CEO COMPENSATION, BOARD DIVERSITY, INNOVATION, AND FIRM RISK

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ABSTRACT

This thesis comprises three studies on internal corporate governance mechanisms. The first study examines whether CEOs with a large portion of inside debt pay reduce firm innovation, which is measured by the number of firm patents and citations. Inside debt compensation is an important component of the total executive pay package. The empirical results show that CEOs with high inside debt incentives decrease innovative output. The negative effect of inside debt compensation on innovative output is due mainly to pension benefits. CEOs with extensive inside debt holdings are associated with lower conversion of R&D spending into patents and a negative impact on innovation efficiency (research quotient).

The second study explores the link between board diversity and CEO pay incentives. This research examines whether multi-dimensionally diverse boards adjust CEO pay incentives to encourage CEOs to follow less risky policies. Overall, the results show that heterogeneous boards reduce CEO equity incentives and increase the inside debt incentives to encourage CEOs to take less risk. The link between board diversity and CEO pay incentives is mainly attributable to the diversity of non-executive directors. More diverse compensation committees also tend to decrease CEO equity incentives and increase the inside debt incentives.

The final study examines the impact of board faultlines and the interactive effect of multi-dimensional board diversity and faultlines on firm risk. This research shows that when the board faultline strength is higher (having greater cohesion between the subgroups in the board), the negative relationship between board diversity and stock return volatility becomes weaker. The diversity of both executive and non-executive directors has a positive association with firm risk when the board faultline strength increases.

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CHAPTER 1. INTRODUCTION

Corporate governance is a system of principles and practices of corporations to control agency problems and improve firms' value, image and reputation (OECD, 2007). Good corporate governance is important to create value and manage risks effectively. There are both internal and external corporate governance mechanisms. In the internal corporate governance system, the board of directors, board committees, and the design of the executive compensation package are among the most critical factors (Chew & Gillan, 2009). To achieve long term firm growth and maximize firm value, a firm should design and implement an appropriate pay package for top executives. In addition, a firm should consider how to structure a board of directors with a range of skills sets and diversity of views. My thesis focuses on two crucial components of the internal corporate governance mechanism, CEO compensation and the diversity of the board of directors.

My thesis comprises three studies. The first study, shown in Chapter 2, explores the effect of CEO compensation on firm activities. Specifically, this study investigates the impact of CEO inside debt compensation on innovative output. Inside debt compensation, including pension benefits and deferred compensation, aligns the interests of top executives with those of creditors. While the research of Cassell, Huang, Sanchez, and Stuart (2012) finds that CEOs with high inside debt incentives choose less risky investment policies by reducing R&D expenditures, my study examines whether CEOs, who hold a large portion of inside debt compensation, reduce innovative output. This research measures innovative output by the number of patents applied for by firms at the United States Patent and Trademark Office (USPTO) and the number of citations received by patents. The number of patents represents the quantity of innovation activities, while the number of citations measures the quality of innovation (Seru, 2014).

The first study contributes to the innovation literature by providing empirical evidence that CEO inside debt compensation negatively affects the firm's innovation activities. This study also adds to the existing literature on the impact of the incentive alignment of executive compensation, especially inside debt compensation, and helps the understanding of how CEOs with inside debt incentives reduce firm risk.

The main findings of my first study are summarised as follows:

- In the baseline models, CEOs with a large holding of pension benefits (high pension based relative leverage and relative incentive ratios) have less incentive to increase the quantity of innovation activities (the number of patents). However, there is no evidence of an association between aggregate inside debt incentives (including pension benefits and deferred compensation) and the number of patents and citations. The reason is that deferred compensation usually has a shorter maturity than pension benefits, and thus may not strongly incentivise top executives to take less risk compared to pension benefits. In the robustness tests, I use another measure of inside debt compensation, that is the ratio of inside debt compensation to cash compensation. The results still hold.
- The results of the propensity score matching (PSM) method show that CEOs with a ratio of pension based relative incentive higher than one tend to reduce the number of patents. Moreover, CEOs with a ratio of inside debt relative incentive higher than one decrease the quality of innovation (the number of citations).
- There is significant evidence that when executives receive pension based relative leverage and incentive ratios which are higher than one, they have less motivation to convert R&D spending into more patents.
- This study also finds that CEO inside debt compensation has a negative impact on innovation efficiency, which is measured by the research quotient created by

Knott (2008). The research quotient measures the percentage increase in revenues when R&D expense increases by one per cent while other inputs are constant.

The second study, presented in Chapter 3, focuses on the relationship between the board of directors and CEO pay incentives. In particular, it examines the effect of board diversity on CEO pay incentives, including equity and inside debt incentives. Corporations increasingly emphasise the heterogeneity of the board of directors. Diverse boards bring benefits to firms from differences in backgrounds, perspectives, expertise, and experience. Boards which are diverse on multiple dimensions tend to reduce firm risk by following conservative policies (Bernile, Bhagwat, & Yonker, 2018). However, little is known about the effect of boards which are heterogeneous on various aspects on CEO pay incentives. Setting a remuneration package for top executives and managing firm risk are vital roles of the board of directors. Therefore, it is important to understand how diverse boards design the CEO compensation package to incentivise CEOs to achieve the corporate risk management target. I empirically examine whether or not heterogeneous boards decrease CEO equity incentives and increase inside debt incentives. Board diversity is measured based upon board gender, age, experience, education, ethnicity, and financial expertise similar to Bernile et al. (2018). I investigate the impact of this board diversity index not only on CEO equity incentives but also on CEO inside debt incentives.

Overall, the second study makes noteworthy contributions to the board diversity literature and enhances the understanding of the impact of heterogeneous boards on CEO pay incentives. Moreover, this research contributes to the CEO pay incentive literature by providing empirical evidence that board diversity is an essential determinant of CEO pay incentives. This study also adds to the research of Prevost and Upadhyay (2018) that financial expertise diversity is positively related to CEO inside debt incentives.

The key results of this second study are as follows:

- In the baseline regressions, there is significant evidence that multi-dimensionally diverse boards reduce CEO equity incentives (vega of stock and options as well as vega of options only) and increase CEO inside debt incentives (the ratio of relative leverage).
- The negative association between board diversity and CEO equity incentives as well as the positive link between board diversity and CEO inside debt incentives are primarily due to the diversity of non-executive directors.
- The negative link between the board diversity index and vega of options is stronger when a firm has higher leverage than the median leverage of the industry.
- The compensation committee diversity index is negatively associated with CEO equity incentives and positively related to CEO inside debt incentives.
- When estimating the influence of specific components of the diversity index on CEO pay incentives, no single source of the diversity index has a significant impact on CEO equity incentives. However, boards which are diverse in gender and financial expertise increase CEO inside debt incentives.

The third study, shown in Chapter 4, examines whether board faultline strength and distance, which create potential conflicts within a diverse board, significantly affect firm risk as well as confound the association between board diversity and corporate risk. This research is important for helping to explain why there are mixed results regarding the relationship between board heterogeneity and firm risk. On the one hand, there is empirical evidence that diverse boards decrease stock return volatility because they make conservative decisions and robust policies thanks to heterogeneous viewpoints, experience, and expertise (Bernile et al., 2018). On the other hand, board diversity is associated with increasing firm risk when there are potential conflicts among directors which impair board performance (Giannetti & Zhao, 2019). This research adds to the prior research of Bernile et al. (2018) and Giannetti and Zhao (2019) by conjecturing that board faultline strength and distance, which generate potential frictions among board members, are critical factors confounding the relationship between a heterogeneous board and firm risk. I measure the potential conflicts within the boardroom by applying the board faultline measurement adopted by Peteghem, Bruynseels, and Gaeremynck (2018). Board faultline measures show how a board is divided into various homogeneous subgroups based on the alignment of the different characteristics of directors. The faultline measurement includes faultline strength (the cohesion degree within a subgroup based on multiple attributes of the directors) and faultline distance (the extent to which different subgroups diverge). Diverse boards with strong faultline strength and/or distance experience a high level of disagreements and conflicts within the boardroom (Peteghem et al., 2018). Firm risk is measured by the monthly annualised stock return volatility. This research calculates board heterogeneity based on the board diversity index (including age, gender, ethnicity, board experience, financial expertise and educational background) created by Bernile et al. (2018).

The third study adds to the understanding of the role of diverse boards in managing firm risk by introducing board faultlines as an important factor influencing the relationship between board heterogeneity and corporate risk. This research contributes to the current literature by finding that the negative relationship between diverse boards and corporate risk weakens when there is high faultline strength (a high cohesion degree of the subgroups within a board), which induces potential frictions among members. The results clarify why the relationship between board heterogeneity and firm risk is mixed in current empirical studies. Moreover, the findings contribute to the understanding of the importance of the design of the structure of diverse boards and suggest that companies should also consider whether their boards have strong faultlines, which can lead to conflicts within the boardroom.

Main findings in the third study include:

- The negative association between board diversity and stock return volatility becomes weaker when directors in each of different subgroups within the boardroom are very similar (high board faultline strength). The directors in each homogeneous subgroup may work together against the other subgroups within the boardroom. Thus, the higher the potential frictions, the higher the probability that the mitigating effect of diverse boards on corporate risk weakens. There is no evidence that board faultline distance significantly affects stock return volatility or the association between board diversity and firm risk. Robustness tests show that main results still hold.
- There is no evidence that a single component of the diversity index (i.e. age, gender, ethnicity, financial expertise, board experience, or education) and/or the interaction of each dimension of diversity with board faultline strength/distance significantly impacts firm risk.
- The negative relationship between firm risk and the diversity of both executive and non-executive directors becomes weaker when there is an increase in board faultline strength.

The rest of the thesis is organised as follows. Chapter 2 examines the impact of CEO inside debt compensation on innovative output. Chapter 3 presents the effect of multi-dimensional board diversity on CEO equity and inside debt incentives. Chapter 4 examines the influence of board faultlines on firm risk and on the association between board diversity and corporate risk. Chapter 5 provides general conclusions.

CHAPTER 2. CEO INSIDE DEBT COMPENSATION AND INNOVATIVE OUTPUT

2.1. Introduction and motivation

The executive compensation arrangement is one of the primary internal corporate governance mechanisms that affects the decisions of executives (Bebchuk & Weisbach, 2010). While some scholars focus on the level of executive compensation (Kaplan, 2008), others debate about the structure of the executive pay package (Mehran, 1995). The use of equity-like compensation such as stocks and stock options is often preferred by many companies to align the interests of managers with those of shareholders. However, top executives with a large portion of stocks and options tend to engage in highly risky activities with a focus on short-term gains in share prices rather than long-term growth opportunities (Murphy, 1999). The failure of many corporations during the global financial crisis has encouraged the idea that companies should pay top managers more debt-based compensation (pension benefits and deferred compensation) rather than more equity-based compensation (Cassell et al., 2012). Although pension plans provide payments for employees after retirement, the pension benefits of CEOs are much more significant than the broad-based pension plans of normal employees. A large portion of the pension benefits held by CEOs is in the form of Supplemental Executive Retirement Plans (SERPs). Deferred compensation is the portion of current compensation that companies will pay to their employees later on a specified date.

The use of debt-like instruments (known as inside debt) as a key component of executive pay has now started to gain considerable attention (Edmans & Liu, 2011). Understanding the incentive effects and economic consequences of debt-like instruments is essential because the inside debt holdings of CEOs account for a substantial part of the total compensation (Cassell et al., 2012). For example, the total present value of inside debt held by Jack Welch, CEO of General Electric Corporation, was $109 million by the time he retired (Sundaram & Yermack, 2007, p. 1552). The value of the deferred compensation of Roberto Goizueta, the former CEO of Coca-Cola, was more than $1 billion (Edmans & Liu, 2011, p. 76). CEO Rex Tillerson of ExxonMobil received supplemental pension benefits of approximately $21.1 million in 2013 (Hymowitz & Collins, 2015). The Wall Street Journal reported that there was an increase of 19% in the pension benefits held by top managers in 2008. The total value of pension benefits and deferred compensation was equal to approximately 43% of the total amount of equity-based pay in 2008 (Anantharaman, Fang, & Gong, 2013).

Some scholars argue that debt-like instruments may align the interests of managers with those of outside debt-holders and thus incentivise top executives to make less risky decisions (Cassell et al., 2012; Edmans & Liu, 2011; Jensen & Meckling, 1976). The pension benefits and deferred compensation of CEOs function as debt-like instruments because they are generally the unsecured and unfunded liabilities of firms. CEOs cannot receive payment from unfunded and unsecured pension benefits and deferred compensation if their firms go bankrupt. Thus, CEOs with high inside debt incentives face default risk, which is similar to that faced by outside debtholders. For instance, the CEO of General Motors, Rick Wagoner, lost nearly $20 million of his pension benefits when GM went bankrupt (Cassell et al., 2012). However, there is still limited empirical evidence of inside debt's economic consequences (Anantharaman et al., 2013; Sundaram & Yermack, 2007). Consistent with the argument that inside debt compensation aligns the interests of executives and creditors, previous empirical studies have found a negative link between inside debt pay and default risk (Sundaram & Yermack, 2007), bond yield spread (Anantharaman et al., 2013), credit default swap spread (Wei & Yermack, 2011), and mergers and acquisitions (Phan, 2014). Managers with high inside debt may follow safer and more conservative managerial policies (Sundaram & Yermack, 2007), and an excessive safety management style of CEOs may make their companies too safe (Campbell, Galpin, & Johnson, 2016).

The research of Cassell et al. (2012) finds that CEOs with high inside debt pay have incentives to reduce firm risk, which is measured by the volatility of stock returns. Their study shows two main channels through which CEOs with high inside debt incentives seek to reduce the riskiness of their firms. Those channels include financial and investment policies. CEOs receiving large inside debt pay prefer less risky financial strategies, such as increasing asset liquidity or decreasing financial leverage. CEOs with high inside debt may also choose less risky investment policies by reducing R&D expenditures. However, it is still unclear whether CEOs with extensive inside debt holdings will have more or fewer incentives to encourage innovative activities in their firms. Substantial investment in R&D spending does not promise a higher innovative output. Also, less investment in R&D expenditures does not mean lower innovative output[1].

My research further investigates whether CEOs with significant inside debt compensation reduce innovative output. The study by Cassell et al. (2012) does not specifically examine the link between CEO inside debt compensation and innovative output. However, are CEOs holding high inside debt pay reluctant to increase innovative output to reduce the riskiness of their firms? Innovative output is measured by the number of patents and citations. The number of patents measures the scale of R&D activity or the quantity of innovative activities. The number of citations measures the novelty of R&D activity or

[1] Deloitte analysis of the USPTO filings and S&P Capital IQ data shows that the firms with the largest R&D spending do not necessarily have the highest patent innovation intensity (Deloitte Insights, 2019).

the quality of innovative activities (Seru, 2014). Patents and citations provide clear signals to outside investors about the success of innovative projects carried out by firms.

Previous theoretical and empirical studies find that high levels of inside debt pay can induce CEOs to pursue conservative management policies and less risky projects (Anantharaman et al., 2013; Edmans & Liu, 2011; Jensen & Meckling, 1976; Phan, 2014; Sundaram & Yermack, 2007; Wei & Yermack, 2011). Innovation is typically risky and unpredictable (Francis, Hasan, & Sharma, 2011) and the default risk of firms increases if many innovative projects are carried out (Eisdorfer & Hsu, 2011). For instance, an increase in patent activities is positively associated with bankruptcy risk because there is an intensity of patent competition in the industry (Eisdorfer & Hsu, 2011). Therefore, downside risks become major concerns of CEOs with a large portion of inside debt holdings. I argue that the association between CEO inside debt compensation and innovation is negative.

My study also investigates whether the impact of R&D expense on innovative output depends on the effect of inside debt incentives. In addition, my research further examines the link between CEO inside debt incentives and the research quotient, which reflects innovation efficiency. This research also examines whether the negative impact of inside debt compensation on innovative output is mainly due to pension benefits or deferred compensation. Deferred compensation usually has shorter maturity than pension benefits, and deferred compensation does not strongly encourage executives to take less risk compared to pension benefits.

Overall, the baseline regression models show that CEOs holding excessive pension benefits reduces the number of patents applied for by corporations. However, the impact of aggregate inside debt incentives on innovative output is insignificant. The explanation is that deferred compensation, one component of inside debt pay, does not always incentivise CEOs to follow less risky policies. In the robustness test, this study utilises another measure of inside debt, which is the ratio of inside debt to cash compensation. I find that firms paying CEOs with higher ratios of pension benefits to cash compensation have a lower number of patents and citations. Using propensity score matching, this study finds that CEOs decrease innovative output when their pension based relative incentive ratio and the aggregate inside debt relative incentive ratio are higher than one. Moreover, CEOs with a pension based relative leverage (incentive) ratio higher than one have less motivation to convert R&D expense into more patents. Finally, inside debt incentives negatively affect innovation efficiency measured by research quotient (the percentage increase in sales when R&D expenditure rises by one per cent while other inputs are constant).

This research provides two main contributions to the existing literature. First, this study contributes to the innovation literature by documenting that CEO inside debt compensation significantly affects the innovative activities of firms. Prior literature primarily focuses on the influence of equity-based compensation (stocks and options) and cash-based compensation (salary and bonus) on innovation (Faurel, Li, Shanthikumar, & Teoh, 2016; Francis et al., 2011; Holthausen, Larcker, & Sloan, 1995; Lerner & Wulf, 2007). These studies find that salary and bonuses do not incentivise top managers to enhance the number of patents and citations because these components of pay only provide short-term incentives for top executives. In contrast, equity-based compensation is positively correlated with innovative output because it gives long-term incentives (Faurel et al., 2016; Francis et al., 2011; Holthausen et al., 1995; Lerner & Wulf, 2007). My study adds to the existing literature by showing that CEO inside debt compensation is negatively associated with innovative outputs, and that the negative impact of inside debt pay is primarily due to pension benefits.

Second, this research contributes to the current literature on the effect of incentive alignment of executive compensation, especially inside debt compensation. The extant literature mainly emphasises the association of inside debt incentives and M&A, investment and financial policies, reactions of investors, loan contract design, and firm risk (Anantharaman et al., 2013; Cassell et al., 2012; Phan, 2014; Sundaram & Yermack, 2007; Wei & Yermack, 2011). However, little is known about the influence of CEO inside debt compensation on innovative activities. My research gives empirical evidence that inside debt compensation incentivises CEOs to reduce firm risk by decreasing both innovative output and innovation efficiency. Overall the findings in this study are useful for understanding how CEOs with high inside debt incentives reduce the firm risk level.

My research is different from the work of Lee (2019)[2]. First, I investigate the association between innovative output and inside debt incentives by using four different measures of the inside debt variable, including the CEO's relative leverage ratio, the CEO's relative incentive ratio, the relative leverage dummy variable, and the relative incentive dummy variable. Those measurements are widely used in the literature of inside debt compensation (Cassell et al., 2012; Phan, 2014; Wei & Yermack, 2011). The research of Lee (2019) uses two measurements of inside debt variables which are different from my study. Lee (2019) calculates the inside debt variable as the value (million dollar) of the aggregate inside debt pay and the ratio of inside debt over one plus equity compensation.

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[2] I started my work well before the paper of Lee (2019) was published. I presented my paper *"Does CEO inside debt discourage innovation output?"* in the Doctoral Symposium – New Zealand Finance Colloquium held in Auckland on February 08, 2017. I presented the paper *"CEO inside debt compensation and innovative output"* in the Auckland Finance Meeting held in Queenstown on December 20, 2017. I also presented my paper at the International Conference on Accounting and Finance held in Da Nang, Vietnam on June 07, 2018. In addition, I presented my revised paper at the Doctoral Symposium – Accounting and Finance Association of Australia and New Zealand held in Auckland on June 28, 2018.

Second, my study also decomposes total inside debt holdings into two sub-components (pension benefits and deferred compensation) to examine the effect of each component on innovative output. Lee (2019) does not explore the influence of separate elements of inside debt compensation on innovative activities. Third, my research also uses the ratio of inside debt to cash compensation as an alternative measure of the inside debt variable for the robustness test while Lee (2019) does not utilise this measurement. Fourth, I further investigate the interactive effect of R&D intensity and inside debt on innovative output to examine whether CEOs with large inside debt holdings have less incentive to convert R&D expenses into more innovative output while Lee (2019) does not. Fifth, I also examine the impact of inside debt on innovation efficiency (research quotient) which is not explored in the paper of Lee (2019). Sixth, my study uses the patent data provided by the United States Patent and Trademark Office while Lee (2019) obtains data from Wisdomain. Seventh, my research employs Poisson regression models, which are usually used for count data (number of patents and citations) while Lee (2019) utilises OLS regressions. Overall, Lee (2019) finds a positive relationship between inside debt compensation (million dollar) and the logarithm of one plus the number of patents and citations. In addition, Lee (2019) reports a negative association between the logarithm of one plus the number of patents and citations and the ratio of inside debt to one plus the equity. My research provides empirical evidence that the negative relationship between CEO inside debt incentives (ratios of relative leverage and incentive) and innovative output is primarily due to pension benefits. In addition, I find that companies with higher ratios of pension benefits to cash compensation have a lower quantity and quality of innovation. Moreover, top executives receiving the pension based on relative leverage (incentive) ratios higher than one have less incentive to convert R&D expenditure into more patents. Also, firms offering CEOs higher inside debt incentives have lower innovation efficiency (research quotient).

The remainder of this chapter is structured as follows. Sections 2.2 and 2.3 provide a literature review and hypotheses development. Section 2.4 describes the data and measurement of variables. Section 2.5 explains the research methods. Section 2.6 shows the summary statistics. Section 2.7 presents a multivariate analysis. Section 2.8 describes the robustness test. Section 2.9 presents the empirical results using propensity score matching. Section 2.10 further explores the interactive effect of R&D intensity and inside debt compensation on innovative output, and investigates the association between inside debt compensation and research quotient. Section 2.11 provides the main conclusions.

2.2. Literature review

2.2.1. Inside debt

The existing research emphasises the prevalence of debt-based compensation (inside debt) including pension benefits and deferred compensation as an efficient mechanism to align the interests of managers with those of debtholders and thus alleviate the agency costs of debt (Edmans & Liu, 2011). The broad-based pension plans of employees in US companies are subject to the Employee Retirement Income Security Act of 1974 (ERISA). The pension plans regulated by ERISA are secured by the Pension Benefit Guaranty Corporation (PBGC). As a result, employees holding ERISA-qualified pension benefits face a limited default risk if their firms become insolvent. However, ERISA-qualified pension plans have specific limits on pension benefits. Therefore, if companies want to pay top executives pension benefits exceeding the limits imposed by ERISA, they have to provide non-qualified pension plans such as Supplemental Executive Retirement Plans (SERPs) (Anantharaman & Fang, 2012). More than 50% of the retirement income of top executives is in the form of non-qualified retirement plans (MacDonald & Kirk, 2007). Unlike qualified plans, those non-qualified plans are not subject to any of the regulations of ERISA. Thus, the main advantage of those non-qualified plans is that they are used to maximise the retirement benefits of top managers and to attract and retain them in the context of high competition for their services. However, the future payments of those non-qualified plans are usually unfunded and unsecured. There is no requirement for those non-qualified plans to be funded by companies. Therefore, the payments of those non-qualified plans are similar to risky debt claims against the companies (Anantharaman et al., 2013; Gerakos, 2010). Due to the limitation of the Execucomp database, it is impossible to decompose pension benefits into Rank-and-File plans and SERPs. However, the majority of the total pension benefits received by top executives are in the form of SERPs. In the hand-collected sample of Anantharaman et al. (2013), the value of the non-qualified pension benefits of CEOs is also much higher than the number of qualified pension benefits. Specifically, the mean (median) value of the SERP relative leverage ratio[3] is 1.064 (0.432), while the mean (median) value of the Rank-and-File relative leverage ratio[4] is 0.192 (0.025).

Deferred compensation is the portion of current compensation which will be paid later on a pre-specified date agreed by employees and employers (Wei & Yermack, 2010). Employees will receive fixed pay-offs in the future. The main advantage of this kind of compensation is the deferral of tax; an executive only pays taxes on deferred compensation when he or she receives it. As non-qualified pension plans of top executives, deferred compensation is also unfunded and unsecured. However, the

[3] The SERP relative leverage ratio is the CEO's pensions from Supplemental Executive Retirement Plans to equity ratio scaled by the debt-to-equity ratio of the firm.
[4] The Rank-and-File relative leverage ratio is the CEO's ERISA qualified pensions to equity ratio scaled by the debt-to-equity ratio of the firm.

maturity of deferred compensation is usually shorter than that of pension plans because managers can withdraw the deferred compensation before retirement (Anantharaman & Fang, 2012).

The value of pensions and deferred compensation is sensitive to the default risk of the firm and the liquidation value in case of bankruptcy (Anantharaman et al., 2013). If the pay package of executives comprises both debt-based and equity-based compensation, their incentives are aligned with both debtholders and shareholders. Managers who hold a large portion of inside debt, including pension benefits and deferred compensation, face the same default risks as unsecured debt-holders because the inside debt is unsecured and unfunded (Sundaram & Yermack, 2007). Executives only receive their pension benefits and deferred compensation when their firms remain solvent. Jensen and Meckling (1976, pp. 352-353) predict that when the ratio of inside debt to inside equity held by the manager is equal to the ratio of total debt to the total equity of the firm, the manager will not transfer wealth from creditors to stockholders. In this case, the conflict between stockholders and debt-holders decreases. If the executive's debt-to-equity ratio is higher than the firm leverage, the executive may reallocate wealth from stockholders to debt-holders. In this situation, Jensen and Meckling conjecture that managers who have excessive inside debt holdings will tend to behave conservatively and be reluctant to make risky decisions. Overall, the results of the prior existing empirical studies support the prediction of Jensen and Meckling (1976).

2.2.2. Empirical evidence of the effect of inside debt

Sundaram and Yermack (2007) report evidence of a negative relationship between the risk of default and inside debt. They measure the default risk by using the distance-to-default statistic. Inside debt is measured by using the CEO's debt-to-equity ratio, which is equal to the actuarial present value of pensions divided by the market value of stocks and options. They did not include deferred compensation in their inside debt calculations because at that time, the disclosure of deferred compensation was limited. Because of this limitation, their estimation of debt-based compensation may be below the actual value. In their sample, the amount of the pension benefits accounts for a substantial fraction of the total compensation of CEOs. For instance, the total amount of the pensions of CEOs aged between 61 and 65 is 40% higher than the base salary and 23% of the total inside equity pay. Moreover, the significance of the inside debt component increases with the age of the CEO, since the CEO's leverage tends to be larger than the firm's leverage when the CEO's age is higher. For example, more than 20 per cent of CEOs in the 61-65 age group have a ratio of personal debt-to-equity holdings exceeding the firm's leverage. Sundaram and Yermack (2007) also find that CEOs with high debt-based compensation tend to adopt a conservative management style to safeguard the value of their pension benefits. Moreover, CEOs decrease R&D expenditure in their last years of tenure to achieve profit maximisation and thus receive higher bonuses. In summary, CEOs have incentives to mitigate the debt default probability and manage the firm more conservatively if they hold a debt-to-equity ratio which is higher than their firm's leverage ratio.

Another study of Wei and Yermack (2011) finds evidence of a negative link between debt-like compensation and credit default swap spreads when top executives' debt-based pay has been publicly disclosed since the new disclosure requirements of Securities and

Exchange Commission (SEC) in 2006. They employ three different measurements of inside debt including the CEO's debt-to-equity ratio, the CEO's relative debt-to-equity ratio, and the CEO's relative incentive ratio represented by changes in the value of the debt and equity of the CEO and the company in response to a unit change in the total value of the firm. CEOs with a relative incentive ratio larger than 1 tend to prefer less risky decisions and implement more conservative management strategies. In contrast, if this ratio is lower than 1, the CEO is expected to choose risky policies. If this ratio is equal to 1, the CEO will not be incentivised to transfer wealth from debt-holders to shareholders at the expense of the former and vice versa. They also find that at the time of disclosing the information on pension benefits and deferred compensation, firms that have CEOs with high inside debt holdings will have increased bond prices.

Following the research of Sundaram and Yermack (2007) and Wei and Yermack (2011), Cassell et al. (2012) examine the influence of CEO inside debt holdings on investment and financial policies. Their empirical results support the hypothesis that top executives with excessive inside debt pursue less risky and more conservative investment and financial policies. In particular, there is a negative relationship between debt-based compensation and stock returns, research and development expenditures, and the leverage ratio. Moreover, there is a positive link between debt-like instruments and diversification as well as asset liquidity.

The negative association between debt-based compensation and the risk-shifting behaviours of top executives is also evidenced by the empirical study of Anantharaman et al. (2013). This paper investigates the influence of debt-like instruments on the design of private loan contracts, including the promised yield and contract covenants. They report that when the ratio of CEO's debt-to-equity to the firm's leverage is higher, the promised yield of private loan contracts is lower and their covenants become fewer. The association becomes even stronger in firms with a high risk of default, which is represented by a low Alman's Z-score or below-investment-grade credit ratings. Their findings imply that debt-based compensation mitigates risk-shifting behaviours by top managers, and that private creditors recognise its incentive-alignment influence, especially in firms with a high probability of insolvency. Their empirical results are consistent with the hypothesis of the incentive-alignment effect of inside debt posited by Jensen and Meckling (1976), Sundaram and Yermack (2007), and Edmans and Liu (2011). Anantharaman et al. (2013) further find that under the Supplemental Executive Retirement Plan, if the CEO has an option to receive a lump-sum payment at the retirement date, the incentive-alignment effect of SERP becomes weaker. The reason is that the lump-sum payoff may reduce the risk of loss suffered by the CEOs if their firms become insolvent. The main implication is that the practice of designing a company's inside debt components may weaken the incentive alignment role of debt-based compensation, as predicted by Bebchuk and Jackson (2005).

2.3. Hypothesis development

Previous theoretical and empirical research suggests that CEOs with a large portion of inside debt compensation may tend to mitigate their risk-taking behaviours and pursue conservative strategies (Anantharaman et al., 2013; Edmans & Liu, 2011; Jensen & Meckling, 1976; Sundaram & Yermack, 2007; Wei & Yermack, 2011). The main reason for this behaviour is that the value of inside debt pay is sensitive to the default risk of firms and the value of liquidation if firms go bankrupt (Anantharaman et al., 2013). CEOs with considerable pension benefits and deferred compensation holdings face the same default risks as outside creditors because the inside debt pay is generally unsecured and unfunded (Sundaram & Yermack, 2007). They are expected to be reluctant to choose risky projects which may increase the firm's default risk. Innovative projects, typically have an extremely high level of default risk (Balkin, Markman, & Gomez-Mejia, 2000; Manso, 2011). Czarnitzki and Kraft (2004) find that if firms carry out too many innovative activities, their default risks may increase because of the high probability of failure. Eisdorfer and Hsu (2011) also report that there is a positive link between the increase in patent activities and their bankruptcy risk because of the intensity of patent competition. Therefore, I predict that CEOs with a large portion of inside debt compensation will pay more attention to the downside risks and become more conservative. As a result, CEOs with extensive inside debt holdings will reduce innovative output.

It is beneficial to examine innovative output (patents and citations) rather than the input (R&D) because the dollar amount spent on R&D may or may not be converted to innovative output efficiently. The efficiency of R&D investment in innovative activities might depend on the incentives of CEOs to encourage innovation. Substantial investment in R&D spending does not promise a higher innovative output. Also, less investment in R&D expenditures does not mean lower innovative output. For example, Deloitte analysis of the USPTO filings and S&P Capital IQ data shows that the firms with the largest R&D spending do not necessarily have the highest patent innovation intensity (Deloitte Insights, 2019). Patents provide a relatively objective measure of new inventions. Patents measure the quantity of innovation. Citations represent the quality of innovation. The generation of patents can be considered as an indicator of corporate R&D effectiveness (Anderson, Duru, & Reeb, 2012; Becker-Blease, 2011; Hall, Jaffe, & Trajtenberg, 2005).

Hypothesis 1: CEO inside debt compensation is negatively associated with innovative output.

Inside debt compensation consists of two components: pension benefits and deferred compensation. Pension benefits and deferred compensation have different characteristics and thus differently impact the behaviour of CEOs needing to enhance innovative output. Deferred compensation has a shorter maturity than pension benefits. Moreover, in some cases, firms allow executives to enjoy flexible withdrawal options[5] (Anantharaman et al., 2013). Thus, CEOs may be able to quickly withdraw the deferred compensation, while they can only obtain pension benefits at the date of retirement. In addition, some firms offer flexible options for CEOs to invest a portion of their deferred compensation in equity (Campbell et al., 2016). Those flexible options in association with deferred compensation in practice may not induce CEOs to take less risk. For instance, the study of Anantharaman et al. (2013) finds that deferred compensation does not have a negative impact on promised yield and loan covenants. In contrast, there is a significantly negative link between pension benefits and promised yield and covenants. Those findings imply that deferred compensation does not strongly align the interests of CEOs with creditors.

Regarding the different characteristics of pension benefits and deferred compensation, I decompose total inside debt holdings into two sub-components to explore the influence of those components on innovative output to test hypotheses H2 and H3 as follows:

Hypothesis 2: CEO pension benefit is negatively associated with innovative output.

Hypothesis 3: CEO deferred compensation is negatively associated with innovative output.

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[5] For example, Enron's top executives withdrew a significant amount of deferred compensation shortly before its bankruptcy announcement (Bebchuk & Fried, 2006)

2.4. Data and variable measurement

2.4.1. Data

The sample includes US companies which have share codes (shrcd) of 10 and 11, from 2006 to 2013. The minimum fiscal year is 2006 because the information on inside debt holdings from Execucomp has only become available since the disclosure requirement of the Securities and Exchange Commission (SEC) in August 2006. This study collects the number of patents and citations up to 2016. However, the number of citations received by a specific patent may be truncated. When the sample period is 2006-2016, it is impossible to know how many citations a patent received after 2016. In addition, the number of citations received by a patent applied for during the final years of the sample period will be less than those received by a patent applied for earlier. Thus, this research only keeps observations up to 2013 to mitigate the problem of citation truncation bias.

- ***Patent database from the United States Patent and Trademark Office (USPTO)***[6]

This dataset provides information on the patents granted by USPTO, including data on the assignees (owners) of patents and citations made to US granted patents. The assignees are chosen if they are classified as organisations, not individuals. The patent dataset includes 5,405,714 patent-year observations from 1976 to 2016. The application year of patents is considered as the year of invention[7]. According to the definition of USPTO, the application date is the earliest date of application filing. This study uses company names and years to match the patent dataset with S&P Compustat (North America) database. It is important to note that USPTO codes the application year based on the calendar year

[6] The database of patents and citations is downloaded from http://www.patentsview.org/download/

[7] This research follows the suggestion of Hall, Jaffe, and Trajtenberg (2001, pp. 9-10) to use the application date as the appropriate time placer for patents instead of using publication date and grant date. The reason is that the application date is considered to be closer to the actual time of invention because inventors are assumed to file for patents as soon as possible to protect their property rights.

instead of the fiscal year. In the S&P Compustat, the fiscal year equals the calendar year (year of datadate) if the fiscal year end month is from June to December. Fiscal year equals calendar year minus one if the fiscal year end month is from January to May. This research allocates the number of patents applied for by firms within the 12-month period to match USPTO with Compustat, based on the fiscal year[8].

In addition, it is necessary to standardise the company names in both the USPTO and S&P Compustat databases before matching them together. This research follows the codes provided by Bronwyn H. Hall (2008) to harmonise company names[9]. First, this research removes the punctuation and some special symbols (e.g. +, `, {, $, and so on). Second, this study standardises the legal entity types (e.g. COMPANY is changed to CO; COOPERATIVE is converted to COOP, and so on). Finally, this research deletes all the leading, ending and trailing spaces of the company names. The company names of USPTO and Compustat are matched based on a fuzzy matching technique (Levenshtein distance). The matched company names based on Levenshtein distance are then manually checked to only keep the cases with typographical errors and a different company legal entity. For instance, INNOVATIVE CONTROL SYSTEMS INC in Compustat may be named as INNOVATIVE CONTROLS SYSTEMS INC in the USPTO database. COCA-COLA REFRESHMENTS USA INC may be named as COCA-COLA REFRESHMENTS USA IN in USPTO database.

Following Hall et al (2001), the total number of patents is the sum of all new patents applied for by each company in a specific year. The total number of citations received by a new patent in a particular application year is the sum of all citations received from the

[8] For example, Lam Research Corp has the datadate in Compustat as June 30th, 2009. Its fiscal year month is June. In this case, fiscal year is recorded as 2009 which means the 12-month period ending June 30th, 2009. In the USPTO database, if Lam Research Corp applies for a patent during the period July 1st, 2008 – June 30th, 2009, the fiscal year of the patent application is 2009. If the firm applies for a patent from July 1st, 2009 to June 30th, 2010, the fiscal year of patent application is 2010.

[9] These codes are provided through https://eml.berkeley.edu/~bhhall/pat/namematch.html

application date to 2016. The number of citations received by a patent reflects the value of innovation or the importance of the cited patent.

- ***S&P Compustat (North America) Execucomp***

The information of CEOs and their compensation is from Execucomp. CEO is identified based on CEO flag (CEOANN). If CEO flag is missing, a person is identified as a CEO if the year he or she became and left as CEO is known.

It is also necessary to consider the change of company names over the years when matching the S&P Compustat and USPTO databases based on company names and fiscal years. S&P Compustat uses the most updated company names. Therefore, historical company names over the prior years in Compustat are traced so they can be correctly matched with the assignee names in the USPTO dataset. Historical company names are in the Center of Research in Security Prices (CRSP) database.

- ***S&P Compustat (North America) Fundamental Annual***

The financial information is from S&P Compustat Fundamental Annual. Financial firms which have SIC codes from 6000 to 6999 and utility firms which have SIC codes from 4900-4999 were removed from the sample[10]. Also, firms with missing research and development (R&D) expenditure are assumed to have zero value of R&D[11].

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[10] This research follows Fama and French (1992, p. 429) to exclude financial and utility firms because those firms normally have higher leverage ratios than other companies. While high leverage is one of the indicators of financial distress faced by non-financial and non-utility companies, high leverage in the financial and utility companies does not necessarily indicate distress.

[11] To deal with the issue of the "missing" R&D expenditures provided by Compustat, this research follows the conventional approach suggested by Hirschey, Skiba, and Wintoki (2012). They suggest setting "missing" R&D expenditure in Compustat to zero because the SEC and the Financial Accounting Standards Board have required listed firms to disclose all material R&D expenditure in the fiscal year. Therefore, the "missing" R&D value in Compustat can be understood as firms not disclosing because their material R&D expenditure is zero. In addition, Hirschey et al. (2012) also randomly check the annual reports of 500 firms with "missing" R&D fields. They find that 99 percent of those companies have no material R&D expenditure. Given their findings, it is reasonable to replace "missing" R&D with "zero".

- ***Osiris***

The information of most updated subsidiaries in 2017 is provided by Osiris. Bessen (2009) notes that the assignees listed in the patent database may be subsidiaries of parent firms in Compustat. Therefore, some parent companies in Compustat may have patents applied for under the names of their subsidiaries instead of under the parent names. Thus, it is necessary to collect the list of subsidiaries to find which parent firms have subsidiaries owning patents at USPTO. The condition to obtain the names of subsidiaries in Osiris is that the parent companies must directly or indirectly own more than 50 per cent of the shares of their subsidiaries. All subsidiaries are matched with the assignees in the USPTO database based on standardised company names to extract the list of subsidiaries which have applied for patents at USPTO.

When counting the number of patents applied for by parent or subsidiary companies, it is crucial to consider the issue of co-owners of patents[12]. If both the parent firm and its subsidiary are named as assignees of the same patent, it is not merely the sum of the number of patents owned by the parent corporation and the number of patents owned by its subsidiary. It is necessary to exclude the number of patents owned by the subsidiaries that have already been counted in the parent company list to avoid a duplicate number of patents. This research considers this problem and finds no case of co-owners of parent and subsidiary firms.

- ***SDC***

Because Osiris only provides the list of subsidiaries in 2017, this research also utilises SDC data to track the change of ownership of subsidiaries from 2006 to 2016. All merger and acquisition deals which have no effective date are removed. Merger and acquisition

[12] For instance, Google Technology Holdings LLC and Cable Television Laboratories Inc are co-owners of the patent number US9078015 (https://www.google.ch/patents/US9078015)

deals from the fiscal years 2006 to 2016 are chosen when the percentage of shares owned by acquirors after a transaction is more than 50 per cent. The status of the M&A deals must be completed, and the nation of acquirers is the US.

To track the change of ownership of subsidiaries owning patents during 2006 – 2016, the research follows five steps. First, acquirers in SDC are matched with parent companies in Compustat based on historical cusip numbers, tickers and company names to find the list of target names that were acquired by parent companies in Compustat during 2006 - 2016. Second, ultimate parent corporations of the target names in SDC are matched with parent companies in Compustat based on historical cusip numbers, tickers and company names to find the list of subsidiaries sold by parent companies in Compustat during 2006 - 2016. Third, all subsidiaries acquired and sold by parent companies in Compustat are merged with assignees in the USPTO dataset to extract the list of acquired and sold subsidiaries which applied for patents at USPTO during the period 2006 – 2016. Fourth, the full list of both old and new subsidiaries owning patents during 2006-2016 is created by combining the list of subsidiaries having patents in Osiris and the list of subsidiaries acquired and sold by parent companies in Compustat. Finally, the study tracks the change of subsidiary ownership over the years to obtain different lists of subsidiaries having patents in different years over the period 2006 – 2016. For example, Tecomet Inc was acquired by Charlesbank Capital Partners from Cardinal Health Inc in 2008. Therefore, Tecomet Inc was a subsidiary of Cardinal Health Inc in 2007. From 2008, Tecomet Inc was removed from the full list of subsidiaries controlled by Cardinal Health Inc. In addition, Innovative Therapies Inc was newly acquired by Cardinal Health Inc in 2014. Innovative Therapies Inc was removed from the list of subsidiaries between 2007 and 2013.

- ***ISS Director***

The year variable of ISS Director refers to the calendar year of the annual meeting date. To match the ISS Director dataset with Compustat, it is necessary to determine whether the annual meeting date occurs before or after the data date in Compustat. Firms which have less than 4 directors are deleted because S&P 1500 companies usually report having at least 4 directors (Cheng, 2008).

After matching all the databases, this study obtains a sample of 6,036 firm-year observations with 1,183 firms during the period 2006 – 2013.

2.4.2. Variable measurement

Measuring innovative output

The innovative output is measured by the number of patents and patent citations made by firms. Patents and citations are widely used as the most critical and appropriate measure of innovative output because the innovative activities of firms are known publicly through a patent announcement by the Patent Office. Moreover, companies in the US increasingly realise the importance of filing their patents at the Patent Office to protect their property rights (Hirshleifer, Hsu, & Li, 2013). Patents can be a good measure of a firm's ability to innovate because it represents the ability to accrue knowledge and create novel ideas (Sharma, 2011). The number of citations measures the quality of innovation (Hall et al., 2001).

Measuring inside debt variable

Following the research of Cassell et al. (2012), Wei and Yermack (2011), and Phan (2014), this research uses four different measures of the inside debt variable including the

CEO's relative leverage ratio, the CEO's relative incentive ratio, the relative leverage dummy variable, and the relative incentive dummy variable.

First, the CEO's relative leverage is equal to the ratio of CEO debt-to-equity to the firm's leverage. The CEO's debt-to-equity ratio is equal to the total inside debt holdings divided by the total equity holdings. The inside debt is the sum of the accumulated value of pension benefits and the aggregate deferred compensation. The inside equity is the sum of the value of stocks and options held by CEOs (Coles, Daniel, & Naveen, 2006; Wei & Yermack, 2011). The value of the stocks is calculated by multiplying the stock price at the end of the fiscal year by the number of shares held by CEOs. The value of stock options are calculated based on the option valuation formula suggested by Black and Scholes (1973) and modified by Merton (1973). The firm's leverage is the ratio of the book value of total debt to the market value of total equity at the end of the fiscal year. The CEO's relative leverage can measure the incentive alignment of CEOs with shareholders versus creditors (Wei & Yermack, 2011).

