)		(0.008)		(0.201)
Firm size	0.412***	0.412***	0.421***	0.421***	0.675***	0.675***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Leverage	-0.107**	-0.107**	-0.148**	-0.147**	-0.036*	-0.036*
	(0.006)	(0.006)	(0.006)	(0.006)	(0.036)	(0.036)
Firm age	-0.011	-0.011	-0.050*	-0.050*	-0.201***	-0.201***
	(0.147)	(0.153)	(0.028)	(0.029)	(0.000)	(0.000)
ROA	-0.200***	-0.199***	-0.230***	-0.229***	0.311***	0.312***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Tangibility	0.917***	0.917***	0.737***	0.737***	0.165	0.164
	(0.000)	(0.000)	(0.000)	(0.000)	(0.120)	(0.121)
Capital expenditure	-0.512**	-0.513**	0.076	0.074	-0.603***	-0.603***
	(0.003)	(0.003)	(0.508)	(0.521)	(0.000)	(0.000)
Cash holding	0.181***	0.181***	0.356***	0.355***	0.295***	0.296***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cash dividend	0.029**	0.029**	0.001	0.001	0.011	0.011
	(0.005)	(0.004)	(0.930)	(0.924)	(0.188)	(0.186)
MTB	0.019***	0.019***	0.026***	0.026***	-0.000	-0.000
	(0.001)	(0.001)	(0.000)	(0.000)	(0.908)	(0.904)
CONS	-0.427*	-0.428*	2.605***	2.604***	1.262**	1.261**
	(0.033)	(0.033)	(0.000)	(0.000)	(0.001)	(0.001)
Observations	30144	30144	30144	30144	29833	29833
$Firm \times Industry \times Year$ FE	YES	YES	YES	YES	YES	YES
adj. R-sq	0.216	0.216	0.532	0.532	0.282	0.282

Notes: This table displays the findings of a panel fixed effects regression analysis that looked at the impact of geopolitical risk on firm innovation. We hypothesise R&D cut as the underlying mechanism because R&D is considered an innovation input that directly leads to patent output (and citations). For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 4–3: Effects of extreme geopolitical risks on innovation stability (USA)

	Number of fillings$_{t+3}$		Number of fillings$_{t+1}$	Number of cites$_{t+3}$		Number of cites$_{t+1}$	Efficiency$_{t+3}$		Efficiency$_{t+1}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GPR_99$_{US,t}$ × High_R&DCut	-0.064***			-0.089+			-0.043***		
	(0.001)			(0.061)			(0.000)		
GPR_99$_{US,t}$ × High_R&DCut_Other		-0.061*			-0.088+			-0.036*	
		(0.015)			(0.056)			(0.028)	
GPR_99$_{US,t}$ × High_R&DCut_REM			-0.118+			-0.151*			-0.158+
			(0.072)			(0.036)			(0.089)
Firm size	0.332***	0.332***	0.396***	0.289***	0.289***	0.377***	0.422***	0.422***	0.586***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Leverage	-0.102**	-0.102*	-0.122**	-0.122***	-0.122***	-0.153***	-0.115***	-0.115***	-0.116***
	(0.010)	(0.010)	(0.008)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Firm age	-0.092*	-0.092*	-0.054*	-0.151***	-0.151***	-0.108***	-0.198***	-0.198***	-0.180***
	(0.019)	(0.019)	(0.027)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
ROA	-0.067***	-0.067***	-0.106***	0.009	0.008	-0.086***	-0.012	-0.012	0.055**
	(0.000)	(0.000)	(0.000)	(0.406)	(0.412)	(0.000)	(0.162)	(0.158)	(0.002)
Tangibility	0.365***	0.365***	0.633***	-0.038	-0.038	0.242**	0.125*	0.125*	0.150+
	(0.001)	(0.001)	(0.000)	(0.767)	(0.771)	(0.008)	(0.016)	(0.015)	(0.090)
Capital expenditure	-0.075	-0.075	-0.072	0.710***	0.710***	0.602***	0.147	0.147	-0.065
	(0.742)	(0.742)	(0.442)	(0.000)	(0.000)	(0.000)	(0.622)	(0.622)	(0.135)
Cash holding	0.059	0.059	0.183*	0.031	0.031	0.231**	-0.069	-0.069	0.065**
	(0.505)	(0.504)	(0.011)	(0.725)	(0.723)	(0.003)	(0.275)	(0.276)	(0.002)
Cash dividend	-0.016	-0.016	0.011	-0.058*	-0.058*	-0.012	-0.010	-0.010	0.005
	(0.187)	(0.186)	(0.279)	(0.011)	(0.011)	(0.402)	(0.155)	(0.154)	(0.400)
MTB	0.031***	0.031***	0.028***	0.041***	0.041***	0.034***	0.035***	0.035***	0.036***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CONS	0.396***	0.395***	-3.269***	3.714***	3.714***	-4.542***	2.752***	2.752***	-1.597***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)
Observations	23980	23980	29055	23980	23980	29055	21659	21659	26091
Firm × Industry × Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
adj. R-sq	0.191	0.191	0.199	0.579	0.579	0.546	0.181	0.181	0.224

Notes: This table presents the results from difference-in-difference analyses for the effects of extreme geopolitical events on firm innovation. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , * , ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 4–4: Financing innovation under uncertainties in different firm life stages

	$Numberoffillings_{t+3}$	$Numberoffillings_{t+3}$	$Numberoffillings_{t+1}$	$Numberofcites_{t+3}$	$Numberofcites_{t+3}$	$Numberofcites_{t+1}$	$Efficiency_{t+1}$	$Efficiency_{t+3}$	$Efficiency_{t+1}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$GPR\_99_{US,t} \times HighR\&DCut \times Birthstage$	-0.027			-0.097			-0.031		
	(0.443)			(0.285)			(0.376)		
$GPR\_99_{US,t} \times HighR\&DCut \times Growthstage$	-0.085**			-0.037			-0.113***		
	(0.005)			(0.653)			(0.000)		
$GPR\_99_{US,t} \times HighR\&DCut \times Maturestage$	-0.069**			-0.128**			-0.082+		
	(0.006)			(0.010)			(0.054)		
$GPR\_99_{US,t} \times HighR\&DCut \times Declinestage$	-0.040**			-0.027			0.053*		
	(0.002)			(0.192)			(0.040)		
$GPR\_99_{US,t} \times HighR\&DCut\_Other \times Birthstage$		-0.038			-0.086			-0.035	
		(0.286)			(0.247)			(0.189)	
$GPR\_99_{US,t} \times HighR\&DCut\_Other \times Growthstage$		-0.067**			-0.031			-0.098***	
		(0.009)			(0.666)			(0.000)	
$GPR\_99_{US,t} \times HighR\&DCut\_Other \times Maturestage$		-0.057*			-0.121*			-0.032	
		(0.032)			(0.023)			(0.499)	
$GPR\_99_{US,t} \times HighR\&DCut\_Other \times Declinestage$		-0.045			-0.041			0.025	
		(0.235)			(0.131)			(0.543)	
$GPR\_99_{US,t} \times HighR\&DCut\_REM \times Birthstage$			-0.120*			-0.157*			-0.168*
			(0.045)			(0.014)			(0.033)
$GPR\_99_{US,t} \times HighR\&DCut\_REM \times Growthstage$			-0.168+			-0.247*			-0.215*
			(0.054)			(0.011)			(0.044)
$GPR\_99_{US,t} \times HighR\&DCut\_REM \times Maturestage$			-0.127			-0.163			-0.187+
			(0.149)			(0.107)			(0.087)
$GPR\_99_{US,t} \times HighR\&DCut\_REM \times Declinestage$			-0.056			-0.059			-0.122
			(0.338)			(0.471)			(0.137)
CONS	0.461**	0.461**	-3.287***	3.818***	3.817***	-4.496***	2.877***	2.877***	-1.527**
	(0.002)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)
Observations	22398	22398	27120	22398	22398	27120	20389	20389	24529
Firm × Industry × Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
adj. R-sq	0.197	0.197	0.205	0.592	0.592	0.563	0.187	0.186	0.229

Notes: This table presents the results from firm life-cycle analysis for the impact of geopolitical risk on technological performance. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by +, *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 4–5: Geopolitical risk (global) and US military involvement

	Number of fillings			Number of cites			Efficiency		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$GPR_{world,t} \times US\,military\,involvement$	-0.085**			-1.304***			-0.097*		
	(0.003)			(0.000)			(0.041)		
$GPT_{world,t} \times US\,military\,involvement$		0.010**			0.013*			0.008*	
		(0.002)			(0.029)			(0.030)	
$GPA_{world,t} \times US\,military\,involvement$			-0.079**			-1.216***			-0.090*
			(0.003)			(0.000)			(0.041)
Firm size	0.382***	0.382***	0.382***	0.414***	0.414***	0.414***	0.679***	0.679***	0.679***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Leverage	-0.091*	-0.091*	-0.091*	-0.137*	-0.137*	-0.137*	-0.039*	-0.039*	-0.039*
	(0.030)	(0.030)	(0.030)	(0.011)	(0.011)	(0.011)	(0.039)	(0.039)	(0.039)
Firm age	-0.012	-0.012	-0.012	-0.094***	-0.094***	-0.094***	-0.197***	-0.197***	-0.197***
	(0.418)	(0.418)	(0.418)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ROA	-0.143***	-0.143***	-0.143***	-0.160***	-0.160***	-0.160***	0.183***	0.183***	0.183***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tangibility	0.598***	0.598***	0.598***	0.531***	0.531***	0.531***	-0.018	-0.018	-0.018
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.879)	(0.879)	(0.879)
Capital expenditure	-0.379*	-0.379*	-0.379*	0.160	0.160	0.160	-0.675**	-0.675**	-0.675**
	(0.016)	(0.016)	(0.016)	(0.192)	(0.192)	(0.192)	(0.007)	(0.007)	(0.007)
Cash holding	0.142**	0.142**	0.142**	0.321***	0.321***	0.321***	0.243***	0.243***	0.243***
	(0.006)	(0.006)	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cash dividend	0.037*	0.037*	0.037*	0.028	0.028	0.028	0.020+	0.020+	0.020+
	(0.014)	(0.014)	(0.014)	(0.129)	(0.129)	(0.129)	(0.058)	(0.058)	(0.058)
MTB	0.020***	0.020***	0.020***	0.034***	0.034***	0.034***	0.004*	0.004*	0.004*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.023)	(0.023)	(0.023)
CONS	-0.291+	-0.433*	-0.309+	4.302***	2.355***	4.037***	1.308**	1.152**	1.288**
	(0.092)	(0.012)	(0.073)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)	(0.002)
Observations	32401	32401	32401	32401	32401	32401	28264	28264	28264
$Firm \times Industry \times Year$ FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
adj. R-sq	0.142	0.142	0.142	0.368	0.368	0.368	0.244	0.244	0.244