Second, the CEO's relative incentive ratio represents the changes in the value of debt and equity of the CEO and the company in response to a unit change in the total value of the firm (Cassell et al., 2012; Wei & Yermack, 2011).

Relative incentive = (ΔCEO inside debt / ΔCEO inside equity) / (Δfirm debt / Δfirm equity)

where ΔCEO inside debt is assumed to be equal to CEO inside debt, ΔCEO inside equity is calculated by totalling the number of shares and the number of options times the option delta, which is measured based on Black and Scholes (1973)'s and Merton (1973)'s method of option valuation for each option tranche; Δfirm debt is assumed to be equal to total debt; and Δfirm equity is calculated similarly to the ΔCEO inside equity, but the inputs for the valuation include the number of the outstanding stock options of the employees and the mean exercise price. The assumption of the remaining life of all options held by employees is four years (Cassell et al., 2012, p. 608).

Third, the CEO's relative leverage > 1 dummy variable equals 1 if the CEO relative leverage ratio is higher than 1, and 0 otherwise (Cassell et al., 2012; Phan, 2014; Wei & Yermack, 2011)

Fourth, the CEO's relative incentive > 1 dummy variable equals 1 if the CEO's relative incentive ratio is higher than 1, and 0 otherwise (Cassell et al., 2012; Phan, 2014; Wei & Yermack, 2011)

This research also investigates the incentive-alignment effect of two different components of inside debt compensation that is pension benefits and deferred compensation. This is because deferred compensation may have shorter maturity than pension benefits. Moreover, some firms allow CEOs to invest a certain percentage of the deferred compensation in equity. As a result, deferred compensation does not necessarily induce CEOs to take less risk or follow conservative policies as pension benefits do. CEO's relative leverage ratio is divided into two components, pension-based and deferred compensation-based relative leverage ratios, as suggested by Anantharaman et al. (2013). Similarly, I split the CEO's relative incentive ratio into two components, pension-based and deferred compensation-based relative incentive ratios. Moreover, the pension-based relative leverage and the pension-based relative incentive dummy variables take the value of 1 if the pension-based relative leverage or incentive is higher than 1, and 0 otherwise. The deferred compensation-based relative leverage or incentive dummy variables take the value of 1 if the deferred compensation-based relative leverage or incentive is higher than 1, and 0 otherwise.

Measuring control variables

This research utilises three primary groups of control variables: executive characteristics, corporate governance characteristics, and firm-specific characteristics. In terms of executive traits, this study will control for CEO tenure and CEO age as suggested by Faleye, Kovacs, and Venkateswaran (2014) because CEOs near retirement probably become more short-sighted and follow conservative management policies, which discourage innovation. CEO overconfidence is also controlled for because if a CEO is more confident, he or she will tend to innovate more (Sunder, Sunder, & Zhang, 2017). CEO overconfidence is a dummy variable, which equals one if the vested options held by CEOs are at least 67 per cent in the money (Sunder et al., 2017).

In the second group of control variables, this research will control for the monitoring role of the board of directors (board independence) as the independent board of directors may positively influence the innovative outcomes through reducing agency costs and improving the corporate governance quality (Balsmeier, Fleming, & Manso, 2017). The control variables also include the incentive effect of equity-based compensation as measured by CEO vega and delta. The CEO's portfolio delta measures the change in the wealth of the CEO per one percent change in the stock price. The CEO's vega captures the change in the wealth of the CEO per 0.01 change in stock return volatility. The equity-based compensation incentivises CEOs to carry out more risky projects such as innovative activities (Anantharaman et al., 2013; Cassell et al., 2012; Francis et al., 2011; Sharma, 2011). This study adopts the formula to calculate vega and delta suggested by Core and Guay (2002), Faleye et al. (2014), and Cassell et al. (2012) based on the SAS code provided by Coles et al. (2006) and Coles, Daniel, and Naveen (2013).

The control variables also include the measures of important firm characteristics (firm size, R&D intensity, growth opportunities, profitability, financial constraint, and stock performance). Firm size, which is measured by total assets, is positively associated with innovation because larger firms may have advantages in economies of scale in innovative activities (Faleye et al., 2014). Moreover, firms with high growth opportunities, which can be measured by sales growth, may enhance innovative activities to strengthen competitive advantages and achieve new opportunities. Also, profitability, which is measured by returns on assets, may improve innovation (Becker-Blease, 2011). Firms with higher profitability may have more capital to invest in innovative projects. R&D intensity, which is calculated by R&D expenditure scaled by total sales, can be an appropriate measurement of the effort of firms to invest in long-term and risky innovation projects (Becker-Blease, 2011). Furthermore, firms with high financial constraints are expected to reduce innovation because of the limited resources for investment in risky projects and increased managerial risk aversion (Becker-Blease, 2011; Faleye et al., 2014). This study includes leverage as a proxy for financial constraint. Stock performance (buy-and-hold return) is also positively correlated with innovative activities (Sunder et al., 2017).

Table 2.1 summarises the variables and definitions used in this study.

Table 2.1 Variables and description		
Variables	Description	Sources
Dependent variables (innovation)		
Patent	The number of patents.	Becker-Blease (2011); Hall et al. (2005)
Citation	The number of citations.	Hall et al. (2005)
Quotient	The natural log of the research quotient. Research quotient measures the percentage increase in revenues when R&D expense rises by 1% while other inputs are constant.	Knott (2008)
Explanatory variables (inside debt)		
Ln_CEO relative leverage	The natural log of one plus the CEO's debt-to-equity ratio scaled by the debt-to-equity ratio of the firm.	Cassell et al. (2012), Wei and Yermack (2011), Phan (2014)
Ln_CEO relative incentive	The natural log of one plus the CEO relative incentive ratio. Relative incentive = (ΔCEO inside debt / ΔCEO inside equity) / (Δfirm debt / Δfirm equity).	Cassell et al. (2012), Wei and Yermack (2011), Phan (2014)
CEO relative leverage > 1	The dummy variable is equal to 1 if the CEO relative leverage ratio is larger than 1, and zero otherwise.	Cassell et al. (2012), Wei and Yermack (2011), Phan (2014)
CEO relative incentive > 1	The dummy variable is equal to 1 if the CEO relative incentive ratio is larger than 1, and zero otherwise.	Cassell et al. (2012), Wei and Yermack (2011), Phan (2014)
Ln_pension relative leverage	The natural log of one plus pension-to-equity ratio scaled by the debt-to-equity ratio of the firm.	Anantharaman et al. (2013)

Ln_pension relative incentive	The natural log of one plus pension relative incentive ratio. Pension relative incentive = (ΔCEO pension / ΔCEO inside equity) / (Δfirm debt / Δfirm equity).	Anantharaman et al. (2013)
Pension relative leverage > 1	The dummy variable is equal to 1 if the pension relative leverage ratio is larger than 1, and zero otherwise.	Anantharaman et al. (2013)
Pension relative incentive >1	The dummy variable is equal to 1 if the pension relative incentive ratio is larger than 1, and zero otherwise.	Anantharaman et al. (2013)
Ln_defer relative leverage	The natural log of one plus deferred compensation-to-equity ratio scaled by the debt-to-equity ratio of the firm.	Anantharaman et al. (2013)
Ln_defer relative incentive	The natural log of one plus deferred compensation relative incentive ratio. Defer relative incentive = (ΔCEO deferred compensation / ΔCEO inside equity) / (Δfirm debt / Δfirm equity).	Anantharaman et al. (2013)
Defer relative leverage > 1	The dummy variable is equal to 1 if the deferred compensation relative leverage ratio is larger than 1, and zero otherwise.	Anantharaman et al. (2013)
Defer relative incentive >1	The dummy variable is equal to 1 if the deferred compensation relative incentive ratio is larger than 1, and zero otherwise.	Anantharaman et al. (2013)
Ln_inside debt-to-cash	The natural log of one plus the ratio of total inside debt holdings to salary and bonus.	
Ln_pension-to-cash	The natural log of one plus the ratio of pension benefits to salary and bonus.	

Ln_defer-to-cash	The natural log of one plus the ratio of deferred compensation to salary and bonus.	
Control variables		
Firm_size	The natural logarithm of total assets.	Faleye et al. (2014)
RD_intensity	The R&D expenditure divided by total sales.	Becker-Blease (2011)
ROA	The income before extraordinary items divided by total assets.	Becker-Blease (2011), Faleye et al. (2014)
Sales_growth	The percentage change in sales from the prior year to the current year.	Yuan and Wen (2018)
Leverage	The ratio of long-term debt to total assets.	Faleye et al. (2014)
Stock return	The 12 month buy-and-hold return over this fiscal year.	Sunder et al. (2017)
Overconfidence	Dummy variable which is equal to 1 if vested options held by CEOs are at least 67% in the money.	Sunder et al. (2017)
Ln_CEO age	The natural log of the age of CEOs in years.	Faleye et al. (2014)
Ln_CEO tenure	The natural log of the number of years that the CEO has worked for the company.	Faleye et al. (2014)
Ln_CEO delta	The natural log of one plus the change of CEO stock and option holdings per 1% change of stock price.	Faleye et al. (2014)
Ln_CEO vega	The natural log of one plus the change of CEO stock and option holdings per 0.01 change of stock returns volatility.	Faleye et al. (2014)
Ln_in_directors	The natural log of one plus the ratio of the number of independent directors to the total number of board directors.	Balsmeier et al. (2017)

2.5. Research methods

This research tests the Hypotheses 1, 2, and 3 with the following model specification:

$$Innovation_{i,t+1} = \alpha + \beta_1 Insidedebt_{i,t} + \gamma Control_{i,t} + Year\ FE + Firm\ FE + \varepsilon_{i,t}$$

- "$Innovation_{i,t+1}$" denotes innovative output (the number of patents or citations) of firm i in time t+1.
- "$Insidedebt_{i,t}$" denotes CEO inside debt of firm i in time t.
- "$Control_{i,t}$" denotes control variables of firm i in time t.

This research uses the Poisson regression model with firm and year fixed effects when the dependent variable is a count variable (the number of patents and citations).

Moreover, when investigating the effect of CEO inside debt compensation on the research quotient, which represents innovation efficiency, this study uses OLS regression models with firm and year fixed effects because the dependent variable is a continuous variable.

2.6. Summary statistics

Table 2.2 describes the distribution of the firms in the sample during the period 2006-2013. The average percentage of firms with patents (citations) in the sample is 57.44% (47.23%). Moreover, the rate of firms with citations becomes lower overtime because patents applied for by firms more recently will receive fewer citations.

Table 2.3 reports the descriptive statistics of 6,036 firm-year observations from 2006-2013. Panel A of Table 2.3 states that the mean (median) number of patents applied for by firms is 46 (1). The mean (median) number of citations of patents applied for by firms is 119 (0). The distribution of patents and citations is right skewed because there are a lot of firms which did not apply for patents during 2006-2013. Panel B of Table 2.3 shows that the mean (median) value of the inside debt holdings of CEOs is 6,255 (1,138) thousand US Dollars per year. The mean value of pension benefits held by CEOs (3,365) is higher than that of deferred compensation (2,890). The mean (median) value of salary and bonus is 1,045 (881) thousand US Dollars per year. The mean and median value of the inside debt holdings of CEOs is larger than the total salary and bonus received by CEOs. The mean (median) value of the CEO debt to equity ratio is 0.39 (0.07). The mean (median) of the CEO relative leverage ratio is 16.04 (0.33). The mean (median) of the CEO relative incentive ratio is 21.84 (0.39). In addition, the mean of the CEO relative leverage > 1 and the CEO relative incentive > 1 is 0.34 and 0.36 respectively. The mean value of the pension-based relative leverage (incentive) ratio is 6.76 (9.97). The mean value of the deferred compensation-based relative leverage (incentive) ratio is 9.28 (11.87). Table A2.2 in the Appendices of Chapter 2 shows the correlation matrix of all variables used in the regression models. All the control variables are not strongly correlated with the main independent variables (inside debt) and with each other. Thus, correlation between explanatory and control variables does not cause any multicollinearity problems.

Table 2.4 shows the mean value of the number of patents and citations by year. The mean number of patents was 40 in 2006 and 2007. The number of patents increased to 49 in 2011 and 58 in 2012. The mean number of citations was 225 in 2006 and 176 in 2007. The number of citations decreased over time because patents which have been created more recently will receive fewer citations. More than 30 per cent of firms in the sample have CEO relative leverage and incentive ratios higher than one during the period 2006-2013. More than 16 per cent of firms in the sample have pension based and deferred compensation based relative leverage and incentive ratios higher than one.

The mean number of patents and citations by industry is shown in Table 2.5. The industry with SIC code 01 (Agricultural Production – Crops) has a large mean number of patents and citations (464 and 539 respectively). The company in this industry is Monsanto Company, a modern agricultural biotechnology company. The mean number of patents and citations in the industry with SIC code 99 (Non-classifiable Establishments) is 657 and 1,776 respectively. The corporation in this industry includes Honeywell International Incorporation, which produces aerospace products, navigation technologies, automotive goods, and so on. Companies in the sectors Industrial and Commercial Machinery and Computer Equipment (SIC code 35), Electronic & Other Electric Equipment & Components (SIC code 36), Transportation Equipment (SIC code 37), and Business Services (SIC code 73) also have a mean number of patents higher than 90. Many large corporations in those industries include International Business Machines Corporation, Microsoft Corporation, Oracle Corporation, Alphabet Corporation, Cisco System Incorporation, HP Incorporation, Xerox Corporation, Qualcomm Incorporation, and Apple Incorporation.

Table 2.2 The distribution of firms by year

Table 2.2 reports the total number of firms in the sample and the number of firms with patents and citations from 2006 to 2013

Year	Number of firms	Number of firms with patents	Percentage of firms with patents	Number of firms with citations	Percentage of firms with citations
2006	565	296	52.39%	277	49.03%
2007	774	436	56.33%	392	50.65%
2008	797	451	56.59%	405	50.82%
2009	793	442	55.74%	385	48.55%
2010	780	453	58.08%	374	47.95%
2011	778	473	60.80%	375	48.20%
2012	779	462	59.31%	351	45.06%
2013	770	454	58.96%	292	37.92%
Total	6,036	3,467	57.44%	2,851	47.23%

Table 2.3 Summary statistics

Table 2.3 reports the summary statistics of 6,036 firm-year observations during 2006-2013. The description and definition of variables are provided in Table 2.1

Variable	N	mean	median	25th quartile	75th quartile	Std. Dev
Panel A: Patents and Citations						
Number of patents	6,036	46	1	0	16	258
Number of citations	6,036	119	0	0	20	732
Panel B: CEO compensation, relative inside debt ratios						
CEO inside debt (1000$)	6,036	6,255	1,138	0	6,224	14,287
CEO deferred compensation (1000$)	6,036	2,890	287	0	2,008	9,880
CEO pension compensation (1000$)	6,036	3,365	0	0	2,905	8,018
CEO equity compensation (1000$)	6,036	126,000	18,438	7,608	45,449	1,340,000
Salary & bonus (1000$)	6,036	1,045	881	658	1,121	1,436
CEO delta (1000$)	6,036	1,379	252	99	627	13,514
CEO vega (1000$)	6,036	186	79	24	212	419
CEO debt to equity ratio	6,036	0.39	0.07	0	0.31	4.55
CEO relative leverage	6,036	16.04	0.33	0	1.66	252.21
CEO relative leverage > 1	6,036	0.34	0	0	1	0.47
CEO relative incentive	6,036	21.84	0.39	0	1.87	336.42
CEO relative incentive >1	6,036	0.36	0	0	1	0.48
Pension relative leverage	6,036	6.76	0	0	0.6	145.56
Pension relative leverage > 1	6,036	0.2	0	0	0	0.4
Pension relative incentive	6,036	9.97	0	0	0.67	212.41
Pension relative incentive >1	6,036	0.2	0	0	0	0.4
Defer relative leverage	6,036	9.28	0.05	0	0.56	182.06
Defer relative leverage > 1	6,036	0.18	0	0	0	0.38
Defer relative incentive	6,036	11.87	0.06	0	0.66	217
Defer relative incentive > 1	6,036	0.2	0	0	0	0.4

Table 2.4 The mean value of key variables by year

	2006	2007	2008	2009	2010	2011	2012	2013	Total sample
	N=565	N=774	N=797	N=793	N=780	N=778	N=779	N=770	N=6,036
Number of patents	40	40	47	40	42	49	58	49	46
Number of citations	225	176	168	128	104	91	60	26	119
Ln_CEO relative leverage	0.70	0.67	0.69	0.73	0.72	0.70	0.67	0.60	0.68
CEO relative leverage > 1	0.36	0.32	0.34	0.36	0.36	0.33	0.32	0.31	0.34
Ln_CEO relative incentive	0.77	0.73	0.75	0.79	0.77	0.74	0.69	0.61	0.73
CEO relative incentive >1	0.38	0.36	0.35	0.39	0.39	0.35	0.34	0.31	0.36
Ln_pension relative leverage	0.40	0.38	0.42	0.43	0.40	0.39	0.35	0.29	0.38
Pension relative leverage > 1	0.22	0.18	0.21	0.22	0.21	0.19	0.20	0.16	0.20
Ln_pension relative incentive	0.44	0.41	0.45	0.46	0.43	0.41	0.36	0.29	0.40
Pension relative incentive >1	0.23	0.19	0.21	0.23	0.22	0.20	0.20	0.16	0.20
Ln_defer relative leverage	0.39	0.38	0.38	0.42	0.44	0.42	0.41	0.39	0.40
Defer relative leverage > 1	0.16	0.17	0.17	0.19	0.20	0.19	0.16	0.17	0.18
Ln_defer relative incentive	0.45	0.43	0.42	0.46	0.47	0.44	0.43	0.40	0.44
Defer relative incentive > 1	0.19	0.20	0.19	0.22	0.22	0.20	0.17	0.17	0.20

Table 2.5 The mean number of patents and citations by industry

SIC code	Industry	N	Number of patents	Number of citations
1	Agricultural Production - Crops	2	464.00	539.50
2	Agricultural Production - Livestock and Animal Specialties	6	0.00	0.00
7	Agricultural Services	7	0.14	0.00
10	Metal Mining	21	5.81	4.10
12	Coal Mining	29	0.03	0.00
13	Oil and Gas Extraction	323	12.41	37.98
14	Mining and Quarrying of Nonmetallic Minerals, Except Fuels	27	1.85	3.33
16	Heavy Construction, Except Building Construction, Contractor	37	24.54	78.38
17	Construction - Special Trade Contractors	15	1.73	3.20
20	Food and Kindred Products	248	7.47	5.02
21	Tobacco Products	13	6.00	9.38
22	Textile Mill Products	23	9.74	33.52
23	Apparel, Finished Products from Fabrics & Similar Materials	104	2.16	1.60
24	Lumber and Wood Products, Except Furniture	30	0.37	2.80
25	Furniture and Fixtures	55	13.15	58.85
26	Paper and Allied Products	114	13.28	22.28
27	Printing, Publishing and Allied Industries	74	1.41	1.85
28	Chemicals and Allied Products	556	34.94	99.91
29	Petroleum Refining and Related Industries	59	31.02	58.71
30	Rubber and Miscellaneous Plastic Products	68	69.88	91.16
31	Leather and Leather Products	35	6.46	1.97
32	Stone, Clay, Glass, and Concrete Products	26	2.38	4.27
33	Primary Metal Industries	118	5.45	21.36
34	Fabricated Metal Products	126	23.88	22.81
35	Industrial and Commercial Machinery and Computer Equipment	454	90.59	360.12
36	Electronic & Other Electrical Equipment & Components	461	130.89	275.96
37	Transportation Equipment	158	100.46	182.00
38	Measuring, Photographic, Medical, & Optical Goods, & Clocks	472	59.25	194.01
39	Miscellaneous Manufacturing Industries	81	35.30	98.98
40	Railroad Transportation	33	1.15	1.06

Table 2.5 The mean number of patents and citations by industry (cont.)

SIC code	Industry	N	Number of patents	Number of citations
42	Motor Freight Transportation	61	3.18	8.33
44	Water Transportation	39	0.13	0.13
45	Transportation by Air	66	0.94	2.05
47	Transportation Services	4	0.00	0.00
48	Communications	141	31.32	114.11
50	Wholesale Trade – Durable Goods	207	0.36	1.63
51	Wholesale Trade – Non-durable Goods	111	2.72	1.80
52	Building Materials, Hardware, Garden Supplies & Mobile Homes	24	2.08	0.42
53	General Merchandise Stores	95	10.64	9.94
54	Food Stores	37	1.62	4.22
55	Automotive Dealers and Gasoline Service Stations	62	0.00	0.00
56	Apparel and Accessory Stores	101	0.64	0.07
57	Home Furniture, Furnishings and Equipment Stores	21	2.67	6.00
58	Eating and Drinking Places	134	0.30	0.37
59	Miscellaneous Retail	125	3.13	22.30
70	Hotels, Rooming Houses, Camps, and Other Lodging Places	8	0.50	0.00
72	Personal Services	25	0.92	0.68
73	Business Services	637	113.99	246.73
75	Automotive Repair, Services and Parking	20	0.00	0.00
78	Motion Pictures	15	4.00	7.20
79	Amusement and Recreation Services	44	28.68	109.18
80	Health Services	144	1.33	1.97
82	Educational Services	27	1.85	2.00
83	Social Services	1	0.00	0.00
87	Engineering, Accounting, Research, and Management Services	101	1.51	3.02
99	Non-classifiable Establishments	11	657.82	1776.09
	Total	6,036	45.93	119.00

2.7. Multivariate analysis

Table 2.6[13] shows the multivariate analysis of the impact of CEO inside debt compensation on the number of patents. Models (1) – (4) present the association between *Ln_CEO relative leverage, Ln_CEO relative incentive, CEO relative leverage > 1*, and *CEO relative incentive > 1* and the number of patents. There is no evidence of a relationship between the number of patents and *Ln_CEO relative leverage, Ln_CEO relative incentive, CEO relative leverage > 1*, and *CEO relative incentive > 1*. In Models (1) – (4), the CEOs' inside debt compensation measures include pension benefits and deferred compensation. Deferred compensation may weakly induce CEOs to take less risk compared to pension benefits. The explanation is that deferred compensation offers shorter maturity than pension benefits.

Models (5) – (8) of Table 2.6 present the association between the number of patents and *Ln_pension relative leverage (incentive) ratios, Ln_defer relative leverage (incentive) ratios, Pension relative leverage (incentive) > 1*, and *Defer relative leverage (incentive) > 1*. This is to investigate the incentive-alignment effects of the two different components of inside debt pay, pension benefits and deferred compensation.

In terms of the impact of deferred compensation, there is insignificant evidence of an association between the number of patents and *Ln_defer relative leverage, Ln_defer relative incentive, Defer relative leverage >1*. However, the coefficient of *Defer relative incentive > 1* is -0.129 and significant at the level of 10%.

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[13] The number of observations in regressions is less than the total number of observations in the full sample. The main reason is that the dependent variable (the number of patents and citations) is calculated in year t+1 and other independent variables are calculated in year t. In addition, the Poisson regression model with firm and year fixed effects drops observations that are singletons as well as observations that have numbers of patents and citations that do not change.

Table 2.6 CEO inside debt compensation and the number of patents

Table 2.6 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is $Patent_{t+1,}$ which is the number of patents in year t+1. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable: $Patent_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative $leverage_t$	-	-0.007			
		(0.047)			
Ln_CEO relative $incentive_t$	-		-0.005		
			(0.043)		
CEO relative leverage > 1_t	-			0.066	
				(0.053)	
CEO relative incentive > 1_t	-				0.023
					(0.051)
$Firm\_size_t$	+	0.233**	0.233**	0.240***	0.239**
		(0.094)	(0.095)	(0.093)	(0.096)
$RD\_intensity_t$	+/-	0.659	0.654	0.601	0.631
		(0.834)	(0.838)	(0.820)	(0.823)
ROA_t	+	-0.002	-0.002	0.008	0.002
		(0.302)	(0.300)	(0.299)	(0.301)
$Sales\_growth_t$	+	0.056	0.056	0.054	0.055
		(0.038)	(0.037)	(0.036)	(0.036)
$Leverage_t$	-	-0.296	-0.285	-0.197	-0.248
		(0.297)	(0.289)	(0.336)	(0.342)
Ln_CEO age_t	-	-0.046	-0.045	-0.024	-0.040
		(0.309)	(0.308)	(0.310)	(0.310)
Ln_CEO $tenure_t$	-	-0.032	-0.033	-0.037	-0.034
		(0.036)	(0.036)	(0.035)	(0.035)
Ln_CEO $delta_t$	+	0.020	0.021	0.026	0.023
		(0.032)	(0.031)	(0.029)	(0.029)
Ln_CEO $vega_t$	+	0.006	0.006	0.004	0.005
		(0.020)	(0.020)	(0.020)	(0.020)
$Ln\_in\_directors_t$	+	0.794	0.796	0.833	0.810
		(0.492)	(0.492)	(0.517)	(0.508)
$Overconfidence_t$	+	0.062	0.062	0.062	0.062
		(0.052)	(0.052)	(0.052)	(0.053)
Stock $return_t$	+	0.006	0.006	0.008	0.006
		(0.025)	(0.025)	(0.025)	(0.025)
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,316	3,316	3,316	3,316
Wald chi2		27.56	27.72	31.88	27.55
Prob>chi2		0.010	0.010	0.003	0.011

Table 2.6 CEO inside debt compensation and the number of patents (cont.)

Table 2.6 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is *Patent*$_{t+1}$ which is the number of patents in year t+1. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable: Patent$_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative leverage$_t$	-	-0.203**			
		(0.096)			
Ln_defer relative leverage$_t$	-	0.041			
		(0.033)			
Ln_pension relative incentive$_t$	-		-0.166**		
			(0.077)		
Ln_defer relative incentive$_t$	-		0.036		
			(0.034)		
Pension relative leverage > 1$_t$	-			-0.153*	
				(0.081)	
Defer relative leverage > 1$_t$	-			0.020	
				(0.049)	
Pension relative incentive > 1$_t$	-				-0.232***
					(0.057)
Defer relative incentive > 1$_t$	-				-0.129*
					(0.076)
Firm_size$_t$	+	0.211**	0.216**	0.210**	0.158*
		(0.087)	(0.091)	(0.094)	(0.084)
RD_intensity$_t$	+/-	0.445	0.454	0.435	0.519
		(0.768)	(0.757)	(0.707)	(0.684)
ROA$_t$	+	-0.023	-0.042	-0.063	-0.005
		(0.287)	(0.287)	(0.270)	(0.222)
Sales_growth$_t$	+	0.048	0.051	0.057	0.051
		(0.033)	(0.034)	(0.036)	(0.033)
Leverage$_t$	-	-0.462*	-0.393	-0.442	-0.711**
		(0.265)	(0.252)	(0.280)	(0.279)
Ln_CEO age$_t$	-	-0.067	-0.043	-0.040	0.004
		(0.299)	(0.294)	(0.296)	(0.283)
Ln_CEO tenure$_t$	-	-0.017	-0.025	-0.035	-0.009
		(0.036)	(0.034)	(0.032)	(0.035)
Ln_CEO delta$_t$	+	-0.000	0.003	0.004	-0.014
		(0.034)	(0.034)	(0.030)	(0.035)
Ln_CEO vega$_t$	+	0.016	0.015	0.015	0.033
		(0.022)	(0.022)	(0.019)	(0.023)
Ln_in_directors$_t$	+	0.829*	0.833*	0.808*	0.689
		(0.437)	(0.452)	(0.477)	(0.495)
Overconfidence$_t$	+	0.068	0.068	0.068	0.081
		(0.053)	(0.053)	(0.053)	(0.067)
Stock return$_t$	+	0.004	0.003	0.005	0.011
		(0.025)	(0.025)	(0.026)	(0.026)
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,316	3,316	3,316	3,316
Wald chi2		31.50	30.49	33.09	77.38
Prob>chi2		0.005	0.007	0.003	0.000

The coefficients of the variables *Ln_pension relative leverage* and *Ln_pension relative incentive* in Table 2.6 are negative (-0.203 and -0.166 respectively) at the significance level of 5%. Also, the coefficient of the dummy variable *Pension relative leverage > 1* is negatively significant at the level of 10% (-0.153). The coefficient of the variable *Pension relative incentive > 1* (-0.232) is significant at the level of 1%. Those results support the hypothesis that CEOs with large pension benefits have less incentive to increase patents. The findings are consistent with the conjecture that the negative effect of inside debt compensation on innovative output is primarily due to pension benefits[14].

Moreover, larger firms have a higher number of patents. This result is in line with the research of Faleye et al. (2014). Large firms have advantages in economies of scale when developing innovative projects and have a higher probability of creating more patents. The coefficient of the variable *leverage* is negatively significant at the level of 10% in model (5) and at the level of 5% in model (8). The firm leverage is negatively associated with the number of patents. This finding is in line with the work of Faleye et al. (2014). Leverage is a proxy of financial constraint. Firms with high leverage ratios may face severe financial constraint, and thus reduce investment in innovation. Moreover, the link between the percentage of independent directors and the number of patents is positive (at the significance level of 10% in models (5)-(7)). This finding is similar to that of the research of Balsmeier et al. (2017). Boards with higher ratios of independent directors have a positive impact on innovation by mitigating agency costs and improving corporate

[14] The results still hold when I re-estimate the models with the sample excluding SIC code 01 (Agricultural Production – Crops) and SIC code 99 (Non-classifiable Establishments). Those industries have only one firm in the sample. Moreover, the distribution of the number of patents and citations is right skewed because there are a lot of companies that have no patents. The results are still robust when this study re-estimates the regressions with the sample omitting firms without patents. In addition, the study still finds robust results when excluding observations which have an extreme number of patents and citations (IBM Corporation has more than 3000 patents and 20000 citations per year).

governance mechanisms. There is no evidence of a relationship between R&D intensity and the number of patents.

Table 2.7 shows the results of the link between the number of citations and CEO inside debt compensation. Models (1) – (4) present the association between the number of citations and *Ln_CEO relative leverage, Ln_CEO relative incentive, CEO relative leverage > 1,* and *CEO relative incentive > 1*. There is no significant evidence of the influence of *Ln_CEO relative leverage, Ln_CEO relative incentive, CEO relative leverage > 1,* and *CEO relative incentive > 1* on the number of citations.

Models (5) – (8) shows the coefficients of *Ln_pension relative leverage, Ln_defer relative leverage, Ln_pension relative incentive, Ln_defer relative incentive, Pension relative leverage > 1, Defer relative leverage > 1, Pension relative incentive > 1,* and *Defer relative incentive > 1*. Only the coefficient of *Defer relative incentive > 1* is negative (-0.183) and significant at the level of 10%. When CEOs have a deferred compensation-based relative incentive ratio higher than one, they tend to reduce the quality of innovation, which is measured by the number of citations[15]. There is no evidence of the influence of CEO relative leverage (incentive) ratios and pension-based relative leverage (incentive) ratios on the number of citations[16].

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[15] The results still hold when I re-estimate the models with the sample excluding SIC code 01 (Agricultural Production – Crops) and SIC code 99 (Non-classifiable Establishments). Those industries have only one firm in the sample. In addition, the results still hold when this study re-estimates the regressions with the sample omitting firms without patents.

[16] When re-estimating the regressions with the sample excluding observations which have an extreme number of patents and citations (IBM Corporation has more than 3000 patents and 20000 citations per year), this study finds that the coefficients of *CEO relative incentive > 1* and *Pension relative leverage > 1* are negative at the significance level of 10%.

Table 2.7 CEO inside debt compensation and the number of citations

Table 2.7 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is $Citation_{t+1}$ which is the number of citations in year t+1. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable: $Citation_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative $leverage_t$	-	-0.104			
		(0.070)			
Ln_CEO relative $incentive_t$	-		-0.069		
			(0.062)		
CEO relative leverage > 1_t	-			0.013	
				(0.057)	
CEO relative incentive > 1_t	-				-0.164
					(0.115)
$Firm\_size_t$	+	0.459**	0.464**	0.485**	0.440**
		(0.180)	(0.181)	(0.197)	(0.175)
$RD\_intensity_t$	+/-	-0.748	-0.823	-0.969	-0.860
		(0.832)	(0.838)	(0.865)	(0.848)
ROA_t	+	-0.498	-0.506	-0.519	-0.491
		(0.333)	(0.337)	(0.350)	(0.334)
$Sales\_growth_t$	+	0.058	0.056	0.049	0.060
		(0.067)	(0.067)	(0.074)	(0.060)
$Leverage_t$	-	-1.218**	-1.100*	-0.868	-0.941*
		(0.601)	(0.615)	(0.533)	(0.520)
Ln_CEO age_t	-	0.371	0.391	0.407	0.444
		(0.526)	(0.531)	(0.542)	(0.521)
Ln_CEO $tenure_t$	-	-0.071	-0.078	-0.085	-0.089
		(0.090)	(0.091)	(0.091)	(0.088)
Ln_CEO $delta_t$	+	-0.022	-0.023	-0.011	-0.015
		(0.051)	(0.053)	(0.051)	(0.051)
Ln_CEO $vega_t$	+	0.033	0.038	0.032	0.033
		(0.041)	(0.043)	(0.042)	(0.042)
$Ln\_in\_directors_t$	+	1.288	1.337	1.421*	1.391*
		(0.849)	(0.867)	(0.860)	(0.829)
$Overconfidence_t$	+	0.040	0.044	0.041	0.041
		(0.061)	(0.060)	(0.060)	(0.060)
Stock $return_t$	+	0.022	0.022	0.020	0.029
		(0.035)	(0.036)	(0.034)	(0.044)
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,919	2,919	2,919	2,919
Wald chi2		35.46	34.60	30.25	50.40
Prob>chi2		0.001	0.001	0.004	0.000

Table 2.7 CEO inside debt compensation and the number of citations (cont.)

Table 2.7 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is *Citation*$_{t+1}$ which is the number of citations in year t+1. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable:Citation$_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative leverage$_t$	-	-0.220			
		(0.135)			
Ln_defer relative leverage$_t$	-	-0.049			
		(0.062)			
Ln_pension relative incentive$_t$	-		-0.111		
			(0.096)		
Ln_defer relative incentive$_t$	-		-0.041		
			(0.067)		
Pension relative leverage > 1$_t$	-			-0.106	
				(0.067)	
Defer relative leverage > 1$_t$	-			-0.046	
				(0.060)	
Pension relative incentive > 1$_t$	-				-0.170
					(0.109)
Defer relative incentive > 1$_t$	-				-0.183*
					(0.104)
Firm_size$_t$	+	0.454**	0.466**	0.475**	0.409**
		(0.179)	(0.182)	(0.194)	(0.168)
RD_intensity$_t$	+/-	-0.808	-0.859	-0.949	-0.737
		(0.804)	(0.830)	(0.840)	(0.797)
ROA$_t$	+	-0.475	-0.504	-0.526	-0.392
		(0.326)	(0.337)	(0.351)	(0.286)
Sales_growth$_t$	+	0.052	0.053	0.051	0.055
		(0.069)	(0.068)	(0.072)	(0.060)
Leverage$_t$	-	-1.258**	-1.100*	-0.981*	-1.219***
		(0.596)	(0.612)	(0.547)	(0.471)
Ln_CEO age$_t$	-	0.313	0.374	0.376	0.456
		(0.512)	(0.521)	(0.520)	(0.477)
Ln_CEO tenure$_t$	-	-0.058	-0.074	-0.075	-0.078
		(0.088)	(0.089)	(0.085)	(0.088)
Ln_CEO delta$_t$	+	-0.037	-0.032	-0.026	-0.052
		(0.054)	(0.057)	(0.050)	(0.060)
Ln_CEO vega$_t$	+	0.041	0.044	0.043	0.061
		(0.042)	(0.047)	(0.041)	(0.047)
Ln_in_directors$_t$	+	1.256	1.316	1.354	1.244
		(0.831)	(0.863)	(0.851)	(0.840)
Overconfidence$_t$	+	0.049	0.050	0.048	0.076
		(0.064)	(0.064)	(0.061)	(0.070)
Stock return$_t$	+	0.017	0.020	0.018	0.030
		(0.034)	(0.036)	(0.033)	(0.044)
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,919	2,919	2,919	2,919
Wald chi2		38.21	36.08	33.71	56.89
Prob>chi2		0.000	0.001	0.002	0.000

2.8. Robustness test

2.8.1. Firms with zero total debt and negative net debt

The measurement of CEO inside debt relative leverage and incentive ratios used in the baseline regressions is based on current studies of Cassell et al. (2012), Wei and Yermack (2011) and Phan (2014). Firm debts are total debts, including short-term and long-term debts. Current literature makes no adjustment of cash from the calculation of total debts of firms.

The CEO relative leverage and incentive ratios are underdefined when the firm debt equals zero. In this case, it is unlikely to measure whether the interests of CEOs are aligned with outside debtholders versus stockholders. In the baseline regressions, the CEO's relative leverage and incentive ratios are set to missing if the value of total firm debt is zero. The number of observations with zero firm debt accounts for approximately 16% of the total sample (2,145 observations). Among these observations, 1,635 observations have zero CEO inside debt compensation and 510 observations have positive inside debt.

It is important to note that many innovative firms hold high levels of cash which leads to negative net debts (total debts minus cash). In the research sample, the number of observations having negative net debt is 3,487 (27%). Among these observations, 2,015 observations have zero CEO inside debt and 1,472 observations have positive CEO inside debt. There is no observation having zero net debt.

In this section, I rerun regressions based on three different criteria as follows:

- Criterion 1: I keep observations which have zero total firm debts. If firm debt is zero and executive inside debt is zero, the CEO relative leverage (incentive) ratio is set to zero. If firm debt is zero and executive inside debt is positive, the CEO relative leverage (incentive) ratio is set to the value of 99 percentile at the industry and year level. (See results shown in Table A2.3 in the Appendix of Chapter 2).

- Criterion 2: I drop observations with negative net debts. There is no firm having zero net debt. (See empirical results presented in Table A2.4 in the Appendix of Chapter 2).
- Criterion 3: I keep firms which have negative net debts. If firm net debt is negative and executive inside debt is zero, the CEO relative leverage (incentive) ratio is set to zero. If firm net debt is negative and executive inside debt is positive, the CEO relative leverage (incentive) ratio is set to the value of 99 percentile at the industry and year level. (See results shown in Table A2.5 in the Appendix of Chapter 2).

In overall, main empirical results still hold with three criteria. Specifically, Table A2.3 shows that the pension relative leverage ratio, pension relative leverage > 1 dummy variable, and pension relative incentive > 1 dummy variable are negatively associated with the number of patents. (The coefficients are -0.111, -0.133, and -0.205 at the significance level of 10%, 10%, and 1% respectively).

Table A2.4 finds that the CEO relative leverage ratio, CEO relative incentive ratio, and CEO relative incentive > 1 dummy variable are negatively associated with the number of citations. (The coefficients are -0.200, -0.142, and -0.133 at the significance level of 1%, 1%, and 10% respectively). In addition, the deferred compensation-based relative leverage ratio and the deferred compensation-based relative incentive ratio negatively affect the number of citations. (The coefficients are -0.139 and -0.124 at the significance level of 1% and 5% respectively).

Finally, Table A2.5 presents that the CEO relative leverage ratio has a negative impact on the number of citations. (The coefficient is -0.087 at the significance level of 5%). The pension relative leverage ratio and deferred compensation-based relative leverage ratio are negatively associated with the number of citations. (The coefficients are -0.098 and -0.070 respectively at the significance level of 10%).

2.8.2. Another measurement of CEO inside debt

This study finds that an increase in the CEO pension based relative leverage (incentive) ratios is associated with a decrease in the quantity of innovation (the number of patents). However, the negative link between innovative output and CEO inside debt may be due to the decrease in equity-based compensation relative to inside debt compensation, which leads to a higher relative leverage ratio.

This research uses cash compensation instead of the equity component as an alternative measurement of inside debt incentives. Cash compensation, including salary and bonus, does not encourage innovative outputs because this kind of compensation is relatively stable with a focus on short-term incentives for executives (Holthausen et al., 1995). The ratio of inside debt to cash compensation does not include the effect of the equity component on innovative output.

The association between *Ln_inside debt-to-cash* and the number of patents and citations is shown in Models (1) and (3) respectively in Table 2.8. In Model (1), the coefficient of *Ln_inside debt-to-cash* is insignificant. In Model (3), the coefficient of *Ln_inside debt-to-cash* becomes negative and significant at the level of 10%. When firms pay CEOs a higher ratio of inside debt to cash compensation, their CEOs have fewer incentives to improve the quality of innovation (the number of citations).

Models (2) and (4) present the impact of *Ln_pension-to-cash* and *Ln_defer-to-cash* on the number of patents and citations. In Model (2), the coefficient of *Ln_pension-to-cash* is -

0.107 at the significance level of 1%. However, the impact of *Ln_defer-to-cash* on the number of patents is insignificant. In Model (4), the coefficient of *Ln_pension-to-cash* is -0.186 and significant at the level of 5%. The association between *Ln_defer-to-cash* and the number of citations is negatively significant at the level of 10% (-0.051). Managers with higher ratios of pension benefits to cash compensation create fewer patents as well as decreasing the quality of innovation (the number of citations). There is weak evidence that executives with larger ratios of deferred compensation to cash compensation decrease the quality of innovation (the number of citations).

Table 2.8 The association between the inside debt-to-cash compensation ratio and innovative output

Table 2.8 presents the results of the link between the inside debt-to-cash compensation ratio and innovative output. The dependent variables include *Patent* (the number of patents) and *Citation* (the number of citations). The independent variables of interest include *Ln_inside debt-to-cash* (natural log of one plus the ratio of total inside debt holdings to salary and bonus), *Ln_pension-to-cash* (natural log of one plus the ratio of pension benefits to salary and bonus), *Ln_defer-to-cash* (natural log of one plus deferred compensation to salary and bonus). The standard errors (in parentheses) are clustered at the firm level. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Variables	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
		$patent_{t+1}$	$patent_{t+1}$	$citation_{t+1}$	$citation_{t+1}$
$Ln\_inside\ debt\text{-}to\text{-}cash_t$	-	-0.001		-0.082*	
		(0.008)		(0.047)	
$Ln\_pension\text{-}to\text{-}cash_t$	-		-0.107***		-0.186**
			(0.035)		(0.088)
$Ln\_defer\text{-}to\text{-}cash_t$	-		0.009		-0.051*
			(0.008)		(0.026)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,313	3,313	2,919	2,919
Wald chi2		27.71	38.17	35.78	55.74
Prob>chi2		0.010	0.000	0.001	0.000

2.9. Propensity score matching

The previous regressions provide significant evidence of a negative relation between inside debt incentives and innovative output. The negative effect mainly comes from pension benefits. In this section, I re-estimate the effect of inside debt incentives on innovative output by using propensity score matching (PSM). The PSM technique is used to decrease biased estimates due to functional form misspecification (Shipman, Swanquist, & Whited, 2016). Shipman et al. (2016) explain that multiple regressions produce biased estimates when there is misspecification of the relation between the dependent variable and the independent variables. The PSM technique reduces reliance on the functional form specification of the relation between the outcome and the explanatory variables.

This research uses PSM to estimate the impact of the treatment (high inside debt incentives) on innovative output by accounting for the confounding factors that predict the treatment. The PSM method controls for the bias estimation by making two groups: firms receiving treatment (pay high inside debt incentives) and firms not receiving treatment (pay low inside debt incentives). Treatment variables include *CEO relative leverage > 1*, *CEO relative incentive > 1*, *Pension relative leverage > 1*, *Pension relative incentive > 1*, *Defer relative leverage > 1*, and *Defer relative incentive > 1*.