Notes: This table presents the results when examine effect of geopolitical risks using GPR index $GPR_{world,t}$ and US military involvement. For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by +, *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Table 4–6: Effects of extreme geopolitical risks on innovation stability (European sample)

Panel A: Summary statistic - 10 European countries pool sample					
Variable	Obs	Mean	Std. Dev.	Min	Max
$Number of fillings_{it}$	13,514	2.637	1.603	0.693	9.150
$Number of cites_{it}$	13,514	3.835	2.630	0.000	12.041
$Efficiency_{it}$	8,673	6.073	2.347	0.043	16.112
$Firm size_{it}$	19,972	6.050	2.688	0.000	18.766
$Leverage_{it}$	19,922	0.577	0.637	0.000	2.310
$Firm age_{it}$	19,987	2.105	0.887	0.000	3.555
ROA_{it}	15,307	-0.058	0.561	-25.456	52.915
$Tangibility_{it}$	19,943	0.208	0.168	0.000	0.969
$Capital expenditure_{it}$	17,161	0.046	0.049	-0.108	0.934
$Cash holding_{it}$	19,944	0.206	0.224	0.000	1.000
MTB_{it}	7,568	3.262	3.060	0.566	12.332
$Cash dividend_{it}$	19,982	1.592	2.306	-0.053	14.657
$Population_{jt}$	19,475	17.220	1.064	15.257	18.236
$GDP per capita_{jt}$	19,475	10.559	0.345	9.482	11.542
$GDP growth_{jt}$	19,475	1.502	2.372	-10.823	6.334
$R\&D\_cut_{it}$	5,542	0.015	0.048	0.000	0.958
$R\&D\_cut\_REM_{it}$	5,542	0.001	0.007	0.000	0.195
$R\&D\_cut\_Other_{it}$	5,542	0.014	0.047	0.000	0.958
GPR_{jt}	19,987	0.276	0.256	0.008	1.189
$GPR\_99_{EU,t}$	19,987	0.064	0.244	0.000	1.000
GPR_99_{jt}	19,987	0.015	0.120	0.000	1.000

	Panel B: Triple difference analyses								
	$Number of fillings_{t+2}$			$Number of cites_{t+2}$			$Efficiency_{t+2}$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$GPR\_99_{EU,t}$ × $GPR\_99_{i,t}$ × $High\_R\&DCut$	-0.36***			-0.47**			-0.22***		
	(0.000)			(0.003)			(0.000)		
$GPR\_99_{EU,t}$ × $GPR\_99_{i,t}$ × $High\_R\&DCut\_Other$		-0.36***			-0.47**			-0.22***	
		(0.000)			(0.003)			(0.000)	
$GPR\_99_{EU,t}$ × $GPR\_99_{i,t}$ × $High\_R\&DCut\_REM$			-0.15*			-0.23+			0.05
			(0.020)			(0.073)			(0.709)
Firm size	0.17***	0.17***	0.16***	-0.05	-0.05	-0.05	0.17***	0.17***	0.16***
	(0.000)	(0.000)	(0.000)	(0.461)	(0.461)	(0.430)	(0.001)	(0.001)	(0.001)
Leverage	-0.10***	-0.10***	-0.10***	0.00	0.00	0.00	0.01	0.01	0.01
	(0.000)	(0.000)	(0.000)	(0.957)	(0.957)	(0.977)	(0.799)	(0.799)	(0.792)
Firm age	-0.00	-0.00	0.00	0.02	0.02	0.02	-0.23	-0.23	-0.22
	(0.991)	(0.991)	(0.926)	(0.838)	(0.838)	(0.793)	(0.102)	(0.102)	(0.114)
ROA	0.10*	0.10*	0.10*	0.27**	0.27**	0.27**	0.32***	0.32***	0.31***
	(0.017)	(0.017)	(0.026)	(0.006)	(0.006)	(0.008)	(0.000)	(0.000)	(0.001)
Tangibility	-0.21+	-0.21+	-0.17	-0.65	-0.65	-0.60	0.35	0.35	0.35
	(0.065)	(0.065)	(0.114)	(0.156)	(0.156)	(0.184)	(0.468)	(0.468)	(0.472)
Capital expenditure	1.94***	1.94***	1.89***	3.89***	3.89***	3.82***	2.42*	2.42*	2.40*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.029)	(0.029)	(0.033)
Cash holding	0.03	0.03	0.03	0.23	0.23	0.23	0.09	0.09	0.09
	(0.757)	(0.757)	(0.762)	(0.346)	(0.346)	(0.358)	(0.172)	(0.172)	(0.161)
Cash dividend	-0.00	-0.00	-0.00	0.01	0.01	0.01	-0.01	-0.01	-0.01
	(0.696)	(0.696)	(0.791)	(0.484)	(0.484)	(0.447)	(0.405)	(0.405)	(0.553)
MTB	0.02*	0.02*	0.02*	-0.00	-0.00	-0.00	0.03+	0.03+	0.03+
	(0.024)	(0.024)	(0.029)	(0.324)	(0.324)	(0.252)	(0.066)	(0.066)	(0.083)
Population	1.10	1.10	1.16	-1.54	-1.54	-1.48	1.57*	1.57*	1.68*
	(0.403)	(0.403)	(0.375)	(0.526)	(0.526)	(0.539)	(0.023)	(0.023)	(0.013)
GDP per capita	0.66+	0.66+	0.65+	0.26	0.26	0.25	0.71*	0.71*	0.67*
	(0.059)	(0.059)	(0.075)	(0.725)	(0.725)	(0.740)	(0.024)	(0.024)	(0.040)
GDP growth	-0.01	-0.01	-0.01	-0.03	-0.03	-0.03	-0.01	-0.01	-0.02
	(0.540)	(0.540)	(0.459)	(0.220)	(0.220)	(0.182)	(0.542)	(0.542)	(0.431)
CONS	-28.69	-28.69	-29.55	22.34	22.34	21.42	-34.17**	-34.17**	-35.71**
	(0.279)	(0.279)	(0.263)	(0.650)	(0.650)	(0.663)	(0.010)	(0.010)	(0.006)
Observations	2842	2842	2842	2842	2842	2842	2434	2434	2434
Country	YES	YES	YES	YES	YES	YES	YES	YES	YES
$Firm \times Industry \times Year$ FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
adj. R-sq	0.386	0.386	0.385	0.527	0.527	0.527	0.357	0.357	0.357

Notes: This table presents the results from triple difference analyses for the effects of extreme geopolitical events on firm innovation in Panel B. While Panel A reports summary statistic for 10 European countries firm-level sample spanning from 1987 - 2020. European sample includes data for Belgium (BEL), Switzerland (CHE), Germany (DEU), Denmark (DNK), Finland (FIN), France (FRA), United Kingdom (GBR), Italy (ITA), Netherland (NLD) and Sweden (SWE). For the definitions of all the control variables and the details of their construction, see Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

Appendix

4.A Appendix A

<div align="center">

Table 4.A.1: Description of variables used

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Feature	Description	Source
	Panel A: Main variables	
GPR_world	The natural logarithm of GPR index using algorithm counting keywords from 11 leading newspapers by Caldara and Iacoviello (CI)	CI (2018)
GPR_jt	The natural logarithm of country-specific GPR index using algorithm counting keywords from 3 US newspapers	CI (2018)
GPT	The natural logarithm of GPT index - The threats of geopolitical risk. Available at http://www.policyuncertainty.com/gpr.html	CI (2018)
GPA	The natural logarithm of GPA index -The realization of geopolitical risk. Available at http://www.policyuncertainty.com/gpr.html	CI (2018)
Number of fillings	Natural logarithm of one add number of invention patent applications filed by focal firm i in sample year t	KPSS (2021)
Number of cites	Natural logarithm of one add number of forward citations received by all successful patent applications filed by focal firm i in sample year t	KPSS (2021)
Efficiency	Log-linearized number of patent counts divided by R&D expenditure	self-calculated
R&D cut	Following Roychowdhury (2006); Gunny (2010) and Bereskin et al. (2018), abnormal R&D Cut is calculated as the residual $(\varepsilon_{i,t}^{R\&D})$ estimated from following regression: $\frac{R\&D_{i,t}}{A_{i,t-1}} = \alpha_0 + \alpha_1 \frac{1}{A_{i,t-1}} + \beta_1 MV_{i,t} + \beta_2 Q_{i,t} + \beta_3 \frac{INT_{i,t}}{A_{i,t-1}} + \beta_4 \frac{R\&D_{i,t-1}}{A_{i,t-1}} + \varepsilon_{i,t}^{R\&D}$; where $R\&D_{i,t}$ is the R&D expense of focal firm i in year t; $A_{i,t-1}$ is the total assets of focal firm i in year $t-1$; $MV_{i,t}$ is the natural log of focal firm i's market value in year t; $Q_{i,t}$ is focal firm i's Tobin's Q in year t; and $INT_{i,t}$ the internal funds of focal firm i in year t. Equation (1) is estimated for each year and industry (defined by SIC 2 digit codes), where there are at least 10 firms in the industry-year group. The lower value of $\varepsilon_{i,t}^{R\&D}$ indicates a deeper, unexpected cut in firm i's R&D expense in year t. As we focus on abnormal cuts to R&D, where $\varepsilon_{i,t}^{R\&D}$ is negative, so we define: $R\&DCut_{i,t} = -1 \times \varepsilon_{i,t}^{R\&D} \times Indicator(\varepsilon_{i,t}^{R\&D} < 0)$; where $Indicator(\varepsilon_{i,t}^{R\&D} < 0)$ is an indiator function that equals one if $\varepsilon_{i,t}^{R\&D} < 0$ and zero otherwise. A higher value of $R\&DCut_{i,t}$ reflects a deeper, unexpected cut in firm i's R&D expenditure in year t.	
R&D cut (Other)	When ROA of focal company-year was out of the range of [0, 0.01], equal to R&D Cut, otherwise equal to 0	self-calculated
R&D cut (REM)	When ROA of focal company-year was in the range of [0, 0.01], equal to R&D Cut, otherwise equal to zero	self-calculated
	Panel B: Control variables	
Firm age	Logarithm of one plus firm age, which is the number of years since the firm's initial public offering (IPO).	Compustat
Firm size	Natural log of book assets.	Compustat
ROA	Return on total assets	Compustat
Tangibility	Sum of investments and net Property, Plant, and Equipment (PP&E) divided by book assets.	Compustat
Market-to-Book (MTB)	Nature logarithm of Market value of stock divided by Book value per share	Compustat
Leverage	Nature logarithm of one plus the ratio of total long-term debt plus total current liabilities over total assets.	Compustat

Table 4.A.1: Description of variables used - continued

Feature	Description	Source
Capital Expenditure	Capital Expenditure divided by book assets.	Compustat
Cash holdings	Cash and short-term equivalents divided by book assets.	Compustat
Cash dividend	Nature logarithm of one plus total dividend in a current year.	Compustat
Population	The population of country j in year t	
GDP growth	The growth rate of GDP of country j in year t	
GDP per capita	The GDP per capita of country j in year t	
Consumer confidence	The monthly, survey-based index of consumer confidence developed by the University of Michigan. Available at http://www.sca.isr.umich.edu/	
Industry economic shock	It is constructed based on the following six firm-level indicators: net income to sales (IB/SALE), sales to assets (SALE/AT), R&D to assets (XRD/AT), capital expenditures to assets (CAPX/AT), return on assets (IB/AT), and sales growth (percentage change in item SALE). For each of 10 industry classification, each year, we take the industry median of the absolute (annual) change in each of the above variables.	self-calculated
VIX	Natural log of daily index of implied volatility released by the Chicago Board Options Exchange, calculated based on trading of S&P 100 options. Available at http://www.cboe.com/products/vix-indexvolatility/volatility-on-stock-indexes	
Return_SD3	The cross-sectional standard deviation of cumulative returns from the past three months, calculated each month.	self-calculated
Sale_growth_SD	The cross-sectional standard deviation of quarter-on-quarter sales growth (percentage change in the Compustat quarterly item SALEQ), calculated each calendar quarter.	self-calculated
Life-cycle	Categorical variable illustrating different of corporate life-cycle stage that firm is classified within.	self-calculated

Table 4.A.2: Distribution statistics (US sample)

State/Province	N	Percent	Patent number		R&D intensity	
			N	Mean (s.d)	N	Mean (s.d)
ALASKA	143	0.06	0	n/a	42	0
ALABAMA	1,379	0.6	125	3.744 (3.2526)	690	0.0062 (0.0131)
ARKANSAS	1,469	0.64	93	4 (5.9545)	816	0.00004 (0.0036)
ARIZONA	3,314	1.44	726	10.2135 (19.9448)	2,534	0.0108 (0.0224)
CALIFORNIA	30,504	13.25	9,560	24.2895 (76.6504)	24,028	0.03436 (0.0544)
COLORADO	4,913	2.13	561	3.6364 (5.91122)	3,905	0.0087 (0.0254)
CONNECTICUT	4,914	2.13	1,490	18.848 (48.5692)	3,328	0.0083 (0.0221)
DISTRICT OF COLUMBIA	589	0.26	124	8.5081 (10.8144)	425	0.0113 (0.0277)
DELAWARE	1,188	0.52	309	52.2977 (50.03442)	774	0.0214 (0.0357)
FLORIDA	10,030	4.36	747	7.1339 (10.8281)	6,875	0.01246 (0.1756)
GEORGIA	7,063	3.07	980	6.4786 (8.9018)	4,690	0.0106 (0.0278)
HAWAII	980	0.43	10	1 (0)	387	0.0017 (0.0029)
IOWA	1,669	0.72	55	1.436 (0.8769)	949	0.003 (0.0107)
IDAHO	612	0.27	116	216.7328 (154.4503)	337	0.0053 (0.0074)
ILLINOIS	11,076	4.81	3,043	21.9619 (45.2614)	7,306	0.0067 (0.0183)
INDIANA	3,837	1.67	619	10.5218 (12.9127)	1,945	0.0056 (0.0109)
KANSAS	1,301	0.57	142	33.2817 (46.179)	720	0.0031 (0.0113)
KENTUCKY	1,227	0.53	182	8.2308 (6.7071)	647	0.0013 (0.0029)
LOUISIANA	1,245	0.54	44	15.5682 (15.945)	661	0.0005 (0.0049)
MASSACHUSETTS	10,869	4.72	3,327	22.6372 (65.9951)	8,780	0.03769 (0.06296)
MARYLAND	3,216	1.4	508	19.1457 (29.5213)	2,160	0.0321 (0.0762)
MAINE	608	0.26	80	3.4625 (2.7046)	266	0.02965 (0.0299)
MICHIGAN	4,288	1.86	1,601	29.0506 (63.0334)	2,475	0.0129 (0.0282)
MINNESOTA	6,366	2.77	1,642	12.7418 (31.1436)	4,557	0.0133 (0.02527)
MISSOURI	3,956	1.72	650	11.4292 (14.8422)	1,978	0.0052 (0.01473)
MISSISSIPPI	822	0.36	0	n/a	134	0
MONTANA	216	0.09	0	n/a	35	0.0005 (0.0018)
NORTH CAROLINA	5,508	2.39	1,064	25.4887 (55.009)	3,105	0.0121 (0.0383)
NORTH DAKOTA	225	0.1	0	n/a	44	0
NEBRASKA	1,135	0.49	292	4.7534 (5.7914)	790	0.0011 (0.0028)
NEW HAMPSHIRE	849	0.37	225	2.16 (1.6694)	532	0.1977 (0.02377)
NEW JERSEY	8,998	3.91	1,240	19.3444 (33.0737)	6,054	0.035 (0.08576)
NEW MEXICO	177	0.08	10	1.1 (0.3162)	13	0.0047 (0.0080)
NEVADA	2,246	0.98	161	2.8944 (8.2216)	1,720	0.0193 (0.0750)
NEW YORK	21,687	9.42	3,151	51.6604 (212.3696)	14,059	0.0143 (0.0566)
OHIO	9,674	4.2	2,076	12.73314 (26.500)	5,322	0.073 (0.026)
OKLAHOMA	2,047	0.89	45	1.2222 (0.4714)	981	0.0005 (0.0032)
OREGON	1,411	0.61	329	14.2614 (21.9023)	904	0.0104 (0.0177)
PENNSYLVANIA	10,491	4.56	1,691	8.5695 (10.3412)	6,267	0.0154 (0.0416)
PUERTO RICO	392	0.17	0	n/a	60	0
RHODE ISLAND	987	0.43	295	8.9119 (8.9176)	713	0.0115 (0.0148)
SOUTH CAROLINA	1,068	0.46	208	2.4471 (2.1006)	593	0.0078 (0.0129)
SOUTH DAKOTA	624	0.27	75	1.6533 (1.1566)	204	0.0115 (0.0076)
TENNESSEE	3,246	1.41	362	7.9309 (8.2273)	2,229	0.0026 (0.0123)
TEXAS	23,517	10.21	2,599	27.1870 (55.4281)	16,258	0.0065 (0.0228)
UTAH	1,549	0.67	203	2.0148 (1.2722)	1,187	0.0276 (0.4389)
VIRGINIA	6,826	2.96	930	8.2656 (11.5499)	4,156	0.007 (0.02746)
VIRGIN ISLANDS	18	0.01	0	n/a	18	0
VERMONT	173	0.08	17	1.4118 (0.7123)	74	0.0589 (0.0994)
WASHINGTON	4,178	1.81	1,015	41.4680 (136.1704)	2,630	0.02970 (0.0468)
WISCONSIN	4,814	2.09	1,320	5.1970 (9.5935)	2,754	0.0113 (0.0234)
WEST VIRGINIA	573	0.25	0	n/a	110	0
WYOMING	26	0.01	0	n/a	0	n/a
Total	230,233	100	44,042		152,221	

This table reports distributional statistic for quarterly firm-level data over federal states of US sample. All variable descriptions are in Appendix.