To first estimate propensity scores, a logit model is used. It is based on the following matching criteria: firm size, R&D intensity, ROA, sales growth, leverage, CEO age, CEO tenure, CEO delta, CEO vega, independent directors, and stock return. Those matching criteria are variables that affect both the treatment variable (inside debt incentives) and the outcome variable (the number of patents and citations). The results of the logit regression are shown in Table 2.9. In particular, the association between firm size and

CEO inside debt incentives is positive and significant at the level of 1%. When the ratio of return on total assets (ROA) increases, the inside debt incentives are higher. Firms with high growth opportunities (higher sale growth) pay less CEO inside debt compensation. The higher leverage ratio (a proxy for financial constraints) is associated with lower executive inside debt incentives. In addition, firms with higher R&D intensity tend to have lower CEO inside debt compensation. CEOs with longer tenure will have larger inside debt incentives. Older CEOs tend to have higher inside debt incentives. Firms with better stock performance (high stock return) and corporate governance (a large percentage of independent directors) give CEOs more inside debt incentives.

Second, each firm-year observation with treatment is matched to one nearest neighbour firm-year observation without treatment, based on propensity scores. Because matching is performed without replacement[17], there is one untreated observation which is matched only once to one treated observation. The caliper distance, which is the maximum acceptable distance between propensity scores of treated and control observations, is 0.1. After matching, the balance across treatment and control groups in the matched sample is checked based on their standardised difference. Table 2.10 summarises the balance for the matched sample. In the case where the treatment variable is *CEO relative leverage > 1*, the number of treated observations is 1,301, which is similar to the number of untreated observations after matching. Before matching, the number of treated observations is 2,032 and the number of untreated observations is 4,004. When the treatment variable is *CEO relative incentive > 1*, the number of treated observations is 1,356. Before matching, the

[17] When performing propensity score matching with replacement, I still find that CEOs with the ratio of pension based relative incentive higher than one (*Pension relative incentive > 1*) are associated with a decrease in the number of patents. This result is consistent with that of propensity score matching without replacement. However, propensity score matching with replacement results in duplicated untreated observations because a control unit may be matched to several treated observations. If a control observation appears multiple times in the sample, that lead to the violation of the statistical assumption of independence of observations and thus introduce biased estimates (Little, 2013).

number of firms which have a ratio of CEO relative incentive higher than one is 2,165 while the number of companies having that ratio lower than one is 3,871. In the case that the treatment variables are *Pension relative leverage > 1* and *Defer relative leverage > 1*, the number of treated observations is 975 and 819 respectively after matching. Before matching, the number of observations which have the ratios of pension based relative leverage and deferred compensation-based relative leverage higher than one is 1,197 and 1,066 respectively. The number of control observations which have the ratios of pension based relative leverage and deferred compensation-based relative leverage lower than one before matching is 4,839 and 4,970 respectively. When the treatment variables include *Pension relative incentive > 1* and *Defer relative incentive > 1*, the number of treated observations is 1,011 and 910 respectively after matching. Before matching, the number of firms with a pension based relative incentive ratio higher than one is 1,232 while the number of control observations is 4,804. Moreover, the number of companies with a deferred compensation-based relative incentive ratio higher than one is 1,181 while the number of untreated observations is 4,855. The p-values of all standardised difference of matching criteria are higher than 5 per cent. This means that the balance across treatment and control groups in the matched sample is achieved.

Finally, this research re-estimates the effect of the treatment (high inside debt incentives) on innovative output based on the matched sample. Panel A of Table 2.11 presents the regression results of the impact of *CEO relative leverage > 1*, *CEO relative incentive > 1*, *Pension relative leverage > 1*, *Pension relative incentive > 1*, *Defer relative leverage > 1*, and *Defer relative incentive > 1* on the number of patents. The coefficient of *Pension relative incentive > 1* is -0.187 and significant at the level of 1%. This finding supports the hypothesis that CEOs with a large portion of pension benefits decrease innovative output (the number of patents). There is insignificant evidence of the association between the number of patents and *CEO relative leverage > 1*, *CEO relative incentive > 1*, *Pension relative leverage > 1*, *Defer relative leverage > 1* and *Defer relative incentive > 1*.

Panel B of Table 2.11[18] shows the empirical findings of the association between the number of citations and *CEO relative leverage > 1*, *CEO relative incentive > 1*, *Pension relative leverage > 1*, *Pension relative incentive > 1*, *Defer relative leverage > 1*, and *Defer relative incentive > 1*. The variable *CEO relative incentive > 1* is negatively associated with the number of citations at the significance level of 5% (-0.214). This result is consistent with the conjecture that CEOs with an inside debt relative incentive ratio higher than one will reduce the quality of innovation (the number of citations). There is no evidence that *CEO relative leverage > 1*, *Pension relative leverage > 1*, *Pension relative incentive > 1*, *Defer relative leverage > 1*, and *Defer relative incentive > 1* have significant influence on the number of citations.

Overall, the results of propensity score matching support Hypothesis 2, "*CEO pension benefit is negatively associated with innovative output"* and Hypothesis 1, "*CEO inside debt compensation is negatively associated with innovative output"*. Companies with a ratio of CEO pension based relative incentive higher than one have a lower quantity of innovation (the number of patents). Moreover, firms will have a decreased quality of innovation (number of citations) when their CEOs receive inside debt relative incentive ratios higher than one.

[18] The number of observations in Table 2.11 is less than the total observations after doing propensity score matching in Table 2.10. The main reason is that the dependent variable (the number of patents and citations) is calculated in year t+1 and other independent variables are calculated in year t. In addition, the Poisson regression model with firm and year fixed effects drops observations that are singletons as well as observations that have the number of patents and citations that does not change.

Table 2.9 Propensity score matching: Logit regression

Table 2.9 presents the empirical results of the Logit regression. The standard errors are in parentheses. The dependent variables include *CEO relative leverage > 1, CEO relative incentive > 1, Pension relative leverage > 1, Defer relative leverage > 1, Pension relative incentive > 1, Defer relative incentive > 1*. The description and definition of the independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

	CEO relative leverage > 1	CEO relative incentive > 1	Pension relative leverage > 1	Defer relative leverage > 1	Pension relative incentive > 1	Defer relative incentive > 1
Firm_size	0.517***	0.476***	0.452***	0.401***	0.409***	0.356***
	(0.028)	(0.028)	(0.031)	(0.032)	(0.030)	(0.031)
RD_intensity	-3.273***	-3.650***	-4.300***	-0.495	-4.702***	-0.684
	(0.789)	(0.770)	(0.989)	(0.859)	(0.979)	(0.819)
ROA	5.356***	4.745***	5.050***	4.720***	4.611***	4.091***
	(0.503)	(0.477)	(0.585)	(0.600)	(0.565)	(0.556)
Sales_growth	-0.936***	-0.901***	-1.218***	-0.352*	-1.179***	-0.311
	(0.175)	(0.171)	(0.214)	(0.201)	(0.210)	(0.191)
Leverage	-4.852***	-4.704***	-3.032***	-6.804***	-2.842***	-6.259***
	(0.257)	(0.249)	(0.286)	(0.353)	(0.278)	(0.327)
Ln_CEO age	2.924***	2.780***	4.155***	1.455***	4.231***	1.077***
	(0.302)	(0.294)	(0.365)	(0.361)	(0.359)	(0.342)
Ln_CEO tenure	0.294***	0.298***	0.123**	0.403***	0.123**	0.409***
	(0.054)	(0.053)	(0.062)	(0.066)	(0.061)	(0.063)
Ln_CEO delta	-0.704***	-0.733***	-0.669***	-0.619***	-0.705***	-0.657***
	(0.041)	(0.040)	(0.048)	(0.048)	(0.048)	(0.047)
Ln_CEO vega	0.245***	0.283***	0.254***	0.247***	0.279***	0.297***
	(0.029)	(0.029)	(0.034)	(0.036)	(0.034)	(0.035)
Ln_in_directors	3.878***	3.531***	3.974***	3.187***	3.786***	2.367***
	(0.512)	(0.497)	(0.611)	(0.630)	(0.599)	(0.590)
Stock return	0.125*	0.145**	0.104	0.178**	0.095	0.177**
	(0.066)	(0.065)	(0.077)	(0.079)	(0.075)	(0.075)
Constant	-15.704***	-14.479***	-21.264***	-9.890***	-20.986***	-7.447***
	(1.227)	(1.193)	(1.498)	(1.453)	(1.474)	(1.373)
Observations	6,036	6,036	6,036	6,036	6,036	6,036
LR chi2	1242	1212	817.4	802.3	793.5	772.1
Prob>chi2	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.161	0.154	0.136	0.143	0.130	0.129

Table 2.10 Propensity score matching: Summary of balance for the matched sample

	Treatment variable: CEO relative leverage > 1				Treatment variable: CEO relative incentive > 1				Treatment variable: Pension relative leverage > 1			
	Treated (Mean)	Control (Mean)	Standardized difference	P-value	Treated (Mean)	Control (Mean)	Standardized difference	P-value	Treated (Mean)	Control (Mean)	Standardized difference	P-value
Firm_size	8.02	8.08	-0.041	0.292	7.96	8.04	-0.059	0.126	8.42	8.37	0.032	0.477
RD_intensity	0.02	0.02	-0.005	0.895	0.02	0.02	0.03	0.437	0.02	0.02	0.006	0.896
ROA	0.06	0.06	-0.001	0.982	0.06	0.06	0	0.998	0.06	0.06	0.009	0.843
Sales_growth	0.07	0.06	0.016	0.674	0.07	0.07	0.002	0.966	0.04	0.04	0.009	0.845
Leverage	0.2	0.19	0.044	0.260	0.2	0.19	0.035	0.360	0.19	0.19	0.005	0.916
Ln_CEO age	4.03	4.03	-0.049	0.212	4.02	4.03	-0.033	0.384	4.05	4.05	-0.018	0.697
Ln_CEO tenure	1.88	1.88	-0.003	0.937	1.88	1.88	0.007	0.862	1.84	1.83	0.018	0.689
Ln_CEO delta	5.42	5.44	-0.011	0.773	5.4	5.4	-0.001	0.989	5.41	5.38	0.025	0.588
Ln_CEO vega	4.34	4.38	-0.03	0.439	4.3	4.32	-0.013	0.736	4.49	4.44	0.031	0.497
Ln_in_directors	0.59	0.59	0.009	0.817	0.58	0.58	-0.01	0.793	0.59	0.59	-0.034	0.447
Stock return	0.12	0.12	-0.002	0.957	0.13	0.13	0.004	0.926	0.13	0.15	-0.059	0.191
Observations (after matching)	1,301	1,301			1,356	1,356			975	975		
Observations (before matching)	2,032	4,004			2,165	3,871			1,197	4,839		

	Treatment variable: Defer relative leverage > 1				Treatment variable: Pension relative incentive > 1				Treatment variable: Defer relative incentive > 1			
	Treated (Mean)	Control (Mean)	Standardized difference	P-value	Treated (Mean)	Control (Mean)	Standardized difference	P-value	Treated (Mean)	Control (Mean)	Standardized difference	P-value
Firm_size	8.11	8.19	-0.044	0.369	8.35	8.23	0.081	0.069	8.06	8.14	-0.047	0.316
RD_intensity	0.03	0.03	-0.016	0.752	0.02	0.02	0.027	0.540	0.03	0.03	0.01	0.837
ROA	0.07	0.07	0.034	0.494	0.06	0.06	0.057	0.202	0.07	0.07	-0.005	0.909
Sales_growth	0.07	0.07	-0.005	0.922	0.04	0.04	0.044	0.323	0.07	0.06	0.053	0.262
Leverage	0.15	0.15	-0.012	0.802	0.2	0.19	0.013	0.776	0.16	0.16	-0.031	0.505
Ln_CEO age	4.03	4.02	0.03	0.545	4.05	4.05	-0.012	0.795	4.02	4.03	-0.023	0.622
Ln_CEO tenure	1.9	1.89	0.023	0.647	1.84	1.84	-0.001	0.989	1.9	1.89	0.008	0.861
Ln_CEO delta	5.48	5.46	0.019	0.704	5.36	5.25	0.085	0.056	5.46	5.48	-0.015	0.748
Ln_CEO vega	4.45	4.46	-0.007	0.884	4.45	4.35	0.065	0.141	4.45	4.49	-0.028	0.547
Ln_in_directors	0.59	0.59	-0.036	0.463	0.59	0.59	0.013	0.771	0.59	0.59	-0.019	0.678
Stock return	0.15	0.13	0.04	0.412	0.13	0.13	-0.012	0.779	0.15	0.15	-0.007	0.887
Observations (after matching)	819	819			1,011	1,011			910	910		
Observations (before matching)	1,066	4,970			1,232	4,804			1,181	4,855		

Table 2.11 Propensity score matching: CEO inside debt compensation and the number of patents and citations

Table 2.11 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: The dependent variable is *Patent* which is the number of patents.

Dependent variable: $Patent_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
CEO relative leverage > 1_t	-	0.062 (0.073)					
CEO relative incentive > 1_t	-		0.041 (0.056)				
Pension relative leverage > 1_t	-			-0.049 (0.088			
Defer relative leverage > 1_t	-				-0.064 (0.065)		
Pension relative incentive > 1_t	-					-0.187*** (0.065)	
Defer relative incentive > 1_t	-						0.101 (0.087)
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,760	1,859	1,383	1,024	1,398	1,130
Wald chi2		45.95	119.1	21.83	40.01	47.07	73.37
Prob>chi2		0.000	0.000	0.058	0.000	0.000	0.000

Panel B: The dependent variable is *Citation* which is the number of citations.

Dependent variable: $Citation_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
CEO relative leverage > 1_t	-	-0.089 (0.072)					
CEO relative incentive > 1_t	-		-0.214** (0.089)				
Pension relative leverage > 1_t	-			0.090 (0.130			
Defer relative leverage > 1_t	-				0.004 (0.070)		
Pension relative incentive > 1_t	-					-0.122 (0.154)	
Defer relative incentive > 1_t	-						0.140 (0.208)
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		1,564	1,611	1,242	888	1,258	998
Wald chi2		143.9	129.6	22.40	286.7	45.36	201.1
Prob>chi2		0.000	0.000	0.050	0.000	0.000	0.000

2.10. Additional results

2.10.1. The interactive effect of R&D intensity and inside debt compensation on innovation

This section further investigates whether CEOs with high inside debt incentives will have less incentive to convert R&D spending into more innovative output. On the one hand, a more risk-averse CEO might attempt to monetise the value of R&D through patents more aggressively than a more risk-tolerant CEO. CEOs with high inside debt holdings may first go through a patenting process, instead of aggressively going to the market with an innovation. The explanation is that a more risk-averse CEO might be afraid that someone else will copy the firm's innovative ideas. Therefore, a risk-averse CEO attempts to patent new invention to have legal protection for new ideas. On the other hand, CEOs holding large inside debt pay may be conservative when investing R&D expenditures in innovative projects to avoid the default risk. Innovative projects, typically have an extremely high level of default risk (Balkin, Markman, & Gomez-Mejia, 2000; Manso, 2011). If firms carry out too many innovative activities, the default risks may increase because of the high probability of failure (Czarnitzki and Kraft, 2004). Eisdorfer and Hsu (2011) also report that there is a positive link between the increase in patent activities and the firm's bankruptcy risk because of the intensity of patent competition. In addition, risk-averse CEOs may want to avoid costs associated with patent application. As a result, the number of patents and citations might be reduced. Overall, there are two opposite predictions about the interactive effect of R&D intensity and inside debt compensation on innovative output. That comes an empirical question to investigate further[19].

[19] This section does not focus on the variability of the payoff of innovative projects. Further research can be done to examine the variability of the payoff.

To examine the interactive effect of R&D intensity and inside debt compensation on innovative output, this study includes the interaction between R&D intensity and inside debt incentives in the regression models. Firms which always report zero or missing R&D expense during the whole period from 2006 to 2013 are excluded from the sample.

Table 2.12 shows the interactive effect of R&D intensity and CEO inside debt compensation on the number of patents. Models (1) – (4) of Table 2.12 present the empirical results of the interactive effect of *RD_intensity* and *Ln_CEO relative leverage, Ln_CEO relative incentive, CEO relative leverage > 1,* and *CEO relative incentive > 1* on the number of patents. All coefficients in Models (1) – (4) are insignificant. There is no evidence of the interactive impact of *RD_intensity* and *Ln_CEO relative leverage, Ln_CEO relative incentive, CEO relative leverage > 1,* and *CEO relative incentive > 1* on the number of patents.

Models (5) – (8) of Table 2.12 present the regression results of the impact of the interaction between the R&D intensity and pension and deferred compensation-based relative leverage (incentive) ratios on the number of patents. Model (6) shows that the coefficient of the interaction *Ln_defer relative incentive * RD_intensity* is negatively significant at the level of 10% (-0.509). In Models (7) and (8), the coefficients of the interaction *Pension relative leverage > 1 * RD_intensity* and *Pension relative incentive > 1 * RD_intensity* are negative and significant at the significance level of 5% and 1% (-3.167 and -2.859 respectively). This suggests that firms with a ratio of the CEO pension-based relative leverage (incentive) higher than one have a more negative relationship between R&D intensity and the number of patents compared to companies with a ratio of CEO pension-based relative leverage (incentive) lower than one. These findings support the hypothesis that the association between R&D intensity and the number of patents is more negative if CEOs have higher inside debt incentives mostly from pension benefits.

Table 2.13 presents the regression results of the interactive effect of R&D intensity and CEO inside debt compensation on the number of citations. Models (1) – (4) of Table 2.13 present the empirical results of the interactive effect of *RD_intensity* and *Ln_CEO relative leverage, Ln_CEO relative incentive, CEO relative leverage > 1,* and *CEO relative incentive > 1*. Models (5) – (8) of Table 2.12 present the regression results of the impact of interaction between R&D intensity and pension and deferred compensation-based relative leverage (incentive) ratios on the number of citations. All coefficients of the interaction variables are insignificant. There is no evidence of the effect of the interaction between R&D intensity and CEO inside debt incentives on the number of citations.

In conclusion, the results suggest that CEOs holding large pension-based incentives are less motivated to convert R&D expenses into more patents. There is weak evidence of the interactive effect of deferred compensation-based incentives and R&D intensity on the number of patents. However, there is no evidence that CEOs with high inside debt incentives are less motivated to invest R&D expenditures into innovative projects which create a high quality of innovation (a large number of citations received by patents).

Table 2.12 The interactive effect of R&D intensity and CEO inside debt compensation on the number of patents

Table 2.12 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is *Patent* which is the number of patents. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable: $Patent_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative $leverage_t$	+/-	-0.018 (0.049)			
Ln CEO relative $leverage_t$ * Rd $intensity_t$	-	0.054 (0.334)			
Ln CEO relative $incentive_t$	+/-		-0.008 (0.046)		
Ln CEO relative $incentive_t$ * Rd $intensity_t$	-		-0.064 (0.310)		
CEO relative leverage > 1_t	+/-			0.087 (0.083)	
CEO relative leverage > 1_t * Rd $intensity_t$	-			-0.339 (0.986)	
CEO relative incentive> 1_t	+/-				0.033 (0.078)
CEO relative incentive> 1_t * Rd $intensity_t$	-				-0.451 (1.067)
Rd $intensity_t$	+/-	0.663 (1.023)	0.759 (1.042)	0.732 (0.901)	0.808 (0.922)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,153	2,153	2,153	2,153
Wald chi2		37.90	38.06	39.22	37.07
Prob>chi2		0.001	0.001	0.000	0.001

Table 2.12 The interactive effect of R&D intensity and CEO inside debt compensation on the number of patents (cont.)

Table 2.12 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is *Patent* which is the number of patents. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable: $Patent_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln_pension relative $leverage_t$	+/-	-0.206**			
		(0.085)			
Ln_pension relative $leverage_t$ * Rd_$intensity_t$	-	-0.304			
		(1.433)			
Ln_defer relative $leverage_t$	+/-	0.075*			
		(0.043)			
Ln_defer relative $leverage_t$ * Rd_$intensity_t$	-	-0.426			
		(0.290)			
Ln_pension relative $incentive_t$	+/-		-0.170**		
			(0.071)		
Ln_pension relative $incentive_t$ * Rd_$intensity_t$	-		-0.532		
			(1.371)		
Ln_defer relative $incentive_t$	+/-		0.081*		
			(0.046)		
Ln_defer relative $incentive_t$ * Rd_$intensity_t$	-		-0.509*		
			(0.298)		
Pension relative leverage > 1_t	+/-			0.009	
				(0.098)	
Pension relative leverage > 1_t * Rd_$intensity_t$	-			-3.167**	
				(1.431)	
Defer relative leverage > 1_t	+/-			0.030	
				(0.064)	
Defer relative leverage > 1_t * Rd_$intensity_t$	-			-0.167	
				(0.873)	
Pension relative incentive > 1_t	+/-				-0.100
					(0.071)
Pension relative incentive > 1_t * Rd_$intensity_t$	-				-2.859***
					(1.099)
Defer relative incentive > 1_t	+/-				-0.114
					(0.085)
Defer relative incentive > 1_t * Rd_$intensity_t$	-				-0.092
					(0.932)
Rd_$intensity_t$	+/-	0.799	0.895	0.528	0.579
		(0.956)	(0.946)	(0.790)	(0.758)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,153	2,153	2,153	2,153
Wald chi2		45.02	43.40	51.88	124.8
Prob>chi2		0.000	0.000	0.000	0.000

Table 2.13 The interactive effect of R&D intensity and CEO inside debt compensation on the number of citations

Table 2. 13 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is *Citation* which is the number of citations. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable: $Citation_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative $leverage_t$	+/-	-0.138*			
		(0.077)			
Ln CEO relative $leverage_t$ * Rd $intensity_t$	-	0.416			
		(0.288)			
Ln CEO relative $incentive_t$	+/-		-0.095		
			(0.067)		
Ln CEO relative $incentive_t$ * Rd $intensity_t$	-		0.282		
			(0.251)		
CEO relative leverage > 1_t	+/-			-0.018	
				(0.089)	
CEO relative leverage > 1_t * Rd $intensity_t$	-			0.565	
				(1.056)	
CEO relative incentive> 1_t	+/-				-0.055
					(0.132)
CEO relative incentive> 1_t * Rd $intensity_t$	-				-1.732
					(1.853)
Rd intensity	+/-	-1.171	-1.119	-1.117	-0.467
		(1.001)	(1.026)	(0.942)	(1.009)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,047	2,047	2,047	2,047
Wald chi2		36.84	36.96	46.07	66.42
Prob>chi2		0.001	0.001	0.000	0.000

Table 2.13 (cont.)

The interactive effect of R&D intensity and CEO inside debt compensation on the number of citations

Table 2.13 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is *Citation,* which is the number of citations. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable: $Citation_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative $leverage_t$	+/-	-0.291**			
		(0.137)			
Ln pension relative $leverage_t$ * Rd $intensity_t$	-	1.904			
		(2.159)			
Ln defer relative $leverage_t$	+/-	-0.073			
		(0.070)			
Ln defer relative $leverage_t$ * Rd $intensity_t$	-	0.227			
		(0.247)			
Ln pension relative $incentive_t$	+/-		-0.156		
			(0.097)		
Ln pension relative $incentive_t$ * Rd $intensity_t$	-		1.189		
			(1.868)		
Ln defer relative $incentive_t$	+/-		-0.064		
			(0.075)		
Ln defer relative $incentive_t$ * Rd $intensity_t$	-		0.200		
			(0.247)		
Pension relative leverage > 1_t	+/-			-0.142	
				(0.134)	
Pension relative leverage > 1_t * Rd $intensity_t$	-			1.092	
				(2.582)	
Defer relative leverage > 1_t	+/-			-0.102	
				(0.082)	
Defer relative leverage > 1_t * Rd $intensity_t$	-			1.136	
				(0.979)	
Pension relative incentive > 1_t	+/-				-0.165
					(0.125)
Pension relative incentive > 1_t * Rd $intensity_t$	-				-0.777
					(2.716)
Defer relative incentive > 1_t	+/-				0.003
					(0.206)
Defer relative incentive > 1_t * Rd $intensity_t$	-				-2.956
					(2.738)
Rd $intensity_t$	+/-	-1.178	-1.186	-1.263	-0.184
		(0.987)	(1.016)	(0.903)	(1.025)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,047	2,047	2,047	2,047
Wald chi2		40.50	39.97	46.93	59.44
Prob>chi2		0.001	0.001	0.000	0.000

2.10.2. CEO inside debt compensation and the research quotient

This section examines the impact of CEO inside debt compensation on innovation efficiency. This study uses the research quotient, which is considered a measure of innovation efficiency. The research quotient is the output elasticity of R&D expense. It measures the percentage increase in revenues when R&D expense rises by one per cent while other inputs are constant (Knott, 2008). The research quotient represents a firm's ability to use its R&D spending to create more revenues in dollars.

I conjecture that CEOs with large inside debt compensation will have less incentive to increase innovation efficiency. The explanation is that CEOs with high inside debt pay prefer less risky policies and have less motivation to focus on developing innovative activities. As a result, firms with high inside debt incentives will have decreased innovation efficiency.

This research utilises the research quotient database created by Knott (2008), the data of which is available from the WRDS portal. Knott (2008) estimates the research quotient from the production function of a firm as below.

$$O_{i,t} = F_i \, C_{i,t}^{\propto} L_{i,t}^{\beta} R_{i,t-1}^{\curlyvee} S_{i,t-1}^{\delta} A_{i,t}^{\Phi} \, e_{i,t}$$

where $O_{i,t}$ is output of firm i in time t, F_i is a firm fixed effect, $C_{i,t}$ is capital of firm i in time t, $L_{i,t}$ is labour of firm i in time t, $R_{i,t-1}$ is R&D expense of firm i in time t-1, $S_{i,t-1}$ is spillovers of firm i in time t-1, and $A_{i,t}$ is advertising of firm i in time t. The research quotient is estimated from the exponent $\curlyvee$ in the production function.

This study measures the dependent variable *Quotient* as the natural logarithm of the research quotient and investigates the impact of inside debt incentives in time t on the research quotient in time t+1 ($Quotient_{t+1}$) and time t+2 ($Quotient_{t+2}$). The research quotient in time t+1 represents the percentage increase in revenues when R&D spending in time t rises by one per cent when other inputs are constant. The research quotient in time t+2 measures the output elasticity of R&D expense in time t+1. I expect that it may take one or two years to see the effect of inside debt incentives on the research quotient. Firms which always report zero or missing R&D expenses during the whole 2006-2013 period are excluded from the sample.

Table 2.14 shows the empirical findings of the influence of CEO inside debt compensation on the research quotient. Panel A of Table 2.14 shows the impact of CEO inside debt incentives in time t on the research quotient in time t+1. In Model (6), the deferred compensation based relative incentive ratio (*Ln_defer relative incentive*) in time t is negatively associated with the research quotient in time t+1 at the significance level of 10% (-0.027). There is no evidence of any association between the research quotient and *Ln_CEO relative leverage, Ln_CEO relative incentive, CEO relative leverage > 1, CEO relative incentive > 1, Ln_pension relative leverage, Ln_defer relative leverage, Ln_pension relative incentive, Pension relative leverage > 1, Defer relative leverage > 1, Pension relative incentive > 1,* and *Defer relative incentive >1.*

Table 2.14 CEO inside debt compensation and the research quotient

Table 2.14 presents the empirical results of the OLS model with firm and year fixed effects in the full sample. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is *Quotient* which is the natural log of the research quotient. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: Dependent variable is $Quotient_{t+1}$

Dependent variable: $Quotient_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative $leverage_t$	-	-0.012			
		(0.014)			
Ln_CEO relative $incentive_t$	-		-0.013		
			(0.014)		
CEO relative leverage > 1_t	-			0.024	
				(0.025)	
CEO relative incentive > 1_t	-				-0.017
					(0.028)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,054	2,054	2,054	2,054
Adj R-squared		0.614	0.614	0.614	0.614
F statistics		1.138	1.162	1.177	1.057
Prob>F		0.324	0.305	0.294	0.395
Dependent variable: $Quotient_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative $leverage_t$	-	0.000			
		(0.019)			
Ln_defer relative $leverage_t$	-	-0.024			
		(0.015)			
Ln_pension relative $incentive_t$	-		0.004		
			(0.018)		
Ln_defer relative $incentive_t$	-		-0.027*		
			(0.015)		
Pension relative leverage > 1_t	-			-0.013	
				(0.026)	
Defer relative leverage > 1_t	-			-0.012	
				(0.026)	
Pension relative incentive > 1_t	-				-0.040
					(0.025)
Defer relative incentive > 1_t	-				-0.012
					(0.027)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,054	2,054	2,054	2,054
Adj R-squared		0.615	0.615	0.614	0.614
F statistics		1.206	1.280	0.973	1.233
Prob>F		0.268	0.216	0.480	0.248

Panel B of Table 2.14 presents the relationship between CEO inside debt incentives in time t and the research quotient in time t+2. In Models (1) and (2) of Panel A, the coefficients of *Ln_CEO relative leverage* and *Ln_CEO relative incentive* are significantly negative (-0.036 and -0.036 respectively). Models (5) and (6) of Panel A show that the variables *Ln_defer relative leverage* and *Ln_defer relative incentive* negatively influence the research quotient at the significance level of 10% (-0.028 and -0.033 respectively). In Model (7), the coefficient of *Pension relative leverage > 1* is -0.047 and significant at the level of 10%. Model (8) presents the negative relation between *Defer relative incentive > 1* and the research quotient at the level of 5% (-0.080).

Overall, it takes two years to see any significant effect of CEO inside debt incentives on innovation efficiency (the research quotient). In particular, firms with higher CEO relative leverage (incentive) ratios, larger deferred compensation based relative leverage (incentive) ratios, pension based relative leverage higher than one, and a deferred compensation based relative incentive higher than one have lower innovation efficiency (a lower research quotient). Those results are consistent with the conjecture that firms with higher executive inside debt holdings have lower innovation efficiency.

Table 2.14 CEO inside debt compensation and research quotient (cont.)

Table 2.14 presents the empirical results of the OLS model with firm and year fixed effects in the full sample. The standard errors (in parentheses) are clustered at the firm level. The dependent variable is *Quotient* which is the natural log of the research quotient. The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel B: Dependent variable is $Quotient_{t+2}$

Dependent variable: $Quotient_{t+2}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative leverage$_t$	-	-0.036**			
		(0.014)			
Ln_CEO relative incentive$_t$	-		-0.036***		
			(0.013)		
CEO relative leverage > 1_t	-			-0.011	
				(0.029)	
CEO relative incentive > 1_t	-				-0.032
					(0.027)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		1,527	1,527	1,527	1,527
Adj R-squared		0.640	0.640	0.638	0.638
F statistics		7.813	7.950	6.938	7.002
Prob>F		0.000	0.000	0.000	0.000
Dependent variable: $Quotient_{t+2}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative leverage$_t$	-	-0.038			
		(0.023)			
Ln_defer relative leverage$_t$	-	-0.028*			
		(0.017)			
Ln_pension relative incentive$_t$	-		-0.032		
			(0.021)		
Ln_defer relative incentive$_t$	-		-0.033*		
			(0.017)		
Pension relative leverage > 1_t	-			-0.047*	
				(0.028)	
Defer relative leverage > 1_t	-			-0.048	
				(0.036)	
Pension relative incentive > 1_t	-				-0.042
					(0.025)
Defer relative incentive > 1_t	-				-0.080**
					(0.040)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		1,527	1,527	1,527	1,527
Adj R-squared		0.640	0.641	0.639	0.640
F statistics		7.349	7.475	6.879	6.920
Prob>F		0.000	0.000	0.000	0.000

2.11. Conclusions

CEO compensation is one of the most important internal corporate governance mechanisms, The pay incentives affect the decisions made by top executives. Corporations often use equity-based compensation to align the interests of CEOs with those of stockholders and to encourage top executives to increase firm value. However, CEOs with excessive equity-based incentives implement highly risky policies which may destroy the long-term values of firms. The failure of many companies was seen in the global financial crisis that encouraged firms to pay their top executives more inside debt compensation instead of stocks and stock options. Inside debt compensation aligns the interests of top managers with those of creditors. Therefore, inside debt pay encourages CEOs to implement less risky policies.

This study examines whether CEOs with intensive inside debt holdings are reluctant to increase innovation in order to decrease firm risk. In particular, this research examines the association between the inside debt holdings of CEOs and innovative output measured by the number of patents and citations. Overall, in the baseline regressions, companies which pay CEOs high pension benefits incentives have fewer innovative outputs (the number of patents). There is weak evidence of a negative relationship between deferred compensation-based incentives and innovative outputs. The negative impact of inside debt compensation on innovative output is primarily due to the effect of pension benefits. The explanation is that pension benefits strongly encourage top executives to take less risk compared with deferred compensation because pension plans usually have longer maturity than deferred compensation.

Moreover, the results still hold when this study uses another measure of inside debt incentives, the ratio of inside debt to cash compensation. Firms with higher ratios of pension benefits to cash compensation have a lower number of patents and citations. When using propensity score matching, this research finds that firms have a lower number of patents when their CEOs receive a ratio of pension based relative incentive higher than one. In addition, CEOs with a ratio of inside debt relative incentive higher than one decrease the quality of innovation, which is measured by the number of citations.

This chapter also finds that CEOs with a higher ratio of pension based relative leverage (incentive) have less incentive to convert R&D expenditures into more innovative output (the number of patents). Moreover, this study investigates further the relationship between CEO inside debt incentives and innovation efficiency. This is measured by the research quotient which represents the output elasticity of R&D spending while other inputs are constant. Overall, the empirical results show a negative association between the research quotient and CEO inside debt incentives.

CHAPTER 3. DIVERSITY IN THE BOARDROOM AND CEO PAY INCENTIVES

3.1. Introduction and motivation

Board diversity is getting increasing attention and it has become one of the most critical factors in corporate governance. Apart from supervising the management team and aligning the interests of managers with those of shareholders, heterogeneous board members are also expected to bring varied knowledge, expertise, valuable resources, and different perspectives to the company (Hillman, Cannella Jr, & Harris, 2002; Pfeffer & Salancik, 2003). Because of the importance of board diversity in corporate governance, the US Securities and Exchange Commission (SEC) approved new rules in December 2009[20], which require public companies to disclose how they consider diversity in nominating new directors. Corporations also need to disclose how their board diversity policy is implemented and how the efficiency of that policy enhances the transparent information provided to investors. US public firms also need to disclose that information in their proxy statements.

Many previous studies have focused on how diverse boards affect firm performance, value, risk levels, and corporate policies (Adams & Ferreira, 2009; Bernile et al., 2018; Carter, D'Souza, Simkins, & Simpson, 2010; Carter, Simkins, & Simpson, 2003; Miller & del Carmen Triana, 2009). However, little is known about the impact of board heterogeneity on CEO pay incentives. Designing the CEO compensation package is one of the most important roles of the board of directors: they set the company's goals and creates a suitable CEO compensation plan in order to incentivise the CEO to achieve their

[20] The details of SEC announcement can be obtained from the link https://www.sec.gov/news/press/2009/2009-268.htm

targets. CEOs may receive high equity-based incentives which motivate them to mitigate risk-aversion and make more risk-taking decisions (Coles et al., 2006; Guay, 1999; Murphy, 1999). Alternatively, they may have high inside debt-based incentives which encourage them to follow less risky policies (Jensen & Meckling, 1976; Sundaram & Yermack, 2007). The board of directors also considers whether the CEO's pay incentives are consistent with the firm's risk management strategies. There is empirical evidence that diverse boards tend to prefer conservative strategies and reduce firm risk (Bernile et al., 2018). However, when diverse boards follow less risky policies, will they also adjust the CEO pay incentives to be in line with the conservative risk management strategies? In particular, will diverse boards prefer an executive compensation package which incentivises CEOs to take less or more risk? This research examines whether diversity in the boardroom influences the board decisions relating to CEO equity and inside debt incentives. This research has two main questions:

(1) Is there an association between board diversity and CEO equity incentives?

(2) Is there a link between board diversity and CEO inside debt incentives?

The research uses a sample of 8,568 firm-year observations from 2007 to 2016. The dependent variables are CEO equity incentives, which is measured by vega (Core & Guay, 2002) and CEO inside debt incentives, which are the ratios of CEO inside debt relative leverage and relative incentive (Cassell et al., 2012; Phan, 2014; Wei & Yermack, 2011). The primary variable of interest is diversity. The multidimensional diversity index is calculated based on the formula suggested by Bernile et al. (2018). The diversity index includes six dimensions: age, gender, board experience, ethnicity, financial expertise, and educational background diversity.

Overall, this research finds that diverse boards tend to decrease CEO equity incentives and increase CEO inside debt incentives to encourage top executives to implement less risky policies. In addition, I find that a negative relation between the vega of stock options and the board diversity index is stronger in firms which have leverage higher than the median values of the whole industry. Next, when examining whether the impact of board diversity on CEO pay incentives is mainly due to the diversity of executive or non-executive directors in the boardroom, I find that the association between the board diversity index and CEO pay incentives is predominantly due to the diversity of non-executive directors. Finally, there is evidence that a more diverse compensation committee tends to decrease CEO equity incentives and increase inside debt incentives.

This study contributes to the board diversity and CEO compensation literature, and suggests that a critical determinant of CEO pay incentives is board diversity. This study finds that board diversity is associated with a decrease in CEO equity incentives and an increase in CEO inside debt incentives. This study is closely related to the research exploring how diverse board affects firm performance, value, risk levels, and corporate policies (Adams & Ferreira, 2009; Bernile et al., 2018; Carter et al., 2010; Carter et al., 2003; Miller & del Carmen Triana, 2009). The findings of this study also contribute to the understanding of the influence of diverse boards on the setting of CEO incentives in corporations. However, this research is different from the papers of Prevost and Upadhyay (2018) and Bugeja, Matolcsy, and Spiropoulos (2016), since Prevost and Upadhyay (2018) only focus on one dimension of diversity, that of gender diversity. Prevost and Upadhyay (2018) find that boards which have a higher percentage of women directors sitting on the boards significantly increase the inside debt compensation held by CEOs. However, their research finds an insignificant relation between CEO equity incentives and gender diversity. My research complements the results found by Prevost and Upadhyay (2018), since I investigate the impact of not only gender diversity but also multi-dimensional board diversity on both CEO equity and inside debt incentives. I find a significantly negative link between the multi-dimensional board diversity index and CEO equity incentives, and there is evidence of a positive relationship between the multi-dimensional board diversity index and CEO inside debt incentives. When investigating the effect of each component of the diversity index on CEO inside debt incentives, this research finds that it is not just gender diversity that positively affects CEO inside debt incentives; financial expertise diversity also has a positive impact on CEO inside debt incentives. The paper of Bugeja et al. (2016) emphasises the association between gender-diverse compensation committees and the total compensation of CEOs and finds that gender-diverse compensation committees decrease the total value of executive pay. My research adds to the Bugeja et al. (2016) results by finding that multi-dimensional diverse compensation committees are associated with lower CEO equity incentives and higher inside debt incentives.

The remaining parts of this research are structured as follows. Sections 3.2 and 3.3 provide the literature review and hypothesis development respectively. Section 3.4 explains the data sample and how to measure key variables. Section 3.5 describes the research methods. Section 3.6 shows the summary statistics. Section 3.7 presents the multivariate analysis. Some additional tests are explained in Section 3.8. Section 3.9 includes the main conclusions.

3.2. Literature review

3.2.1. CEO pay incentives

The agency problem is a critical issue for corporations with separated ownership and control (Fama, 1980; Jensen & Meckling, 1976). Stockholders who have a portfolio of assets can diversify away firm-specific risk while it is difficult for managers to do so. The main reason for this is that their wealth is directly tied to the firms they work for. The managers may be more risk-averse and prefer less risky investment projects to protect their wealth instead of maximising the value of the shareholders. Moreover, the shareholders are not able to oversee the behaviour of managers directly. As a result, increased agency costs lead to more incentive problems for firms (Holmstrom, 1989). Researchers suggest tying the wealth of executives to their companies by using equity-based compensation, including stocks and stock options, to mitigate risk-aversion and incentivise top executives to make more risk-taking decisions (Murphy, 1999). Managers become one of the owners of their firm if they hold stocks and stock options. As a result, they are willing to maximise the shareholders' value by preferring risky projects. Existing empirical studies find that CEO equity incentives significantly enhance risk-taking activities. For instance, CEO equity incentives encourage more risky investment policies (Coles et al., 2006), increase the firms' stock return volatility (Guay, 1999), negatively correlate with hedging strategies (Rajgopal & Shevlin, 2002), and enhance innovative activities (Faurel et al., 2016; Francis et al., 2011; Holthausen et al., 1995; Lerner & Wulf, 2007).

However, excessive equity incentives may encourage top executives to make extremely risky decisions, which may destroy long-term growth opportunities (Murphy, 1999). Therefore, the failure of many firms during the global financial crisis prompted some market participants to encourage companies to pay CEOs more debt-based compensation, including pension benefits and deferred compensation, since inside debt compensation aligns the interests of top executives with creditors. The existing empirical research is consistent with the expectation of Jensen and Meckling (1976), that managers holding excessive inside debt incentives tend to implement less risky policies. For example, CEO inside debt incentives are negatively related to default risk (Sundaram & Yermack, 2007), R&D expenditures (Cassell et al., 2012), bond yield spread (Anantharaman et al., 2013), credit default swap spread (Wei & Yermack, 2011), and M&A propensity (Phan, 2014).

3.2.2. Board diversity

The board directors are agents of the shareholders. They are responsible for governing the organisation, providing strategic direction, and continuously supervising the progress of the firm to increase shareholder value (Adams, Hermalin, & Weisbach, 2010). The effectiveness of corporate board performance is essential for the long-term success of the organisation, so diversity in the boardroom is of potential interest for every company. The board of directors is required to have a wide range of experiences, skills, information, and viewpoints to manage the company in the context of globalisation (Mishra & Jhunjhunwala, 2013). This suggests that the composition of the directors sitting on the board should be heterogeneous to improve the effectiveness of the board's performance.

Heterogeneity in boards brings a variety of benefits for firms. First, a heterogeneous board of directors enhances creativity and enables finding a wide range of solutions to issues due to differences in backgrounds, skills, and perspectives (Miller & del Carmen Triana, 2009). A diverse team will gather varied information and different views from each member to make novel and comprehensive decisions (Bantel & Jackson, 1989). Second, directors with different characteristics may have a better understanding of global markets and customers to help the firm perform well and sustainably (Hillman, 2015). Third, a diverse board may add benefits to the firm by using its wide range of networks and resources. Finally, if the board hires women, minorities, minority shareholders, customers, or suppliers, it may improve their corporate reputation in the markets (Miller & del Carmen Triana, 2009).

However, firms with diverse boards also face a number of constraints. First, conflicts may arise among director members because of inefficient communication, different cultures, positions, views, and languages (Carter et al., 2003; Mishra & Jhunjhunwala, 2013). Second, board diversity cannot enhance the efficiency of board performance if the directors sitting on the board do not add more skills, knowledge, or experience (Mishra & Jhunjhunwala, 2013). Baranchuk and Dybvig (2008) suggest that the performance of diverse boards will be more effective if their director members can bring valuable information to the corporations, although their interests may conflict with those of others to some extent. The effectiveness of board diversity will decrease if the majority of the directors are closely aligned with the management team or if they have identical preferences.