Table 4.A.2: Geopolitical risk and firm innovation

	Number of patents			Number of cites			Innovation Efficiency		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GPR	-0.04***			-0.16***			-0.04***		
	(0.002)			(0.000)			(0.001)		
GPT		-0.02***			-0.16***			-0.04***	
		(0.005)			(0.000)			(0.001)	
GPA			-0.05***			-0.10***			-0.06***
			(0.000)			(0.000)			(0.000)
L.Number of patents	0.34***	0.34***	0.34***						
	(0.000)	(0.000)	(0.000)						
L.Number of cites				0.26***	0.26***	0.27***			
				(0.000)	(0.000)	(0.000)			
L.Innovation Efficiency							0.34***	0.34***	0.34***
							(0.000)	(0.000)	(0.000)
R&D intensity	0.35	0.35	0.35	-1.48**	-1.47**	-1.44**	-8.82***	-8.82***	-8.77***
	(0.248)	(0.250)	(0.253)	(0.020)	(0.021)	(0.026)	(0.000)	(0.000)	(0.000)
Firm size	0.03***	0.03***	0.03***	0.02***	0.02***	0.01*	0.07***	0.06***	0.07***
	(0.000)	(0.000)	(0.000)	(0.003)	(0.002)	(0.097)	(0.000)	(0.000)	(0.000)
Leverage	-0.01***	-0.01***	-0.01***	-0.01*	-0.01*	-0.01**	0.00	0.00	0.00
	(0.007)	(0.007)	(0.003)	(0.058)	(0.066)	(0.026)	(0.655)	(0.635)	(0.831)
Firm age	-0.03***	-0.03***	-0.03***	-0.03**	-0.03**	-0.03**	-0.04***	-0.04***	-0.04***
	(0.000)	(0.000)	(0.000)	(0.027)	(0.026)	(0.026)	(0.000)	(0.000)	(0.000)
ROA	-0.18	-0.18	-0.24	-0.74	-0.76	-0.71	0.57	0.57	0.54
	(0.435)	(0.450)	(0.314)	(0.293)	(0.283)	(0.317)	(0.118)	(0.117)	(0.140)
Capital intensity	0.42***	0.42***	0.36***	0.81***	0.81***	0.86***	0.44**	0.44**	0.40**
	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.000)	(0.011)	(0.010)	(0.021)
Cash holding	0.01	0.01	0.01	-0.05	-0.04	-0.08	0.02	0.03	0.02
	(0.664)	(0.674)	(0.810)	(0.423)	(0.462)	(0.145)	(0.508)	(0.504)	(0.609)
Cash flow	0.15	0.14	0.21	0.82	0.83	0.87	-0.37	-0.37	-0.32
	(0.554)	(0.564)	(0.417)	(0.273)	(0.265)	(0.243)	(0.340)	(0.343)	(0.408)
Market to book ratio	0.00	0.00	0.01	0.01	0.01	0.01	-0.02***	-0.02***	-0.02**
	(0.373)	(0.380)	(0.260)	(0.597)	(0.596)	(0.543)	(0.007)	(0.007)	(0.011)
Stock return volatility	0.03***	0.03***	0.03***	0.06***	0.06***	0.06***	0.04***	0.04***	0.05***
	(0.002)	(0.003)	(0.000)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.000)
Industry economic shock	-0.00	-0.00	0.01	0.02	0.01	0.05*	-0.01	-0.01	0.01
	(0.997)	(0.973)	(0.613)	(0.562)	(0.716)	(0.093)	(0.738)	(0.710)	(0.809)
Return_SD3	0.00	0.00	0.01	0.00	-0.00	0.02	0.01	0.01	0.01
	(0.658)	(0.678)	(0.343)	(0.881)	(0.971)	(0.402)	(0.607)	(0.636)	(0.346)
Sale_growth_SD	0.00*	0.00*	0.00	-0.00	-0.00	-0.01	0.01*	0.01*	0.01
	(0.066)	(0.065)	(0.167)	(0.636)	(0.734)	(0.256)	(0.054)	(0.051)	(0.137)
VIX	-0.00	-0.00	0.00	0.08***	0.09***	0.08***	0.02	0.02	0.02
	(0.801)	(0.791)	(0.793)	(0.000)	(0.000)	(0.001)	(0.367)	(0.358)	(0.243)
Consumer confidence	-0.05*	-0.06**	-0.02	0.08	0.07	0.09	-0.03	-0.03	0.01
	(0.057)	(0.040)	(0.584)	(0.153)	(0.221)	(0.132)	(0.523)	(0.457)	(0.824)
Constant	0.20	0.20	0.06	-0.20	-0.14	-0.63**	0.25	0.26	0.09
	(0.167)	(0.162)	(0.651)	(0.497)	(0.633)	(0.029)	(0.218)	(0.213)	(0.652)
Observations	14283	14283	14283	14283	14283	14283	10225	10225	10225
Hansen J Stat	4.48	2.66	29.15	38.25	31.76	95.55	7.79	6.88	13.03
Hansen J Stat (p-value)	0.35	0.62	0.00	0.00	0.00	0.00	0.10	0.14	0.01
R2	0.92	0.92	0.92	0.86	0.86	0.86	0.93	0.93	0.93
Endogeneity test (p-value)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

This table reports our baseline results about the impact of geopolitical risk on technological performance. We form the panel sample for our investigation of the relationship between geopololitical risk and firm innovation output, also known as patent stocks, using the universe of firms included in the Compustat database. Accounting data are obtained from Quarterly Compustat while stock price and return data are from the Center for Research in Security Prices (CRSP) database. We then merge Compustat data with GPR data and patent database published by Kogan et al. since 2017. All variable descriptions are in Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by + , *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.
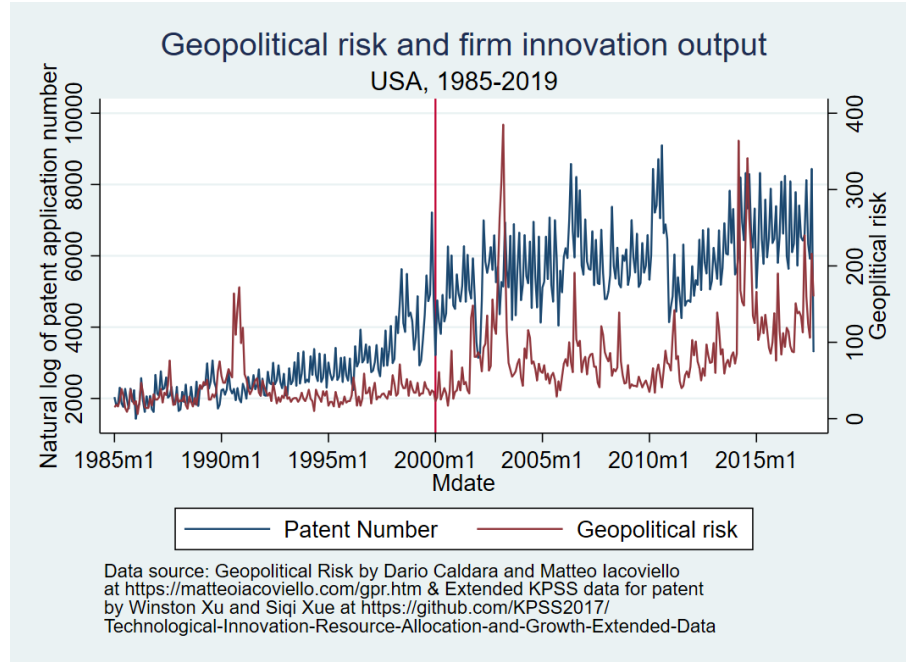
Table 4.A.3: Geopolitical risk and policy persistence

	$Ads\_persale_{t+1}$ (1)	$CAPEX_{t+1}$ (2)	$R\&D\_intensity_{t+1}$ (3)	$Leverage_{t+1}$ (4)	$Cashdividend_{t+1}$ (5)	$Policy\_index_{t+1}$ (6)	$Policy\_index_{t+2}$ (7)	$Policy\_index_{t+3}$ (8)	$Policy\_index_{t+4}$ (9)
Geopolitical threat index (GPR)	0.00	0.11***	0.00**	0.01	0.15***	0.36***	0.73***	0.39**	0.14+
	(0.950)	(0.000)	(0.002)	(0.305)	(0.000)	(0.000)	(0.000)	(0.002)	(0.069)
Ads_persale#GPR	-0.02								
	(0.803)								
CAPEX#GPR		-0.02***							
		(0.000)							
R&D_intensity#GPR			-0.38***						
			(0.000)						
Leverage#GPR				0.01					
				(0.106)					
Cash_dividend#GPR					-0.03***				
					(0.000)				
Policy_index						1.07***	1.28***	1.03***	1.06***
						(0.000)	(0.000)	(0.000)	(0.000)
Policy_index#GPR						-0.03**	-0.08***	-0.02+	-0.02*
						(0.001)	(0.000)	(0.062)	(0.044)
Constant	0.01	-0.35***	-0.02**	-0.06+	-0.54***	-1.26***	-2.86***	-1.33*	-0.35
	(0.472)	(0.000)	(0.002)	(0.073)	(0.000)	(0.004)	(0.000)	(0.022)	(0.326)
Observations	60190	151591	121070	121051	64847	15695	14983	14353	14478
adj. R-sq	0.881	0.858	0.053	0.895	0.873	0.885	0.841	0.856	0.955

This table reports 2nd stage IV regression estimates of models where the dependent variable is indicated in the column title. GPR index and its interaction with the relevant policy variable are instrumented with religious tension. Policy index is the sum of the normalized values of CAPEX, (Advertising/Sales), Net Book leverage, (Dividends/Assets), and (R&D/Assets). All variable definitions are in Appendix. The corresponding robust standard errors are reported in parentheses. Significance levels are indicated by $+$, *, ** and *** and correspond to the 10%, 5%, 1% and 0.1% significance levels, respectively.

4.B   Appendix B

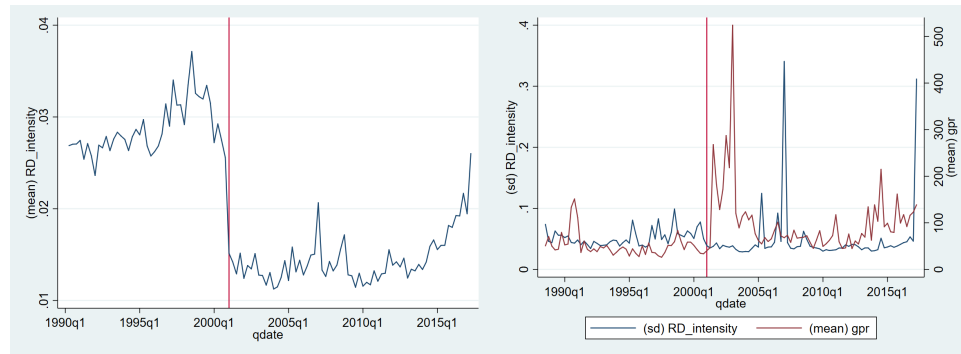**Figure 4.B.1:** Geopolitical risk index with patent number (USA - monthly data)

(a) Aggregated   quarterly-level R&D intensity (mean)

(b) Average quarterly data of R&D intensity (std)

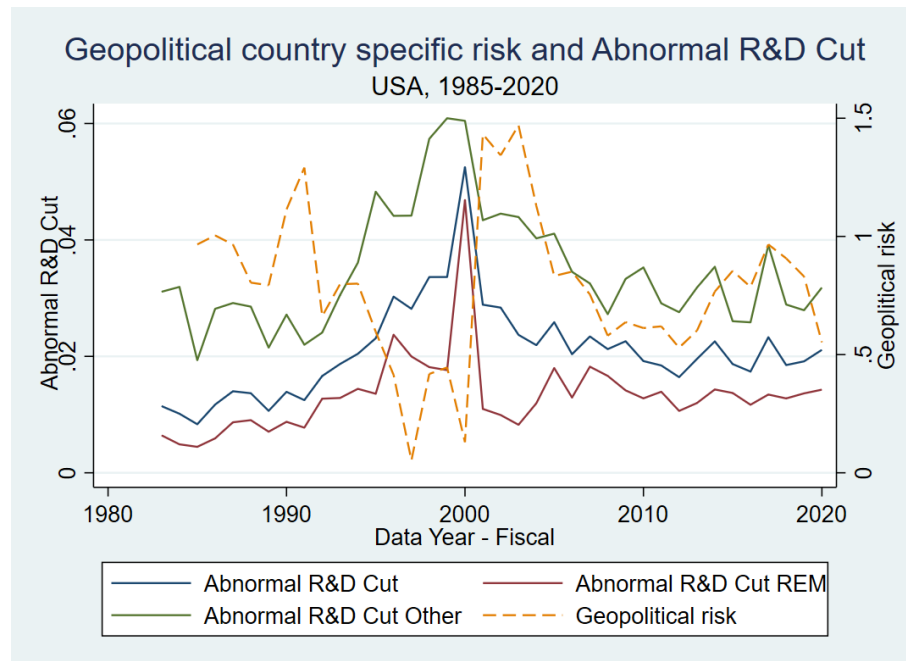**Figure 4.B.2:** Quarterly data of R&D investment (USA)

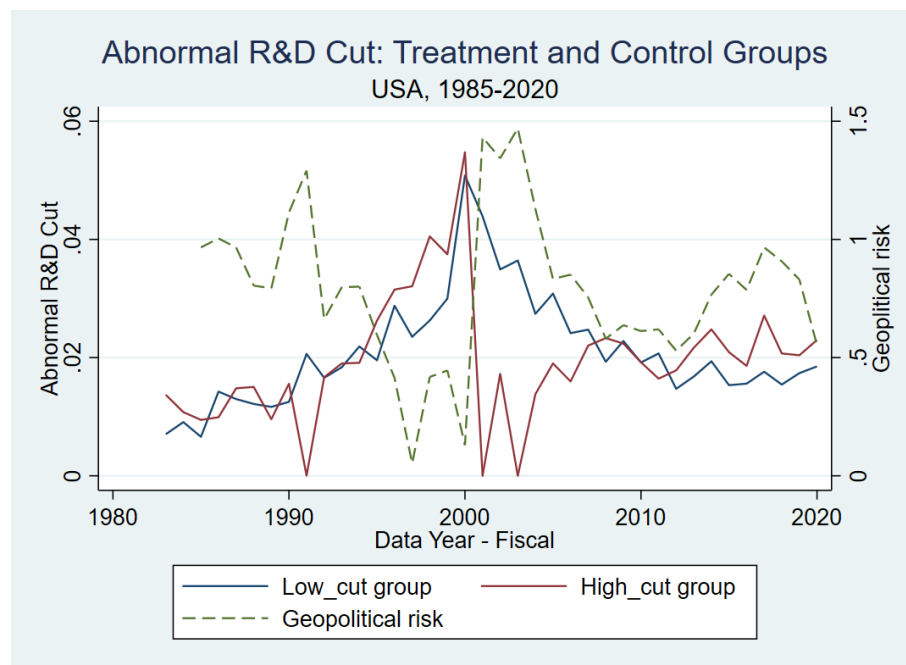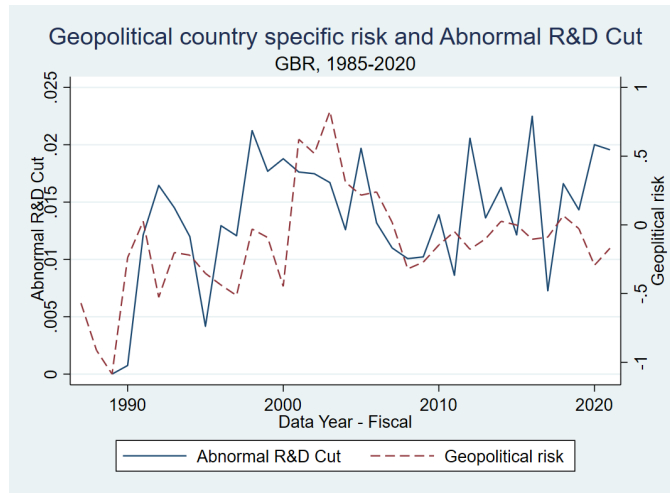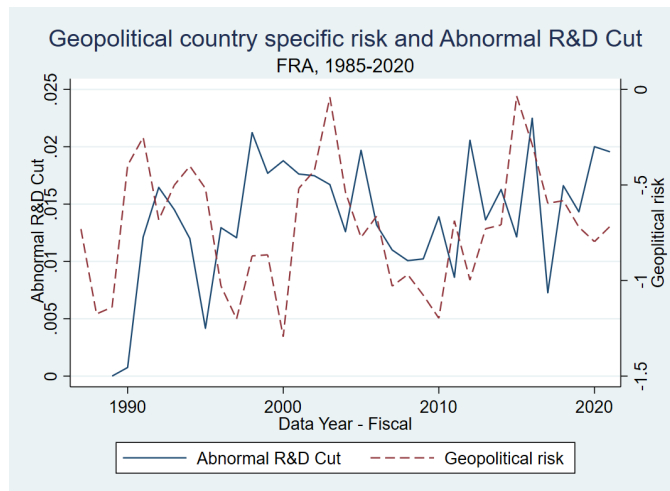**Figure 4.B.3:** Geopolitical risk and Abnormal R&D cut (USA)

Figure 4.B.4: Difference-in-difference parallel trend with high R&D cut group and low R&D cut group

(a) United Kingdom (GBR)

(b) France (FRA)
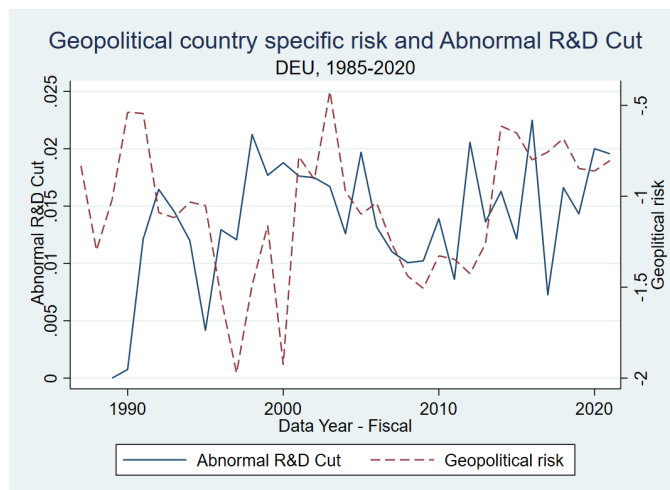
(c) Germany (DEU)

Figure 4.B.5: Geopolitical risk and Abnormal R&D cut (GBR, FRA and DEU)