There are two main types of diversity: demographic and cognitive diversity (Bernile et al., 2018). Demographic diversity includes gender, age, tenure, ethnic group, and cultural diversity. Gender diversity is the balance between male and female members. Most of the studies on diverse boards focus on the gender dimension (Hillman, 2015). Female directors are believed to ask tougher questions (Konrad, Kramer, & Erkut, 2008) and they are less likely to reduce the value of shareholders (Levi, Li, & Zhang, 2014). Age diversity means a combination of directors of different ages. Young directors tend to prefer to take risks and initiate changes while old directors bring more experience (Wiersema & Bantel, 1992). Tenure diversity implies a mix of old and new members. Directors sitting on the board for a long time understand the organisational system well (Sturman, 2003). However, they may not keep up with changes in the business environment, become less independent, and be unwilling to take risks or generate group think (Bantel & Jackson, 1989). Newly appointed directors can balance the limitations of the old directors, particularly if they include a mix of all kinds of ethnic groups. A socially diverse board can also have different perspectives and more experience (Miller & del Carmen Triana, 2009). National cultural diversity, that is including directors from different countries, is also suggested since foreign directors make significant contributions to firm value by providing their global perspectives and knowledge (Frijns, Dodd, & Cimerova, 2016). Nevertheless, boards with cultural diversity may suffer inefficient communications, misunderstandings (Anderson, Reeb, Upadhyay, & Zhao, 2011) and low levels of intragroup trust (Bjørnskov, 2008).

The other category of board diversity is cognitive diversity. This kind of diversity involves expertise, experience, and educational diversity (Mishra & Jhunjhunwala, 2013). Board members who have been working in a specific industry for a long time gain expertise and specialised knowledge in that area. For example, directors with expertise in accounting and finance will be more sensitive to financial issues. Heterogeneity of board experience means the number of corporate boards that a specific director works for. If directors already hold a variety of board positions in different companies in varied industries, they will give significant benefit to the corporations by contributing their comprehensive knowledge and insights (Anderson et al., 2011). Educational diversity is measured based on the levels of education or the majors of their education. Scholars posit that educational heterogeneity has specific effects on the cognition and decision-making practice of corporate boards (Kagzi & Guha, 2018).

Theoretical and empirical studies on the importance of board diversity emphasise how heterogeneous board characteristics are correlated with firm value, performance, risk, and corporate policies. However, the impact of board diversity on corporation outcomes is still inconclusive. Adams and Ferreira (2009) report that the more gender diversity there is, the lower the firm performance, especially in companies with fewer takeover defences. Firm value declines when there is too much emphasis on monitoring from female board members (Adams & Ferreira, 2007). If CEOs are monitored too intensively by board directors, they will be reluctant to share all the information they have or to collaborate with board members closely. As a result, directors will not be able to provide qualified advice and make appropriate decisions without sufficient information from CEOs. In this case, the advisory and supervisory roles of boards may conflict instead of complementing each other.

In contrast, Carter et al. (2003) find that a gender-diverse board is positively related to firm performance. The mixed findings of the relationship between board diversity and firm performance encouraged researchers to investigate the intermediate factors which may affect that association. Miller and del Carmen Triana (2009) report that gender and racial diversity significantly enhances innovation and thus improves firm performance. Their results are consistent with the behavioural theory of the firm which proposes that a group will make innovative decisions if they obtain better information during the decision-making process (Cyert & March, 1963).

Bernile et al. (2018) employ a multidimensional index of board diversity, including the six dimensions of gender, age, ethnicity, education, financial expertise and board experience. Their empirical results show that board diversity is negatively associated with firm risk. These findings are explained by the argument that diverse boards may prefer conservative financial policies.

Other scholars studied the role of female directors sitting on compensation committees in setting executive compensation. Adams and Ferreira (2009) report that there are few female directors sitting on compensation committees. Moreover, they do not have any impact on CEO pay. One explanation for the underrepresentation of women on compensation committees is that powerful CEOs can nominate new directors who have the same demographic characteristic as themselves (Westphal & Zajac, 1995). However, Bugeja et al. (2016) provide empirical findings that gender diversity in the compensation committee is negatively linked with the total value of CEO compensation. Their results support the argument of Konrad et al. (2008), that women ask tougher questions than men and are perceived as being more "outsiders".

3.3. Hypothesis development

Executive pay incentives and risk oversight are among the most essential functions of the board of directors. Directors are responsible for overseeing firm risk and executive remuneration to make sure that firm risk management and executive pay arrangement are consistent with the firm's strategies. Diverse boards tend to reduce firm risk because they follow less risky financial policies (Bernile et al., 2018). Moreover, heterogeneity in boards leads to moderation and scrutiny in the decisions made by directors. Diverse boards have different viewpoints, backgrounds, and skills. Therefore, they tend to discuss more carefully all aspects of a specific problem before reaching final consensus decisions. As a result, diverse boards reduce firm risk.

This research conjectures that when diverse boards follow less risky policies, they adjust CEO pay incentives to control firm risk. CEO pay incentives include equity and inside debt incentives. Previous studies document that a CEO with intensive equity incentives tends to engage in more in risk-taking activities. CEOs with high equity incentives prefer risky investment policies (Coles et al., 2006). Also, there is a positive association between CEO equity incentives and firm stock return volatility (Guay, 1999). In contrast, CEO inside debt incentives encourage top executives to take less risk and have conservative policies. Sundaram and Yermack (2007) report evidence of a negative relationship between CEO inside debt incentives and the firm's default risk.

This study hypothesises that diverse boards adjust CEO pay incentives by enhancing inside debt incentives and/or decreasing equity incentives to moderate the firm's risk. This research expects that the higher the board diversity, the lower the CEO equity incentives and the higher the inside debt incentives. There are two hypotheses as follows.

Hypothesis 1: Board diversity is negatively associated with CEO equity incentives

Hypothesis 2: Board diversity is positively associated with CEO inside debt incentives

In addition, this research conjectures that the relationship between board heterogeneity and CEO pay incentives is stronger in firms with high leverage. The firm leverage ratio is considered as a proxy for firm risk, and a larger leverage ratio is associated with higher corporation risk. Diverse boards in companies with high risk have more incentives to reduce executive equity-base incentives and/or increase inside debt-based incentives and thus encourage CEOs to implement less risky policies. This leads to the following two hypotheses.

Hypothesis 3: The association between board diversity and CEO equity incentives is more negative in firms with high leverage.

Hypothesis 4: The association between board diversity and CEO inside debt incentives is more positive in firms with high leverage.

3.4. Data and variable measurement

3.4.1. Data

The sample is collected from databases including S&P Compustat (North America) Execucomp and Fundamental Annual, Compustat and Center for Research on Security Prices (CRSP), ISS Director, and BoardEx. The sample comprises 8,568 firm-year observations including US non-financial and non-utility companies from 2007 to 2016. The start year of the sample is 2007 because the ISS Director database provides the information on financial expertise from 2007.

This study uses the information on director gender, age, financial expertise, board experience and ethnicity from ISS Director to calculate the board diversity index. Moreover, the data on the educational background of directors is retrieved from the BoardEx dataset. The full names and last names of the directors and company names in the ISS Director and BoardEx databases are fuzzy matched based on the Levenshtein edit distance algorithm provided by Reif (2015) to identify the education information of the directors. All names which are fuzzy matched are manually rechecked to make sure they are similar.

3.4.2. Variable measurement

CEO equity incentives

This study calculates the CEO equity incentive which is measured by the vega. It follows the formula for calculating vega used by Core and Guay (2002), Faleye et al. (2014), and Cassell et al. (2012), based on the SAS code provided by Coles et al. (2006) and Coles et al. (2013).

First, the vega of stock options is the change of CEO stock options per 0.01 change of stock return volatility. The vega of stock options represents the sensitivity of the value of CEO stock options to stock return volatility. The vega of stock options is calculated by the formula used by Core and Guay (2002) as follows:

Vega of options = [∂(option value)/ ∂(stock volatility)] * 0.01 = $e^{-dT} N'(Z)ST^{(1/2)}*(0.01)$

where $Z = [\ln(S/X) + T(r-d+\sigma^2/2)]/ \sigma T^{(1/2)}$, N' is the normal density function, d is the natural log of expected dividend yield over the life of the option, T is time to maturity of the options in years, , S is the stock price, X is the option exercise price, σ is the expected stock return volatility, and r is the natural log of the risk-free interest rate. This research multiplies the option vega by the number of options.

Second, this study follows Cassell et al. (2012) and Faleye et al. (2014) for estimating the vega of options and stock holdings as the sum of the vega of options and the vega of stock holdings. The vega of stock holdings is calculated by multiplying the value of the stock and restricted shareholdings by stock volatility*0.01. The vega of stocks and options is the change of CEO stocks and options per 0.01 change of stock return volatility. The vega of options and stock holdings represents the sensitivity of the value of CEO stocks and options to stock return volatility.

CEO inside debt incentives

This research measures CEO inside debt incentives by using the CEO's relative leverage ratio and relative incentive ratio, following the papers of Cassell et al. (2012), Wei and Yermack (2011), and Phan (2014). First, the CEO's relative leverage is the CEO debt-to-equity scaled by the firm's leverage. The CEO debt-to-equity is the ratio of the total inside debt compensation to the total equity compensation. Inside debt compensation includes the accumulated value of pension benefits and the aggregate deferred compensation. The firm leverage is the book value of total debt divided by the market value of the total equity. The CEO relative leverage measures the incentive alignment of CEOs with debtholders versus stockholders (Wei & Yermack, 2011). Second, the CEO's relative incentive ratio measures the marginal change in the value of CEO inside debt to equity scaled by the firm's marginal change in the leverage ratio (Cassell et al., 2012; Wei & Yermack, 2011).

Diversity index

This research follows Bernile et al. (2018) to calculate the multidimensional index of board diversity including the six dimensions of gender, age, ethnicity, education, financial expertise and board experience. The diversity index is constructed to measure the joined effect of the multi-dimensions of board diversity. The diversity index is the sum of the standardised values of each component of diversity. Each diversity dimension is standardised by using its sample mean and standard deviation. The board diversity index is also then standardised by its sample mean and standard deviation.

The formula of the non-standardised multidimensional index of board diversity is as follows:

Board diversity (non-standardised) = sdz(gender_diversity) + sdz(age_diversity) + sdz(boardexp_diversity) – sdz(ethnicity_hhi) – sdz(edu_hhi) – sdz(finexpert_hhi)

The formula of the standardised multidimensional index of board diversity is as follows:

$$\textit{Board diversity (standardised)} = \frac{\textit{Board diversity (non-standardised)} - \textit{Sample mean}}{\textit{Sample standard deviation}}$$

where sdz denotes standardised value, gender_diversity is the percentage of female directors at the firm-year level; age_diversity is the standard deviation of the age of board members at the firm-year level; boardexp_diversity is the mean number of other board memberships in public companies; ethnicity_hhi is the Herfindahl concentration index for ethnicity groups; edu_hhi is the Herfindahl concentration index for the different names of education institutions providing bachelor degrees; and finexpert_hhi is the Herfindahl concentration index for financial expertise (the smaller the Herfindahl concentration index, the higher the level of diversity). The standardised diversity index will have a mean value which equals zero and a standard deviation which equals one.

Control variables

Many other important independent variables are also controlled in the baseline regression model. Following the research of Huang, Jiang, Lie, and Que (2017), Prevost and Upadhyay (2018), Bugeja et al. (2016), and Campbell et al. (2016), this study adds control variables to the baseline regression model. This study controls for firm-specific characteristics including the natural logarithm of total assets (firm_size), the ratio of R&D expenditure to total sales (RD_intensity), the ratio of total operating income to total assets (ROA), the market to book ratio (MB), the ratio of long-term debt to total assets (Leverage), stock return (Stock return), cash flow volatility (Cash flow volatility), sales growth (Sales growth), capital expenditure (Capital expenditure), tangibility (Tangibility), age of firm (Firm age), tax loss indicator (Tax-loss indicator), Herfindahl Index (HHI), and liquidity constraint (Constraint).

Moreover, CEO characteristics such as the CEO's age (Ln_CEO age) and tenure (Ln_CEO tenure), CEO duality (CEO chair), and the value of cash compensation (Ln_cash_compensation), are controlled in the regression.

Finally, corporate governance characteristics including board size (Ln_boardsize) and the ratio of the number of independent directors to the board size (Ln_in_directors) are also added to the model.

Table 3.1 Variables and description		
Variables	Description	Sources
Dependent variables (CEO incentives)		
Ln_vega	The natural log of one plus the change of CEO stock and option holdings per 0.01 change of stock returns volatility.	Cassell et al. (2012)
Ln_vega_options	The natural log of one plus the change of CEO option holdings per 0.01 change of stock returns volatility.	Core and Guay (2002)
Ln_CEO relative leverage	The natural log of one plus the CEO's debt-to-equity ratio scaled by the debt-to-equity ratio of the firm.	Cassell et al. (2012), Wei and Yermack (2011), Phan (2014)
Ln_CEO relative incentive	The natural log of one plus the CEO relative incentive ratio. Relative incentive = (ΔCEO inside debt / ΔCEO inside equity) / (Δfirm debt / Δfirm equity) .	Cassell et al. (2012), Wei and Yermack (2011), Phan (2014)
Explanatory variables (Diversity)		
Diversity_index	The sum of the standardised values of gender, age, board experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of directors in the boardroom. The diversity index is then	Bernile et al. (2018)

	standardised by its sample mean and standard deviation.	
Gender_diversity	The percentage of female directors in the boardroom at the firm-year level.	Bernile et al. (2018)
Age_diversity	The standard deviation of the age of board members in the boardroom at the firm-year level.	Bernile et al. (2018)
Boardexp_diversity	The mean number of other board memberships in public companies of directors in the boardroom.	Bernile et al. (2018)
Ethnicity_hhi	Herfindahl concentration index for the ethnicity groups of directors in the boardroom.	Bernile et al. (2018)
Finexpert_hhi	Herfindahl concentration index for the financial expertise of directors in the boardroom.	Bernile et al. (2018)
Edu_hhi	Herfindahl concentration index for the educational background (by education institutions providing bachelor degrees) of directors in the boardroom.	Bernile et al. (2018)
Ex_diversity_index	The sum of the standardised values of gender, age, board experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of executive directors in the	Bernile et al. (2018)

	boardroom. The diversity index of executive directors is then standardised by its sample mean and standard deviation.	
Nonex_diversity_index	The sum of the standardised values of gender, age, board experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of non-executive directors in the boardroom. The diversity index of non-executive directors is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
Diversity_index_comp	The sum of the standardised values of gender, age, board experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of directors sitting on compensation committees. The diversity index of directors sitting on compensation committees is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
		Bernile et al. (2018)
Instrumental variables		
Diversity_index_county	The sum of the standardised values of gender, age, board	The diversity index is calculated based on the

	experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of directors in the boardroom at the county level. The county-level diversity index is then standardised by its sample mean and standard deviation.	formula of Bernile et al. (2018); the construct of calculating diversity at the county level adopted from the research of Prevost and Upadhyay (2018)
Control variables		
Firm_size	The natural logarithm of total assets in the current fiscal year.	Campbell et al. (2016); Prevost and Upadhyay (2018); Huang et al. (2017)
Lagged RD_intensity	The R&D expenditure divided by total sales in the prior fiscal year.	Campbell et al. (2016); Prevost and Upadhyay (2018); Huang et al. (2017)
ROA	The operating income divided by total assets.	Bugeja et al. (2016)
Lagged ROA	The operating income divided by total assets in the prior fiscal year.	Prevost and Upadhyay (2018); Huang et al. (2017)
Lagged MB	The market to book ratio in the prior fiscal year.	Prevost and Upadhyay (2018); Huang et al. (2017)
Lagged leverage	The ratio of long-term debt to the total assets in the prior fiscal year.	Prevost and Upadhyay (2018); Huang et al. (2017)

Stock return	The 12-month stock return.	Prevost and Upadhyay (2018); Huang et al. (2017)
Lagged stock return	The 12-month stock return in the prior fiscal year.	Prevost and Upadhyay (2018); Huang et al. (2017)
Lagged cash flow volatility	The standard deviation of annual earnings before interest and taxes plus depreciation and amortisation scaled by total assets for the five years ending the prior fiscal year.	Prevost and Upadhyay (2018); Huang et al. (2017)
Lagged sales growth	The percentage change in sales in the prior fiscal year.	Prevost and Upadhyay (2018); Huang et al. (2017)
Lagged capital expenditure	The capital expenditure divided by total assets in the prior fiscal year.	Prevost and Upadhyay (2018); Huang et al. (2017)
Lagged tangibility	The net property, plant, and equipment scaled by total assets in the prior fiscal year.	Prevost and Upadhyay (2018); Huang et al. (2017)
Firm age	The number of years from the IPO date of the firm.	Prevost and Upadhyay (2018); Huang et al. (2017)
Tax-loss indicator	The binary variable which is equal to 1 if the firm reports its tax loss carry-forwards in the current year and zero otherwise.	Prevost and Upadhyay (2018); Huang et al. (2017)

HHI	The Herfindahl Index of the firm based on a 3-digit SIC code.	Prevost and Upadhyay (2018); Huang et al. (2017)
Constraint	The binary variable which is equal to 1 if the operating cash flow is negative and zero otherwise.	Prevost and Upadhyay (2018); Huang et al. (2017)
CEO chair	The binary variable which is equal to 1 if the CEO is also the chairman of the board and zero otherwise.	Prevost and Upadhyay (2018); Huang et al. (2017)
Ln_age	The natural log of the age of CEOs in years.	Campbell et al. (2016)
Ln_tenure	The natural log of the number of years that CEOs have worked for the companies.	Bugeja et al. (2016); Campbell et al. (2016)
Ln_cash_compensation	The natural log of one plus the salary and bonus of the CEO.	Bugeja et al. (2016)
Ln_in_dir	The natural log of one plus the ratio of the number of independent directors to the total number of board directors.	Bugeja et al. (2016)
Ln_boardsize	The natural log of the number of board members.	Bugeja et al. (2016)
High leverage	The dummy variable which is equal to 1 if the firm leverage is higher than the median leverage of the industry.	

3.5. Research methods

This research test Hypothesis H1 with the following model specification

Model (1): CEO equity incentives$_{i,t}$ $= \alpha + \beta_1 Diversity_{i,t} + \gamma Control_{i,t}$ *+ Year fixed effects + Firm fixed effects* $+ \varepsilon_{i,t}$

Hypothesis H2 is tested with the following model specification

Model (2): CEO inside debt incentives$_{i,t}$ $= \alpha + \beta_1 Diversity_{i,t} + \gamma Control_{i,t}$ *+ Year fixed effects + Firm fixed effects* $+ \varepsilon_{i,t}$

This research test Hypothesis H3 with the following model specification

Model (3): CEO equity incentives$_{i,t}$ $= \alpha + \beta_1 Diversity_{i,t} + \beta_2 High\ leverage_{i,t} + \beta_3 Diversity_{i,t} * High\ leverage_{i,t} + \gamma Control_{i,t}$ *+ Year fixed effects + Firm fixed effects* $+ \varepsilon_{i,t}$

Hypothesis H4 is tested with the following model specification

Model (4): CEO inside debt incentives$_{i,t}$ $= \alpha + \beta_1 Diversity_{i,t} + \beta_2 High\ leverage_{i,t} + \beta_3 Diversity_{i,t} * High\ leverage_{i,t} + \gamma Control_{i,t}$ *+ Year fixed effects + Firm fixed effects* $+ \varepsilon_{i,t}$

- "CEO equity incentives$_{i,t}$" denotes CEO equity-based incentives of firm i in time t.
- "CEO inside debt incentives$_{i,t}$" denotes CEO debt-based incentives of firm i in time t.
- "Diversity$_{i,t}$" denotes board diversity of firm i in time t.
- "High leverage$_{i,t}$" is a dummy variable which is equal to one if the leverage ratio of firm i in time t is higher than the median leverage of the industry or zero otherwise.
- "Diversity$_{i,t}$ *High leverage$_{i,t}$" denotes the interaction between board diversity and the high leverage of firm i in time t.
- "Control$_{i,t-1}$" denotes the control variables of firm i in time t.

The Ordinary Least Squares (OLS) estimation method is used with year and firm fixed effects. Table 3.1 gives detailed descriptions of the variables.

It is important to note that the OLS regression is estimated based on the assumption that the independent variables are exogenous. There is a concern about the correlation between the primary explanatory variable of interest (diversity index) and other unobserved variables which are not included in the regression. The model may face an endogeneity problem due to the omitted variables. As a result, the OLS model provides a biased estimation of variable coefficients. One of the methods used to account for the endogeneity issue is a two-stage least squares (2SLS) regression with instrumental variables. A valid instrument should only affect the outcome variable through the variable that it instrumented out (Cameron & Trivedi, 2005).

This study uses an instrument for the board diversity variable, that is the diversity index at the county level[21] (*diversity_index_county*). The county-level diversity of directors is expected to be positively linked with the board diversity of firms in each county each year. The research of Prevost and Upadhyay (2018) used the gender ratio at the county level as an instrument for gender diversity. They found that the number of female directors in a particular county positively influences the proportion of female directors for firms in that county. The percentage of female directors at the county level represents the supply of women who can become board members of firms in each county, so the county-level diversity index represents the supply of directors sitting on diverse boards. The county-level diversity index can be a valid instrument when it is strongly associated with the firm-level board diversity index and only affects CEO pay incentives through

[21] Bernile et al. (2018) use another instrumental variable which is the diversity index of non-local potential directors who live within a non-stop flight from the location of firm headquarters. This research cannot obtain the same database used by Bernile et al. (2018) to calculate that instrumental variable.

the board diversity of the firm (or, does not have any direct effect on the outcome variable).

3.6. Summary statistics

Table 3.2 describes the summary statistics of 8,568 firm-year observations during 2007-2016. Panel A of Table 3.2 reports that the mean (median) value of the equity held by CEOs per year is 140,000 (17,483) thousand US Dollars. The mean (median) value of inside debt pay is 5,546 (597) thousand US Dollars. The mean (median) value of vega is 167 (64) thousand US Dollars per year. The mean (median) of CEO relative leverage is 16.27 (0.30) while the mean (median) of CEO relative incentive is 20.73 (0.33).

Panel B of Table 3.2 shows the summary statistics of specific components of the diversity index. The mean (median) value of the Herfindahl concentration index of education is 0.16 (0.14). The Herfindahl concentration indexes of ethnicity and financial expertise have the mean values of 0.87 and 0.64 respectively. Boards of directors in US companies are more diverse in educational background than in ethnicity and financial expertise. The mean (median) value of gender diversity is 0.13 (0.13). On average, the number of female directors accounts for nearly 13 per cent of the total number of board members. The age diversity, which is the standard deviation of the age of board members, has a mean value of 7.68. The board experience diversity, the mean number of other board memberships of directors, has a mean value of 0.84.

The mean values of the diversity index and its specific components by year are shown in Table 3.3. The diversity index increased from 2007 to 2016. Before 2013, the diversity index was negative. After 2012, the diversity index became more positive. The increase in the diversity level in US firms during the period 2007-2016 was mainly due to the increase in gender and ethnicity diversity. In 2007, the number of female directors sitting on the board was only 10.8% of the total number. However, the ratio of women directors increased over time. That figure went up to 13.4% in 2013 and 16.4% in 2016. The ethnicity diversity level of boards of directors in US companies also increased over time. The Herfindahl concentration index of ethnicity in 2007 was 0.884. In 2016, ethnicity HHI decreased to 0.869. The Herfindahl concentration indexes of education, financial expertise, and age diversity did not change much during the period 2007 – 2016. The board experience diversity decreased from 0.918 in 2007 to 0.834 in 2016.

Table A3.2 in the Appendices of Chapter 3 presents the correlation matrix of all variables in the regression models. All the control variables are not strongly correlated with the main explanatory variable (diversity index) and with each other. Thus, correlation between independent variables does not cause multicollinearity concern. The board size and firm size are highly correlated with the diversity index (0.522 and 0.464 respectively). Firms with large assets and board size have a higher board diversity.

Table 3.4 presents the mean values of the diversity index and its components by industry[22]. The Railroad Transportation (SIC code 40) and the Agricultural Production – Crops industry (SIC code 01) have a high diversity index (3.25). In those industries, about 25% of the board of directors are women. In the Agricultural Production – Crops industry, there is Monsato Company, which is an agricultural biotechnology company and known as one of the top diverse companies. The Railroad Transportation industry includes CSX Corporation, a rail-based transportation company, which is recognised for its dedication to diversity in the boardroom.

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[22] Estee Lauder Companies Incorporation in the Chemicals and Allied Products industry (SIC code 28) has the highest diversity index in the sample (8.78) in 2016. Estee Lauder Companies Incorporation is highly diverse in many aspects. Specifically, its gender diversity is 0.47, its ethnicity HHI is 0.66,its education HHI is 0.11, the financial expertise HHI is 0.55, its age diversity is 11.23, and its board experience diversity is 1.47. Other companies with high diversity indexes include Hologic Incorporation (7.94) in the Measuring Photographic, Medical & Optical Goods & Clocks industry with a SIC code of 38, Kraft Heinz Company (7.59) in the Food and Kindred Products industry with a SIC code of 20, Advanced Micro Devices (5.88) in the Electronic & Other Electrical Equipment & Components industry with a SIC code of 36, Walt Disney Company (5.43) in the Communications industry with a SIC code of 48 and International Business Machines Corporation (5.25) in the Business Services industry with a SIC code of73.

Table 3.2 Summary statistics

Table 3.2 reports summary statistics of 8,568 firm-year observations during 2007-2016. The description and definition of variables are provided in Table 3.1.

Variable	N	mean	median	25th quartile	75th quartile	Std. Dev
Panel A: CEO pay incentives						
CEO vega (1000$)	8,568	167	64	17	187	379
Ln_vega	8,568	4	4	3	5	2
CEO vega of options (1000$)	8,295	163	63	14	189	332
Ln_vega_options	8,295	4	4	3	5	2
CEO equity (1000$)	8,568	140,000	17,483	7,021	46,219	1,690,000
CEO inside debt (1000$)	8,568	5,546	597	0	4,802	13,899
CEO deferred compensation (1000$)	8,568	2,620	93	0	1,706	9,487
CEO pension compensation (1000$)	8,568	2,926	0	0	1,266	7,882
Salary (1000$)	8,568	846	800	593	1,000	409
Bonus (1000$)	8,568	139	0	0	0	1,030
CEO relative leverage	7,299	16.27	0.30	0.00	1.55	271.72
Ln_CEO relative leverage	7,299	0.65	0.26	0.00	0.94	1.00
CEO relative incentive	7,110	20.73	0.33	0.00	1.63	339.27
Ln_CEO relative incentive	7,110	0.68	0.28	0.00	0.97	1.03
Panel B: Diversity (non-standardised)						
Edu_hhi	8,568	0.16	0.14	0.11	0.17	0.08
Ethnicity_hhi	8,568	0.87	0.85	0.78	1.00	0.14
Finexpert_hhi	8,568	0.64	0.58	0.52	0.72	0.15
Gender_diversity	8,568	0.13	0.13	0.00	0.20	0.10
Age_diversity	8,568	7.68	7.39	6.04	9.10	2.32
Boardexp_diversity	8,568	0.84	0.80	0.50	1.17	0.47

Table 3.3 The mean value of the diversity index and components of diversity index by year

Year	N	Diversity _index	Edu _hhi	Ethnicity _hhi	Finexpert _hhi	Gender _diversity	Age _diversity	Boardexp _diversity
2007	661	-0.223	0.160	0.884	0.648	0.108	7.705	0.918
2008	888	-0.147	0.158	0.887	0.636	0.113	7.639	0.903
2009	928	-0.192	0.157	0.884	0.633	0.113	7.610	0.863
2010	925	-0.178	0.156	0.877	0.641	0.116	7.661	0.844
2011	919	-0.119	0.156	0.867	0.643	0.120	7.655	0.824
2012	899	-0.028	0.154	0.868	0.635	0.125	7.644	0.814
2013	903	0.033	0.153	0.872	0.642	0.134	7.706	0.815
2014	884	0.267	0.150	0.870	0.635	0.144	7.760	0.827
2015	847	0.274	0.152	0.868	0.639	0.153	7.698	0.817
2016	714	0.359	0.156	0.869	0.642	0.164	7.759	0.834
Total	8,568	0.000	0.155	0.874	0.639	0.129	7.681	0.844

Table 3.4 The mean value of the diversity index and components of diversity index by industry

SIC code	Industry	N	Diversity _index	Edu _hhi	Ethnicity _hhi	Finexpert _hhi	Gender _diversity	Age _diversity	Boardexp _diversity
1	Agricultural Production - Crops	5	3.25	0.10	0.74	0.56	0.25	8.02	0.73
2	Agricultural Production - Livestock and Animal Specialties	8	-4.27	0.35	1.00	0.82	0.16	10.65	0.21
7	Agricultural Services	10	-3.71	0.25	1.00	0.52	0.00	7.64	0.28
10	Metal Mining	29	1.04	0.11	0.95	0.62	0.18	7.42	1.12
12	Coal Mining	14	-0.80	0.14	0.98	0.60	0.04	7.25	1.10
13	Oil and Gas Extraction	391	-1.26	0.16	0.95	0.65	0.07	7.15	0.89
14	Mining and Quarrying of Nonmetallic Minerals, Except Fuels	38	-1.28	0.14	0.89	0.71	0.12	6.70	0.66
16	Heamy Construction, Except Building Construction, Contractor	72	-0.51	0.17	0.88	0.62	0.11	6.20	1.02
17	Construction - Special Trade Contractors	325	-0.58	0.15	0.90	0.57	0.03	7.80	0.83
20	Food and Kindred Products	14	0.50	0.15	0.84	0.67	0.19	7.16	0.81
21	Tobacco Products	29	2.69	0.12	0.64	0.61	0.13	7.23	1.13
22	Textile Mill Products	123	-0.04	0.19	0.88	0.61	0.18	8.11	0.66
23	Apparel, Finished Products from Fabrics & Similar Materials	42	-1.91	0.19	1.00	0.61	0.08	6.84	0.86
24	Lumber and Wood Products, Except Furniture	74	0.84	0.13	0.83	0.62	0.18	6.76	0.83
25	Furniture and Fixtures	139	0.28	0.13	0.90	0.63	0.15	6.71	0.97
26	Paper and Allied Products	87	0.85	0.13	0.88	0.62	0.20	7.39	0.79
27	Printing, Publishing and Allied Industries	776	0.60	0.14	0.87	0.63	0.15	7.25	0.93
28	Chemicals and Allied Products	68	1.26	0.12	0.84	0.59	0.13	5.94	1.30
29	Petroleum Refining and Related Industries	86	0.76	0.13	0.86	0.64	0.15	7.52	0.94
30	Rubber and Miscellaneous Plastic Products	60	-0.86	0.23	0.86	0.70	0.17	8.82	0.60
31	Leather and Leather Products	38	-2.66	0.19	0.98	0.64	0.03	7.49	0.64
32	Stone, Clay, Glass, and Concrete Products	143	-0.86	0.16	0.88	0.66	0.11	6.67	0.84
33	Primary Metal Industries	179	-0.40	0.16	0.92	0.64	0.13	7.61	0.85
34	Fabricated Metal Products	638	0.39	0.14	0.86	0.62	0.11	7.21	1.01
35	Industrial and Commercial Machinery and Computer Equipment	792	-0.25	0.16	0.84	0.64	0.08	8.09	0.82
36	Electronic & Other Electrical Equipment & Components	248	-0.70	0.15	0.92	0.65	0.10	7.46	0.83
37	Transportation Equipment	706	-0.23	0.16	0.89	0.64	0.13	7.84	0.84
38	Measuring, Photographic, Medical, & Optical Goods, & Clocks	94	-0.76	0.19	0.86	0.66	0.13	7.90	0.65
39	Miscellaneous Manufacturing Industries	42	0.98	0.14	0.79	0.58	0.11	6.09	1.14
40	Railroad Transportation	5	3.25	0.10	0.74	0.56	0.25	8.02	0.73

Table 3.4 Mean value of the diversity index and components of diversity index by industry (cont.)

SIC code	Industry	N	Diversity _index	Edu _hhi	Ethnicity _hhi	Finexpert _hhi	Gender _diversity	Age _diversity	Boardexp _diversity
41	Local & Suburban Transit & Interurban Highway Transportation	3	2.53	0.25	1.00	0.59	0.30	14.32	0.73
42	Motor Freight Transportation	93	-2.12	0.24	0.95	0.65	0.13	7.59	0.64
44	Water Transportation	47	-0.02	0.15	0.89	0.59	0.08	7.89	0.92
45	Transportation by Air	91	0.34	0.13	0.88	0.65	0.14	7.36	0.95
47	Transportation Services	26	-2.69	0.26	0.85	0.77	0.04	9.38	0.57
48	Communications	195	1.51	0.13	0.83	0.63	0.17	8.71	0.85
50	Wholesale Trade - Durable Goods	261	0.14	0.15	0.88	0.62	0.11	7.55	0.92
51	Wholesale Trade - Non-durable Goods	145	0.06	0.15	0.85	0.64	0.15	7.20	0.79
52	Building Materials, Hardware, Garden Supplies & Mobile	35	1.23	0.12	0.89	0.61	0.15	7.22	1.17
53	General Merchandise Stores	103	1.58	0.14	0.85	0.59	0.20	8.18	0.82
54	Food Stores	39	1.03	0.17	0.82	0.59	0.18	8.10	0.74
55	Automotive Dealers and Gasoline Service Stations	72	0.20	0.18	0.90	0.61	0.13	9.48	0.69
56	Apparel and Accessory Stores	190	-0.01	0.16	0.90	0.63	0.19	7.67	0.66
57	Home Furniture, Furnishings and Equipment Stores	29	-0.11	0.18	0.78	0.74	0.18	8.57	0.48
58	Eating and Drinking Places	174	0.24	0.17	0.87	0.62	0.14	8.62	0.73
59	Miscellaneous Retail	168	-0.09	0.19	0.88	0.65	0.17	7.82	0.88
70	Hotels, Rooming Houses, Camps, and Other Lodging Places	9	-0.14	0.20	0.87	0.58	0.19	5.39	1.05
72	Personal Services	27	0.42	0.13	0.85	0.63	0.13	7.81	0.76
73	Business Services	1054	-0.11	0.15	0.87	0.65	0.12	8.13	0.77
75	Automotive Repair, Services and Parking	22	2.79	0.12	0.81	0.57	0.21	8.39	1.03
78	Motion Pictures	18	0.40	0.14	1.00	0.59	0.14	8.77	0.93
79	Amusement and Recreation Services	48	0.75	0.16	0.83	0.64	0.16	8.34	0.81
80	Health Services	178	-0.74	0.19	0.90	0.66	0.11	8.75	0.69
82	Educational Services	64	2.50	0.12	0.72	0.66	0.17	9.42	0.83
87	Engineering, Accounting, Research, and Management Services	176	-0.46	0.15	0.90	0.65	0.14	7.00	0.85
99	Nonclassifiable Establishments	12	2.19	0.13	0.67	0.57	0.19	5.02	1.02
	Total	8,568	0.00	0.16	0.87	0.64	0.13	7.68	0.84

3.7. Multivariate analysis

3.7.1. The impact of the board diversity index on CEO equity incentives

Table 3.5[23] shows the empirical results of the relation between CEO equity incentives and the board diversity index with firm and year fixed effects. Models (1) and (2) show the results of the OLS models in which the dependent variables are *ln_vega* (log of one plus vega of both stock and options) and *ln_vega_options* (log of one plus vega of options only). The coefficients of the diversity index in both models are insignificant. In the OLS regressions, there is no evidence of a relation between the board diversity index and CEO equity incentives.

The empirical results of the OLS regressions are estimated based on the assumption that the board diversity index is exogenous. To account for endogeneity due to omitted variables, this research uses two-stage least squares (2SLS) regressions with instrumental variables. In the paper of Prevost and Upadhyay (2018), the gender ratio at the county level is used as an instrument for gender diversity because the number of female directors in a particular county positively influences the supply of female directors for firms in that county. Following Prevost and Upadhyay (2018), this study uses the diversity index at the county level (*diversity_index_county*) as an instrument for the board diversity index. The county-level diversity index represents the diversity of the whole supply of directors within each county. It can be an appropriate instrument because the county-level diversity of directors may positively impact the board diversity of firms in each county. Moreover,

[23] The number of observations in regressions is less than the total number of observations in the full sample. The main reason is that the OLS regression model with firm and year fixed effects drops observations that are singletons. In the 2SLS regression model, a county which has less than four firms is set to missing.

the county-level diversity index can only impact the CEO pay incentives of firms through the firm-level board diversity index.

Table 3.5 Board diversity and CEO equity incentives

Table 3.5 reports the empirical results of the OLS and 2SLS models with firm and year fixed effects. Models (1) and (2) show the results of the OLS model. Models (3) and (4) demonstrate the results of the 2SLS models. The independent variable *diversity_index* (board diversity index) is standardised by its sample mean and standard deviation. The instrumental variable is *diversity_index_county* (diversity index at the county level).The dependent variables include *ln_vega* (log of one plus vega of both stock and options) and *ln_vega_options* (log of one plus vega of options only). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 3.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1)	Model (2)	Model (3)		Model (4)	
		OLS	OLS	First stage-2SLS	Second stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_vega	Ln_vega_options	Diversity_index	Ln_vega	Diversity_index	Ln_vega_options
diversity_index	-	-0.005	-0.032		-0.705**		-0.622*
		(0.031)	(0.036)		(0.295)		(0.339)
diversity_index_county	+			0.132***		0.130***	
				(0.018)		(0.018)	
firm_size	+	0.173**	0.197**	0.004	0.229**	0.014	0.245**
		(0.072)	(0.085)	(0.044)	(0.092)	(0.046)	(0.103)
lagged rd_intensity	+	-0.750	-1.118	-0.571	-1.332	-0.560	-1.430
		(1.122)	(1.351)	(0.546)	(1.261)	(0.550)	(1.530)
roa	+	0.906***	1.061***	0.043	0.833***	0.034	0.955***
		(0.165)	(0.183)	(0.089)	(0.197)	(0.091)	(0.210)
lagged roa	+	-0.075	0.023	-0.146	-0.255	-0.154	-0.090
		(0.157)	(0.179)	(0.093)	(0.186)	(0.095)	(0.208)
lagged mb	+/-	0.001	0.001	-0.000*	0.001	-0.000**	0.001
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
lagged leverage	-	-0.299	-0.269	-0.196	-0.882**	-0.201	-0.946**
		(0.246)	(0.280)	(0.138)	(0.343)	(0.141)	(0.379)
stock return	+/-	-0.008	0.002	0.018	0.023	0.025	0.020
		(0.028)	(0.029)	(0.017)	(0.038)	(0.018)	(0.039)
lagged stock return	+/-	-0.015	-0.007	-0.002	0.000	-0.005	0.001
		(0.024)	(0.028)	(0.015)	(0.032)	(0.017)	(0.038)
lagged cash flow volatility	+/-	-0.172	-0.659	-0.630	-0.787	-0.653	-1.038
		(0.701)	(0.853)	(0.508)	(0.855)	(0.507)	(0.961)
lagged sales growth	-	-0.049	-0.080*	-0.041*	-0.068	-0.044*	-0.101**
		(0.038)	(0.045)	(0.024)	(0.042)	(0.025)	(0.048)
lagged capital expenditure	+/-	-0.045	0.344	0.105	-0.319	0.113	-0.010
		(0.600)	(0.725)	(0.327)	(0.812)	(0.337)	(0.917)
lagged tangibility	-	-0.128	-0.315	-0.153	-0.067	-0.082	-0.116
		(0.433)	(0.510)	(0.294)	(0.557)	(0.273)	(0.628)
ceo chair	+	0.012	-0.053	0.009	0.008	0.003	-0.075
		(0.058)	(0.063)	(0.031)	(0.073)	(0.032)	(0.078)
ln_age	-	-0.471	-0.641	-0.311	-0.613	-0.296	-0.738
		(0.389)	(0.427)	(0.196)	(0.489)	(0.209)	(0.522)
ln_tenure	+	0.431***	0.436***	-0.016	0.383***	-0.014	0.403***
		(0.051)	(0.056)	(0.026)	(0.064)	(0.027)	(0.069)
ln_cash_compensation	+	0.046	0.101**	0.018	0.071	0.030	0.131***
		(0.038)	(0.042)	(0.025)	(0.049)	(0.023)	(0.048)
ln_in_dir	+	0.304	0.301	0.730**	1.272*	0.820**	0.911
		(0.461)	(0.528)	(0.345)	(0.653)	(0.332)	(0.724)
ln_boardsize	+	-0.179	-0.071	0.979***	0.527	0.995***	0.560
		(0.167)	(0.193)	(0.106)	(0.363)	(0.102)	(0.415)
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		8,438	8,163	6,103	6,103	5,900	5,900
Adj R-squared		0.737	0.750				
F statistics		9.277	8.360		7.152		8.024
P-value of F statistics		0.000	0.000		0.000		0.000
Endogeneity test					6.294		3.287
P-value of Endogeneity test					0.012		0.069
P-value of SW F test of weak identification					0.000		0.000
P-value of SW chi-squared test of under-identification					0.000		0.000

The 2SLS estimation results are reported in Models (3) – (4) of Table 3.5. The standard errors are clustered at the firm level[24]. In the first stage of the 2SLS regressions, the coefficients of the county-level diversity index (*diversity_index_county*) in both Models (3) and (4) is positive and significant (0.132 and 0.130). Those coefficient estimates imply that a one standard deviation increase in the board diversity index at the county level is correlated with a 0.132 (0.130) standard deviation rise in the board diversity index at the firm level. Those findings support the argument that the diversity of directors at the county level positively impacts the diversity of directors of firms.

In the second stages of 2SLS regressions, the board diversity index is negatively correlated with CEO equity incentives (*ln_vega* and *ln_vega_options*). The coefficients of the board diversity index are significant at the significance level of 5% and 10% (-0.705 and -0.622 in Models 3 and 4 respectively). This evidence supports the hypothesis that the higher the board diversity index, the lower the equity incentives for CEOs. Specifically, the coefficient of the diversity index in Model (3) implies that when the board diversity index increases by one standard deviation, the value of the vega of both stock and options held by CEOs decreases by 0.705 percentage points[25]. The coefficient of the diversity index in Model (4) implies that when the board diversity index rises by one standard deviation, the value of the vega of options declines by 0.622 percentage points[26]. The diagnostic test for endogeneity shows that there is evidence of endogeneity

[24] The results still hold when this study runs regressions in which the standard errors are clustered at both firm and year levels. However, the endogeneity test cannot be run in the 2SLS regressions because the number of clusters by year is insufficient to calculate a robust covariance matrix. The data sample is from 2007 to 2016 (10 years). The number of clusters by year in the research is only 10, which is not large enough to satisfy the assumption that the number of clusters goes to infinity (Cameron & Miller, 2015).

[25] This study finds that the coefficient of the board diversity index is -0.401 when standardising all variables in Model (3) by their sample mean and standard deviation. It means that the value of the vega of both stock and options reduces by 0.401 standard deviation when the board diversity index increases by one standard deviation.

[26] The coefficient of the board diversity index is -0.314 when all variables in Model (4) are standardised by their sample mean and standard deviation. It means that there is a decrease in the vega of options by 0.314 standard deviation when the board diversity index increases by one standard deviation.

at the significance level of 10%. When the p-value of the endogeneity test is lower than 10%, the null hypothesis that the endogenous regressors can be treated as exogenous ones is rejected at the significance level of 10%. Table 3.5 also presents further diagnostic tests for under-identification and weak identification as suggested by Sanderson and Windmeijer (2016). In the 2SLS regressions, the instrument (diversity_index_county) is relevant because the p-value of the Sanderson-Windmeijer (SW) chi-squared test of under-identification is lower than 1%. The null hypothesis that the instrument is not relevant (or the endogenous regressor in question is unidentified) is rejected. Moreover, the instrument (diversity_index_county) is not weak because the p-value of the Sanderson-Windmeijer (SW) F statistics test of weak identification is lower than 1%. The null hypothesis that the instrument is weak (or the instrument is weakly correlated with the endogenous regressors) is rejected.