(a) US sample

(b) EU sample

(c) US sample

(d) EU sample

(e) US sample

(f) EU sample
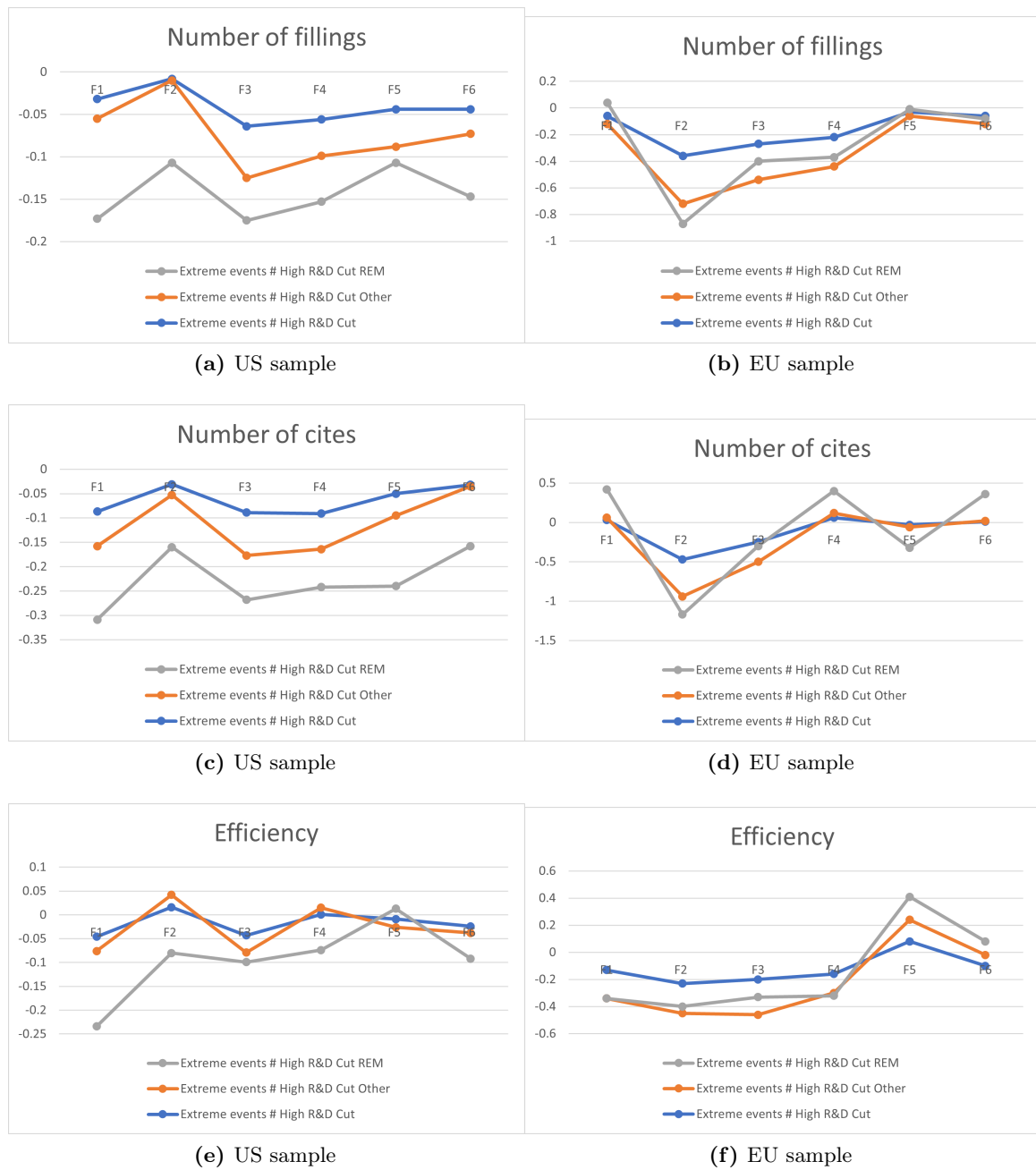
Figure 4.B.6: Persistence of geopolitical risk on firm innovation

4.C   Appendix C

4.C.1   GPR index and country-specific GPR index

GPR index is created and developed by Caldara and Iacoviello since 2018. They uses text searching techniques to count the occurrence of words related to geopolitical tensions in 11 leading international newspapers (namely The Boston Globe, Chicago Tribune, The Daily Telegraph, Financial Times, The Globe and Mail, The Guardian, Los Angeles Times, The New York Times, The Times, The Wall Street Journal, and The Washington Post) from January 1985 to the present.

In general, the GPR index effectively captures geopolitical events. In comparison with other existing measures, Caldara and Iacoviello (2018) show that their index moves in correspondence with the number of international crises per month based on the International Crisis Behavior (ICB) database. For example, the GPR index moves in accordance with the number of crises as per the database, during WWI, the Gulf War, and the Iraq War. Higher geopolitical risk foreshadows lower investment, stock prices, and employment. Higher geopolitical risk is also associated with higher probability of economic disasters and with larger downside risks to the global economy.

According to Caldara and Iacoviello (2018), their GPR index is advantageous compared to other available indices, which have the following inherent shortcomings: (1) they are often qualitative and subjective; (2) they either remain relatively constant over time or are only available over a short period; and (3) some of the measures, although quantitative, are constructed on the basis of variables meant to indicate market conditions, not measure GPR (e.g., gold prices, the dollar index, and several other financial market indicators). Compared with other uncertainties, the GPR index is more "exogenous" to economic conditions than other uncertainty measures are.

The search identifies six groups of words. The first group includes words that explicitly mention geopolitical risk and military tensions. Next, the second group involves words associated with nuclear tensions. The third and fourth groups include war and terrorist threats, respectively, while the fifth and sixth groups capture negative events leading to increasing geopolitical uncertainty, including the start of a war or terrorist acts. The GPR index is obtained by calculating the proportion of GPR-related news among the total number of news articles for each month. This GPR index is normalised to 100 for the period 2000–2009.

The baseline GPR index is constructed on the basis of all six groups while two sub-indices, geopolitical threats (hereafter, GPT) and geopolitical acts (hereafter, GPA), are constructed on the basis of Groups 1 to 4 and Groups 5 and 6, respectively. Caldara and Iacoviello (2018) constructed the two sub-indices to differentiate between the possibility of geopolitical action and the actuality of geopolitical events. Further data and detailed construction description are available online.

Figure 4.B.1 plots the GPR index and aggregated firm innovation since January 1985. As shown, GPR has experienced several spikes, each corresponding to key geopolitical events. For example, the index spikes in January 1991, which corresponds to the outbreak of the Gulf War. We observe two other spikes in September 2001 and March 2003, which correspond to the 9/11 attacks and the beginning of the Iraq War, respectively. Some smaller spikes are observed more recently, such as the 2015 Paris terrorist attack and Russia's annexation of Crimea in 2014.

On the other hand, the country-specific GPR index reflects automated text-search results of the electronic archives of three U.S newspapers: The New York Times, Chicago Tribune and The Washington Post. For each of the 39 countries, Caldara and Iacoviello calculate the country-specific index by counting the monthly share of all newspaper articles from 1900 to 2020 (or 1985 to 2020 for the Recent Index) that both (1) meet the criterion for inclusion in the GPR index and (2) mention the name of the country or its major cities. Each index is expressed as a monthly share of newspaper articles. The resulting indices capture the U.S. perspective on risks posed by, or involving, the country in question.

4.C.2   Patent databases: Extended data following Kogan et al.(2017) and PATSTAT

In this section we provide a summary about patent databases that we use in this study. For US sample we employ the extended data version of Kogan et al. (2017) (KPSS) developed by Winston Xu and Siqi Xue [20]. The advantage of using KPSS or extended verison of KPSS is the matching identifier $CRSP\_PERMNO - PERMCO$ that we can later use to merge KPSS and COMPUSTAT/ CRSP firm-level data.

For EU sample, we utilize PATSTAT, which is extracted from the European Patent Office (EPO)'s databases. For matching with COMPUSTAT, we exploit Fuzzy matching techniques on company name.

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[20]`https://github.com/KPSS2017/Technological-Innovation-Resource-Allocation-and-Growth-Extended-Data`

4.C.3 Firm's life-cycle

We adopt Anthony and Ramesh (1992); Koh et al. (2015) method of classifying firms into the four lifecycle classifications: birth, growth, maturity and decline, based on the following four lifecycle descriptors: annual dividends, scaled by income; percentage of sales growth; capital expenditure as a proportion of firm value; and the age of the firm:

1. Annual dividend as a percentage of income (DP)

$$DP_t = \left(\frac{DIV_t}{IBED_t}\right) \times 100$$

2. Percent sales growth (SG)

$$SG_t = \left(\frac{SG_t}{SG_{t-1}}\right) \times 100$$

3. Capital expenditure as a percentage of total value of the firm (CEV)

$$CEV_t = \left(\frac{CE_t}{VALUE_t}\right) \times 100$$

4. Age of the Firm (Age)

DIV_t is the common dividends for a firm in year t. $IBED\_t$ is the income before extraordinary items and discontinued operations in year t. $SALES\_t$ is the net sales in year t. CE_t is the capital expenditure in year t. VALUE_t is the market value of equity plus book value debt at year t. Finally, AGE_t is the number of years where information is available for the firm on CRSP/Compustat.

Since industries vary in their dividend payment, sales growth, capital expenditure and age, we control for industry effects when grouping firms into the four lifecycle categories. We first calculate the four lifecycle descriptors for each year for each sample firm, then compute median values of the descriptors for each firm–year, using five years' data (i.e., current year and the four previous years).