3.7.2. The impact of the board diversity index on CEO inside debt incentives

The estimated results of the relation between CEO inside debt incentives and the board diversity index with firm and year fixed effects are reported in Table 3.6. Models (1) and (2) show the estimation of the OLS model, in which the dependent variables include *ln_CEO relative leverage* (the natural logarithm of one plus the CEO's debt-to-equity scaled by the debt-to-equity ratio of the firm) and *ln_CEO relative incentive* (the natural logarithm of one plus the marginal change in the value of CEO inside debt to equity scaled by the firm's marginal change in the leverage ratio). In Model (1), the coefficient of the board diversity index is insignificant. In Model (2), the diversity index is positively associated with the CEO relative incentive ratio at the significance level of 10%.

In order to account for endogeneity, the 2SLS regressions with instrumental variables are used. Following Prevost and Upadhyay (2018), the instrumental variable used in the 2SLS regressions is the diversity index of directors at the county level (*diversity_index_county*). The 2SLS estimated results are reported in Models (3) – (4). Models (3) and (4) present the findings of the first stage of 2SLS regressions in which the dependent variable of the second stage is *ln_CEO relative leverage* and *ln_CEO relative incentive* respectively. The coefficients of the county-level diversity index (*diversity_index_county*) in the first stages of both Models (3) and (4) are positively significant (0.138 and 0.142) at the level of 1%. Those coefficient estimates imply that a one standard deviation increase in the board diversity index at the county level is associated with a 0.138 (0.142) standard deviation rise in the board diversity index at the firm level. Those findings support the argument that the number of directors at the county level positively impacts the supply of directors of firms in each county.

The second stages of the 2SLS regressions of Models (3) and (4) show that the board diversity index positively affects CEO inside debt incentives (*ln_CEO relative leverage* and *ln_CEO relative incentive*). The coefficients of the board diversity index are positive and significant at the level of 1% and 5% (0.363 and 0.283 in Models 3 and 4 respectively). This evidence supports the hypothesis that firms with diverse boards tend to increase the inside debt incentives to induce CEOs to take less risk. Specifically, the coefficient of the diversity index in Model (3) implies that when the board diversity index increases by one standard deviation, the relative leverage ratio goes up by 0.363 percentage points[27]. The coefficient of the diversity index in Model (4) implies that when the board diversity index rises by one standard deviation, the relative incentive ratio

[27] This study finds that the coefficient of the board diversity index is 0.364 when standardising all variables in Model (3) by their sample mean and standard deviation. It means that the relative leverage ratio increases by 0.364 standard deviation when the board diversity index increases by one standard deviation.

increases by 0.283 percentage points[28]. The diagnostic test for endogeneity shows that there is evidence of endogeneity at the significance level of 5% in Model (3). In the 2SLS regressions, the instrument (*diversity_index_county*) is relevant and not weak because the p-values of the Sanderson-Windmeijer (SW) chi-squared test of under-identification and the SW F statistics test of weak identification are lower than 1%.

[28] The coefficient of the board diversity index is 0.275 when all variables in Model (4) are standardised by their sample mean and standard deviation. It means that the relative incentive ratio goes up by 0.275 standard deviation when the board diversity index increases by one standard deviation.

Table 3.6 Board diversity and CEO inside debt incentives

Table 3.6 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Models (1) and (2) show the results of the OLS model. Models (3) and (4) demonstrate the results of the 2SLS models. The independent variable *diversity_index* (board diversity index) is standardised by its sample mean and standard deviation. The instrumental variable is *diversity_index_county* (diversity index at the county level). The dependent variables include *Ln_CEO relative leverage* (log of one plus the CEO's debt-to-equity ratio scaled by the debt-to-equity ratio of the firm) and *Ln_CEO_relative incentive* (log of one plus the CEO's relative incentive ratio). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 3. 1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1)	Model (2)	Model (3)		Model (4)	
		OLS	OLS	First stage-2SLS	Second stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_CEO relative leverage	Ln_CEO relative incentive	Diversity_index	Ln_CEO relative leverage	Diversity_index	Ln_CEO relative incentive
diversity index	+	0.027	0.039*		0.363***		0.283**
		(0.019)	(0.020)		(0.136)		(0.141)
diversity_index_county	+			0.138***		0.142***	
				(0.019)		(0.020)	
firm_size	+/-	-0.151***	-0.156***	0.001	-0.152***	0.002	-0.155***
		(0.047)	(0.053)	(0.046)	(0.052)	(0.047)	(0.060)
lagged rd_intensity	-	0.914	0.807	-0.909	1.482	-0.840	1.284
		(1.380)	(1.448)	(0.670)	(1.605)	(0.663)	(1.665)
roa	+	0.141	0.176	0.061	-0.035	0.057	-0.005
		(0.148)	(0.158)	(0.121)	(0.167)	(0.123)	(0.173)
lagged roa	+	0.053	0.010	-0.300**	0.038	-0.307**	-0.045
		(0.170)	(0.186)	(0.119)	(0.194)	(0.121)	(0.209)
lagged mb	+	0.001**	0.001**	-0.000*	0.001**	-0.000*	0.001**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lagged leverage	+/-	-1.073***	-1.090***	-0.203	-0.836***	-0.238*	-0.848***
		(0.140)	(0.150)	(0.143)	(0.162)	(0.144)	(0.172)
stock return	+/-	-0.014	-0.011	0.009	-0.008	0.009	-0.003
		(0.020)	(0.021)	(0.018)	(0.027)	(0.018)	(0.028)
lagged stock return	+/-	0.000	0.009	-0.009	0.012	-0.007	0.013
		(0.022)	(0.023)	(0.017)	(0.024)	(0.017)	(0.026)
lagged cash flow volatility	+/-	0.008	0.017	-0.938	0.371	-0.898	0.232
		(0.418)	(0.438)	(0.587)	(0.540)	(0.585)	(0.555)
lagged sales growth	-	0.027	0.032	-0.047	0.055	-0.044	0.056
		(0.034)	(0.037)	(0.029)	(0.042)	(0.029)	(0.043)
lagged capital expenditure	-	0.228	0.334	0.249	0.039	0.272	0.325
		(0.356)	(0.385)	(0.338)	(0.439)	(0.343)	(0.482)
lagged tangibility	+/-	-0.070	-0.112	0.116	-0.099	0.196	-0.093
		(0.232)	(0.238)	(0.317)	(0.292)	(0.319)	(0.289)
firm age	+	0.071	0.064	-0.037	0.066	-0.070	0.136
		(0.116)	(0.094)	(0.096)	(0.171)	(0.095)	(0.131)
tax loss indicator	+	0.031	0.026	-0.002	0.045	-0.008	0.044
		(0.033)	(0.034)	(0.034)	(0.041)	(0.035)	(0.042)
HHI	+	0.253	0.105	-0.398	0.429	-0.354	0.360
		(0.281)	(0.307)	(0.341)	(0.332)	(0.344)	(0.342)
constraint	+/-	-0.102*	-0.172**	-0.010	-0.090	-0.022	-0.156*
		(0.061)	(0.070)	(0.053)	(0.081)	(0.050)	(0.090)
ceo chair	+	-0.014	-0.020	0.009	0.021	0.006	0.012
		(0.034)	(0.035)	(0.033)	(0.041)	(0.033)	(0.042)
ln_age	+	0.801***	0.853***	-0.382*	0.778***	-0.371*	0.832***
		(0.239)	(0.252)	(0.199)	(0.287)	(0.207)	(0.309)
ln_tenure	+	0.089***	0.100***	-0.010	0.110***	-0.007	0.122***
		(0.030)	(0.032)	(0.028)	(0.035)	(0.028)	(0.037)
ln_cash_compensation	+	0.041	0.038	0.036	0.028	0.041	0.024
		(0.028)	(0.030)	(0.031)	(0.034)	(0.031)	(0.036)
ln_in_dir	+	0.264	0.205	0.640*	0.288	0.562	0.379
		(0.363)	(0.388)	(0.387)	(0.448)	(0.386)	(0.464)
ln_boardsize	+	0.071	0.071	0.954***	-0.278	0.962***	-0.209
		(0.096)	(0.104)	(0.119)	(0.183)	(0.121)	(0.194)
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		7,157	6,964	5,094	5,094	4,963	4,963
Adj R-squared		0.676	0.675				
F statistics		6.207	6.493		3.973		4.762
P-value of F statistics		0.000	0.000		0.000		0.000
Endogeneity test					5.748		2.699
P-value of Endogeneity test					0.017		0.100
P-value of SW F test					0.000		0.000
P-value of SW chi-squared test					0.000		0.000

3.7.3. The interactive effect of high leverage and board diversity on CEO equity incentives

The baseline regressions provide significant evidence that board diversity leads to lower equity incentives and higher inside debt incentives. In this section, I further examine when board diversity matters more for CEO pay incentives. I investigate whether the impact of board diversity on CEO pay incentives depends on the firm leverage. More specifically, I explore further whether the negative relation between the board diversity index and CEO equity incentives is stronger in the case that a firm has higher leverage.

When a firm's leverage is higher than the median value in the industry, its risk level may be higher than other firms in the same industry. A strongly diverse board in a firm with a higher risk has more incentives to reduce CEO equity incentives, because they want to induce its CEO to take less risk and lower the firm risk. To test this hypothesis, a dummy variable (*high leverage*) and the interaction between *high leverage* and *diversity_index* are added to the regressions. *High leverage* is the dummy variable which equals one if the leverage is larger than the median value of the industry and zero otherwise. Models (1) and (2) of Table 3.7 present the OLS regression results of the interactive effect of high leverage and the board diversity index on CEO equity incentives. The coefficients of the interaction (*diversity_index*high leverage)* are negatively significant at the level of 5% (-0.093 and -0.115 in Model 1 and 2 respectively). The results reported in Models (1) and (2) are consistent with the conjecture that diverse boards in firms which have higher leverage than the median leverage of the industry have more incentives to decrease CEO equity incentives (*ln_vega* and *ln_vega_options*) to reduce firm risk than firms with lower leverage.

To account for the endogeneity, this study utilises 2SLS regressions with instruments. This research uses an instrument (*diversity_index_county*) for the endogenous variable (*diversity_index*). It is reasonable to assume that the interaction variable (*high leverage* * *diversity_index*) is also endogenous. In this case, Wooldridge (2010) recommends that it is necessary to add another instrument, which is the interaction between the exogenous variable and the instrumental variable. Specifically, this research adds another instrument (*high leverage* * *diversity_index_county*) for the endogenous interaction variable (*high leverage* * *diversity_index*). Models (3) – (4) show the results of the 2SLS models. The instrument (*diversity_index_county*) is positively associated with the endogenous variable (*diversity_index*). The coefficient of the instrument (*high leverage* * *diversity_index_county*) is positive and significant at the level of 1%. In the 2SLS regressions, the instruments (*diversity_index_county* and *high leverage* * *diversity_index_county*) are relevant and not weak because the p-values of the Sanderson-Windmeijer (SW) chi-squared test of under-identification and the F statistics test of weak identification are lower than 1%. In Model (3), the diagnostic test for endogeneity shows that there is an endogeneity issue at the significance value of 5% (the p-value of the endogeneity test is lower than 5%). The coefficient estimates of the 2SLS regressions in Model (3) are more efficient than those of the OLS regressions in Model (1). Model (3) reports that the coefficient of the interaction between *high leverage* and *diversity index* is insignificant. In Model (4) there is no evidence of endogeneity because the p-value of the endogeneity test is higher than 5%. Therefore, the estimated results of the OLS regressions in Model (2) are more efficient than the 2SLS regressions in Model (4). In conclusion, there is significant evidence of a negative interactive effect of high leverage and the board diversity index on the vega of options.

Table 3.7 The interactive effect of high leverage and board diversity on CEO equity incentives

Table 3.7 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Models (1) and (2) show the results of the OLS model. Models (3) and (4) present the results of the 2SLS model. The independent variable *diversity_index* (board diversity index) is standardised by its sample mean and standard deviation. The instrumental variables include *diversity_index_county* (diversity index at the county level) and *diversity_index_county * high leverage* (the interaction between the diversity_index_county and high leverage variables). The dependent variables include *ln_vega* (log of one plus vega of both stock and options) and *ln_vega_options* (log of one plus vega of options only). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 3. 1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1)	Model (2)	Model (3)			Model (4)		
		OLS	OLS	First stage-2SLS	First Stage -2SLS	Second stage-2SLS	First stage-2SLS	First Stage -2SLS	Second stage-2SLS
	Expected sign	Ln_vega	Ln_vega_ options	Diversity _index	Diversity_index * High leverage	Ln_vega	Diversity_ index	Diversity_index * High leverage	Ln_vega _options
diversity_index	+/-	0.040	0.026			-0.514			-0.424
		(0.038)	(0.046)			(0.319)			(0.366)
diversity_index * high leverage	-	-0.093**	-0.115**			-0.287			-0.287
		(0.047)	(0.056)			(0.187)			(0.221)
high leverage	+/-	-0.060	-0.074	-0.005	0.051	-0.109*	-0.005	0.060	-0.130*
		(0.049)	(0.056)	(0.029)	(0.044)	(0.064)	(0.030)	(0.045)	(0.072)
diversity_index_county				0.130***	-0.070***		0.128***	-0.072***	
				(0.022)	(0.022)		(0.022)	(0.023)	
diversity_index_county * high leverage				0.004	0.277***		0.004	0.279***	
				(0.022)	(0.032)		(0.022)	(0.033)	
Control variables		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations		8,438	8,163	6,103	6,103	6,103	5,900	5,900	5,900
Adj R-squared		0.737	0.751						
F statistics		8.933	8.106			7.017			7.887
P-value of F statistics		0.000	0.000			0.000			0.000
Endogeneity test						6.921			3.422
P-value of Endogeneity test						0.031			0.181
P-value of SW F test of weak identification						0.000			0.000
P-value of SW chi-squared test of under-identification						0.000			0.000

3.7.4. The interactive effect of high leverage and board diversity on CEO inside debt incentives

Next, I investigate whether the effect of board diversity on CEO inside debt incentives depends on the firm leverage. A firm with high leverage may be associated with a high risk level. Therefore, I expect that a strongly diverse board in a corporation with a higher risk level may have more motivation to increase CEO inside debt incentives to encourage its CEO to follow conservative policies to reduce firm risk. To test that hypothesis, a dummy variable (*high leverage*) and the interaction between *high leverage* and *diversity_index* are added to the regression model. *High leverage* is the dummy variable which equals one if the leverage is higher than the median value of the industry and zero otherwise. Models (1) and (2) of Table 3.8 present the OLS regression results of the interactive effect of high leverage and the board diversity index on CEO equity incentives. The coefficients of the interaction term between *diversity_index* and *high leverage* are not significant. Those findings do not support the argument that diverse boards in firms which have higher leverage than the median leverage of the industry have more incentives to give CEOs more inside debt incentives (*ln_CEO relative leverage* and *ln_CEO relative incentive*) in order to reduce the firms' risk level than firms which have lower leverage. Models (3) – (4) re-estimate the coefficients of the diversity index by running 2SLS regressions with an instrument. The 2SLS models in Table 3.8 use an instrumental variable (*diversity_index_county*) for the endogenous variable (*diversity_index*) and another instrument (*high leverage * diversity_index_county*) for the endogenous interaction term (*high leverage * diversity_index*). Overall, the empirical results of the 2SLS regressions show that there is no evidence that the effect of board diversity on CEO inside debt incentives depends on the firm leverage.

Table 3.8. The interactive effect of high leverage and board diversity on CEO inside debt incentives

Table 3.8 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Models (1) and (2) show the results of the OLS model. Models (3) and (4) present the results of the 2SLS model. The independent variable *diversity_index* (board diversity index) is standardised by its sample mean and standard deviation. The instrumental variables include *diversity_index_county* (diversity index at the county level) and *diversity_index_county * high leverage* (the interaction between diversity_index_county and high leverage variables). The dependent variables include *Ln_CEO relative leverage* (log of one plus the CEO's debt-to-equity ratio scaled by the debt-to-equity ratio of the firm) and *Ln_CEO_relative incentive* (log of one plus the CEO's relative incentive ratio). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 3. 1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1)	Model (2)	Model (3)			Model (4)		
		OLS	OLS	First stage-2SLS	First Stage -2SLS	Second stage-2SLS	First stage-2SLS	First Stage -2SLS	Second stage-2SLS
	Expected sign	Ln_CEO relative leverage	Ln_CEO relative incentive	Diversity _index	Diversity_index * High leverage	Ln_CEO relative leverage	Diversity _index	Diversity_index * High leverage	Ln_CEO relative incentive
diversity_index	+/-	0.042	0.060**			0.426***			0.334*
		(0.029)	(0.030)			(0.165)			(0.173)
diversity_index * high leverage	+	-0.023	-0.034			-0.068			-0.048
		(0.027)	(0.029)			(0.098)			(0.104)
high leverage	+/-	-0.303***	-0.300***	-0.011	0.074*	-0.280***	-0.024	0.071	-0.271***
		(0.030)	(0.031)	(0.030)	(0.050)	(0.035)	(0.030)	(0.046)	(0.035)
diversity_index_county				0.138***	-0.091***		0.136***	-0.097***	
				(0.025)	(0.027)		(0.026)	(0.029)	
diversity_index_county * high leverage				0.000	0.295***		0.010	0.303***	
				(0.024)	(0.035)		(0.024)	(0.036)	
Control variables		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations		7,157	6,964	5,094	5,094	5,094	4,963	4,963	4,963
Adj R-squared		0.679	0.678						
F statistics		7.467	7.459			4.399			4.938
P-value of F statistics		0.000	0.000			0.000			0.000
Endogeneity test						6.960			3.751
P-value of Endogeneity test						0.031			0.153
P-value of SW F test of weak identification						0.000			0.000
P-value of SW chi-squared test of under-identification						0.000			0.000

3.8. Additional results

3.8.1. The impact of diversity of executive and non-executive directors on CEO pay incentives

In this section, I repeat the baseline regressions by splitting the influence of the diversity of executive versus non-executive board members on CEO pay incentives. It is interesting to investigate the effect of the diversity of the executive and non-executive directors separately because the diversity of executive directors may have less influence on CEO pay incentives. There is where executive directors have opportunities to discuss and interact with each other every day. As a result, directors who serve as executives of the firm have more homogeneous opinions about decisions relating to CEO pay incentives (Bernile et al., 2018), while non-executive board members have fewer occasions to meet and work together frequently than their executive colleagues. This suggests that there is a higher probability that non-executive directors provide diverse views on CEO pay incentives. Therefore, I expect that the relation between CEO pay incentives and board diversity is mainly due to the diversity of non-executive directors.

3.8.1.1. The impact of the diversity index of executive and non-executive directors on CEO equity incentives

Table 3.9 reports the OLS and 2SLS regression results of the relation between CEO equity incentives (*ln_vega* and *ln_vega_options*) and the diversity index of the executive directors (*ex_diversity_index*) and non-executive directors (*nonex_diversity_index*). Panel A of Table 3.9 shows that the coefficients of the variable *ex_diversity_index* (the diversity of executive directors) are insignificant in both the OLS and 2SLS regression models.

Table 3.9 The diversity index of executive and non-executive directors and CEO equity incentives

Table 3.9 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Models (1) and (2) show the results of the OLS model. Models (3) and (4) demonstrate the results of the 2SLS models. The independent variables *ex_diversity_index* (board diversity of executive directors) and *nonex_diversity_index* (board diversity of non-executive directors) are standardised by their sample mean and standard deviation. The instrumental variable is *diversity_index_county* (diversity index at the county level). The standard errors (in parentheses) are clustered at the firm level. The dependent variables include *ln_vega* (log of one plus vega of both stock and options) and *ln_vega_options* (log of one plus vega of options only). The description and definition of independent variables are provided in Table 3. 1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: Diversity index of executive directors

		Model (1)	Model (2)	Model (3)		Model (4)	
		OLS	OLS	First stage-2SLS	Second stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_vega	Ln_vega_options	Ex_diversity_index	Ln_vega	Ex_diversity_index	Ln_vega_options
ex_diversity_index	-	-0.016	-0.031		-0.943		-0.726
		(0.029)	(0.031)		(0.623)		(0.654)
diversity_index_county	+			0.084***		0.086***	
				(0.029)		(0.030)	
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		6,263	6,055	4,466	4,466	4,314	4,314
Adj R-squared		0.746	0.766				
F statistics		6.223	6.192		4.509		5.925
P-value of F statistics		0.000	0.000		0.000		0.000
Endogeneity test					2.848		1.261
P-value of Endogeneity					0.091		0.261
P-value of SW F test of weak identification					0.004		0.004
P-value of SW chi-squared test of under-identification					0.004		0.004

Panel B: Diversity index of non-executive directors

		Model (1)	Model (2)	Model (3)		Model (4)	
		OLS	OLS	First stage-2SLS	Second stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_vega	Ln_vega_options	Nonex_diversity_index	Ln_vega	Nonex_diversity_index	Ln_vega_options
nonex_diversity_index	-	0.000	0.012		-0.892**		-0.748*
		(0.027)	(0.031)		(0.393)		(0.429)
diversity_index_county	+			0.100***		0.104***	
				(0.019)		(0.019)	
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		8,399	8,125	6,077	6,077	5,875	5,875
Adj R-squared		0.738	0.751				
F statistics		9.491	8.364		6.653		7.475
P-value of F statistics		0.000	0.000		0.000		0.000
Endogeneity test					5.775		3.320
P-value of Endogeneity					0.016		0.068
P-value of SW F test of weak identification					0.000		0.000
P-value of SW chi-squared test of under-identification					0.000		0.000

In panel B of Table 3.9, Model (3) and (4) report a significantly negative link between the variable *nonex_diversity_index* (the diversity of non-executive board members) and CEO equity incentives (*ln_vega* and *ln_vega_options*) in the 2SLS regressions with an instrumental variable (*diversity_index_county*). The coefficients of the diversity index of non-executive directors (*nonex_diversity_index*) are -0.892 and -0.748 in Models 3 and 4 respectively. The endogeneity test shows that there is an endogeneity issue because the p-value of the endogeneity test is lower than 10%. The instrumental variable (*diversity_index_county*) is relevant and not weak because the p-values of under-identification and the weak identification tests are smaller than 1%. Therefore, the 2SLS regression with an instrumental variable is more efficient than the OLS regression. Overall, the findings support the conjecture that the negative association between board diversity and CEO equity incentives is predominantly due to the diversity of non-executive directors.

3.8.1.2. The impact of the diversity index of executive and non-executive directors on CEO inside debt incentives

Table 3.10 presents the OLS and 2SLS regression results of the relation between CEO inside debt incentives (*ln_CEO relative leverage* and *ln_CEO relative incentive*) and the diversity index of executive directors (*ex_diversity_index*) and non-executive directors (*nonex_diversity_index*). In Panel A of Table 3.10, the coefficients of the variable *ex_diversity_index* (the diversity of executive directors) are insignificant in the OLS regression models. However, Model (3) shows that the variable *ex_diversity_index* has a positive impact on *Ln_CEO relative leverage* at the significance level of 10% (0.405). The estimates of the 2SLS regressions are more efficient than the OLS models because there is an endogeneity issue (p-value is lower than 5% in Model 3).

Panel B of Table 3.10 reports a significantly positive association between the variable *nonex_diversity_index* (the diversity of non-executive board members) and CEO inside debt incentives (*ln_CEO relative leverage* and *ln_CEO relative incentive*). In the OLS models, the coefficients of the diversity index of non-executive directors (*nonex_diversity_index*) are 0.029 and 0.038 in Models 1 and 2 respectively.

Models (3) and (4) of Panel B present the second stage results of 2SLS regressions with an instrumental variable (*diversity_index_county*). The coefficients of the diversity index of non-executive directors (*nonex_diversity_index*) are 0.520 and 0.406 in Models 3 and 4 respectively. The endogeneity test shows that there is an endogeneity issue because the p-value of the endogeneity test is lower than 10%. In addition, the instrumental variable (*diversity_index_county*) is relevant and not weak because the p-values of the under-identification and weak identification tests are lower than 1%. Therefore, the 2SLS regression with an instrumental variable is more efficient than the OLS regression. Overall, the findings support the conjecture that the positive relation between board diversity and CEO inside debt incentives is predominantly due to the diversity of non-executive directors.

Table 3.10 The diversity index of executive and non-executive directors and CEO inside debt incentives

Table 3.10 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Models (1) and (2) show the results of the OLS model. Models (3) and (4) demonstrate the results of the 2SLS models. The independent variables *ex_diversity_index* (board diversity of executive directors) and *nonex_diversity_index* (board diversity of non-executive directors) are standardised by their sample mean and standard deviation. The instrumental variable is *diversity_index_county* (diversity index at the county level). The dependent variables include *Ln_CEO relative leverage* (log of one plus the CEO's debt-to-equity ratio scaled by the debt-to-equity ratio of the firm) and *Ln_CEO_relative incentive* (log of one plus the CEO's relative incentive ratio). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 3. 1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: Diversity index of executive directors

		Model (1)	Model (2)	Model (3)		Model (4)	
		OLS	OLS	First stage-2SLS	Second stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_CEO relative leverage	Ln_CEO relative incentive	Ex_diversity _index	Ln_CEO relative leverage	Ex_diversity _index	Ln_CEO relative incentive
ex_diversity_index	+	-0.012	-0.016		0.405*		0.320
		(0.015)	(0.015)		(0.211)		(0.229)
diversity_index_county	+			0.104***		0.099***	
				(0.030)		(0.031)	
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		5,395	5,259	3,800	3,800	3,714	3,714
Adj R-squared		0.690	0.689				
F statistics		5.048	5.011		2.984		3.517
P-value of F statistics		0.000	0.000		0.000		0.000
Endogeneity test					4.846		2.636
P-value of Endogeneity					0.028		0.104
P-value of SW F test of weak identification					0.000		0.001
P-value of SW chi-squared test of under-identification					0.000		0.001

Panel B: Diversity index of non-executive directors

		Model (1)	Model (2)	Model (3)		Model (4)	
		OLS	OLS	First stage-2SLS	Second stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_CEO relative leverage	Ln_CEO relative incentive	Nonex_ diversity _index	Ln_CEO relative leverage	Nonex_ diversity _index	Ln_CEO relative incentive
nonex_diversity_index	+	0.029*	0.038**		0.520***		0.406**
		(0.017)	(0.018)		(0.194)		(0.194)
diversity_index_county	+			0.099***		0.102***	
				(0.019)		(0.020)	
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		7,128	6,935	5,077	5,077	4,946	4,946
Adj R-squared		0.680	0.679				
F statistics		6.231	6.621		3.910		4.862
P-value of F statistics		0.000	0.000		0.000		0.000
Endogeneity test					7.359		3.685
P-value of Endogeneity					0.007		0.055
P-value of SW F test of weak identification					0.000		0.000
P-value of SW chi-squared test of under-identification					0.000		0.000

3.8.2. The impact of the compensation committee diversity index on CEO pay incentives

This study further examines where diverse compensation committees can affect CEO pay incentives. A heterogeneous board can make decisions relating to CEO compensation packages through the compensation committee. The compensation committee functions as an advisor to the board of directors regarding executive pay packages.

The diversity of executive directors may impact CEO pay incentives because the New York Stock Exchange (NYSE) suggests that the compensation committee need to discuss with the board of directors to determine the long-term incentives for CEOs[29]. Therefore, I expect that the compensation committee should discuss with the whole board of directors (including both executive and non-executive directors) regarding CEO compensation. The compensation committee needs to make sure that the executive pay is consistent with the overall firm policies and provides appropriate incentives for CEOs to achieve expected targets. I hypothesise that the more diverse the compensation committee, the lower the CEO equity incentives, and the larger the CEO inside debt incentives.

3.8.2.1. The impact of the compensation committee diversity index on CEO equity incentives

To investigate the association between compensation committee diversity and CEO equity incentives, I estimate the OLS and 2SLS regressions with firm and year fixed effects. The dependent variables include *ln_vega* (logarithm of one plus vega of both stock and options) and *ln_vega_options* (logarithm of one plus vega of options only). The independent variable of interest is *diversity_index_comp* (the diversity index of the

[29] See the link https://corpgov.law.harvard.edu/2017/03/29/2017-compensation-committee-guide/

compensation committee). The empirical results of the OLS models show that the coefficients of the variable *diversity_index_comp* are insignificant (see Models 1 and 2 of Table 3.11). There is no evidence of a relationship between the compensation committee diversity index and CEO equity incentives. However, the estimated results of the OLS regressions can be biased because of the endogeneity problem.

In the next step, I further run the 2SLS regressions with instrumental variables. The instrumental variable used in the 2SLS regressions is *diversity_index_county* (the diversity index of directors at the county level). The diversity index of directors at the county level represents the supply of directors in each county which can become one of the members of the compensation committees. The higher the diversity index at the county level, the higher the diversity index of the compensation committee. Models (3) and (4) of Table 3.11 report the results of the first stage regressions of the 2SLS models. The coefficients of the *diversity_index_county* are positive and significant at the 1% level (0.111 and 0.107 respectively). Those findings are consistent with the conjecture of a positive link between the diversity index at the county level and the diversity index of the compensation committee. If the diversity index at the county level increases by one standard deviation, the diversity index of the compensation committee goes up by 0.111 and 0.107 standard deviation respectively.

Models (3) and (4) of Table 3.11 provide the results of the second stages of the 2SLS regressions. There is significant evidence of a negative association between the diversity index of the compensation committee (*diversity_index_comp*) and CEO equity incentives (*ln_vega and ln_vega_options*). Specifically, the coefficients of the diversity index of the compensation committee (*diversity_index_comp)* are -0.841 and -0.753 in Models (3) and (4) respectively. The endogeneity tests in the 2SLS regressions with instruments indicate that there is an endogeneity concern because the p-values of the endogeneity tests are lower than 10%. In addition, the instrument (*diversity_index_county*) is relevant (the p-value of the under-identification test is lower than 1%) and not weak (the p-value of the weak identification test is lower than 1%). Therefore, the results estimated by the 2SLS models with instruments are more efficient than those predicted by the OLS regressions. Overall, the more heterogeneous the compensation committee, the lower the equity incentives received by executives because the compensation committees mainly comprise non-executive directors.

Table 3.11 Compensation committee diversity and CEO equity incentives

Table 3.11 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Models (1) and (2) show the results of the OLS model. Models (3) and (4) demonstrate the results of the 2SLS models. The independent variable *diversity_index_comp* (diversity index of compensation committee) is standardised by its sample mean and standard deviation. The instrumental variable is *diversity_index_county* (diversity index at the county level). The dependent variable of interest is *diversity_index_comp* (the diversity index of the compensation committee). The dependent variables include *ln_vega* (log of one plus vega of both stock and options) and *ln_vega_options* (log of one plus vega of options only). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 3. 1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1)	Model (2)	Model (3)		Model (4)	
		OLS	OLS	First stage-2SLS	Second stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_vega	Ln_vega _options	Diversity _index	Ln_vega	Diversity _index	Ln_vega_ options
diversity_index_comp	-	-0.014	-0.013		-0.841**		-0.753*
		(0.023)	(0.027)		(0.378)		(0.436)
diversity_index_county	+			0.111***		0.107***	
				(0.024)		(0.024)	
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		8,348	8,076	6,029	6,029	5,828	5,828
Adj R-squared		0.739	0.751				
F statistics		9.024	8.058		7.122		7.837
P-value of F statistics		0.000	0.000		0.000		0.000
Endogeneity test					5.664		3.199
P-value of Endogeneity test					0.017		0.074
P-value of SW F test of weak identification					0.000		0.000
P-value of SW chi-squared test of under-identification					0.000		0.000

3.8.2.2. The impact of the compensation committee diversity index on CEO inside debt incentives

Table 3.12 shows the effect of the compensation committee diversity and CEO inside debt incentives by running OLS and 2SLS regressions with firm and year fixed effects. The dependent variables are *ln_CEO relative leverage* (the logarithm of one plus the CEO's debt-to-equity ratio scaled by the debt-to-equity ratio of the firm) and *ln_CEO relative incentive* (the logarithm of one plus the CEO's relative incentive ratio). The diversity index of the compensation committee (*diversity_index_comp*) is the independent variable of interest. Models (1) and (2) of Table 3.12 provide insignificant evidence of a relation between the diversity index of the compensation committee and the CEO relative leverage and incentive ratios.

The empirical findings of the 2SLS regression models are presented in Models (3) – (4) of Table 3.12. The instrument used in the 2SLS regressions is *diversity_index_county* (the diversity index of directors at the county level). In Models (3) and (4) of Table 3.12, the instrumental variable (*diversity_index_county*) is positively related to the board diversity index at the significance level of 1%. The coefficients of *diversity_index_county* are 0.107 and 0.106 respectively. The coefficients of *diversity_index_comp* (the diversity index of the compensation committee) are positive at the significance level of 5% and 10% (0.478 and 0.367 respectively). The endogeneity tests in the 2SLS regressions indicate that there is an endogeneity concern because the p-values of the endogeneity tests are lower than 5%. In addition, the instrument is relevant and not weak.

Table 3.12 Compensation committee diversity and CEO inside debt incentives

Table 3.12 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Models (1) and (2) show the results of the OLS model. Models (3) and (4) demonstrate the results of the 2SLS models. The independent variable *diversity_index_comp* (diversity index of compensation committee) is standardised by its sample mean and standard deviation. The instrumental variable is *diversity_index_county* (diversity index at the county level). The dependent variable of interest is *diversity_index_comp* (the diversity index of the compensation committee). The dependent variables include *Ln_CEO relative leverage* (log of one plus the CEO's debt-to-equity ratio scaled by the debt-to-equity ratio of the firm) and *Ln_CEO_relative incentive* (log of one plus the CEO's relative incentive ratio) The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 3. 1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1)	Model (2)	Model (3)		Model (4)	
		OLS	OLS	First stage-2SLS	Second stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_CEO relative leverage	Ln_CEO relative incentive	Diversity _index	Ln_CEO relative leverage	Diversity _index	Ln_CEO relative incentive
diversity_index_comp	+	0.004	-0.002		0.478**		0.367*
		(0.015)	(0.016)		(0.192)		(0.199)
diversity_index_county	+			0.107***		0.106***	
				(0.025)		(0.027)	
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		7,095	6,905	5,043	5,043	4,915	4,915
Adj R-squared		0.678	0.676				
F statistics		5.877	6.140		3.483		4.385
P-value of F statistics		0.000	0.000		0.000		0.000
Endogeneity test					7.986		4.037
P-value of Endogeneity test					0.005		0.045
P-value of SW F test of weak identification					0.000		0.000
P-value of SW chi-squared test of under-identification					0.000		0.000

3.8.3. The impact of specific components of board diversity index on CEO pay incentives

3.8.3.1. The impact of specific components of board diversity index on CEO equity incentives

In this section, I investigate the influence of any particular element of the board diversity index on CEO equity incentives. Table 3.13 reports the results of the OLS regressions with firm and year fixed effects. The results of the 2SLS regressions are not shown in Table 3.13 because the endogeneity test shows that there is no endogeneity problem. The independent variables of interest include the Herfindahl index of education (*edu_hhi*), Herfindahl index of ethnicity (*ethnicity_hhi*), Herfindahl index of financial expertise (*finexpert_hhi*), gender diversity (*gender_diversity*), age diversity (*age_diversity*), and board experience diversity (*boardexp_diversity*). All coefficients of the six components of the board diversity index are insignificant. There is no evidence that various components of the board diversity index have a significant impact on CEO equity incentives *(ln_vega* and *ln_vega_options*). Those findings are in line with the results of Bernile et al. (2018). Bernile et al. (2018) also find that there is no single source of the board diversity index which has a significant impact on firm risk. However, there is a negative association between the aggregate board diversity index and firm risk, which implies that the combination of the various components of diversity significantly affect the decision-making process of the board of directors.

3.8.3.2. The impact of the components of the diversity index on CEO inside debt incentives

After investigating the influence of specific sources of the diversity index on CEO equity incentives, I continue to examine the association between various components of the diversity index on CEO inside debt incentives. Table 3.14 reports the results of the OLS regressions in which the dependent variables include the CEO relative leverage ratio

(*Ln_CEO relative leverage*) and the CEO relative incentive ratio (*Ln_CEO relative incentive*). The results of the 2SLS regressions are not shown in Table 3.14 because the endogeneity test shows that there is no endogeneity problem. The main independent variables are the Herfindahl index of education (*edu_hhi*), Herfindahl index of ethnicity (*ethnicity_hhi*), Herfindahl index of financial expertise (*finexpert_hhi*), gender diversity (*gender_diversity*), age diversity (*age_diversity*), and board experience diversity (*boardexp_diversity*). The association between CEO inside debt incentives and the Herfindahl index of education (*edu_hhi*), Herfindahl index of ethnicity (*ethnicity_hhi*), age diversity (*age_diversity*), and board experience diversity (*boardexp_diversity*) is insignificant. The coefficient of the Herfindahl index of financial expertise (*finexpert_hhi*) is negative and significant at the level of 5% (-0.022) in both Models (1) and (2). The board of directors which is more diverse in financial expertise increases the inside debt incentives for CEOs since directors as financial experts are expected to protect the firm from risk. Boards with more members with financial expertise incentivise CEOs to take less risk by increasing inside debt incentives.

Model (2) of Table 3.14 shows that the coefficient of gender diversity (*gender_diversity*) is positive at the significance level of 5% (0.051). This finding is consistent with the result found by Prevost and Upadhyay (2018). Prevost and Upadhyay (2018) also found a positive relationship between gender diversity and CEO inside debt compensation. My research complements the research of Prevost and Upadhyay (2018) by finding that it is not only gender diversity but also financial expertise that positively influences the boards' decisions regarding CEO inside debt incentives. In addition, the aggregate diversity index positively affects CEO inside debt incentives.

Table 3.13 The impact of specific components of the diversity index on CEO equity incentives

Table 3.13 reports the empirical results of the OLS models with firm and year fixed effects. The independent variables include *edu_hhi* (Herfindahl concentration index for the educational background of directors), *ethnicity_hhi* (Herfindahl concentration index for ethnicity groups of directors), *finexpert_hhi* (Herfindahl concentration index for financial expertise of directors), *gender_diversity* (the percentage of female directors in the boardroom at the firm-year level), *age_diversity* (the standard deviation of the age of board members at the firm-year level), and *boardexp_diversity* (the mean number of other board memberships in public companies of directors). Each dimension of diversity index is standardised by its sample mean and standard deviation. The dependent variables include *ln_vega* (log of one plus vega of both stock and options) and *ln_vega_options* (log of one plus vega of options only). The standard errors (in parentheses) are clustered at the firm level. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1) OLS	Model (2) OLS
	Expected sign	Ln_vega	Ln_vega_options
edu_hhi	+	-0.022	-0.017
		(0.029)	(0.040)
ethnicity_hhi	+	0.043	0.059
		(0.037)	(0.042)
finexpert_hhi	+	-0.016	-0.006
		(0.016)	(0.018)
gender_diversity	-	0.013	0.018
		(0.036)	(0.042)
age_diversity	-	-0.029	-0.049
		(0.031)	(0.035)
boardexp_diversity	-	-0.029	-0.032
		(0.039)	(0.046)
Control variables		Yes	Yes
Firm and year FE		Yes	Yes
Observations		8,438	8,163
Adj R-squared		0.737	0.751
F statistics		7.890	7.048
P-value of F statistics		0.000	0.000

Table 3.14 The impact of specific components of the diversity index on CEO inside debt incentives

Table 3.14 presents the empirical results of the OLS models with firm and year fixed effects. The independent variables include *edu_hhi* (Herfindahl concentration index for the educational background of directors), *ethnicity_hhi* (Herfindahl concentration index for ethnicity groups of directors), *finexpert_hhi* (Herfindahl concentration index for financial expertise of directors), *gender_diversity* (the percentage of female directors in the boardroom at the firm-year level), *age_diversity* (the standard deviation of the age of board members at the firm-year level), and *boardexp_diversity* (the mean number of other board memberships in public companies of directors). Each dimension of the diversity index is standardised by its sample mean and standard deviation. The dependent variables include *Ln_CEO relative leverage* (log of one plus the CEO's debt-to-equity ratio scaled by the debt-to-equity ratio of the firm) and *Ln_CEO_relative incentive* (log of one plus the CEO's relative incentive ratio). The standard errors (in parentheses) are clustered at the firm level. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1) OLS	Model (2) OLS
	Expected sign	Ln_CEO relative leverage	Ln_CEO relative incentive
edu_hhi	-	-0.005	-0.004
		(0.019)	(0.020)
ethnicity_hhi	-	0.028	0.030
		(0.021)	(0.022)
finexpert_hhi	-	-0.022**	-0.022**
		(0.010)	(0.011)
gender_diversity	+	0.034	0.051**
		(0.022)	(0.022)
age_diversity	+	-0.016	-0.004
		(0.021)	(0.022)
boardexp_diversity	+	0.014	0.022
		(0.019)	(0.020)
Control variables		Yes	Yes
Firm and year FE		Yes	Yes
Observations		7,157	6,964
Adj R-squared		0.677	0.676
F statistics		5.555	5.822
P-value of F statistics		0.000	0.000

3.9. Conclusions

In recent years, regulators and corporations have increasingly recognised the importance of board diversity. Board diversity is one of the key corporate governance issues. It is increasingly recognised that board heterogeneity is more than just one dimension of diversity, such as gender. Many organisations also concentrate on improving other forms of board diversity, such as age, ethnicity, education, board experience, and financial expertise. Board diversity has both costs and benefits. This study investigates whether diverse boards decrease CEO equity incentives and increase CEO inside debt incentives in order to follow less risky policies. The primary purpose of this research is to examine whether there is a significant association between board diversity and CEO pay incentives (both equity and inside debt incentives). This study considers multi-dimensions of board diversity by using a board diversity index which combines age, gender, ethnicity, education, board experience, and financial expertise diversity.

In baseline models, I find that diverse boards decrease CEO equity incentives and increase CEO inside debt incentives to encourage executives to follow less risky policies. These findings support the hypothesis that heterogeneous boards decrease CEO equity incentives and increase CEO inside debt incentives to moderate firm risk. I also find that board diversity matters more for CEO equity incentives from stock options when the firm leverage is higher than the median leverage of the industry. A diverse board of a firm which has higher leverage than the industry median value has more motivation to decrease CEO equity incentives to induce its CEO to lower firm risk. That is because heterogeneous boards bring more pressure to decrease risk if the level of their firm risk is high compared to the industry median. Moreover, the association between the board diversity index and CEO pay incentives is mainly due to the diversity of non-executive directors. Diverse boards also make decisions relating to CEO pay incentives through the compensation committee. The higher the diversity of the compensation committee, the lower the CEO equity incentives, and the larger the CEO inside debt incentives. Lastly, this research adds to the study of Prevost and Upadhyay (2018) by finding that CEO inside debt incentives are positively associated with not only board gender diversity but also financial expertise diversity.

CHAPTER 4. FAULTLINES IN DIVERSE BOARDS AND FIRM RISK

4.1. Introduction and motivation

The studies on the relationship between board diversity and firm risk have mixed findings. On the one hand, some argue that heterogeneous boards reduce firm risk because they make moderated decisions and implement robust policies (Bernile et al., 2018). More diverse boards bring different views, experience, and opinions to boardroom discussions and think more carefully before reaching a final agreement. On the other hand, diverse boards may be associated with higher firm risk because possible frictions and conflicts in the boardroom make the outcomes unpredictable (Giannetti & Zhao, 2019). Board diversity has both positive and negative sides. The diverse backgrounds, knowledge, and perspectives of directors are advantageous to corporate boards. However, the disadvantages of diversity also include potential conflicts, incoordination, and misunderstandings (Goodstein, Gautam, & Boeker, 1994). Thus the downside of board heterogeneity may negatively affect the decision-making process of boards.

This study complements the research of Bernile et al. (2018) and Giannetti and Zhao (2019) by conjecturing that potential conflicts may confound the association between board diversity and firm risk. Specifically, this research proposes to examine the impact of potential frictions within a diverse board on firm risk as well as the interactive effect of the multi-dimensional board diversity index (including age, gender, ethnicity, education, financial expertise, board experience diversity) and potential conflicts on firm risk. Corporate risk is calculated by monthly annualised stock return volatility (Bernile et al., 2018; Giannetti & Zhao, 2019). The possible frictions within the boardroom can be captured by the measurement of board faultline as suggested by Peteghem et al. (2018).

The faultline measurement was first presented by Lau and Murnighan (1998). *"Faultlines are hypothetical dividing lines that split a group into two or more subgroups based on the alignment of one or more individual attributes"* (Thatcher & Patel, 2012, p. 969). In particular, faultline measurement considers several attributes of members in a group at the same time. Faultline indicates how a group is divided into multiple homogeneous subgroups based on the alignment of specific characteristics. A board of a firm is diverse based on a variety of demographic and cognitive aspects of the directors. Individuals who have similar attributes tend to be attracted to each other and thus classify themselves into a certain subgroup (Thatcher, Jehn, & Zanutto, 2003). Several characteristics of the board members may lead them to form many homogeneous coalitions in the boardroom based on the alignment of similar attributes. Faultlines are formed and separate the boardroom into different subgroups in which directors have common characteristics (Peteghem et al., 2018; Tuggle, Schnatterly, & Johnson, 2010). However, the faultlines may lead to conflicts within a team when a variety of homogeneous subgroups are created (Lau & Murnighan, 1998). Disputes among directors increase the costs of board diversity[30] (Bernile et al., 2018; Giannetti & Zhao, 2019) and make the board performance less effective (Peteghem et al., 2018). The faultline measurement includes faultline strength (cohesion degree within a subgroup based on multiple attributes of the directors) and faultline distance (the extent to which different subgroups diverge).

[30] Faultline is a different from diversity. Two different firms with the same level of board diversity may have dissimilar board faultlines (different ways in which multiple subgroups are created within the boardroom). For example, the board of directors of company X has two American female members and two Japanese male members. The board of directors of company Y has one American man, one American woman, one Japanese man, and one Japanese women. Both companies X and Y have the same level of board diversity based on two dimensions including gender and nationality (the gender diversity and nationality diversity is both 0.5). However, each company has different faultlines. Company X possibly has stronger board faultlines than company Y. In company X, two American female directors may form a homogeneous subgroup and two Japanese men may join another coalition. The directors in each subgroup have very similar characteristics such as gender and nationality, and may work closely together within their subgroup. The two subgroups within the boardroom of company X face potential conflicts.

In the baseline regression models, this study finds that when the board faultline strength is high, diverse boards are associated with an increase in firm risk (monthly annualised stock return volatility). Specifically, when the faultline strength increases by one standard deviation, a one standard deviation increase in board diversity lead to an increase in monthly annualised stock return volatility by 0.046 percentage points. When the board faultline strength is high, the directors in each coalition within the boardroom are more similar in multiple characteristics. The directors in each homogeneous subgroup may cooperate actively, and work against other subgroups in the board. Therefore, conflicts arising among different subgroups within the boardroom lead to lower risk minimisation strategies being carried out by the board of directors. In a robustness test, this study provides empirical results that diverse boards in firms which have a higher board faultline strength than the median value of the whole industry tend to increase more stock return volatility than companies with a lower board faultline strength.

Moreover, this research shows that when the board faultline strength is high, board diversity indexes omitting one specific component of diversity are positively associated with stock return volatility. However, there is no evidence that a single element of diversity is related to corporate risk when the board faultlines are high. These findings are consistent with those of Bernile et al. (2018) that the combination of various dimensions of diversity has a significant impact on firm risk while there is no evidence of an association between a single component of diversity and firm risk. In addition, this research finds significant evidence that the diversity of executive and non-executive directors has a positive relationship with stock return volatility when there is an increase in board faultline strength.

This study contributes to the theory on the impact of board diversity on firm risk by introducing board faultlines as a crucial confounding factor affecting the association between board diversity and firm risk. This research extends the studies of Bernile et al. (2018) and Giannetti and Zhao (2019). While their papers focus on exploring the association between board heterogeneity and firm risk, this study emphasises the influence of board faultlines on firm risk as well as the interactive effect of board diversity and board faultlines on firm risk. This research contributes to the understanding of the influence of board faultlines as proxies for potential frictions and conflicts on corporate risk levels. This study provides a key implication, that it is crucial for corporations to carefully consider the internal structure of a diverse board; constructing a diverse board is more than just combining the various dimensions of diversity. It is important to create a heterogeneous board with fewer conflicts as this can make the functioning of the diverse board less effective. One of the ways to reduce potential extreme friction among directors is to create a diverse boardroom with weak faultline strength and distance.

This research is different from the study of Peteghem et al. (2018), who examine the impact of board faultline strength and distance on firm performance (ROA or Tobin's Q), CEO turnover performance sensitivity, and abnormal CEO compensation. My study investigates the effect of board faultline strength and distance on firm risk (monthly annualised stock return volatility) as well as the interactive impact of the board diversity index adopted by Bernile et al. (2018) and board faultline strength and distance on firm risk. Peteghem et al. (2018) find that boards with strong faultline strength and distance negatively affect firm performance and CEO turnover performance sensitivity and have a positive impact on abnormal CEO compensation. My research adds that high board faultline strength is detrimental to the risk minimisation strategy of a diverse board. In particular, diverse boards are associated with higher firm risk when there is an increase in the faultline strength within the boardroom.

The remains of this study are structured as follows. Section 4.2 presents the literature review regarding the relationship between board diversity and firm risk, the general concept of faultlines and board faultlines. Section 4.3 provides hypothesis development. The data sample and measurements of key variables in the regression models are shown in Section 4.4. Section 4.5 and 4.6 show the research methods used in this study as well as the summary statistics respectively. Section 4.7 presents the baseline empirical results. Section 4.8 shows a robustness test. Some additional findings are explained in Section 4.9. Section 4.10 includes the main conclusions.

4.2. Literature review

4.2.1. Board diversity and firm risk

Investors are challenging corporations to increase the level of board diversity. Both investors and organisations believe that an appropriate level of boardroom diversity will enhance the effectiveness of board performance and corporate outcomes. Realising the importance of board diversity, organisations currently pay more attention to achieving board heterogeneity. For example, the Oracle Corporation's proxy statement in 2018 specified that "*The Board and the Governance Committee value the diversity of backgrounds, experience, perspectives and leadership in different fields when identifying nominees*." The Intel Corporation's proxy statement in 2018 stated that *"Our Board is committed to actively seeking quality women and minority director candidates for consideration."*

On the one hand, board heterogeneity provides substantial benefits for corporations by encouraging creative ideas and improving the group decision-making process (Miller & del Carmen Triana, 2009). Directors with different characteristics bring to the board diverse viewpoints, skills, and experience. Directors may also have intensive knowledge of international markets and clients, which helps their companies develop in the long term (Hillman, 2015). Moreover, heterogeneous boards get benefits from the variety of networks and resources contributed by their diverse director members. Companies that focus on improving their gender, racial, and ethnic diversity have a good reputation in the markets (Miller & del Carmen Triana, 2009).

On the other hand, board diversity also brings costs to firms. Board heterogeneity will be less effective if there are severe conflicts and disagreements among the directors because of their differences in culture, viewpoints, and language (Carter et al., 2003; Mishra & Jhunjhunwala, 2013). In addition, diverse boards will have ineffective performance if there is a close alignment of the majority of the directors and the executive team (Baranchuk & Dybvig, 2008).

Because there are both disadvantages and advantages with board diversity, the impact of board diversity on corporate outcomes is currently inconclusive, and the research on the effect of board diversity on firm risk is still mixed. The monitoring of corporate risk is one of the most crucial responsibilities of the board of directors. Directors are responsible for overseeing firm risk and making sure that the risk management policies of their firm are consistent with the firm's strategies. Whether board diversity helps a firm to reduce risk is an empirical question. Bernile et al. (2018) investigate whether there is a significant association between board diversity and firm risk. They measure the firm risk by stock return volatility. Instead of focusing on one specific dimension of board heterogeneity, Bernile et al. (2018) recommend considering multi-dimensional diversity. They create a new board diversity index which includes six components: gender, age, ethnicity, education, financial expertise, and board experience. They find that a greater board diversity index is associated with lower firm risk. Bernile et al. (2018) explain that less diverse boards, which have homogeneous opinions, backgrounds and incentives among directors, have less scrutiny in the decision-making process and make more idiosyncratic decisions. Idiosyncratic decisions may lead to more volatile corporate outcomes. As a result, homogeneous boards of directors are associated with higher firm risk. The findings of Bernile et al. (2018) suggest that heterogeneous boards make moderated decisions thanks to dissimilarity in age, gender, ethnicity, education, financial expertise, and board experience. Board diversity mitigates problems relating to "groupthink" and encourages more scrutiny in making important decisions. Firms with diverse boards tend to adopt more stable and persistent policies and thus achieve lower risk levels. Bernile et al. (2018) also find that no single element of board diversity index but the aggregate board diversity index has a negative impact on stock return volatility. In addition, board diversity indexes excluding any one of the individual elements from the index negatively affect firm risk. These findings imply that the joint impact of various dimensions of board diversity affects the risk management function of the board of directors. Moreover, the negative relationship between board diversity and firm risk is mainly due to the diversity of non-executive directors. There is a high probability that executive directors interact with each other every day and tend to have more homogeneous opinions. Thus, diversity brought to the board by executive directors may not lead to lower firm risk. Bernile et al. (2018) also show that the moderating effect of board diversity on firm risk is stronger or weaker in different circumstances. In particular, the negative relationship between board diversity on stock return volatility is stronger when the firm risk level is higher (larger R&D intensity and market-to-book ratios). Conversely, heterogeneous boards are less effective in decreasing firm risk when there is a high level of market-wide volatility. This result implies that the moderating effect of board diversity on firm risk decreases when corporations operate in a more volatile business environment. In extremely volatile market conditions, it is necessary for the board of directors to quickly respond to changing circumstances. However, conflicts within the diverse board make the board react slowly to unstable conditions.

In contrast to the study of Bernile et al. (2018), Giannetti and Zhao (2019) find a positive association between the ancestral diversity of the board and stock return volatility when controlling for other dimensions of board diversity such as gender, age, tenure, industry experience, outside directorships, financial expertise, and education. The board ancestral diversity is measured by using information on the country of origin of the director names. The ancestral diversity is different from ethnicity diversity. Ethnicity diversity is calculated based on different ethnic groups such as White/Caucasian, African-American, Hispanic, Asian, and Other (Bernile et al., 2018). Ancestral diversity of the board is associated with higher firm risk because of potential conflicts due to cultural and genetic dissimilarities among the directors. The findings of Giannetti and Zhao (2019) are in line with the conjecture of Arrow (2012), that the decisions and strategies of a diverse group are volatile and hard to predict. It is difficult for a group of several individuals to aggregate different preferences into collective preferences. Therefore, the final voting results of a team are difficult to predict (Arrow, 2012). Conflicts also arise within the group. The downside of board diversity is that there may be disagreements among board members which lead to erratic decision-making processes. Organisations with heterogeneous boards may have inconsistent policies because of their difficulties in gathering diverse opinions in board meetings (Giannetti & Zhao, 2019).

4.2.2. The concept of faultlines

The term faultline was first used in the research of Lau and Murnighan (1998). Lau and Murnighan (1998) recommend that the research on the efficiency of workgroups should investigate not only a single attribute of team members but also the interrelationships of their multiple characteristics. Faultlines are defined as hypothetical lines that divide a team into relatively homogeneous coalitions which are aligned based on numerous characteristics (Thatcher & Patel, 2012). The definition and measurement of faultlines focus on the formation of the subsets of members within a team. A faultline exists within a team when there is a formation of particular subgroups, which are different from each other based on various attributes of individuals. Faultline measurement allows scholars to investigate further how the context of a workgroup affects the performance and outcomes of a group (Thatcher et al., 2003). The strength of faultlines can vary within a diverse team. A group can have stronger faultlines when its members are aligned in the same way based on a variety of attributes (Meyer, Glenz, Antino, Rico, & Gonzalez-Roma, 2014). For example, when all of the women members are Chinese, and all of the men are American, there is a strong faultline dividing the team into two homogeneous subgroups based on the alignment of gender and nationality attributes.

Thatcher et al. (2003) explain that the concept of faultlines is based on the theories of self-categorisation, social identity, the attraction paradigm and coalition. People tend to categorise themselves into specific social groups to define their social identity based on their characteristics (Tajfel, 1974; Turner, 1982). Byrne's study in 1971 posits that people who have some common attributes are attracted to each other, communicate more frequently and thus form a particular group (as cited in Thatcher et al., 2003). Individuals in an overall group possibly form many coalitions (subgroups). Each coalition includes several individuals who share similar characteristics and are coherent in making decisions (Murnighan & Brass, as cited in Thatcher et al., 2003).

The faultline measurement includes faultline strength and faultline distance. Faultline strength is the cohesion degree within a subgroup based on the various characteristics of members of a team (Thatcher et al., 2003). When members of subgroups within a team are strongly aligned with others in the same subgroups based on multiple similar characteristics of the individuals, the faultline strength is high. High faultline strength induces individuals to be aware of their connection with particular coalitions and desire to remain in their familiar subgroups. However, faultline strength does not take into account how far apart subgroups are. Faultline distance measures the extent to which different subgroups diverge. When there are extreme differences among members belonging to different coalitions within a team, a large faultline distance is present. A large faultline distance may lead to incompatible interactions between different subgroups (Bezrukova, Jehn, Zanutto, & Thatcher, 2009).

Many studies focus on the adverse effects on the outcomes of workgroups caused by strong faultlines in diverse groups. The main reason is that faultlines may create an informal structure for potential conflicts and ineffective communication within a group (Lau & Murnighan, 2005). In a diverse group, the dissimilarities among its members are positively associated with the probability that individuals may identify themselves as belonging to specific social subgroups which are different from others (Meyer, Shemla, & Schermuly, 2011). When some members in a team have a variety of similar characteristics, they may create relatively homogeneous coalitions because they experience comfortable social interactions with each other in the same coalitions. The formation of different subgroups within a group increases the likelihood of intense conflicts between various members of in-groups and out-groups (Stevenson, Pearce, & Porter, 1985; Thatcher et al., 2003). If a group has intense conflicts which drive members apart, its members will moderate the frequency of their interactions. The behavioural disintegration in a group leads to the limitation of crucial information exchange among individuals, ineffective coordination, inefficient decision-making process, and thus poor performance (Li & Hambrick, 2005).

In general, empirical studies show that faultline strength and distance negatively affect group performance and are positively related to conflicts (Thatcher & Patel, 2012). In particular, the research of Thatcher et al. (2003) shows that workgroups in a Fortune 500 information-processing company with extremely strong faultlines have more conflicts and more reduced performance than those with medium faultlines. The study of Zanutto, Bezrukova, and Jehn (2011) report that faultlines in diverse groups are positively associated with conflicts and negatively related to group performance and satisfaction. Moreover, Molleman (2005) find that both faultline strength and distance have a negative influence on the functioning of a team by increasing conflicts within a group and reducing team cohesion.

4.2.3. Board faultlines

The faultline theory is applied to boards of directors in the studies of Peteghem et al. (2018) and Tuggle et al. (2010). The research of Tuggle et al. (2010) calculates board faultlines following Lau and Murnighan (1998) based on multiple attributes including tenure, functional background, and the firm/industry background of the board members. Tuggle et al. (2010) report that boards with strong faultlines allocate less time to discussion on corporation issues. This result implies that strong faultlines in the boardroom decrease board attention to firm problems and thus reduce board performance. Boards with strong faultlines face the challenge of behavioural disintegration and conflicts, which do not allow for active discussion and cohesion within the boardroom.

The study of Peteghem et al. (2018) examines board faultlines to explain why there is mixed evidence on the impact of board diversity on corporate performance. Their paper measures board faultlines based on nine director characteristics including independence, insider, affiliated outsider, financial expertise, multiple board membership, age, gender, tenure, and share ownership. To calculate board faultlines, Peteghem et al. (2018) run a cluster analysis on each firm in a specific year to classify directors into subgroups based on the similarities and differences in nine director attributes. The number of subsets is then used in the measurement of faultlines developed by Thatcher et al. (2003) and Zanutto et al. (2011). Peteghem et al. (2018) find that board faultlines tend to reduce the effectiveness of board performance due to potential conflicts within the boardroom. In particular, board faultlines are negatively associated with firm performance (ROA or Tobin's Q) and CEO turnover performance sensitivity. In addition, there is a positive relationship between board faultlines and abnormal CEO compensation. The findings of Peteghem et al. (2018) imply that how the boardroom is structured significantly affects the board performance. Peteghem et al. (2018) suggest that the structure of a diverse board itself may form a certain number of homogeneous subgroups along faultlines. Strong board faultlines, which increase the likelihood of disagreements and conflicts, have a negative impact on the communication and decision-making process and make the advisory and monitoring functions of the board less effective.

4.3. Hypothesis development

Recent empirical studies show that the impact of board diversity on firm risk is still inconclusive. There is an argument that diverse boards help to mitigate firm risk because heterogeneous boards make moderate decisions and prefer conservative financial policies (Bernile et al., 2018). Board diversity brings benefits to a firm from different backgrounds, knowledge, experience, skills, and perspectives. Diverse boards discuss carefully before making decisions. However, board diversity comes with costs if there are severe conflicts among board members, and those conflicts within the boardroom may negatively affect the board's performance and decision-making process. For example, Giannetti and Zhao (2019) find that board ancestral diversity is associated with an increase in firm risk.

A board of directors is diverse based on the various attributes of its members such as age, gender, education, financial expertise, experience. A certain number of directors have characteristics which are similar to others in the boardroom. Individuals with common attributes tend to be attracted to each other and categorise themselves into a specific subgroup in which they experience comfortable interactions (Thatcher et al., 2003). Directors possibly form relatively homogeneous subgroups within the boardroom based on the alignment of multiple similar characteristics of the board members. Thus, faultlines exist and divide the boardroom into different coalitions in which the directors have relatively identical attributes. These coalitions create potential frictions and conflicts in a diverse group of directors (Peteghem et al., 2018; Tuggle et al., 2010). Diverse boards with possible conflicts and incoordination have ineffective performance and make the corporate outcomes volatile (Giannetti & Zhao, 2019).

A diverse board with a structure that does not potentially create intense friction and conflicts among directors will bring more benefits than costs to its firm. In contrast, a heterogeneous board which is constructed in a way that possibly induces conflicts within the boardroom will reduce the effectiveness of board diversity. A diverse group with strong faultline strength (a high cohesion degree within a subgroup based on the multiple characteristics of individuals) and/or strong faultline distance (a high extent to which different subgroups diverge) has more conflicts among its members (Molleman, 2005; Thatcher et al., 2003; Thatcher & Patel, 2012; Zanutto et al., 2011). Therefore, a heterogeneous board with strong faultline strength and/or faultline distance may experience potential friction and disagreements within the boardroom (Peteghem et al., 2018). The increasing conflicts within the diverse board make the decision-making process more erratic and increase firm volatility because it is hard to reconcile different opinions in board meetings (Giannetti & Zhao, 2019). Therefore, this study hypothesises that boards with strong faultline are positively associated with firm risk.

Hypothesis 1: Board faultline is positively associated with firm risk.

Moreover, board diversity brings more benefits than costs if there is no extreme conflict among the directors which is detrimental to the functioning of the board in terms of risk management (Bernile et al., 2018; Giannetti & Zhao, 2019). Diverse boards moderate firm risk effectively if there are fewer conflicts within the boardroom (Bernile et al., 2018). In contrast, diverse boards are associated with higher firm risk if there is strong friction among the board members (Giannetti & Zhao, 2019). Therefore, the effect of board diversity on firm risk also depends on whether the structure of a diverse board creates more or fewer conflicts among the directors. Diverse boards with strong faultline strength and distance have more potential conflicts (Peteghem et al., 2018). Board faultline strength is high when the cohesion degree with a subgroup of directors increases. Also, high board faultline strength means that directors within a subgroup are very similar and may have homogeneous perspectives. Directors within a particular coalition may work against or disagree with other members of different subgroups. Thus, conflicts may arise when there is strong board faultline strength. Moreover, in the case of high board faultline distance, directors within different subgroups will be exceptionally dissimilar based on a certain number of characteristics and conflicts between in-groups and out-groups will potentially increase. In general, heterogeneous boards will experience potential frictions among directors because of strong board faultline strength and distance. Figure 4.1 shows an example of boards which have a high diversity level and a strong or weak faultline strength. Figure 4.2 presents an example of boards with a high diversity level and a strong or weak faultline distance. Figure 4.3 illustrates an example of boards with a low diversity level and a strong or weak faultline strength. Figure 4.4 shows the case where boards have a low diversity level and a strong or weak faultline distance.

This research conjectures that the impact of board diversity on firm risk will change depending on the different levels of board faultline strength and distance. In particular, this study expects that the negative association between board diversity and firm risk becomes weaker in the presence of strong board faultline.

Hypothesis 2: The negative relationship between board diversity and firm risk becomes weaker in the presence of strong board faultline.

Figure 4.1 An example of boards of directors which have high diversity level and strong or weak faultline strength

Companies with a high level of board diversity may have strong or weak faultline strength. For instance, firm A has a board of directors that includes two 40-year-old Chinese women and two 50-year-old German men. The board of firm B has one 40-year-old German woman, one 40-year-old Chinese woman, one 50-year-old Chinese man, and one 50-year-old German man. Both company A and B have the same level of board diversity based on the three attributes of age, nationality, and gender (age diversity is the standard deviation of age which is 5.77, nationality diversity is 0.5, and gender diversity is 0.5). However, firm A has stronger board faultline strength than firm B. Specifically, in company A, the two 40-year-old Chinese female directors may become a subgroup and the two 50-year-old German male members may create another coalition. The members in each subgroup have identical characteristics including age, gender, and nationality, which means that the cohesion degree within the subgroups in the board of directors of firm A is very strong. In contrast, in company B, two 40-year-old female directors may form a subgroup but they have very different nationalities. It means that the cohesion level within the subgroups in the board of directors (faultline strength) of firm B is lower than that of firm A.

Figure 4.2 An example of boards of directors which have a high diversity level and a strong or weak faultline distance

An example of diverse boards that can have a strong or weak faultline distance is as follows. The board of firm C includes two 40-year-old Chinese females and two 60-year-old German male members. In the boardroom of firm D, there are one 57-year-old German woman, one 58-year-old Chinese woman, one 59-year-old Chinese man, and one 60-year-old German man. Firm C has stronger board faultline distance than firm D. In firm C, the subgroup of two 40-year-old Chinese women and the subgroup comprising two 60-year-old German men are very different based on the age, nationality and gender of the directors. This means that the extent to which the two subgroups in the board of firm C diverge (faultline distance) is very high. In firm D, the directors may join into two coalitions based on gender or nationality but their ages are nearly similar. Therefore, the board faultline distance of firm D is lower than that of firm C.

Figure 4.3 An example of boards of directors which have a low diversity level and a strong or weak faultline strength

Firms with a low level of board diversity may have a strong or weak faultline strength. For example, the board of firm E comprises two Japanese women and eight American men. The board of firm F has one Japanese woman, one American woman, one Japanese man, and seven American men. Both company E and F have the same level of board diversity based on gender and nationality (both nationality and gender diversity is 0.25). However, firm E has a higher board faultline strength than firm F. In firm E, the first subgroup includes two Japanese female directors and the second coalition has eight American male members. The directors in each subgroup have very similar gender and nationality. In firm F, the two women may form a subgroup and the eight male directors create another coalition. The members in each subgroup have the same gender but are not exactly similar in nationality. Thus, the cohesion degree within the subgroups (faultline strength) of firm E is larger than that of firm F.

Figure 4.4 An example of boards of directors which have a low diversity level and a strong or weak faultline distance

Boards which have a low level of diversity may have a strong or weak faultline distance. For instance, company G has a board of directors consisting of two 45-year-old women and eight 65-year-old men. The board of company H has a 58-year-old woman, a 63-year-old woman, a 59-year-old man, a 60-year-old man, and six 62-year-old men. Both company G and H are not very diverse in gender and age. However, company G has higher board faultline distance than company H. In company G, the first subgroup includes two 45-year-old female directors and the second subgroup has eight 65-year-old male members, so the two subgroups in the board of company G highly diverge from each other. In company H, the directors may form two coalitions based on gender but their ages are not very dissimilar. Thus, the board faultline distance of company H is lower than that of company G.

4.4. Data and variable measurement

4.4.1. Data

The final sample of this study has 8,338 firm-year observations including US non-financial and non-utility companies from 2007 to 2016. The data was mainly collected from S&P Compustat (North America) Execucomp and Fundamental Annual, Compustat and Center for Research on Security Prices (CRSP), ISS Director, and BoardEx. The board diversity and board faultlines were calculated based on the information on director gender, age, financial expertise, board experience and ethnicity from ISS Director. The data of director education was retrieved from BoardEx[31].

4.4.2. Variable measurement

The measurement of the board diversity index is shown in section 3.4.2 of Chapter 3.

Board faultlines

The board faultlines are calculated based on the procedure provided by Meyer and Glenz (2013)[32]. The ASW faultline calculation technique of Meyer and Glenz (2013) uses cluster analysis for splitting two or more homogeneous subgroups within a group based on the multiple attributes of the members. The ASW algorithm detects the number of homogeneous subsets. Based on the number of subgroups identified by the ASW algorithm, this study calculates the board's faultline strength and distance. The estimates of board faultline strength and distance follow the formulas recommended by Thatcher et

[31] See section 3.4.1 of Chapter 3 for more details of matching the names of directors in the ISS Director dataset with those in the BoardEx database.
[32] The faultlines are calculated using the ASW.CLUSTER package available in R program with the function FAULTLINES ( ) provided by Meyer and Glenz (2013) from http://www.group-faultlines.org/manual.htm.

al. (2003) and Bezrukova et al. (2009). Faultline strength represents the cohesion degree within a coalition based on the multiple characteristics of the members.

$$Fau\_strength = \frac{\sum_{j=1}^{p}\sum_{k=1}^{q} n_k^g\,(\overline{X}_{.jk}-\overline{X}_{.j.})^2}{\sum_{j=1}^{p}\sum_{k=1}^{q}\sum_{i=1}^{n}(X_{ijk}-\overline{X}_{.j.})^2} \qquad (1)$$

- X_{ijk} is the value of the jth attribute of the ith person of subgroup k.
- $\overline{X}_{.j.}$ is the total group mean of the attribute j.
- $\overline{X}_{.jk}$ is the mean value of the attribute j in the subgroup k
- n_k^g represents the number of people of the subgroup k under the split g

Faultline distance measures the extent to which different subgroups diverge.

$$Fau\_distance = \sqrt{\sum_{j=1}^{p}(\overline{X}_{1j.} - \overline{X}_{2j.})^2} \qquad (2)$$

- $\overline{X}_{1j.}$ is the mean value of the attribute j in the subgroup 1
- $\overline{X}_{2j.}$ is the mean value of the attribute j in the subgroup 2

If the number of subsets is higher than two, the faultline distance equals the average of all possible distances among different subgroups.

This study measures board faultline strength and distance using the nine director attributes adopted by Peteghem et al. (2018). Specifically, the nine director characteristics are independence, insider, affiliated outsider, financial expertise, multiple board membership, age, gender, tenure, and share ownership. Independence is a dummy variable which equals one if a director is identified as an independent member and zero otherwise. Insider is a binary variable which equals 1 when a director is qualified as an insider member and zero otherwise. Affiliated outsider is a dummy variable which equals one if a director is an affiliated outside director[33] and zero otherwise. Financial expertise is a dummy variable which equals one if a director has financial expertise and zero otherwise. Multiple board membership is a dummy variable which equals one when a director is also a board member in another company. Age is a dummy variable which equals one when a director's age is higher than 65 and zero otherwise. Gender is a dummy variable which equals one when a director is female and zero otherwise. The tenure variable is the number of years a director has been sitting on the board. The share ownership variable is the number of shares held by a director.

Firm risk

This study uses the stock return volatility over the 12-month period as a proxy for firm risk following the research of Giannetti and Zhao (2019) and Bernile et al. (2018). The total monthly annualised volatility equals the standard deviation of monthly stock returns multiplied by the square root of 12.

Control variables

Following the studies of Bernile et al. (2018) and Giannetti and Zhao (2019), this research also includes a number of control variables. These include firm-specific characteristics, that is the natural logarithm of total assets (Firm_size), the market to book ratio (MB), the ratio of long-term debt to total assets (Leverage), the net property, plant, and equipment scaled by total asset (Tangibility), the ratio of cash and short-term equivalents to total assets (Cash), a dummy variable which equals 1 if firms pay dividends and zero otherwise (Dividend_pay), the ratio of total operating income to total assets (ROA), the ratio of R&D expenditure to total sales (RD_expense), the number of years from the IPO

[33] An affiliated outside director is defined as an outside director who is not independent in the ISS Director database. Affiliated outside directors can be former CEOs, former non-CEO executives, family members, or people who have transactional, professional, financial, and charitable relationships

date of the firm (Firmage). CEO characteristics include CEO tenure (Ln_tenure) and CEO duality (CEO chair). Corporate governance characteristics including the number of board members (Ln_boardsize) and the average ages of directors (Boardage) are added to the regression. This research also controls for the population of each county (Ln_population), the growth rate of the population at the county level (Population_growth), the per capita income of the county (Ln_income), and the growth rate of per capita income at the county level (Income_growth).

Table 4.1 Variables and description		
Variables	Description	Sources
Dependent variables (Volatility)		
Monthly_volatility	The natural log of the monthly annualised volatility over the 12-month period. The monthly annualised volatility equals the standard deviation of monthly stock returns multiplied by the square root of 12.	Giannetti and Zhao (2019); Bernile et al. (2018)
Explanatory variables (Faultlines)		
Fau_strength	The degree of cohesion within the subgroups of the board of directors.	Meyer and Glenz (2013); Peteghem et al. (2018)
Fau_distance	The mean distance between the subgroups of the board of directors based on the directors' attributes.	Meyer and Glenz (2013); Peteghem et al. (2018)
Strength	The dummy variable which is equal to one if the board faultline strength is higher than the median value of the industry.	Meyer and Glenz (2013); Peteghem et al. (2018)
Distance	The dummy variable which is equal to one if the board faultline distance is higher than the median value of the industry.	Meyer and Glenz (2013); Peteghem et al. (2018)
Explanatory variables (Diversity)		
Diversity_index	The sum of the standardised values of gender, age, board experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of directors in the boardroom. The diversity index is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)

Gender_diversity	The percentage of female directors in the boardroom at the firm-year level.	Bernile et al. (2018)
Age_diversity	The standard deviation of the age of board members in the boardroom at the firm-year level.	Bernile et al. (2018)
Boardexp_diversity	The mean number of other board memberships in public companies of directors in the boardroom.	Bernile et al. (2018)
Ethnicity_hhi	Herfindahl concentration index for ethnicity groups of directors in the boardroom.	Bernile et al. (2018)
Finexpert_hhi	Herfindahl concentration index for the financial expertise of directors in the boardroom.	Bernile et al. (2018)
Edu_hhi	Herfindahl concentration index for the educational background (by education institutions) of directors in the boardroom.	Bernile et al. (2018)
Index_exgender	Diversity index excluding gender diversity. This index is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
Index_exage	Diversity index excluding age diversity. This index is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
Index_exboardexp	Diversity index excluding board experience diversity. This index is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
Index_exedu	Diversity index excluding the education Herfindahl index. This index is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
Index_exethnicity	Diversity index omitting the ethnicity Herfindahl index. This	Bernile et al. (2018)

	index is then standardised by its sample mean and standard deviation.	
Index_exfinexpert	Diversity index omitting the financial expertise Herfindahl index. This index is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
Ex_diversity_index	The sum of the standardised values of gender, age, board experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of the executive directors in the boardroom. The diversity index of the executive directors is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
Nonex_diversity_index	The sum of the standardised values of gender, age, board experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of the non-executive directors in the boardroom. The diversity index of the non-executive directors is then standardised by its sample mean and standard deviation.	Bernile et al. (2018)
Instrumental variables		
Diversity_index_county	The sum of the standardised values of gender, age, board experience diversity minus the sum of the standardised values of ethnicity, financial expertise, and education Herfindahl index of the directors in the boardroom at the county level. The county-level diversity index is	The diversity index is calculated based on the formula of Bernile et al. (2018); the idea of calculating diversity at the county level is adopted from the research of Prevost and Upadhyay (2018)

	then standardised by its sample mean and standard deviation.	
Gender_diversity_county	The percentage of female directors in the boardroom at the county level.	
Age_diversity_county	The standard deviation of the age of board members in the boardroom at the county level.	
Boardexp_diversity_county	The mean number of other board memberships in public companies of directors at the county level.	
Ethnicity_hhi_county	Herfindahl concentration index for ethnicity groups of directors at the county level.	
Finexpert_hhi_county	Herfindahl concentration index for financial expertise of directors at the county level.	
Edu_hhi_county	Herfindahl concentration index for the educational background (by education institutions) of directors at the county level.	
Index_exgender_county	Diversity index excluding gender diversity at the county level. This index is then standardised by its sample mean and standard deviation.	
Index_exage_county	Diversity index excluding age diversity at the county level. This index is then standardised by its sample mean and standard deviation.	
Index_exboardexp_county	Diversity index excluding board experience diversity at the county level.	
Index_exedu_county	Diversity index excluding education Herfindahl index at the county level. This index is then	

	standardised by its sample mean and standard deviation.	
Index_exethnicity_county	Diversity index omitting ethnicity Herfindahl index at the county level. This index is then standardised by its sample mean and standard deviation.	
Index_exfinexpert_county	Diversity index omitting financial expertise Herfindahl index at the county level. This index is then standardised by its sample mean and standard deviation.	
Control variables		
Firm_size	The natural logarithm of total assets in the current year.	Bernile et al. (2018); Giannetti and Zhao (2019)
MB	The market to book ratio in the current year.	Bernile et al. (2018)
Leverage	The ratio of long-term debt to the total assets in the current year.	Bernile et al. (2018); Giannetti and Zhao (2019)
Tangibility	The ratio of the net property, plant, and equipment to total assets in the current year.	Bernile et al. (2018)
Cash	The ratio of cash and short-term equivalents to book assets in the current year.	Bernile et al. (2018)
Dividend_pay	The dummy variable equals 1 if the dividends are higher than zero in the existing year and zero otherwise.	Bernile et al. (2018)
ROA	The operating income divided by total assets in the current year.	Bernile et al. (2018); Giannetti and Zhao (2019)
RD_expense	The R&D expenditure divided by total assets in the current year.	Bernile et al. (2018)

Ln_firmage	The natural log of one plus the total number of years from the IPO date of the firm.	Bernile et al. (2018); Giannetti and Zhao (2019)
Ln_boardsize	The natural log of the number of board members in the current year.	Bernile et al. (2018); Giannetti and Zhao (2019)
Ln_boardage	The natural log of the average age of board members in the current year.	Bernile et al. (2018)
Ln_tenure	The natural log of the total number of years since a CEO has held the position.	Bernile et al. (2018)
Ceochair	The dummy variable equals 1 if the CEO is the board chairman and zero otherwise.	Bernile et al. (2018); Giannetti and Zhao (2019)
Ln_population	The natural log of the number of population at the county level in the current year.	Bernile et al. (2018)
Population_growth	The growth rate of population from the previous to the current year at the county level.	Bernile et al. (2018)
Ln_income	The natural log of the per capita income at the county level in the current year.	Bernile et al. (2018)
Income_growth	The growth rate of the per capita income from the previous to the current year at the county level.	Bernile et al. (2018)

4.5. Research methods

The proposed regression models are based on the papers of Bernile et al. (2018) and Giannetti and Zhao (2019). To test hypotheses H1a and H1b, the research uses the following model:

Model (1): $Stock\ return\ volatility_{i,t} = \alpha + \beta_1 Diversity_{i,t} + \beta_2 Faultlines_{i,t} + \gamma Control_{i,t} + Year\ fixed\ effects + Firm\ fixed\ effects + \varepsilon_{i,t}$

To test hypotheses H2a and H2b, the study utilises the regression model as follows:

Model (2): $Stock\ return\ volatility_{i,t} = \alpha + \beta_1 Diversity_{i,t} + \beta_2 Diversity_{i,t} * Faultlines_{i,t} + \beta_3 Faultlines_{i,t} + \gamma Control_{i,t} + Year\ fixed\ effects + Firm\ fixed\ effects + \varepsilon_{i,t}$

- "Stock return $volatility_{i,t}$" denotes stock return volatility over the 12-month period of firm i in time t
- "$Diversity_{i,t}$" denotes board diversity index of firm i at the end of fiscal year at time t
- "$Faultlines_{i,t}$" denotes board faultline strength or faultline distance of firm i at the end of fiscal year at time t
- "$Control_{i,t}$" denotes for control variables of firm i at the end of fiscal year at time t

The Ordinary Least Squares (OLS) estimation method is used with year and firm fixed effects. Table 4.1 shows detailed descriptions of variables.

In addition to OLS regressions, this research utilises two-stage least squares (2SLS) regressions with instrumental variables. 2SLS models are used because the OLS estimation may be biased due to the endogeneity issue caused by omitted variables. Specifically, the board diversity (*diversity_index*) may be correlated with other variables which are not included in the regression. Following Prevost and Upadhyay (2018), this study uses one instrument (*diversity_index_county*) which is the diversity index of directors at the county level. Prevost and Upadhyay (2018) suggest using the county-level gender ratio as an appropriate instrument for gender diversity at the firm level. The county-level ratio of female directors represents the total supply of female directors at the firm level. Their empirical results show that there is a significantly positive relation between the county-level gender ratio and the firm-level percentage of female directors sitting on boards. The county-level diversity index can be an appropriate instrumental variable. The county-level board diversity positively affects the firm-level diversity index because the county-level board diversity index represents the degree of diversity of the total supply of directors in each county. When the total supply of directors in each county is more diverse, corporations have more chance to diversify their boards of directors. Cameron and Trivedi (2005) suggest that a valid instrumental variable should only affect the dependent variable through the variable that it instrumented out. In this case, the county-level diversity index is likely to affect firm risk only through the firm-level diversity index.

If the diversity index (*diversity_index*) is assumed to be endogeneous, the interaction between the diversity index and faultlines (*fau_strength* * *diversity_index* and *fau_distance* * *diversity_index*) is also expected to be endogeneous. Therefore, in the 2SLS regressions, there are two endogeneous variables including the diversity index and the interaction between the diversity index and board faultlines. The county-level diversity index (*diversity_index_county*) is considered as an instrument for the firm-level diversity index. For the case of endogeneity of an interaction variable, Wooldridge (2010) suggests that it is necessary to add an instrument which is the interaction between the instrument and the exogenous variable. Following Wooldridge (2010), this study uses the interaction between the county-level diversity index and faultline strength (*fau_strength*

* *diversity_index_county*) as an instrument for the interaction variable of interest (*fau_strength* * *diversity_index*). The interaction between the county-level diversity index and faultline distance (*fau_distance* * *diversity_index_county*) is used as an instrument for the interaction (*fau_distance* * *diversity_index*).

4.6. Summary statistics

Table 4.2 shows the summary statistics of 8,338 firm-year observations during 2007-2016. Panel A of Table 4.2 reports that the mean (median) value of monthly annualised volatility is 35.3% (31.07%). Panel B of Table 4.2 shows that the mean (median) values of board faultline strength and distance are 0.65 (0.66) and 2.39 (2.28) respectively. The mean (median) values of board faultline strength and distance of this research are nearly similar to those of the study of Peteghem et al. (2018). The summary statistics of Peteghem et al. (2018) show that the mean (median) values of board faultline strength and distance are 0.606 (0.611) and 1.460 (1.440) respectively. Faultline strength measures the cohesion degree within a subgroup based on nine characteristics of directors including independence, insider, affiliated outsider, financial expertise, multiple board membership, age, gender, tenure, and share ownership. When board members within subgroups are very similar based on the nine attributes, the faultline strength is exceptionally high. The faultline distance represents the extent to which various subgroups within the team diverge. When the faultline distance is high, subgroups within the boardroom are very different from each other. The faultline strength and faultline distance are significantly positively correlated. However, their correlation is not high because the correlation coefficient is 0.19. The correlation between the diversity index and faultline strength is very low and insignificant (-0.00496). The diversity index has a weakly positive correlation with faultline distance (0.0368). The correlation between independent variables is not strong so that there is no concern of multicollinearity (see Table A4.2 in the Appendices of Chapter 4).

Panel C of Table 4.2 shows the summary statistics of the diversity index and various components of the diversity index. The average percentage of female directors on the board is 13%. The mean standard deviation of the age of directors within a firm is 7.71. The mean number of other board memberships in public companies of directors is 0.84. The mean Herfindahl concentration index for the educational background of board members is 0.16. It means that the boards of directors in the sample are highly diverse in education. The mean Herfindahl concentration index for ethnicity is 0.88. This figure shows that the level of diversity in ethnicity in the boardroom is lower than that of education diversity. The mean Herfindahl concentration index for financial expertise is 0.64. The financial expertise diversity is not high in the boardroom of US companies.

Table 4.3 summarises the mean values of monthly annualised stock return volatility, faultline strength, faultline distance, diversity index, and various components of diversity index by year. During 2008-2009, the average stock return volatility was high (50.45% and 48.88%) due to the financial crisis. The mean values of faultline strength and faultline distance did not change much during the period 2007-2016. The average diversity index increased over time from 2007 to 2016. While the mean diversity index was -0.241 in 2007, it reached 0.371 in 2016. The increase in the diversity index was mainly due to the increase in gender diversity. There were 10.8% of women directors in 2007. However, the percentage of female directors was up to 16.3% in 2016.

Table 4.4 presents the mean values of monthly annualised volatility, the diversity index, faultline strength and faultline distance by industry. The industry is classified based on the 2-digit SIC code. The Coal Mining industry[34] (SIC code 12) has the highest mean value of stock return volatility (51.29%). The Automotive Repair, Services and Parking industry[35] (SIC code 75) has the highest mean value of diversity index (2.81) and also has high mean faultline strength (0.72). The Agricultural Production - Livestock and Animal Specialties industry[36] (SIC code 02) has the lowest mean value of diversity index (-4.24) while its faultline strength is 0.75 and its faultline distance is 2.41.

[34] The Coal Mining industry includes Cloud Peak Energy Incorporation which is a coal producer.

[35] In this industry, Ryder System Incorporation specialises in providing transportation and supply chain solutions. Ryder System Incorporation had a board diversity index of 5.94, faultline strength of 0.86, and faultline distance of 2.34 in 2008.

[36] In this industry, Cal-Maine Foods Incorporation, an egg producer, had a low diversity index because of low ethnicity diversity.

Table 4.2 Summary statistics

Table 4.2 reports summary statistics of 8,338 firm-year observations during 2007-2016. The description and definition of variables are provided in Table 4.1.