Next, using SIC's 10 industry grouping, we split the median values of the descriptors (for each industry) into quartiles and group the firms by lifecycle category. Once a firm–year is assigned to a category, it is given a score (median values less than Q1 = 1, between Q1 and less than Q2 = 2, between Q2 and less than Q3 = 3 and equal to Q3 and above = 4). We tally the scores for each firm–year and split all observations into quartiles again. Firms are finally categorized into a lifecycle classification based on the cut-off values of the quartiles.

4.C.4 Does geopolitical risk affect firm innovation: Structural approach

4.C.4.1 Methodology

In this section we show the development of empirical models:

The naive empirical model is specified as follows:

$$Patent_{it} = \alpha + \beta_1 GPR_{it} + \gamma R\&D\_Investment_{i,t} + X_{it} + \phi_i + Quarter_t + \varepsilon_i \quad (4.4)$$

where i denotes the firm; t denotes the year; GPR is the logarithm of the GPR index, as developed by Caldara and Iacoviello (2018), and β is the primary variable of interest; X_{it} is a set of variables controlling for firm characteristics as well as macroeconomic conditions, ϕ_i is a vector of fixed effects (firm and industry), capturing firm-specific differences as well as industry-level characteristics. Controlling these two fixed effect also help us to reduce the concern of omitted variables problem. The quarter dummy variable, $Quarter_t$ captures the possible time trend in the output of innovation. Standard errors are clustered by firm and year to control for potential cross-sectional and serial correlation in the error term.

There are two common sources of endogeneity, which are omitted unobserved factors and reverse causality[21]. To address those issues and accurately measure the influence of geopolitical risk on firm innovation output (patents), we employ an empirical model that takes into account the influence of unobserved heterogeneity and past realizations of risks as well as patents.

We revise the concept of real options of R&D investment under uncertainties, a term that originates with MYERS (1977). This led to work on the valuation of the option to wait before committing to investments (MCDONALD AND SIEGEL (1986)) and a vast literature on real options in general. Major types are described by DIXIT (1989); TRIGEORGIS ET AL. (1996). NEWTON AND PEARSON (1994) describe real options analysis of R&D, pointing out the interesting twist that an option on R&D is applied to the future value of a project that will only exist if the option is exercised, in contrast with the usual situation in which the asset already exists. This adds complexity to an already difficult valuation where uncertainty, in the form of underlying asset volatility is unknown and is practically taken

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[21]From the VAR analysis (see Supplementary), we show that both can be the case in the study of geopolitical risk and patent. Originally, the endogeneity problem is particularly relevant in the context of time series analysis of causal processes. It is common for some factors within a causal system to be dependent for their value in period t on the values of other factors in the causal system in period t_p with $p \in N$. In this instance, we actually explore from the VAR analysis that in the short-run, innovation output of U.S firm Granger cause nuclear threat, terrorist threat, and war acts, which are elements of GPR index.

as constant. DOCTOR ET AL. (2001) gain unusual access to internal company data in order to assess projects in the portfolio of the UK chemicals division of a diversified (unnamed) multinational company and find real options analysis to be a useful aid in assessment of projects in the division's portfolio when combined with a Monte Carlo method and decision trees. Nevertheless, they conclude that more attention needs to be paid to documentation of projects and that data availability is a significant issue.

Meanwhile WEEDS (2002) considers R&D, patents and the option to wait under two different scenarios, pre-emptive leader-follower and optimal cooperative investment. She finds that investment is more delayed when firms act non-cooperatively, with each firm holding back from investing for fear of starting a patent race. BLOOM AND VAN REENEN (2002) find that while patenting feeds into market values immediately, it appears to have a slower effect on productivity. Higher market uncertainty, which increases the value of real options, reduces the impact of new patents on productivity. BLOOM (2007) considers time varying uncertainty and simulates of R&D under low, medium and high uncertainty to show that R&D rates change only slowly over time and the impact of the "delay effect" depends on the relationship between desired R&D and lagged R&D [22].

The aforementioned theoretical discussion implies a version of empirical application with structural form as. We therfore undertake a direct baseline estimation with geopolitical risk as a regressor and further suggest the use of IV-GMM estimator with religious tension as instrumental variable.

$$
\begin{aligned}
Patent_{i,t} &= \sum_{k=0}^{N} R\&D_{i,t-k} + \sum_{j=1}^{N} Patent_{i,t-j} + \eta_i + \tau_t + \vartheta_{it} \\
R\&D_{i,t} &= \sum_{k=1}^{N} R\&D_{i,t-k} + \sum_{m=0}^{N} Uncertainty_{i,t-m} + \eta_i + \tau_t + \varepsilon_{it}
\end{aligned}
\tag{4.5}
$$

where PAT is the patent stock, and geopolitical risk is the proxy for $Uncertainty$, the exogenous shock that is believed to impede R&D accumulation.

However, after conducting two stage least square estimator regressions with geopolitical risk as instrumental variable, the test of overidentifying restrictions to verify the validity of our excluded instruments are rejected and we reconsider whether including geopolitical risk as a regressor made sense. We also used IV-GMM and fixed effects estimators and

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[22]The direct impact of uncertainty depends on the difference between optimal R&D and lagged R&D. If optimal R&D is higher than lagged R&D - so that firms want to increase R&D - then higher uncertainty reduces R&D, a negative "delay-effect". If optimal R&D is below lagged R&D - or firms want to cut R&D - then higher uncertainty increases R&D, a positive "delay-effect". In Appendix, we also presents the alternative model including the lagged observations of both patent counts and R&D intensity

compare the results of both models. We also test for the endogeneity of geopolitical risk in the IV-GMM model. We argue that the IV-GMM model presented in this paper is the most suitable for estimating the relationship between geopolitical risk and firm innovation output due to the presence of both unobserved heterogeneity and the influence of past risks on the number of patents issued by firms. Empirical specifications that only exploit within-firm variations such as IV-GMM and fixed effects may lead to hypothesis tests that are extremely underpowered if there is little time-series variation in the data. The GMM estimator is developed for dynamic panel models by Arellano and Bover (1995) and Blundell and Bond (1998). This method jointly estimates the baseline regression in differences using lagged levels as instruments, with the regression in levels using lagged differences as instruments.

$$Patent_{i,t} = \alpha + \sum_{s=1}^{p} \beta_s Patent_{i,t-s} + \sum_{j=0}^{p} \delta_j Geopolitical\_Risk_{i,t-j} +$$

$$\gamma R\&D\_Investment_{i,t} + X_{i,t} + \varepsilon_{i,t} \quad (4.6)$$

Religious tension as instrumental variable

To further address endogeneity concerns, following PAN (2019), we employ a measure of religious tension as an instrumental variable. This variable is recorded in the International Country Risk Guide (ICRG) database, published by Duke University and PRS. Also, based on ICRG, religious tension might arise from a religious group that seeks to replace civil law by religious law and to exclude other religions from the political and/or social process. The lower the religious tension score, the higher the level of conflict and disagreement among religious groups. To simplify the interpretation of the estimation results, we multiply ICRG's religion tension score by -1 and use the transformed religious tension score in instrumental analysis. Overall, the instrumental variable analysis results suggest that religious tension is a good instrument in the IV-GMM results.

Table 4.A.2 provides the distributional statistics for firm-level observations over industries based on SIC codes, and over federal states, respectively. From Panel A, we can see that California, Texas and New York are top 3 states that reach the highest R&D investment intensity while top 3 of states in terms of patent stock publication are California, Massachusetts and New York. It is due to the fact that the Silicon Valley in California is a global center for high technology and innovation. While Massachusetts was transformed into a manufacturing center during the Industrial Revolution, marking it's economy shifted from manufacturing to services so that now it is a global leader in biotechnology, engineering,

higher education, finance, and maritime trade. Overall, the number of R&D intensity figure reported and collected from COMPUSTAT is about 65%. While conducting regression analysis, we make sure that there are non-missing firm-year observations and non-missing R&D expense data, which, therefore, results as unbalanced panel.

4.C.4.2 Results

Main results

The estimation results of our baseline regression models are shown in table 4.A.3. The VAR analysis and auto-regression identification were used to justify the lag observations. We begin by examining the impact of geopolitical risk (GPR) on patents. As pointed out in the identification strategy part, we run the IV-GMM two-step models with religious tension as main instrument variable along with other lags of GPR [23].

The number of patents issued by a corporation is inversely associated with GPR at the 0.1 percent significance levels, as shown by the findings of Iv-GMM models presented in column (1). The coefficient of GPR is -0.04, so in a nutshell, a 1% increase in the predictor is associated with a minus 0.03% change in the patent outcomes, approximately. Using the exact method, if geopolitical risk doubles, patent stock drops by 1.19% on average [24]. Despite the fact that this is a modest quantity, it can be a huge source of concern for innovative companies and industries. We may easily deduce, based on this view, that the more inventive a company is (say one that registers patents at a faster rate than others), the more sensitive it is to geopolitical risk. In the literature on endogenous growth models, this is what is meant by "perfect scaling." However, we will question this perspective in this study in order to better understand the immense effect of geopolitical risk on firm technical performance in small, young, and high-tech enterprises.

We observe that the negative relationship between GPR and number of patents remains when adding firm characteristics and macroeconomic controls. Interestingly, across all the models, while the size of firms show statistically significant positive impacts on the number of patents, firm age is negatively associated with the number of patents issued. These results indicate that young firms tend to invest more in innovation than long-live

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[23]High levels of religious tension are linked to a high level of the GPR index, which is caused by a lot of religious conflicts. However, R&D decisions and firm technological performance are unlikely to be directly correlated to religious tension. (see AGNEW (2006); STURM (2013); PAN (2019)). Since GPR and religious tension measures are crosssectionally invariant, we follow GULEN AND ION (2016) and PAN (2019) to run a time-series regression in the first stage and a panel regression in the second stage.