Variable	N	mean	median	25th quartile	75th quartile	Std. Dev
Panel A: Volatility						
Monthly annualised volatility (%)	8,338	35.30	31.07	22.73	42.64	19.09
Panel B: Faultlines						
Fau_strength	8,338	0.65	0.66	0.49	0.82	0.21
Fau_distance	8,338	2.39	2.28	2.01	2.61	0.60
Panel C: Diversity (non-standardised)						
Gender_diversity	8,338	0.13	0.13	0.00	0.20	0.10
Age_diversity	8,338	7.71	7.42	6.07	9.13	2.33
Boardexp_diversity	8,338	0.84	0.80	0.50	1.17	0.47
Edu_hhi	8,338	0.16	0.14	0.11	0.17	0.08
Ethnicity_hhi	8,338	0.88	0.86	0.78	1.00	0.14
Finexpert_hhi	8,338	0.64	0.59	0.53	0.72	0.15

Table 4.3 The mean value of key variables by year

Year	N	Monthly annualised volatility (%)	Fau _strength	Fau _distance	Diversity _index	Gender _diversity	Age _diversity	Boardexp _diversity	Edu _hhi	Ethnicity _hhi	Finexpert _hhi
2007	643	33.000	0.647	2.352	-0.241	0.108	7.706	0.916	0.161	0.886	0.649
2008	871	50.453	0.647	2.403	-0.152	0.113	7.667	0.900	0.158	0.889	0.636
2009	906	48.883	0.642	2.391	-0.196	0.112	7.645	0.857	0.158	0.885	0.632
2010	902	35.498	0.641	2.391	-0.182	0.116	7.699	0.841	0.157	0.879	0.642
2011	898	34.609	0.649	2.383	-0.120	0.120	7.686	0.820	0.157	0.868	0.643
2012	874	29.099	0.648	2.386	-0.044	0.124	7.656	0.810	0.154	0.870	0.636
2013	873	26.923	0.645	2.397	0.039	0.133	7.735	0.814	0.153	0.873	0.642
2014	859	27.344	0.643	2.386	0.282	0.143	7.782	0.826	0.151	0.871	0.634
2015	819	32.008	0.643	2.424	0.296	0.152	7.730	0.820	0.152	0.868	0.639
2016	693	33.414	0.652	2.413	0.371	0.163	7.783	0.838	0.157	0.869	0.643
Total	8,338	35.302	0.646	2.393	0.000	0.128	7.707	0.843	0.156	0.876	0.639

Table 4.4 The mean value of key variables by industry

SIC code	Industry	N	Monthly annualised volatility (%)	Diversity _index	Fau _strength	Fau _distance
2	Agricultural Production - Livestock and Animal Specialties	8	27.80	-4.24	0.75	2.41
7	Agricultural Services	10	27.64	-3.69	0.47	2.09
10	Metal Mining	29	48.27	1.05	0.72	2.18
12	Coal Mining	6	51.29	-1.16	0.83	2.66
13	Oil and Gas Extraction	390	44.04	-1.25	0.65	2.35
14	Mining and Quarrying of Nonmetallic Minerals, Except Fuels	38	34.05	-1.26	0.73	2.19
16	Heamy Construction, Except Building Construction, Contractor	72	37.91	-0.41	0.61	2.28
17	Construction - Special Trade Contractors	18	32.40	-0.68	0.57	2.18
20	Food and Kindred Products	318	26.23	0.58	0.60	2.32
21	Tobacco Products	14	17.83	2.67	0.68	2.39
22	Textile Mill Products	29	38.56	0.76	0.61	2.50
23	Apparel, Finished Products from Fabrics & Similar Materials	132	38.17	-0.03	0.63	2.39
24	Lumber and Wood Products, Except Furniture	38	40.49	-1.91	0.66	2.33
25	Furniture and Fixtures	73	39.65	0.91	0.59	2.33
26	Paper and Allied Products	138	32.59	0.29	0.65	2.31
27	Printing, Publishing and Allied Industries	84	37.69	0.71	0.65	2.53
28	Chemicals and Allied Products	733	32.32	0.52	0.65	2.40
29	Petroleum Refining and Related Industries	62	32.23	1.29	0.70	2.35
30	Rubber and Miscellaneous Plastic Products	86	35.00	0.77	0.63	2.48
31	Leather and Leather Products	60	41.08	-0.83	0.52	2.31
32	Stone, Clay, Glass, and Concrete Products	38	47.24	-2.65	0.64	2.41
33	Primary Metal Industries	146	44.14	-0.84	0.63	2.49
34	Fabricated Metal Products	178	33.08	-0.37	0.61	2.47
35	Industrial and Commercial Machinery and Computer Equipment	615	36.13	0.40	0.69	2.35
36	Electronic & Other Electrical Equipment & Components	793	38.71	-0.22	0.65	2.45
37	Transportation Equipment	238	34.88	-0.77	0.66	2.37
38	Measuring, Photographic, Medical, & Optical Goods, & Clocks	675	31.22	-0.33	0.65	2.33
39	Miscellaneous Manufacturing Industries	94	40.78	-0.73	0.64	2.53

Table 4.4 The mean value of key variables by industry (cont.)						
SIC code	Industry	N	Monthly annualised volatility (%)	Diversity _index	Fau _strength	Fau _distance
40	Railroad Transportation	42	26.09	1.00	0.69	2.31
41	Local & Suburban Transit & Interurban Highway Transportation	3	39.86	2.55	0.45	1.98
42	Motor Freight Transportation	93	28.22	-2.10	0.68	2.50
44	Water Transportation	47	37.46	-0.01	0.61	2.13
45	Transportation by Air	92	39.48	0.41	0.62	2.41
47	Transportation Services	26	31.58	-2.67	0.63	2.13
48	Communications	165	29.02	1.71	0.66	2.49
50	Wholesale Trade - Durable Goods	258	31.78	0.19	0.60	2.22
51	Wholesale Trade - Non-durable Goods	146	33.25	0.08	0.65	2.29
52	Building Materials, Hardware, Garden Supplies & Mobile Homes	28	25.14	2.17	0.65	2.35
53	General Merchandise Stores	103	35.19	1.61	0.61	2.37
54	Food Stores	39	23.71	1.06	0.56	2.58
55	Automotive Dealers and Gasoline Service Stations	70	45.52	0.29	0.59	2.37
56	Apparel and Accessory Stores	193	43.64	0.01	0.61	2.47
57	Home Furniture, Furnishings and Equipment Stores	29	35.86	-0.08	0.74	2.93
58	Eating and Drinking Places	173	34.61	0.26	0.61	2.43
59	Miscellaneous Retail	169	37.09	-0.02	0.66	2.54
70	Hotels, Rooming Houses, Camps, and Other Lodging Places	9	47.44	-0.12	0.54	2.42
72	Personal Services	27	28.29	0.43	0.61	2.44
73	Business Services	1015	33.93	-0.06	0.65	2.41
75	Automotive Repair, Services and Parking	22	32.78	2.81	0.72	2.24
78	Motion Pictures	19	46.66	0.43	0.74	2.49
79	Amusement and Recreation Services	48	46.25	0.77	0.70	2.32
80	Health Services	178	36.44	-0.72	0.68	2.42
82	Educational Services	54	45.72	2.34	0.63	2.75
87	Engineering, Accounting, Research, and Management Services	163	32.11	-0.41	0.69	2.40
99	Nonclassifiable Establishments	12	32.56	2.22	0.79	2.19
	Total	8,338	35.30	0.00	0.65	2.39

4.7. Multivariate analysis

4.7.1. The impact of board diversity on firm risk

Before investigating the impact of board faultlines or the interactive effect of board diversity and board faultlines on firm risk, this research examines the association between board diversity index and firm risk based on the model of Bernile et al. (2018).

Table 4.5[37] shows the results of the OLS and 2SLS regressions with firm and year fixed effects. The dependent variable is *ln_monthly_vol* (logarithm of monthly annualised stock return volatility). The main variable of interest is *diversity_index* (board diversity index). The OLS regression results are shown in Model (1). The 2SLS regression results are presented in Model (2a) and Model (2b). In the 2SLS model, the instrument is *diversity_index_county* (the diversity index of all directors at the county level). Both *diversity_index* and *diversity_index_county* are standardised by their sample mean and standard deviation.

In Models (1) and (2b) of Table 4.5, the coefficient of the variable *diversity_index* is not significant. There is no evidence that board diversity alone is associated with firm risk. This finding is not in line with the results found by Bernile et al. (2018)[38] that the board diversity index is negatively associated with the stock return volatility. The different findings are possibly due to the difference in the sample and the instrument. Bernile et al. (2018) use the sample during the period 1996-2014. My research collects the data from 2007 to 2016 because the ISS director database only has information on the financial

[37] The number of observations in regressions is less than the total number of observations in the full sample. The main reason is that the OLS regressions with firm and year fixed effects drop observations that are singletons. In the 2SLS regression, a county which has less than four firms is set to missing. Thus, the number of observations in the 2SLS regression is lower than that of the OLS regression.

[38] My research also finds no evidence of a relationship between the board diversity index and firm risk when controlling for headquarter county, industry and year fixed effects as well as measuring firm risk by daily annualised stock return volatility like the study of Bernile et al. (2018).

expertise of directors from 2007. Moreover, Bernile et al. (2018) measure the instrument by calculating the diversity index of non-local directors who live one non-stop flight away from the location of the company headquarters.

Table 4.5 The impact of board diversity on firm risk

Table 4.5 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Model (1) shows the results of the OLS model. Models (2a) and (2b) present the results of the first stage and second stage of the 2SLS model. The instrumental variable is *diversity_index_county* (diversity index at the county level). The independent variable *diversity_index* (board diversity index) is standardised by its sample mean and standard deviation. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The standard errors (in parentheses) are clustered at the firm level. The description and definition of the independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Model (1)	Model (2a)	Model (2b)
		OLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Diversity_index	Ln_monthly_vol
diversity_index_county	+		0.130***	
			(0.019)	
diversity_index	-	-0.004		-0.085
		(0.009)		(0.086)
firm_size	-	-0.091***	0.018	-0.085***
		(0.021)	(0.047)	(0.025)
mb	+	-0.000	0.000	-0.000
		(0.000)	(0.000)	(0.000)
leverage	+	0.448***	-0.149	0.383***
		(0.065)	(0.139)	(0.080)
tangibility	+	0.273**	0.029	0.216
		(0.123)	(0.299)	(0.142)
cash	+/-	-0.279***	-0.006	-0.251***
		(0.070)	(0.145)	(0.081)
dividend_pay	-	-0.053***	0.039	-0.050**
		(0.020)	(0.049)	(0.023)
roa	-	-0.374***	-0.032	-0.367***
		(0.065)	(0.095)	(0.070)
rd_expense	+/-	-0.789***	-0.216	-0.813**
		(0.305)	(0.523)	(0.343)
ln_firmage	+/-	0.068	0.101	0.096*
		(0.045)	(0.105)	(0.057)
ln_boardsize	+/-	0.027	0.976***	0.128
		(0.043)	(0.110)	(0.098)
ln_boardage	-	-0.144	-2.301***	-0.399
		(0.177)	(0.450)	(0.300)
ln_tenure	-	-0.015*	-0.017	-0.012
		(0.008)	(0.020)	(0.010)
ceochair	+/-	-0.004	0.009	0.015
		(0.014)	(0.031)	(0.017)
ln_population	+/-	0.002	0.014	0.009
		(0.005)	(0.015)	(0.006)
population growth	+/-	-0.000	0.000	-0.000
		(0.000)	(0.000)	(0.000)
ln_income	+/-	-0.002	-0.006	-0.004
		(0.007)	(0.016)	(0.007)
income growth	+/-	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)
Firm and year FE		Yes	Yes	Yes
Observations		8,216	5,912	5,912
Adj R-squared		0.602		
F statistics		9.528		77.46
P-value of F statistics		0.000		0.000
Endogeneity test				1.103
P-value of Endogeneity test				0.294
P-value of SW F test of weak identification				0.000
P-value of SW chi-squared test of under-identification				0.000

4.7.2. The impact of board faultlines on firm risk

This section explains the empirical results of the baseline regressions with firm and year fixed effects. The standard errors are clustered at the firm level[39]. Table 4.6[40] presents the effect board faultlines on corporate risk. To investigate the impact of board faultlines on stock return volatility, this research adds either the board faultline strength variable (*fau_strength*) or the faultline distance variable (*fau_distance*) to the main regression models. Model (1) of Panel A of Table 4.6 shows the estimation of the impact of board faultline strength on stock return volatility in the OLS regression. Model (1) of Panel B of Table 4.6 reports the coefficient of board faultline distance estimated by the OLS model. The coefficients of both board faultline strength and distance are not significant. Therefore, there is no evidence of a relationship between stock return volatility and board faultline strength or distance.

In Model (1) of Panel A and B, the coefficient of the variable *firm_size*, which is the natural logarithm of the total assets, is negative and significant at the level of 1%. It means that large firms are associated with lower risk than small companies. Large companies can have more experience in managing risk. The variable *leverage*, which is the ratio of long-term debt to the total assets, is positively related to stock return volatility at the significance level of 1%. Firms with high leverage ratios have a higher probability of default risks than those with low leverage ratios (Sila, Gonzalez, & Hagendorff, 2016). The variable *tangibility*, which is the ratio of the net property, plant, and equipment to

[39] The results still hold when this study runs regressions in which the standard errors are clustered at both firm and year levels. However, the endogeneity test cannot be run in the 2SLS regressions because the number of clusters by year is insufficient to calculate a robust covariance matrix. The data sample is from 2007 to 2016 (10 years). The number of clusters by year in the research is only 10, which is not large enough to satisfy the assumption that the number of clusters goes to infinity (Cameron & Miller, 2015).
[40] The number of observations in regressions is less than the total number of observations in the full sample. The main reason is that the OLS regressions with firm and year fixed effects drop observations that are singletons. In the 2SLS regression, a county which has less than four firms is set to missing. Thus, the number of observations in the 2SLS regression is lower than that of the OLS regression.

total assets, has a positive relationship with stock return volatility. Companies with more tangible assets can have more chances to obtain external funds. These firms can increase their leverage to finance their growth opportunities and take more risk. The coefficient of the variable *cash*, which is the ratio of cash and short-term equivalents to book assets, is negative at the significance level of 1%. Firms with high cash holdings are associated with lower risk. Companies can have extensive cash holdings to prevent them from facing financial constraints and accessing expensive external funds, which increases firm risk (Acharya, Davydenko, & Strebulaev, 2012). The variable *dividend_pay* (the dummy variable which is equal to one if the dividends are higher than zero and zero otherwise) has a negative impact on stock return volatility at the significance level of 1%. Firms, which do not pay dividends, may want to reinvest their profits into new growth opportunities, and thus take more risk (Baskin, 1989). There is a negative link between firm risk and ROA (the operating income divided by total assets in the current year). Firms with a high ROA ratio have high profitability and can be associated with lower stock return volatility (Bernile et al., 2018; Sila et al., 2016). The coefficient of the variable *rd_expense* (the R&D expenditure divided by total assets) is negative and significant at the level of 1%. If corporations invest R&D expenses in innovation projects successfully, they can gain a competitive advantage compared to their rivals (Bromiley, Rau, & Zhang, 2017). The increasing reputation and creditworthiness thanks to efficient innovative activities reduces stock return volatility. The tenure of CEOs (*ln_tenure*) is negatively related to firm risk at the significance level of 10%. Top executives with longer tenure have more experience in business-risk management and may pursue capital structures with lower leverage, and thus reduce firm risk (Berger, Ofek, & Yermack, 1997).

Model (2a) and (2b) show the empirical results of the first-stage and second-stage of the 2SLS regressions with an instrumental variable. The diversity index of all directors at the county level (*diversity_index_county*) is used as an instrument for the board diversity index. In Models (2a) of Panel A and B, the coefficient of *diversity_index_county* is positive (0.130) and significant at the level of 1%. This figure means that a one standard deviation increase in the county-level diversity index leads to a rise in the firm-level diversity index of 0.130 standard deviations. The positive link between the county-level and the firm-level diversity index shows the diversity of directors at the county level represents the supply of board members at the firm level and positively affects the firm-level diversity.

Model (2b) of Panel A and B shows the findings of the second stage of the 2SLS regression. The coefficient of board faultline strength (*fau_strength*) in Model (2b) of Panel A and the coefficient of board faultline distance (*fau_distance*) in Model (2b) of Panel B are insignificant. Thus, Hypothesis H1 that board faultline is positively associated with firm risk is rejected.

Table 4.6 The impact of board faultlines on firm risk

Table 4.6 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Model (1) and (2) show the results of the OLS and 2SLS models respectively. The instrument is *diversity_index_county* (diversity index at the county level). The independent variables *diversity_index* (board diversity index), *fau_strength* (board faultline strength) and *fau_distance* (board faultline distance) are standardised by the sample mean and standard deviation. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The standard errors (in parentheses) are clustered at the firm level. The description and definition of the independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: The impact of faultline strength on firm risk

		Model (1)	Model (2a)	Model (2b)
		OLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Diversity_index	Ln_monthly_vol
diversity_index_county	+		0.130***	
			(0.019)	
fau_strength	+	-0.002	-0.001	0.003
		(0.005)	(0.010)	(0.006)
diversity_index	-	-0.004		-0.085
		(0.009)		(0.086)
firm_size	-	-0.091***	0.018	-0.085***
		(0.021)	(0.047)	(0.025)
mb	+	-0.000	0.000	-0.000
		(0.000)	(0.000)	(0.000)
leverage	+	0.449***	-0.149	0.383***
		(0.065)	(0.139)	(0.080)
tangibility	+	0.273**	0.029	0.216
		(0.123)	(0.299)	(0.142)
cash	+/-	-0.280***	-0.007	-0.250***
		(0.070)	(0.144)	(0.081)
dividend_pay	-	-0.053***	0.039	-0.050**
		(0.020)	(0.049)	(0.023)
roa	-	-0.375***	-0.033	-0.366***
		(0.065)	(0.095)	(0.070)
rd_expense	+/-	-0.789***	-0.216	-0.813**
		(0.305)	(0.523)	(0.343)
ln_firmage	+/-	0.068	0.101	0.096*
		(0.045)	(0.105)	(0.057)
ln_boardsize	+/-	0.027	0.976***	0.128
		(0.043)	(0.110)	(0.098)
ln_boardage	-	-0.148	-2.303***	-0.395
		(0.177)	(0.449)	(0.300)
ln_tenure	-	-0.015*	-0.017	-0.012
		(0.008)	(0.020)	(0.010)
ceochair	+/-	-0.003	0.009	0.014
		(0.014)	(0.032)	(0.017)
ln_population	+/-	0.002	0.014	0.009
		(0.005)	(0.015)	(0.006)
population growth	+/-	-0.000	0.000	-0.000
		(0.000)	(0.000)	(0.000)
ln_income	+/-	-0.002	-0.006	-0.004
		(0.007)	(0.016)	(0.007)
income growth	+/-	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)
Firm and year FE		Yes	Yes	Yes
Observations		8,216	5,912	5,912
Adj R-squared		0.602		
F statistics		9.028		75.03
P-value of F statistics		0.000		0.000
Endogeneity test				1.120
P-value of Endogeneity test				0.290
P-value of SW F test				0.000
P-value of SW chi-squared test				0.000

Table 4.6 The impact of board faultlines on firm risk (cont.)

Table 4.6 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Model (1) and (2) show the results of the OLS and 2SLS models respectively. The instrument is *diversity_index_county* (diversity index at the county level). The independent variables *diversity_index* (board diversity index), *fau_strength* (board faultline strength) and *fau_distance* (board faultline distance) are standardised by the sample mean and standard deviation. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The standard errors (in parentheses) are clustered at the firm level. The description and definition of the independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel B: The impact of faultline distance on firm risk

		Model (1)	Model (2a)	Model (2b)
		OLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Diversity_index	Ln_monthly_vol
diversity_index_county	+		0.130***	
			(0.019)	
fau_distance	+	-0.002	0.004	0.004
		(0.005)	(0.011)	(0.006)
diversity_index	-	-0.004		-0.085
		(0.009)		(0.086)
firm_size	-	-0.091***	0.018	-0.085***
		(0.021)	(0.047)	(0.025)
mb	+	-0.000	0.000	-0.000
		(0.000)	(0.000)	(0.000)
leverage	+	0.449***	-0.149	0.383***
		(0.065)	(0.139)	(0.080)
tangibility	+	0.274**	0.026	0.212
		(0.123)	(0.300)	(0.142)
cash	+/-	-0.279***	-0.006	-0.251***
		(0.070)	(0.145)	(0.081)
dividend_pay	-	-0.053***	0.039	-0.050**
		(0.020)	(0.049)	(0.023)
roa	-	-0.374***	-0.032	-0.367***
		(0.065)	(0.095)	(0.070)
rd_expense	+/-	-0.788**	-0.216	-0.813**
		(0.306)	(0.523)	(0.342)
ln_firmage	+/-	0.069	0.099	0.095*
		(0.045)	(0.105)	(0.057)
ln_boardsize	+/-	0.026	0.976***	0.129
		(0.043)	(0.110)	(0.098)
ln_boardage	-	-0.144	-2.301***	-0.399
		(0.177)	(0.450)	(0.299)
ln_tenure	-	-0.015*	-0.017	-0.012
		(0.008)	(0.020)	(0.010)
ceochair	+/-	-0.003	0.009	0.015
		(0.014)	(0.031)	(0.017)
ln_population	+/-	0.003	0.014	0.009
		(0.005)	(0.015)	(0.006)
population growth	+/-	-0.000	0.000	-0.000
		(0.000)	(0.000)	(0.000)
ln_income	+/-	-0.002	-0.006	-0.004
		(0.007)	(0.016)	(0.007)
income growth	+/-	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)
Firm and year FE		Yes	Yes	Yes
Observations		8,216	5,912	5,912
Adj R-squared		0.602		
F statistics		9.027		75.51
P-value of F statistics		0.000		0.000
Endogeneity test				1.101
P-value of Endogeneity test				0.294
P-value of SW F test				0.000
P-value of SW chi-squared test				0.000

4.7.3. The interactive effect of board diversity and board faultlines on firm risk

Table 4.7 shows the interactive impact of board diversity and board faultlines on stock return volatility. To investigate the interactive effect of board diversity and faultlines on firm risk, this study adds to the regressions either the interaction between the diversity index and faultline strength (*fau_strength* * *diversity_index*) or the interaction between the diversity index and faultline distance (*fau_distance* * *diversity_index*)[41]. Model (1) of Panel A of Table 4.7 shows the coefficient estimates of board faultline strength and the interaction between the board diversity and faultline strength (*fau_strength* * *diversity_index*) in the OLS regression. The coefficients of board faultline distance and the interaction variable between board diversity and faultline distance (*fau_distance* * *diversity_index*), which are estimated by the OLS method, are reported in Model (1) of Panel B of Table 4.7. Model (1) of both Panel A and B shows that the coefficients of the interaction between board diversity and faultline strength/faultline distance are not significant. The coefficients of the board diversity index and board faultlines are also insignificant. However, estimation by OLS models may be biased in the presence of the endogeneity problem.

To account for endogeneity, this research also uses 2SLS regressions with an instrument. The diversity index of all directors at the county level (*diversity_index_county*) is used as an instrument for the board diversity index. In addition, the interaction between the diversity index at the county level and faultline strength (*fau_strength* * *diversity_index_county*) is used as an instrument for the interaction variable (*fau_strength* * *diversity_index*). The interaction between the county-level diversity index and faultline distance (*fau_distance* * *diversity_index_county*) is used as an instrument for the

[41] When this study includes board diversity index, faultline strength, faultline distance, diversity index * faultline strength, and diversity index * faultline distance in the same regression, the results are the same.

interaction variable (*fau_distance * diversity_index*). Models (2a) and (2b) of Panel A present the results of the first stage regression in which the dependent variables are *diversity_index* and *fau_strength * diversity_index* respectively. The coefficient of *diversity_index_county* is positive (0.131) and significant at the level of 1%. This figure means that a one standard deviation increase in the county-level diversity index leads to a rise in the firm-level diversity index of 0.131 standard deviations. The coefficient of the interaction (*fau_strength * diversity_index_county)* is also positive (0.313) and significant at the 1% level. The positive link between the county-level and the firm-level diversity index shows the diversity of directors at the county level represents the supply of board members at the firm level and positively affects the firm-level diversity.

Model (2c) of Panel A shows the empirical results of the second stage of 2SLS regression. The coefficient of the interaction variable (*fau_strength * diversity_index*) is positive (0.046) and significant at the 5% level. This means that the negative link between board diversity and firm risk becomes weaker in the presence of strong board faultline strength. When the faultline strength increases by one standard deviation, a one standard deviation increase in board diversity lead to an increase in monthly annualised stock return volatility by 0.046 percentage points. The coefficients of both board faultlines and board diversity variables alone are not significant. The endogeneity test confirms that the *diversity index* and *fau_strength * diversity_index* are endogenous at the significance level of 5% because the p-value of the endogeneity test is lower than 5%. The instruments *diversity_index_county* and *fau_strengh * diversity_index_county* are relevant because the p-value of the SW chi-squared test of under-identification is lower than 1%. Those instruments are also not weak because the p-value of the SW F test of weak identification is lower than 1%. Overall, the estimated results of the 2SLS regressions with instrumental variables are more efficient than those of the OLS regressions. The significantly positive coefficient of the interaction variable (*fau_strength * diversity_index*) supports Hypothesis H2 that the negative relationship between board diversity and firm risk is weaker in the presence of strong board faultline.

Models (2a) and (2b) of Panel B present the results of the first stage regression in which the dependent variables include the diversity index (*diversity_index*) and the interaction variable between board faultline distance and the diversity index (*fau_distance * diversity_index*) respectively. The results in the first stage regressions show that the instrument (the county-level diversity index) positively affects the firm-level diversity index at the significance level of 1%. Moreover, the instrument (*fau_distance * diversity_index_county*) has a positive impact on the interaction variable between board faultline distance and the firm-level diversity index.

Model (2c) of Panel B also shows the empirical results of the second stage of the 2SLS regression in which the independent variables of interest are faultline distance (*fau_distance*) and the interaction (*fau_distance * diversity_index)*. The coefficient of the interaction between the board diversity index and faultline distance is insignificant. There is no evidence of a significant interactive effect of board diversity and faultline distance on firm risk. Moreover, the coefficient of the board faultline distance is also not significant.

In conclusion, there is no evidence that board diversity or board faultline strength or faultline distance alone is associated with firm risk. Instead, board diversity and board faultlines (which create more conflicts within the boardroom) interact with each other. Specifically, the effect of board diversity on firm risk significantly depends on the level of faultline strength within the boardroom (but not the board faultline distance). When directors in each of different subgroups within the boardroom are extremely similar (high board faultline strength or a high degree of cohesion within the subgroup), the negative relationship between board diversity and firm risk becomes weaker. The findings support the argument that if there are potential conflicts among board members (high faultline strength), the negative link between board heterogeneity and stock return volatility weakens[42]. Diverse boards in which directors tend to form relatively homogenous coalitions face potential frictions with other subgroups within the boardroom. As a result, the firms of diverse boards with high faultline strength have a higher risk. The results can explain why the results found by Giannetti and Zhao (2019) and Bernile et al. (2018) are mixed. The findings are in line with the conjecture of Peteghem et al. (2018) that when the formation of homogenous subgroups within the board is stronger, the board's performance becomes less effective. The results of this study also support the argument of Giannetti and Zhao (2019) that heterogeneous boards with increasing conflicts and friction lead to more volatile corporate outcomes.

[42] I also further examine whether a positive relationship between firm risk and the interaction between board diversity and board faultlines is stronger in the case of a high level of market-wide volatility. The motivation from this analysis is that diverse boards can be less effective in mitigating corporate risk when firms do business in an unstable environment. Board members slowly react to volatile conditions if there are conflicts within the boardroom. I use VIX index (the CBOE Volatility Index) as a proxy for the level of market-wide volatility which is adopted by Bernile et al. (2018). The historical data of VIX index can be obtained from http://www.cboe.com/vix. However, I find no evidence that the association between corporate risk and the interaction between board diversity and faultlines is stronger when VIX index is higher than the median VIX index.

Table 4.7 The interactive effect of board diversity and board faultlines on firm risk

Table 4.7 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Model (1) and (2) show the results of the OLS and 2SLS models respectively. The instruments include *diversity_index_county* (diversity index at the county level), *fau_strength * diversity_index_county* (the interaction between faultline strength and diversity index at the county level), and *fau_distance * diversity_index_county* (the interaction between faultline distance and the diversity index at the county level). The independent variables *diversity_index* (board diversity index), *fau_strength* (board faultline strength) and *fau_distance* (board faultline distance) are standardised by the sample mean and standard deviation. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: The interactive effect of board diversity and faultline strength on firm risk

		Model (1)	Model (2a)	Model (2b)	Model (2c)
		OLS	First stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Diversity_index	Fau_strength * diversity_index	Ln_monthly_vol
diversity_index_county	+/-		0.131***	-0.047	
			(0.019)	(0.037)	
fau_strength * diversity_index_county	+		-0.007	0.313***	
			(0.008)	(0.033)	
fau_strength	+/-	-0.003	-0.001	0.099***	-0.002
		(0.005)	(0.010)	(0.037)	(0.006)
diversity_index	-	-0.004			-0.078
		(0.009)			(0.087)
fau_strength * diversity_index	+	0.006			0.046**
		(0.005)			(0.019)
firm_size	-	-0.091***	0.018	0.068	-0.087***
		(0.021)	(0.047)	(0.066)	(0.025)
mb	+	-0.000	0.000	0.000	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)
leverage	+	0.449***	-0.149	-0.240	0.394***
		(0.065)	(0.139)	(0.191)	(0.080)
tangibility	+	0.270**	0.030	0.636	0.184
		(0.123)	(0.299)	(0.410)	(0.144)
cash	+/-	-0.281***	-0.007	0.257	-0.261***
		(0.070)	(0.144)	(0.234)	(0.081)
dividend_pay	-	-0.053***	0.038	-0.050	-0.046**
		(0.020)	(0.049)	(0.074)	(0.023)
roa	-	-0.377***	-0.032	0.381**	-0.384***
		(0.065)	(0.095)	(0.161)	(0.070)
rd_expense	+/-	-0.788***	-0.224	0.068	-0.797**
		(0.305)	(0.524)	(0.775)	(0.344)
ln_firmage	+/-	0.069	0.099	-0.113	0.103*
		(0.045)	(0.105)	(0.154)	(0.058)
ln_boardsize	+/-	0.026	0.977***	0.104	0.115
		(0.043)	(0.110)	(0.170)	(0.099)
ln_boardage	-	-0.149	-2.304***	-0.030	-0.376
		(0.177)	(0.449)	(0.672)	(0.300)
ln_tenure	-	-0.015*	-0.017	0.020	-0.013
		(0.008)	(0.020)	(0.032)	(0.010)
ceochair	+/-	-0.003	0.009	-0.120**	0.020
		(0.014)	(0.032)	(0.054)	(0.017)
ln_population	+/-	0.002	0.014	0.014	0.008
		(0.005)	(0.015)	(0.024)	(0.006)
population growth	+/-	-0.000	0.000	-0.000	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)
ln_income	+/-	-0.002	-0.006	0.040***	-0.006
		(0.007)	(0.016)	(0.015)	(0.008)
income growth	+/-	0.000	0.000	-0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)
Firm and year FE		Yes	Yes	Yes	Yes
Observations		8,216	5,912	5,912	5,912
Adj R-squared		0.602			
F statistics		8.691			72.60
P-value of F statistics		0.000			0.000
Endogeneity test					8.020
P-value of Endogeneity test					0.018
P-value of SW F test					0.000
P-value of SW chi-squared test					0.000

Table 4.7 The interactive effect of board diversity and board faultlines on firm risk (cont.)

Table 4.7 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Model (1) and (2) show the results of the OLS and 2SLS models respectively. The instruments include *diversity_index_county* (diversity index at the county level), *fau_strength * diversity_index_county* (the interaction between faultline strength and diversity index at the county level), and *fau_distance * diversity_index_county* (the interaction between faultline distance and diversity index at the county level). The independent variables *diversity_index* (board diversity index), *fau_strength* (board faultline strength) and *fau_distance* (board faultline distance) are standardised by the sample mean and standard deviation. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel B: The interactive effect of board diversity and faultline distance on firm risk

		Model (1)	Model (2a)	Model (2b)	Model (2c)
		OLS	First stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Diversity_index	Fau_distance * diversity_index	Ln_monthly_vol
diversity_index_county	+/-		0.130*** (0.019)	0.003 (0.033)	
fau_distance * diversity_index_county	+		0.000 (0.010)	0.321*** (0.039)	
fau_distance	+/-	-0.004 (0.005)	0.004 (0.011)	0.224*** (0.047)	0.005 (0.007)
diversity_index	-	-0.005 (0.009)			-0.084 (0.086)
fau_distance * diversity_index	+	0.006 (0.005)			-0.003 (0.018)
firm_size	-	-0.091*** (0.021)	0.018 (0.047)	-0.020 (0.064)	-0.085*** (0.025)
mb	+	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
leverage	+	0.451*** (0.065)	-0.149 (0.139)	-0.153 (0.179)	0.382*** (0.080)
tangibility	+	0.276** (0.123)	0.026 (0.300)	-0.145 (0.363)	0.212 (0.142)
cash	+/-	-0.277*** (0.070)	-0.006 (0.144)	-0.065 (0.237)	-0.251*** (0.081)
dividend_pay	-	-0.053*** (0.020)	0.039 (0.049)	-0.044 (0.061)	-0.050** (0.023)
roa	-	-0.374*** (0.065)	-0.032 (0.095)	0.047 (0.147)	-0.367*** (0.070)
rd_expense	+/-	-0.785** (0.307)	-0.216 (0.524)	-0.266 (0.807)	-0.815** (0.342)
ln_firmage	+/-	0.069 (0.045)	0.099 (0.105)	-0.064 (0.134)	0.094* (0.057)
ln_boardsize	+/-	0.025 (0.043)	0.976*** (0.110)	0.160 (0.150)	0.129 (0.098)
ln_boardage	-	-0.142 (0.177)	-2.301*** (0.450)	-0.137 (0.556)	-0.399 (0.300)
ln_tenure	-	-0.015* (0.008)	-0.017 (0.020)	0.038 (0.030)	-0.012 (0.010)
ceochair	+/-	-0.003 (0.014)	0.009 (0.031)	-0.093** (0.045)	0.014 (0.017)
ln_population	+/-	0.002 (0.005)	0.014 (0.015)	0.021 (0.017)	0.009 (0.006)
population_growth	+/-	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
ln_income	+/-	-0.002 (0.007)	-0.006 (0.016)	0.016 (0.024)	-0.004 (0.007)
income_growth	+/-	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)
Firm and year FE		Yes	Yes	Yes	Yes
Observations		8,216	5,912	5,912	5,912
Adj R-squared		0.602			
F statistics		8.634			72.89
P-value of F statistics		0.000			0.000
Endogeneity test					1.441
P-value of Endogeneity test					0.486
P-value of SW F test					0.000
P-value of SW chi-squared test					0.000

4.8. Robustness test

This study further investigates the influence of board faultlines as well as the interactive effect of board diversity and faultlines on stock return volatility by changing the measurement of board faultlines. This research creates two dummy variables *strength* (which equals one if the firm-level board faultline strength is higher than the median value of the industry and zero otherwise) and *distance* (which is equal to one when the board faultline distance is larger than the median value of the industry and zero otherwise). To examine whether the impact of board diversity on firm risk is different between firms with high and weak board faultlines, this study adds two interaction variables *strength* * *diversity_index* and *distance* * *diversity_index* to the regression models. This research expects that the coefficients of the interaction variables *strength* * *diversity_index* and *distance* * *diversity_index* are positive. It means that the mitigating effect of diverse boards on firm risk weakens when there is higher board faultline strength (or faultline distance). This expectation is in line with Hypothesis H2. Observations in the industry which has less than 4 companies are set to missing.

Table 4.8[43] presents the empirical results of the robustness test. Model (1) of both Panel A and B shows that there is no evidence of the effect of board faultline strength (*strength*), interaction between faultline strength and board diversity (*strength* * *diversity_index*), faultline distance (*distance*), and interaction between faultline distance and board diversity (*distance* * *diversity_index*) on stock return volatility in the OLS regressions.

[43] The number of observations in regressions is less than the total number of observations in the full sample. The main reason is that the OLS regressions with firm and year fixed effects drop observations that are singletons. Observations in an industry which has less than 4 companies are set to missing. In the 2SLS regression, a county which has less than four firms is set to missing. Thus, the number of observations in the 2SLS regression is lower than that of the OLS regression.

These results are consistent with those found in the baseline OLS regressions in Table 4.7.

Models (2a), (2b), and (2c) of both Panel A and B of Table 4.8 shows 2SLS regressions with instruments to account for endogeneity issues. The county-level diversity index (*diversity_index_county*), the interaction between faultline strength dummy variable and the county-level diversity index (*strength * diversity_index_county*), and the interaction between faultline distance and the county-level diversity index (*distance * diversity_index_county*) are used as instruments for the firm-level diversity index, the interaction between faultline strength and the firm-level diversity index, and the interaction between faultline distance and the firm-level diversity index respectively.

The results of the second stage of 2SLS regressions in Model (2c) of Panel A show that the coefficient of the interaction variable (*strength * diversity_index)* is 0.083 at the significance level of 5%. This means that board heterogeneity is associated with higher stock return volatility in corporations which have higher board faultline strength than the median value of the industry compared with those with lower faultline strength. This finding supports Hypothesis H2. The coefficients of the variables *strength* (faultline strength) and *diversity_index* (board diversity index) are not significant. *Diversity index* and *strength * diversity_index* variables are endogenous because the p-value of the endogeneity test is lower than 5%. Moreover, the instruments are relevant and not weak (the p-values of the SW chi-squared test and SW F test are lower than 1%). Thus, the 2SLS regressions with instrumental variables provide more efficient estimates than the OLS regressions.

In Model (2c) of Panel B, there is no evidence of the impact of faultline distance and an interaction between faultline distance and the diversity index on stock return volatility.

Overall, the robustness test shows that the main results still hold. This study finds that the negative relationship between heterogeneous boards and firm risk weakens in firms which have higher faultline strength than the median value of the industry. There is no evidence that faultline distance affects stock return volatility or the relationship between board diversity and firm risk.

Table 4.8 Robustness test: The impact of board diversity and board faultlines on firm risk

Table 4.8 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Model (1) and (2) shows the results of the OLS and 2SLS models respectively. The independent variables *diversity_index* (board diversity index), *strength* (dummy variable which equals 1 if the board faultline strength of a firm is higher than the median value of the industry and zero otherwise) and *distance* (dummy variable which equals 1 if the board faultline distance of a firm is higher than the median value of the industry and zero otherwise) are standardised by the sample mean and standard deviation. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The instruments include *diversity_index_county* (diversity index at the county level), *strength* * *diversity_index_county* (interaction between the county-level diversity index and strength variable), and *distance* * *diversity_index_county* (interaction between the county-level diversity index and distance variable). The standard errors (in parentheses) are clustered at the firm level. The description and definition of the independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: The impact of board diversity and faultline strength on firm risk

		Model (1)	Model (2a)	Model (2b)	Model (2c)
		OLS	First stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Diversity_index	Strength * diversity_index	Ln_monthly_vol
diversity_index_county	+/-		0.129***	-0.126***	
			(0.021)	(0.027)	
strength * diversity_index_county	+		-0.009	0.332***	
			(0.017)	(0.032)	
strength	+/-	-0.013	-0.025	0.080**	-0.014
		(0.009)	(0.018)	(0.036)	(0.012)
diversity_index	-	-0.011			-0.087
		(0.010)			(0.095)
strength * diversity_index	+	0.011			0.083**
		(0.009)			(0.033)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		7,870	5,508	5,508	5,508
Adj R-squared		0.606			
F statistics		8.505			69.96
P-value of F statistics		0.000			0.000
Endogeneity test					6.664
P-value of Endogeneity test					0.036
P-value of SW F test					0.000
P-value of SW chi-squared test					0.000

Panel B: The impact of board diversity and faultline distance on firm risk

		Model (1)	Model (2a)	Model (2b)	Model (2c)
		OLS	First stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Diversity_index	Distance * diversity_index	Ln_monthly_vol
diversity_index_county	+/-		0.130***	-0.102***	
			(0.021)	(0.025)	
distance * diversity_index_county	+		-0.010	0.303***	
			(0.017)	(0.031)	
distance	+/-	-0.012	0.001	0.083**	0.001
		(0.009)	(0.018)	(0.036)	(0.011)
diversity_index	-	-0.011			-0.053
		(0.009)			(0.096)
distance * diversity_index	+	0.012			-0.004
		(0.009)			(0.035)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		7,870	5,508	5,508	5,508
Adj R-squared		0.606			
F statistics		8.525			70.05
P-value of F statistics		0.000			0.000
Endogeneity test					0.315
P-value of Endogeneity test					0.854
P-value of SW F test					0.000
P-value of SW chi-squared test					0.000

4.9. Additional results

4.9.1 The interactive effect of faultlines and the board diversity index excluding each component of diversity on firm risk

The baseline regressions provide significant evidence that when the board faultline strength increases, the mitigating impact of diverse boards on firm risk becomes weaker. The study of Bernile et al. (2018) finds that no specific dimension of the aggregate board diversity index is associated with lower firm risk. However, the combination of multiple components of diversity negatively affects firm risk. Particularly, board diversity indexes excluding one specific element of diversity are significantly associated with a decrease in firm risk (Bernile et al., 2018).

Therefore, this research further investigates whether there is an interactive effect of board diversity indexes excluding each dimension of diversity and faultline strength/distance on firm risk. Following Bernile et al. (2018), this study measures six different diversity indexes: *index_exgender* (diversity index omitting gender diversity), *index_exage* (diversity index omitting age diversity), *index_exboardexp* (diversity index omitting board experience diversity), *index_exedu* (diversity index excluding education HHI), *index_exethnicity* (diversity index excluding ethnicity HHI), and *index_exfinexpert* (diversity index omitting financial expertise HHI). Then this research adds the interaction terms between the diversity index deleting one source of diversity and board faultlines. The interaction variables are *faultlines* * *index_exgender* (the interaction between board faultlines and the diversity index excluding gender diversity), *faultlines* * *index_exage* (the interaction between board faultlines and the diversity index excluding age diversity), *faultlines* * *index_exboardexp* (the interaction between board faultlines and the diversity index omitting board experience diversity), *faultlines* * *index_exedu* (the interaction between board faultlines and the diversity index excluding education HHI), *faultlines * index_exethnicity* (the interaction between board faultlines and the diversity index omitting ethnicity HHI), and *faultlines * index_exfinexpert* (the interaction between board faultlines and the diversity index excluding financial expertise HHI).

Table 4.9 presents the coefficient estimates of the interaction between board faultlines and the diversity index excluding one component of diversity by using 2SLS regressions. The 2SLS regression models use many instrumental variables. The variable *index_exgender_county* (the diversity index excluding gender diversity at the county level) is an instrument for *index_exgender*. The variable *faultlines * index_exgender_county* (the interaction between board faultlines and the diversity index excluding gender diversity at the county level) is an instrument for *faultlines * index_exgender*. The variable *index_exage_county* (the diversity index excluding age diversity at the county level) is an instrument for *index_exage*. The variable *faultlines * index_exage_county* (the interaction between board faultlines and the diversity index excluding age diversity at the county level) is an instrument for *faultlines * index_exage*. The variable *index_exboarexp_county* (the diversity index excluding board experience diversity at the county level) is an instrument for *index_exboardexp*. The variable *faultlines * index_exboardexp_county* (the interaction between board faultlines and the diversity index excluding board experience diversity at the county level) is an instrument for *faultlines * index_exboardexp*. The variable *index_exedu_county* (the diversity index excluding education diversity at the county level) is an instrument for *index_exedu*. The variable *faultlines * index_exedu_county* (the interaction between board faultlines and the diversity index excluding education diversity at the county level) is an instrument for *faultlines * index_exedu*. The variable *index_exethnicity_county* (the diversity index excluding ethnicity diversity at the county level) is an instrument for *index_exethnicity*.

The variable *faultlines* * *index_exethnicity_county* (the interaction between board faultlines and the diversity index excluding ethnicity diversity at the county level) is an instrument for *faultlines* * *index_exethnicity*. The variable *index_exfinexpert_county* (the diversity index excluding financial expertise diversity at the county level) is an instrument for *index_exfinexpert*. The variable *faultlines* * *index_exfinexpert_county* (the interaction between board faultlines and the diversity index excluding financial expertise diversity at the county level) is an instrument for *faultlines* * *index_exfinexpert*.