[24]The exact method is calculated as $2.71^{((log(2)*-0.04))} = 0.988 * Ln(Patents + 1) =$ a 1.19% decrease in number of issued patents, which means a 100% increase in geopolitical risk results a decrease (of patent stock) by 1.19%

firms, which confirms prior studies about relation between firm and firm age (Hansen (1992); Balasubramanian and Lee (2008); Ouimet and Zarutskie (2014); Coad et al. (2016)), which inspires us to link this research with firm life cycle theory context. In summary, our findings support the negative relationship between GPR and patents, but results for different firm types may slightly differ.

Which sources of geopolitical risk matter more for firm innovation?

We examine which components of geopolitical risk are most likely to affect the number of patents in this part. Firms may react differently depending on the likelihood of geopolitical action versus the potential of geopolitical events. Caldara and Iacoviello (2018) divide their GPR index into indexes for Geopolitical Threats (GPT) and Geopolitical Acts (GPA). GPT encompasses geopolitical threats that are not contemporaneously associated with geopolitical activities (at the time of classification), such as tensions escalating before wars. The GPA reflects the actual occurrence of bad geopolitical events. These findings imply that when either Geopolitical Threats (GPT) or Geopolitical Acts (GPA) is high, it will have a detrimental influence on US firms' patent release. Further, among all the components, terrorist threats and terrorist acts show the strongest and consistently deleterious impacts on patents. The coefficient of terrorist threats and terrorist acts are all statistically significant at 0.1% level, regardless of fully-controlled or not. Nuclear threats show the least impacts among all, only statistically significant at 10% level [25].Meanwhile, war threats and acts have statistically significant effects only when firm characteristics and macroeconomic conditions are not controlled for. One possible explanation is that because wars do not directly affect the U.S setting, so that US firm and macroeconomic controls are irrelevant in the model with wars. To address this concern further, we will later use the analysis relating to US military involvement in additional tests section.

How do firm policies react to geopolitical risk?

In this section, we shift our focus on corporate policies to gain insights on the channels through which geopolitical risk affects the firm's financial strategies. In our tests, we focus on the firm's investment in physical assets (Capital expenditures (Capex)/Assets), innovation (R&D/Assets), and brand building (Advertising/Sales), as well as its reliance on debt capital (Net book leverage) and propensity to pay dividends (Dividend/Equity).

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[25]The results about nuclear threats/acts are quite consistent with VAR/SVAR evidence, saying that the shocks in patents number in fact affected nuclear threats more than the reserved side. This interesting implication in fact can be developed more in the future research direction.

Since the importance of these policies differs across firms and industries, we also construct a summary policy index that aggregates the five separate (standardized) policy measures. For each of these variables, we measure the persistence of the corresponding policy from quarter to quarter by estimating the relation between the observed policy one quarter ahead and the current policy. To test whether the persistence of a policy depends on geopolitical risk, we include the interaction between the current policy and the current instrumented GPR– while controlling for the stand-alone effect of GPR.

Table 4.A.3 reports the results from these tests. We find that the coefficient estimated on the interaction between each policy and the instrumented GPR is negative and statistically significant at least at the 10% probability level. This evidence is consistent with the notion that greater uncertainty leads to less persistent policies. Also, we examine whether geopolitical risk affects financial and investment policies. Columns (2)- (3) indicates that the instrumented geopolitical risk has statistically significant impact on the level of firm investment in physical assets as well as R&D investments. Results in columns (4)-(5) of table 4.A.3 show that greater geopolitical risk leads to higher financial risk. In particular, all else equal, firms exposed more with geopolitical risk rely relatively more on debt capital, sustain less cash dividend yields for shareholders and spend less in R&D investment.

Chapter 5

Conclusions and future work

5.1 Remarks and Implications

This thesis investigates the effects of external factors such as regulatory interventions and geopolitical risk on internal governance transition, corporate finance policies and performance outcomes (risk, return, and innovation). More specifically, in Chapter 2 we find strong evidence that there are dynamic relationships between diversity and firm performance, as well as between diversity and innovation output, using a sample of public firms from 1996 to 2017. In general, our research adds to the body of knowledge by providing a synthesised model that integrates the strategic business and corporate governance literatures. It suggests that there is an ideal number of external directors for obtaining ambidexterity. The term "outsider" refers to a group of directors who have less access to inside information than others, which can include both independent and non-traditional directors. Our findings have important policy implications, as regulators have prioritised the mandatory increase in the share of non-traditional directors. When compared to DUCHIN ET AL. (2008), our findings appear to indicate a more distinct root cause of the problem and thus have more practical implications.

It has been shown that the actions taken by regulatory organisations can alter the structure of these non-linear effects. We present a large body of evidence that suggests that, in the era following the implementation of SOX, a decrease in the number of non-traditional directors serving on boards of directors is associated with a reduction in the number of patents registered, improved firm returns, and reduced stock volatility. We can achieve success in reaching this objective by applying the difference-in-difference approach. This impact is experienced to a greater degree by organisations that are, on average, larger in

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size, have a higher number of directors serving on their board who are not linked with the firm, and invest more money overall in capital expenditures.

Secondly, we provide novel empirical evidence on the association between RAC and SOX. In this study, we question how RAC jointly with board diversity, affect firm environmental CSR performance. By applying difference-indifference (DID) and triple difference (DDD) approaches in Chapter 3, we document that RAC and SOX can have great influence on environmental performance. We emphasize here in our study setting that SOX is a SEC-level effort while RAC is of local voluntary. Studying their jointly effects provide policymakers with some implications for the implementation of mandatory disclosure in the future. As we recognise the down sides of mandatory disclosure, such as green-washing, in which firms are induced to use boilerplate language in order to mislead stakeholders about their environmental performance or the environmental benefits of a product or service. Mitigating green-washing is especially difficult in an environment of limited and uncertain regulation as firm's behaviour are becoming sophisticated, complex and prevalent. Nevertheless, our study shows a "robust" trend of effective environmental CSR initiatives in those ex-ante diverse boards under RAC adoption.

Academics and practitioners have paid a significant deal of attention to innovation and its drivers since they are the cornerstone of economic advancement. In addition to their fundamental characteristics, innovation efforts have been impacted by increased geopolitical, economic, and policy insecurity. We provide evidence of GPR will reduce innovation output, measured by number of patents, citation, and innovation efficiency, via R&D cuts in Chapter 4. Particularly, segregating the amount of abnormal R&D cuts into real earning-management and other purposes, we document that the former generates a more severe effect on innovation outcome revealing in a shorter time period than the latter. Within the context of the firm's life cycle, the existing body of research suggests that enterprises that have reached a mature stage experience a decline in the number of innovative activities they do. We contribute to the existing body of knowledge by providing evidence that the effect of a loss in innovation outcome brought about by a reduction in expenditure on R&D is most noticeable among mature companies that are exposed to increasing levels of geopolitical instability. In addition, the behaviour of R&D cuts that can be attributed to a variety of goals (such as REM or others) will have a distinct effect on businesses that are in different stages. Although extraordinary reductions in R&D investment do not provide any conclusive results, R&D cuts related to REM are problematic for companies that are still in the birth or growth stage because they could have an effect on the competitive advantage of companies that are just entering the market.

5.2   Limitation and Scope for future work

As with other research our study is subject to several limitations, which open the opportunities for future research. First and foremost is the concern about data availability. Particularly, we use mostly secondary data for United States (US) in all studies. Although, in the last study, we tried to include and employ the same empirical framework for some European countries, we have to admit the fact that lack of secondary data limits our empirical findings to some extents. Except from that, we also briefly list out the limitations of each study in detail and provide possible future avenues for research.

Topic 1

Over the course of a great number of years, governments all over the world have consistently lent their support to initiatives known as equality, diversity, and inclusion (EDI) programmes. In spite of the challenges that must be surmounted in order to carry out this endeavour across a diverse range of cultures and nations, there is a huge knowledge and research void that must be supplied in order to address the issue. Even among nations that are physically and culturally near to one another, such as the United Kingdom, France, and Germany, there are significant disparities in how diversity is regarded. While diversity management in the United Kingdom (UK) relies on the historical language of multiculturalism, republican ideas of equality are essential in France, and the instrumental rhetoric of integration is prevalent in Germany (TATLI ET AL. (2012)). As a result, the engagement of a diverse range of cultures and organisations contributes significantly to the difficulty of developing EDI standards that are applicable across international borders. Future study might broaden the scope of the existing studies beyond the US context by including studies from the culture area. This would allow the researchers to take into consideration corporate governance improvements in other nations.

Topic 2

Even though we tried to give a full picture of how RAC could be a model for the implementation of semi-mandatory ESG disclosure, we only used data from KLD to get our results, ignoring criticisms about using different sources of ESG metrics (Bloomberg, Thomson Reuters, etc,.), see more discussions from DORFLEITNER ET AL. (2015). In the future, if we get access to the post-2013 data for KLD or if we are able to gain access to additional sources of ESG datasets, we will re-evaluate and broaden the scope of our previous research and bring it up to date.

Topic 3

We have made the decision not to continue including Ukraine and Russia in this study due to the limitations of the matching algorithm and the data that is currently available. This decision was made despite the fact that Ukraine and Russia represent a potential future research area in light of the recent conflicts that have occurred between their respective governments. It is also advised that a long-term examination of the ramifications of the war be conducted, since there will surely be further unexpected impacts that we have not yet discovered. The inclusion of the current situation in Ukraine in our already existing cohort may have an effect on the validity.

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