Panel A of Table 4.9 shows the estimated results of the interactive effect of faultline strength and the board diversity index excluding one component of diversity on firm risk. The coefficients of the interaction variables *faultlines* * *index_exgender, faultlines* * *index_exage, faultlines* * *index_exboardexp, faultlines* * *index_exedu, faultlines* * *index_exethnicity,* and *faultlines* * *index_exfinexpert* are all significantly positive. The coefficient of *faultlines* * *index_exgender* is 0.062. A one standard deviation increase in the board faultline strength and the diversity index excluding gender diversity leads to an increase in the monthly annualised stock return volatility by 0.062 percentage points. The coefficient of *faultlines* * *index_exage, faultlines* * *index_exboardexp,* and *faultlines* * *index_exedu* is 0.046, 0.047, and 0.039 respectively at the significance level of 5%. The coefficients of the interactions *faultlines* * *index_exethnicity* and *faultlines* * *index_exfinexpert* are 0.038 and 0.042 at the significance level of 10% and 5% respectively. A one standard deviation increase in the board faultline strength and the diversity index excluding ethnicity diversity (or diversity index excluding financial expertise diversity) leads to a rise in the stock return volatility by 0.038 (0.042) percentage points. The endogeneity test shown in Panel A indicates that there is an endogeneity problem (p-value is lower than 10%). Therefore, the estimates of the 2SLS regression models are more efficient than those of the OLS regressions. The instruments used in the

2SLS regressions are also relevant (p-value of SW chi-squared test is lower than 1%) and not weak (p-value of SW F test is lower than 1%).

Panel B of Table 4.9 presents the interactive effect of faultline distance and the diversity indexes excluding one component of diversity on firm risk by using 2SLS regressions with instruments. The coefficients of interaction variables (*faultlines * index_exgender, faultlines * index_exage, faultlines * index_exboardexp), faultlines * index_exedu, faultlines * index_exethnicity,* and *faultlines * index_exfinexpert*) are insignificant. There is no evidence that the diversity indexes omitting one specific dimension of diversity are associated with higher firm risk when the faultline distance is high.

Overall, the negative association between board diversity indexes excluding one element of diversity and stock return volatility weakens when the board faultline strength is high. When members in each of various subgroups within the boardroom are extremely similar (high board faultline strength or high level of cohesion within a subset), the risk mitigating effect of boards (which are diverse in a certain number of dimensions) becomes weaker. This finding is in line with the conjecture of Bernile et al. (2018) that the combination of various aspects of diversity has a significant impact on firm risk. However, there is no evidence of the interactive effect of board diversity indexes omitting one component of diversity and faultline distance on firm risk.

Table 4.9 The interactive effect of faultlines and board diversity index excluding each component of diversity on firm risk

Table 4.9 presents the empirical results of the second stage of the 2SLS models with firm and year fixed effects. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The independent variables *index_exgender, index_exage, index_exboardexp, index_exedu, index_exethnicity, index_exfinexpert,* and *faultlines* are standardised by the sample mean and standard deviation. The standard errors (in parentheses) are clustered at the firm level. The description and definition of the independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: The interactive effect of faultline strength and board diversity index excluding each component of diversity on firm risk

	Expected sign	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol
Index_exgender	-	-0.137 (0.093)					
Faultlines * Index_exgender	+	0.062** (0.025)					
Index_exage	-		0.009 (0.100)				
Faultlines * Index_exage	+		0.046** (0.019)				
Index_exboardexp	-			-0.070 (0.088)			
Faultlines * Index_exboardexp	+			0.047** (0.019)			
Index_exedu	-				-0.064 (0.075)		
Faultlines * Index_exedu	+				0.039** (0.018)		
Index_exethnicity	-					-0.107 (0.077)	
Faultlines * Index_exethnicity	+					0.038* (0.021)	
Index_exfinexpert	-						-0.040 (0.070)
Faultlines * Index_exfinexpert	+						0.042** (0.017)
Faultlines	+/-	-0.004 (0.007)	-0.003 (0.006)	0.000 (0.006)	-0.002 (0.006)	-0.002 (0.006)	-0.001 (0.006)
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		5,912	5,912	5,912	5,912	5,912	5,912
F statistics		68.13	74.03	72.82	73.55	71.08	73.60
P-value of F statistics		0.000	0.000	0.000	0.000	0.000	0.000
Endogeneity test		11.250	5.213	7.560	6.203	7.509	7.644
P-value of Endogeneity test		0.004	0.074	0.023	0.045	0.023	0.022
P-value of SW F test		0.000	0.000	0.000	0.000	0.000	0.000
P-value of SW chi-squared test		0.000	0.000	0.000	0.000	0.000	0.000

Table 4.9 The interactive effect of faultlines and the board diversity index excluding each component of diversity on firm risk (cont.)

Table 4.9 presents the empirical results of the second stage of the 2SLS models with firm and year fixed effects. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The independent variables *index_exgender, index_exage, index_exboardexp, index_exedu, index_exethnicity, index_exfinexpert,* and *faultlines* are standardised by the sample mean and standard deviation. The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel B: The interactive effect of faultline distance and board diversity index excluding each component of diversity on firm risk

	Expected sign	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol
Index_exgender	-	-0.150					
		(0.092)					
Faultlines * Index_exgender	+	0.005					
		(0.022)					
Index_exage	-		-0.001				
			(0.098)				
Faultlines * Index_exage	+		-0.004				
			(0.018)				
Index_exboardexp	-			-0.073			
				(0.088)			
Faultlines * Index_exboardexp	+			-0.009			
				(0.022)			
Index_exedu	-				-0.065		
					(0.075)		
Faultlines * Index_exedu	+				-0.003		
					(0.016)		
Index_exethnicity	-					-0.111	
						(0.077)	
Faultlines * Index_exethnicity	+					0.001	
						(0.020)	
Index_exfinexpert	-						-0.043
							(0.070)
Faultlines * Index_exfinexpert	+						-0.006
							(0.017)
Faultlines	+/-	0.002	0.005	0.006	0.005	0.005	0.006
		(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)
Control variables		Yes	Yes	Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes	Yes	Yes
Observations		5,912	5,912	5,912	5,912	5,912	5,912
F statistics		68.45	74.89	73.36	73.83	70.59	74.26
P-value of F statistics		0.000	0.000	0.000	0.000	0.000	0.000
Endogeneity test		2.998	0.485	1.244	1.195	2.553	0.936
P-value of Endogeneity test		0.223	0.784	0.537	0.550	0.279	0.626
P-value of SW F test		0.000	0.000	0.000	0.000	0.000	0.000
P-value of SW chi-squared test		0.000	0.000	0.000	0.000	0.000	0.000

4.9.2 The interactive effect of faultlines and specific components of the diversity index on firm risk

In this section, this study continues to examine the interactive effect of faultlines and each specific component of the diversity index on stock return volatility. Table 4.10 reports the estimated results of the interactive impact of each specific dimension of the board diversity index and faultlines on firm risk. The dependent variable is the monthly annualised stock return volatility. The main independent variables include *faultlines * gender_diversity* (the interaction between board faultlines and gender diversity), *faultlines * age_diversity* (the interaction between board faultlines and age diversity), *faultlines * boardexp_diversity* (the interaction between board faultlines and board experience diversity), *faultlines * edu_hhi* (the interaction between board faultlines and the Herfindahl concentration index for educational background), *faultlines * ethnicity_hhi* (the interaction between board faultlines and Herfindahl index for ethnicity groups of directors), and *faultlines * finexpert_hhi* (the interaction between board faultlines and Herfindahl concentration index for the financial expertise of directors).

The coefficients of the primary variables are estimated based on both OLS and 2SLS regressions with firm and year fixed effects. In the 2SLS models, the instruments are specific dimensions of the diversity index at the county level including *gender_diversity_county* (the county-level gender diversity), *age_diversity_county* (the county-level age diversity), *boardexp_diversity_county* (the county-level board experience diversity), *edu_hhi_county* (the county-level Herfindahl index for educational background), *ethnicity_hhi_county* (the county-level Herfindahl index for ethnicity, and *finexpert_hhi_county* (the county-level Herfindahl index for financial expertise). They are instrumental variables for endogenous variables including *gender_diversity,* *age_diversity, boardexp_diversity, edu_hhi, ethnicity_hhi,* and *finexpert_hhi* respectively. In addition, the interaction between the components of the diversity index at the county level and faultlines are used as instruments for the interaction variables between board faultlines and *gender_diversity, age_diversity, boardexp_diversity, edu_hhi, ethnicity_hhi, and finexpert_hhi*.

Models (1) and (2) report the results of the interactive effect of specific components of the board diversity index and faultline strength on firm risk based on OLS and 2SLS regression respectively. Models (3) and (4) present the estimates of the association between the stock return volatility and the interaction between faultline distance and various components of diversity by using OLS and 2SLS models respectively. The endogeneity test shows that there is an endogeneity issue because the p-value of the endogeneity test is lower than 10%. In addition, the instruments used in the 2SLS regressions are relevant and not weak because p-values of SW chi-squared test of under-identification and F test of weak identification are lower than 1%. Therefore, the estimations of 2SLS models are more efficient than those of OLS regressions.

Models (2) and (4) show that the coefficients of all independent variables of interest are insignificant. There is no evidence that a single component of the diversity index affects the stock return volatility. In addition, this study finds no evidence of the interactive effect of faultlines and a specific element of the aggregate diversity index on firm risk. The results in Table 4.10 are consistent with the findings of Bernile et al. (2018) that no specific component of board diversity index has a significant impact on firm risk. However, the combination of various source of diversity does significantly influence the stock return volatility.

Table 4.10 The interactive effect of specific components of board diversity index and faultlines on firm risk

Table 4.10 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The independent variables *gender_diversity, age_diversity, boardexp_diversity, edu_hhi, ethnicity_hhi, finexpert_hhi,* and *faultlines* are standardised by the sample mean and standard deviation. The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

		Faultline strength		Faultline distance	
		Model (1)	Model (2)	Model (3)	Model (4)
		OLS	Second stage -2SLS	OLS	Second stage -2SLS
	Expected sign	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol	Ln_monthly_vol
gender_diversity	-	0.001	0.220	0.001	0.151
		(0.008)	(0.320)	(0.008)	(0.429)
age_diversity	-	0.002	-0.286	0.002	-0.155
		(0.008)	(0.555)	(0.008)	(0.533)
boardexp_diversity	-	0.012	-0.102	0.012	-0.057
		(0.010)	(0.236)	(0.010)	(0.072)
edu_hhi	+	0.006	0.927	0.007	0.226
		(0.008)	(2.525)	(0.008)	(1.929)
ethnicity_hhi	+	-0.002	-0.078	-0.001	-0.044
		(0.008)	(0.237)	(0.008)	(0.304)
finexpert_hhi	+	0.007	-0.501	0.007	0.051
		(0.005)	(1.939)	(0.005)	(1.687)
faultlines * gender_diversity	+	0.001	0.053	-0.002	-0.037
		(0.005)	(0.299)	(0.005)	(0.391)
faultlines * age_diversity	+	-0.005	0.048	-0.002	0.014
		(0.005)	(0.106)	(0.005)	(0.045)
faultlines * boardexp_diversity	+	-0.004	0.047	0.002	-0.002
		(0.005)	(0.208)	(0.005)	(0.377)
faultlines * edu_hhi	-	-0.004	0.156	0.000	-0.014
		(0.006)	(0.624)	(0.005)	(1.035)
faultlines * ethnicity_hhi	-	-0.004	-0.061	-0.002	-0.012
		(0.005)	(0.084)	(0.005)	(0.134)
faultlines * finexpert_hhi	-	-0.007	-0.063	-0.010**	-0.054
		(0.004)	(0.248)	(0.004)	(1.081)
faultlines	+/-	-0.003	0.021	-0.003	0.003
		(0.005)	(0.077)	(0.005)	(0.053)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		8,216	5,912	8,216	5,912
Adj R-squared		0.602		0.602	
F statistics		6.225	9.914	6.102	38.85
P-value of F statistics		0.000	0.000	0.000	0.000
Endogeneity test			27.51		21.01
P-value of Endogeneity test			0.007		0.050
P-value of SW F test of weak identification			0.000		0.000
P-value of SW chi-squared test of under-identification			0.000		0.000

4.9.3 The interactive effect of board faultlines and the diversity of executive and non-executive directors on firm risk

In this section, this study repeats the main regressions by separating the impact of the diversity of executive and non-executive directors on firm risk. The research of Bernile et al. (2018) finds that the negative effect of board diversity on firm risk is primarily due to the diversity of non-executive directors. The explanation is that executive directors have more chance to work together every day and interact with each other more regularly than non-executive directors. Thus, there is a high probability that non-executive directors have more diverse perspectives and careful discussions before making decisions than executive members (Bernile et al., 2018). Therefore, it is important to examine whether strong board faultlines weaken the risk management function of a diverse group of non-executive versus executive directors. This study conjectures that the relationship between firm risk and diversity of executive versus non-executive directors is positive when board faultlines are high.

Table 4.11 reports the OLS and 2SLS regression results of the interactive effect of board faultlines and the diversity of executive and non-executive directors on firm risk. This research adds the diversity index of executive directors (*ex_diversity_index*) and non-executive directors (*nonex_diversity_index*) in the regression models. This study also includes the interaction between faultline strength and the diversity index of executive directors (*fau_strength * ex_diversity_index*), faultline strength and the diversity index of non-executive directors (*fau_strength * nonex_diversity_index*), faultline distance and the diversity index of executive directors (*fau_distance * ex_diversity_index*), faultline distance and the diversity index of non-executive directors (*fau_distance * nonex_diversity_index*).

Model (1) of Panel A and B of Table 4.11 presents that the coefficients of *ex_diversity_index* (diversity of executive directors), *fau_strength* * *ex_diversity_index* (interaction between faultline strength and diversity of executive directors), *nonex_diversity_index* (diversity of non-executive directors), and *fau_strength* * *nonex_diversity_index* (interaction between faultline strength and diversity of non-executive directors) are insignificant in OLS regressions.

In Model (2c) of Panel A of Table 4.11, the empirical results of the 2SLS model show that the coefficient of *fau_strength* * *ex_diversity_index* (interaction between faultline strength and diversity of executive directors) is positive (0.110) at the significance level of 10%. When the board faultline strength increases by one standard deviation, a one standard deviation increase in the diversity index of executive directors leads to a rise in stock return volatility by 0.110 percentage points. In Model (2c) of Panel B, the coefficient of *fau_strength* * *nonex_diversity_index* (interaction between faultline strength and the diversity of non-executive directors) is also positive (0.052) and significant at the level of 5%. Stock return volatility goes up by 0.052 percentage points due to a one standard deviation increase in the diversity index of non-executive directors when board faultline strength increases by one standard deviation. The coefficient of *fau_strength* * *ex_diversity_index* (0.110) is higher than that of *fau_strength* * *nonex_diversity_index* (0.052)[44]. It means that when there is a one standard deviation increase in board faultline strength, the diversity index of the executive directors is associated with higher stock return volatility than that of non-executive directors. The estimations of 2SLS regressions in Model (2) of Panel A and B are more efficient than those of OLS regressions because there are endogeneity issues (p-value of endogeneity

[44] When this study re-estimates 2SLS regressions in both Panel A and B with the same number of observations, this research also finds that the coefficient of *fau_strength* * *ex_diversity_index* (0.105) is higher than that of *fau_strength* * *nonex_diversity_index* (0.062).

test is lower than 5%). Moreover, the instruments *diversity_index_county* (the county-level diversity index) and *fau_strength* * *diversity_index_county* (interaction between faultline strength and the county-level diversity index) are relevant and not weak because p-values of SW F test and chi-squared test are lower than 5%.

The interactive effects of board faultline distance and the diversity of executive and non-executive directors on firm risk are shown in Panel C and D of Table 4.11. The coefficients of *fau_distance* * *ex_diversity_index* (the interaction between faultline distance and the diversity of executive directors) and *fau_distance* * *nonex_diversity_index* (the interaction between faultline distance and diversity of non-executive directors) are not significant in both OLS and 2SLS regression models.

In conclusion, the relationship between firm risk and the diversity of executive and non-executive directors is positive when the directors in each of different subgroups within the board are extremely similar (high board faultline strength or a high level of cohesion within the subgroup). There is no evidence that board faultline distance influences the association between the diversity of executive and non-executive directors and stock return volatility.

Table 4.11 The interactive effect of board faultlines and diversity of executive and non-executive directors on firm risk

Table 4.11 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Model (1) and (2) show the results of the OLS and 2SLS models respectively. The instruments include *diversity_index_county* (diversity index at the county level), *fau_strength* * *diversity_index_counrty* (the interaction between faultline strength and diversity index at the county level), and *fau_distance* * *diversity_index_counrty* (the interaction between faultline distance and diversity index at the county level). The independent variables ex*_diversity_index* (diversity index of executive directors), *nonex_diversity_index* (diversity index of non- executive directors), *fau_strength* (board faultline strength), and *fau_distance* (board faultline distance) are standardised by the sample mean and standard deviation. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The standard errors (in parentheses) are clustered at the firm level. The description and definition of independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: The interactive effect of faultline strength and diversity of executive directors on firm risk

		Model (1)	Model (2a)	Model (2b)	Model (2c)
		OLS	First stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Ex_diversity_index	Fau_strength * ex_diversity_in	Ln_monthly_vol
diversity_index_county	+/-		0.082***	-0.059	
			(0.030)	(0.040)	
fau_strength * diversity_index_county	+		-0.011	0.150***	
			(0.016)	(0.035)	
fau_strength	+/-	-0.002	0.013	0.035	-0.001
		(0.006)	(0.016)	(0.039)	(0.009)
ex_diversity_index	-	0.000			-0.075
		(0.007)			(0.189)
fau_strength * ex_diversity_index	+	-0.006			0.110*
		(0.005)			(0.059)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		6,096	4,341	4,341	4,341
Adj R-squared		0.614			
F statistics		6.417			49.49
P-value of F statistics		0.000			0.000
Endogeneity test					8.028
P-value of Endogeneity test					0.018
P-value of SW F test					0.000
P-value of SW chi-squared test					0.017

Panel B: The interactive effect of faultline strength and diversity of non-executive directors on firm risk

		Model (1)	Model (2a)	Model (2b)	Model (2c)
		OLS	First stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Nonex_diversity_index	Fau_strength * nonex_diversity_index	Ln_monthly_vol
diversity_index_county	+/-		0.098***	-0.042	
			(0.020)	(0.032)	
fau_strength * diversity_index_county	+		0.002	0.279***	
			(0.011)	(0.035)	
fau_strength	+/-	-0.002	-0.007	0.082**	-0.002
		(0.005)	(0.012)	(0.038)	(0.007)
nonex_diversity_index	-	0.005			-0.113
		(0.008)			(0.117)
fau_strength * nonex_diversity_index	+	0.007			0.052**
		(0.005)			(0.022)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		8,178	5,886	5,886	5,886
Adj R-squared		0.602			
F statistics		8.775			69.12
P-value of F statistics		0.000			0.000
Endogeneity test					7.430
P-value of Endogeneity test					0.024
P-value of SW F test					0.000
P-value of SW chi-squared test					0.000

Table 4.11 The interactive effect of board faultlines and diversity of executive and non-executive directors on firm risk (cont.)

Table 4.11 presents the empirical results of the OLS and 2SLS models with firm and year fixed effects. Model (1) and (2) show the results of the OLS and 2SLS models respectively. The instruments include *diversity_index_county* (diversity index at the county level), *fau_strength* * *diversity_index_counrty* (the interaction between faultline strength and diversity index at the county level), and *fau_distance* * *diversity_index_county* (the interaction between faultline distance and diversity index at the county level). The independent variables ex_*diversity_index* (diversity index of executive directors), *nonex_diversity_index* (diversity index of non- executive directors), *fau_strength* (board faultline strength), and *fau_distance* (board faultline distance) are standardised by the sample mean and standard deviation. The dependent variable is l*n_monthly_vol* (log of monthly annualised stock return volatility). The standard errors (in parentheses) are clustered at the firm level. The description and definition of the independent variables are provided in Table 4.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel C: The interactive effect of faultline distance and diversity of executive directors on firm risk

		Model (1)	Model (2a)	Model (2b)	Model (2c)
		OLS	First stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Ex_diversity_index	Fau_distance * ex_diversity_in	Ln_monthly_vol
diversity_index_county	+/-		0.081***	-0.004	
			(0.030)	(0.035)	
fau_distance * diversity_index_county	+		-0.000	0.171***	
			(0.017)	(0.062)	
fau_distance	+/-	0.005	0.009	0.154***	0.016*
		(0.006)	(0.018)	(0.059)	(0.010)
ex_diversity_index	-	0.000			-0.137
		(0.007)			(0.179)
fau_distance * ex_diversity_index	+	-0.001			-0.015
		(0.005)			(0.044)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		6,096	4,341	4,341	4,341
Adj R-squared		0.614			
F statistics		7.922			53.47
P-value of F statistics		0.000			0.000
Endogeneity test					0.857
P-value of Endogeneity test					0.651
P-value of SW F test					0.005
P-value of SW chi-squared test					0.007

Panel D: The interactive effect of faultline distance and diversity of non-executive directors on firm risk

		Model (1)	Model (2a)	Model (2b)	Model (2c)
		OLS	First stage-2SLS	First stage-2SLS	Second stage-2SLS
	Expected sign	Ln_monthly_vol	Nonex_diversity_index	Fau_distance * nonex_diversity_index	Ln_monthly_vol
diversity_index_county	+/-		0.098***	-0.001	
			(0.020)	(0.029)	
fau_distance * diversity_index_county	+		0.003	0.292***	
			(0.011)	(0.038)	
fau_distance	+/-	-0.002	0.003	0.236***	0.006
		(0.005)	(0.013)	(0.046)	(0.008)
nonex_diversity_index	-	0.005			-0.121
		(0.008)			(0.117)
fau_distance * nonex_diversity_index	+	0.002			-0.003
		(0.005)			(0.020)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		8,178	5,886	5,886	5,886
Adj R-squared		0.602			
F statistics		10.77			68.44
P-value of F statistics		0.000			0.000
Endogeneity test					1.482
P-value of Endogeneity test					0.477
P-value of SW F test					0.000
P-value of SW chi-squared test					0.000

4.10. Conclusions

Board diversity brings both benefits and costs to organisations. Heterogeneous boards provide multiple perspectives, skills, and experience, which may improve corporate performance and minimise firm risk. However, one of the disadvantages of board heterogeneity is the formation of homogenous coalitions which can cause conflicts, friction, and misunderstandings between members of the board. This downside of board diversity can negatively influence board effectiveness and the decision-making process. Prior studies on the association between board diversity and firm risk are still inconclusive (Bernile et al., 2018; Giannetti & Zhao, 2019). This research contributes to the literature by proposing that board faultline strength and distance are critical confounding factors which affect the impact of board diversity on firm risk. The board faultline strength and distance are proxies for the degree of friction within the boardroom.

This research finds that when the board faultline strength increases (the cohesion degree of subgroups within a boardroom based on a certain number of the attributes of directors being higher), the negative relationship between board diversity and firm risk becomes weaker. When board members in each different coalition share many similar characteristics (high faultline strength), there are inherent conflicts among various subgroups. In this case, the risk mitigating effect of board heterogeneity weakens. However, there is no evidence of the interactive effect of the board diversity index and faultline distance (the extent to which different subgroups diverge) on firm risk. In addition, the results in the robustness test are in line with the conjecture that heterogeneous boards in companies with larger board faultline strength than the median value of the industry are associated with higher firm risk than those in firms with lower board faultline strength.

This study further examines whether board faultline strength and distance affect the influence of the board diversity indexes omitting one specific component of diversity on firm risk as well as the impact of a single element of diversity on firm risk. The motivation for this analysis is to investigate the findings of Bernile et al. (2018) that the combination of various elements of diversity has a significant effect on firm risk but not a specific component of diversity. Overall, this research shows that when the board faultline strength is high, the negative link between board diversity indexes omitting one specific component of diversity and stock return volatility becomes weaker. However, there is no evidence that a single element of diversity is related to firm risk when the board faultline strength and distance are high. In addition, this research adds that the mitigating impact of the diversity of both executive and non-executive directors on firm risk weakens when there is an increase in board faultline strength.

CHAPTER 5. GENERAL CONCLUSIONS

5.1. Introduction

This thesis comprises three studies examining important issues in internal corporate governance mechanisms relating to CEO compensation and board diversity. The first study investigates the impact of CEO inside debt compensation on innovative output. The board of directors has a major role in setting CEO pay packages to incentivise CEOs to achieve the firm's targets. The second study examines the association between board diversity and CEO pay incentives, including equity and inside debt incentives. The final study focuses on the impact of board faultline strength/distance on firm risk as well as the interactive effect of board faultline strength/distance and multi-dimensional board diversity on corporate risk.

5.2. Summary of main findings and contributions

This section summarises the main results of the three studies and the key contributions to the current literature. The first study finds that CEOs with large inside debt holdings have fewer incentives to increase innovative activities. This result supports the conjecture of Jensen and Meckling (1976) that inside debt compensation aligns the interests of CEOs with those of debt-holders, and thus incentivises CEOs to choose less risky policies. The negative effect of inside debt compensation mainly comes from pension benefits. Executives with a large portion of pension benefits have less incentive to convert R&D expenditures into more patents. Moreover, there is a significantly negative association between CEO inside debt incentives and innovation efficiency, which is measured by the research quotient.

This study contributes to the existing literature on inside debt compensation (Anantharaman et al., 2013; Cassell et al., 2012; Edmans & Liu, 2011; Jensen & Meckling, 1976; Phan, 2014; Sundaram & Yermack, 2007; Wei & Yermack, 2011) and firm innovation (Balsmeier et al., 2017; Becker-Blease, 2011; Francis et al., 2011; Hall et al., 2005; Sunder et al., 2017) by enhancing the understanding of whether CEOs with large inside debt holdings have less motivation to innovate. Moreover, CEO inside debt compensation is a significant factor affecting the behaviours of top executives in encouraging innovative activities. Overall, the results of this study suggest that the board of directors should consider reducing CEO inside debt compensation if they wish to enhance innovation strategies.

The second study shows that multi-dimensional diverse boards decrease the CEO equity incentives (vega of stocks and options and vega of options only) and increase the CEO inside debt incentives (the CEO relative leverage ratio). Diverse boards in firms with a high leverage ratio tend to decrease CEO equity incentives. The association between board diversity and CEO pay incentives is mainly due to the diversity of non-executive directors. In addition, highly diverse compensation committees are associated with lower CEO equity incentives and higher inside debt incentives. When investigating the effect of a single component of diversity on CEO pay incentives, this study finds that gender diversity is positively related to CEO inside debt incentives. Moreover, boards which are more diverse in financial expertise provide higher CEO inside debt incentives. However, no specific component of the diversity index influences CEO equity incentives.

The findings of this study add substantially to the literature on board diversity (Adams & Ferreira, 2007, 2009; Bernile et al., 2018; Bugeja et al., 2016; Carter et al., 2003; Giannetti & Zhao, 2019; Miller & del Carmen Triana, 2009; Prevost & Upadhyay, 2018) and executive compensation (Anantharaman et al., 2013; Cassell et al., 2012; Coles et al., 2006; Edmans & Liu, 2011; Guay, 1999; Jensen & Meckling, 1976; Phan, 2014; Sundaram & Yermack, 2007; Wei & Yermack, 2011). In particular, this research provides evidence that diverse boards play a key role in setting CEO equity and inside debt incentives.

The third study provides significant evidence that the negative relationship between board diversity and stock return volatility become weaker in the presence of high board faultline strength. However, there is no evidence of an effect of board faultline distance on stock return volatility or the interactive impact of board diversity index and faultline distance on firm risk. When examining the influence of board faultline strength/distance on the relationship between individual components of diversity and firm risk, this study reports insignificant results. However, there is still a positive relationship between firm risk and the interaction between board faultline strength and the board diversity index omitting one specific component of diversity. In addition, in boards with high faultline strength, the negative impact of diversity of both executive and non-executive directors on corporate risk weakens.

The third study contributes to a growing body of literature on board faultlines, board diversity and corporate risk (Bernile et al., 2018; Giannetti & Zhao, 2019; Peteghem et al., 2018) and to the understanding of the risk management role of heterogeneous boards. The results show that board faultline is one of the critical confounding factors affecting the association between multi-dimensional board diversity and firm risk, and that diverse boards with high faultline strength (which creates more possible conflicts within the boardroom) are positively associated with firm risk. These results imply that corporations should carefully consider the internal structure of a diverse board to reduce potential frictions among directors to manage firm risk efficiently.

5.3. Limitations of research

This section briefly discusses the limitations of the thesis. In the first study, there may still be the problem of endogeneity. The propensity score matching method used in this research may not overcome the endogeneity issue. Following the research of Phan (2014) and Cassell et al. (2012), instruments can be the maximum income tax rate for wages by state and year for individuals[45]and the industry median CEO relative leverage (incentive)[46]. I ran a two-step GMM estimation with these instruments; however, these instruments are invalid (the p-value of the Hansen J statistics is lower than 1%).

The second and third studies use 2SLS regressions with instruments to account for the endogeneity problem. I calculate the diversity index of directors at the county level as an instrument for the firm-level diversity index. This instrumental variable is relevant and not weak based on the SW chi-squared test of under-identification and the F test of weak identification. An extension or further robustness test would be to adopt the Bernile et al. (2018)'s instrumental variable. Bernile et al. (2018) measure the instrumental variable for the board diversity index by constructing the diversity index of non-local directors who live one non-stop flight away from the site of the firm's headquarters. However, I was

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[45] The data of state individual tax rates in US is obtained from http://users.nber.org/~taxsim/state-rates/. The state individual tax rates are calculated based on the TAXSIM model suggested by Feenberg and Coutts (1993). The state is assumed to be where the firm headquarters are situated.
Executives who face higher tax rates for wages may want to receive more pension benefits and deferred compensation. There are two main reasons for this argument. First, CEOs are able to decrease the present value of their tax payment if they can delay their tax payment by increasing their pension benefits and deferred compensation. Second, CEOs may also face a lower tax rate at the time of their retirement if their taxable income no longer belongs to the highest tax bracket when they retire (Anantharaman et al., 2013). The significantly positive link between CEO debt-based compensation and the tax rate for wages is supported by the research of Wang, Xie, and Xin (2017) and Anantharaman et al. (2013).

[46] It is expected that the higher the industry median CEO relative leverage (incentive) by year, the larger the CEO relative leverage (incentive) ratio because CEOs also receive compensation depending on the industry practices (Anantharaman et al., 2013; Cassell et al., 2012; Phan, 2014).

unable to collate information on the residence of directors from databases that were available for this study.

5.4. Recommendations for future research

The findings of this thesis provide the following insights for future research.

First, this thesis finds that diverse boards tend to reduce CEO equity incentives and increase inside debt incentives to encourage top executives to take less risk. Further research might investigate whether a high level of board faultline strength/distance (which creates more potential conflicts among directors) is detrimental to the role of the diverse board in setting the CEO's compensation.

Second, board faultline strength and distance are measured based on nine characteristics of directors: independence, insider, affiliated outsider, financial expertise, multiple board membership, age, gender, tenure, and share ownership as adopted by Peteghem et al. (2018). The information on the ancestral origins of the directors (Giannetti & Zhao, 2019) may provide additional information to the measures of board faultline strength and distance. This is because differences in the countries of origin of the directors might represent cultural and genetic dissimilarities which potentially increase disagreements within the boardroom.

Third, this thesis provides evidence that board diversity is positively associated with firm risk when board faultline strength increases. This result implies that board faultline strength reduces the effectiveness of a diverse board in managing firm risk. Future research might focus on examining whether board faultlines also impact the efficiency of a heterogeneous board in conducting firm policies. For example, further study might investigate the impact of board faultlines on the relationship between board diversity and corporate investment, brand development, leverage and dividend-paying policies.

Fourth, there is potential for many future studies using the construct of the board diversity index and board faultlines. For example, it would be interesting to examine the effect of a board, which is diverse in multiple dimensions, on mergers and acquisitions (M&A) decisions. Whether a diverse board efficiently improves M&A deals is an empirical question. There is scant prior literature on whether or not board heterogeneity also significantly affects a firm's M&A propensity or M&A target selection. Further research might investigate whether strong faultline strength/distance negatively affects M&A related decisions and influences the relationship between board diversity and M&A transactions.

Finally, further research can be undertaken to explore the impact of multi-dimensional diversity and faultlines of board committees including audit, remuneration, corporate governance, and nomination committees on firm performance and policies. Board committees which work efficiently should improve the overall performance of the board of directors.

APPENDICES OF CHAPTER 2

Table A2.1 Summary statistics

Table A2.1 reports the summary statistics of 6,036 firm-year observations during 2006-2013. The description and definition of variables are provided in Table 2.1

Variable	N	mean	median	25th quartile	75th quartile	Std. Dev
Panel A: Patents and Citations						
Number of patents	6,036	46	1	0	16	258
Number of citations	6,036	119	0	0	20	732
Panel B: CEO compensation, relative inside debt ratios						
CEO inside debt (1000$)	6,036	6,255	1,138	0	6,224	14,287
CEO deferred compensation (1000$)	6,036	2,890	287	0	2,008	9,880
CEO pension compensation (1000$)	6,036	3,365	0	0	2,905	8,018
CEO equity compensation (1000$)	6,036	126,000	18,438	7,608	45,449	1,340,000
Salary & bonus (1000$)	6,036	1,045	881	658	1,121	1,436
CEO delta (1000$)	6,036	1,379	252	99	627	13,514
CEO vega (1000$)	6,036	186	79	24	212	419
CEO debt to equity ratio	6,036	0.39	0.07	0	0.31	4.55
CEO relative leverage	6,036	16.04	0.33	0	1.66	252.21
CEO relative leverage > 1	6,036	0.34	0	0	1	0.47
CEO relative incentive	6,036	21.84	0.39	0	1.87	336.42
CEO relative incentive >1	6,036	0.36	0	0	1	0.48
Pension relative leverage	6,036	6.76	0	0	0.6	145.56
Pension relative leverage > 1	6,036	0.2	0	0	0	0.4
Pension relative incentive	6,036	9.97	0	0	0.67	212.41
Pension relative incentive >1	6,036	0.2	0	0	0	0.4
Defer relative leverage	6,036	9.28	0.05	0	0.56	182.06
Defer relative leverage > 1	6,036	0.18	0	0	0	0.38
Defer relative incentive	6,036	11.87	0.06	0	0.66	217
Defer relative incentive > 1	6,036	0.2	0	0	0	0.4
Panel C: Firm-level characteristics						
Firm_size	6,036	7.89	7.73	6.79	8.8	1.47
RD_intensity	6,036	0.03	0	0	0.03	0.05
ROA	6,036	0.05	0.06	0.03	0.09	0.09
Sales_growth	6,036	0.08	0.07	-0.01	0.14	0.24
Leverage	6,036	0.22	0.21	0.11	0.31	0.15
Stock return	6,036	0.16	0.13	-0.12	0.37	0.49
Panel D: CEO characteristics						
CEO age	6,036	55.91	56	51	60	6.66
CEO tenure	6,036	7.95	6	3	10.5	7.03
Overconfidence	6,036	0.27	0	0	1	0.45
Panel E: Board size and independent directors						
Ratio of independent directors	6,036	0.79	0.8	0.71	0.88	0.11
Ln_in_directors	6,036	0.58	0.59	0.54	0.63	0.07
Board size	6,036	9.24	9	8	11	2.1
Independent directors	6,036	7.28	7	6	9	2.06

Table A2.2 Correlation matrix

Table A2.2 reports the correlation matrix of variables. The description and definition of variables are provided in Table 2.1 * p< 0.05, ** p<0.01, *** p<0.001

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Patent	1												
2. Citation	0.752***	1											
3. Ln_CEO relative leverage	0.0578***	0.0428***	1										
4. Ln_CEO relative incentive	0.0397**	0.0338**	0.988***	1									
5. CEO relative leverage > 1	0.0790***	0.0687***	0.725***	0.715***	1								
6. CEO relative incentive > 1	0.0708***	0.0683***	0.706***	0.713***	0.911***	1							
7. Ln_pension relative leverage	0.0307*	0.0242	0.717***	0.704***	0.566***	0.544***	1						
8. Ln_pension relative incentive	0.0154	0.0160	0.707***	0.711***	0.556***	0.546***	0.989***	1					
9. Pension relative leverage > 1	0.0664***	0.0586***	0.545***	0.529***	0.698***	0.643***	0.775***	0.763***	1				
10. Pension relative incentive > 1	0.0403**	0.0454***	0.535***	0.533***	0.663***	0.677***	0.765***	0.768***	0.923***	1			
11. Ln_defer relative leverage	0.0678***	0.0542***	0.817***	0.807***	0.533***	0.521***	0.249***	0.241***	0.161***	0.154***	1		
12. Ln_defer relative incentive	0.0500***	0.0450***	0.805***	0.815***	0.524***	0.526***	0.240***	0.242***	0.150***	0.148***	0.989***	1	
13. Defer relative leverage > 1	0.104***	0.0889***	0.615***	0.605***	0.650***	0.608***	0.220***	0.208***	0.177***	0.172***	0.744***	0.735***	1
14. Defer relative incentive > 1	0.0880***	0.0784***	0.594***	0.603***	0.614***	0.659***	0.206***	0.205***	0.168***	0.169***	0.722***	0.733***	0.904***
15. Firm size	0.268***	0.218***	0.0963***	0.0619***	0.189***	0.171***	0.124***	0.0951***	0.177***	0.154***	0.0466***	0.0178	0.0895***
16. RD intensity	0.127***	0.127***	-0.0180	-0.0141	-0.0528***	-0.0569***	-0.0484***	-0.0479***	-0.0610***	-0.0657***	0.0221	0.0269*	0.0147
17. ROA	0.0608***	0.0417**	0.113***	0.0947***	0.113***	0.101***	0.0598***	0.0458***	0.0746***	0.0630***	0.102***	0.0867***	0.103***
18. Sales_growth	-0.00444	0.00628	-0.0560***	-0.0587***	-0.0718***	-0.0771***	-0.0766***	-0.0779***	-0.0775***	-0.0808***	-0.0184	-0.0208	-0.0223
19. Leverage	-0.0256*	-0.0361**	-0.286***	-0.286***	-0.191***	-0.191***	-0.159***	-0.158***	-0.0909***	-0.0856***	-0.273***	-0.273***	-0.234***
20. Ln_CEO age	-0.0177	-0.0128	0.124***	0.115***	0.126***	0.120***	0.140***	0.136***	0.135***	0.136***	0.0575***	0.0484***	0.0605***
21. Ln_CEO tenure	-0.0240	-0.0258*	-0.0209	-0.0217	-0.0372**	-0.0413**	-0.0387**	-0.0372**	-0.0481***	-0.0508***	-0.00276	-0.00367	0.00000516
22. Ln_CEO delta	0.152***	0.136***	-0.0660***	-0.0947***	-0.0384**	-0.0567***	-0.0612***	-0.0822***	-0.0362**	-0.0585***	-0.0326*	-0.0560***	-0.0167
23. Ln_CEO vega	0.143***	0.155***	0.0290*	0.0171	0.0804***	0.0776***	0.0314*	0.0197	0.0700***	0.0569***	0.0338**	0.0243	0.0595***
24. Ln_in_directors	0.0428***	0.0205	0.0839***	0.0784***	0.138***	0.133***	0.0931***	0.0850***	0.119***	0.114***	0.0562***	0.0543***	0.0804***
25. Overconfidence	-0.0250	-0.0337**	-0.0445***	-0.0496***	-0.0591***	-0.0593***	-0.0723***	-0.0758***	-0.0803***	-0.0920***	-0.000937	-0.00407	0.00167
26. Stock return	-0.00957	-0.0161	-0.00339	-0.00961	-0.00384	-0.00330	-0.0115	-0.0141	-0.00400	-0.00801	0.00623	0.00000402	0.00617

Table A2.2 Correlation matrix (cont.)

Table A2.2 reports the correlation matrix of variables. The description and definition of variables are provided in Table 2.1 * p< 0.05, ** p<0.01, *** p<0.001

	14	15	16	17	18	19	20	21	22	23	24	25	26
1. Patent													
2. Citation													
3. Ln_CEO relative leverage													
4. Ln_CEO relative incentive													
5. CEO relative leverage > 1													
6. CEO relative incentive > 1													
7. Ln_pension relative leverage													
8. Ln_pension relative incentive													
9. Pension relative leverage > 1													
10. Pension relative incentive > 1													
11. Ln_defer relative leverage													
12. Ln_defer relative incentive													
13. Defer relative leverage > 1													
14. Defer relative incentive > 1	1												
15. Firm size	0.0730***	1											
16. RD intensity	0.0147	-0.127***	1										
17. ROA	0.0917***	0.116***	-0.182***	1									
18. Sales_growth	-0.0263*	-0.00121	0.0446***	0.199***	1								
19. Leverage	-0.232***	0.198***	-0.164***	-0.152***	-0.00319	1							
20. Ln_CEO age	0.0462***	0.0853***	-0.110***	0.0141	-0.0271*	0.00267	1						
21. Ln_CEO tenure	-0.00652	-0.0750***	-0.0120	0.0341**	0.0702***	-0.0159	0.380***	1					
22. Ln_CEO delta	-0.0354**	0.451***	0.00234	0.328***	0.126***	-0.0374**	0.161***	0.415***	1				
23. Ln_CEO vega	0.0595***	0.497***	0.0965***	0.183***	0.0144	0.0310*	0.0286*	0.114***	0.659***	1			
24. Ln_in_directors	0.0702***	0.183***	0.0484***	-0.000998	-0.0533***	0.0644***	-0.0418**	-0.0719***	-0.0115	0.145***	1		
25. Overconfidence	0.00485	-0.0143	-0.00743	0.195***	0.152***	-0.0513***	0.0103	0.118***	0.272***	0.0220	-0.0197	1	
26. Stock return	0.00346	0.0115	0.0179	0.0370**	-0.0289*	-0.0298*	0.0188	0.0135	0.137***	0.00802	-0.0210	0.160***	1

Table A2.3 CEO inside debt compensation and innovative output (observations with zero total firm debts are kept)

Table A2.3 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variables include *Patent*$_{t+1}$ (the number of patents in year t+1) and *Citation*$_{t+1}$ (the number of citations in year t+1). The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: Dependent variable is the number of patents

Dependent variable: Patent$_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln_CEO relative leverage$_t$	-	0.007			
		(0.035)			
Ln_CEO relative incentive$_t$	-		0.010		
			(0.031)		
CEO relative leverage > 1$_t$	-			0.056	
				(0.056)	
CEO relative incentive > 1$_t$	-				0.025
					(0.055)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		4,017	3,995	4,017	3,995
Wald chi2		50.99	50.70	53.69	50.66
Prob>chi2		0.000	0.000	0.000	0.000
Dependent variable: Patent$_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln_pension relative leverage$_t$	-	-0.111*			
		(0.065)			
Ln_defer relative leverage$_t$	-	0.039			
		(0.029)			
Ln_pension relative incentive$_t$	-		-0.075		
			(0.050)		
Ln_defer relative incentive$_t$	-		0.036		
			(0.029)		
Pension relative leverage > 1$_t$	-			-0.133*	
				(0.079)	
Defer relative leverage > 1$_t$	-			0.030	
				(0.048)	
Pension relative incentive > 1$_t$	-				-0.205***
					(0.052)
Defer relative incentive > 1$_t$	-				-0.095
					(0.075)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		4,017	3,995	4,017	3,995
Wald chi2		57.19	56.81	59.40	83.77
Prob>chi2		0.000	0.000	0.000	0.000

Table A2.3 CEO inside debt compensation and innovative output (observations with zero total firm debts are kept) (cont.)

Table A2.3 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variables include $Patent_{t+1}$ (the number of patents in year t+1) and $Citation_{t+1}$ (the number of citations in year t+1). The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable is the number of citations

Dependent variable: $Citation_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative $leverage_t$	-	-0.039 (0.054)			
Ln_CEO relative $incentive_t$	-		-0.012 (0.046)		
CEO relative leverage > 1_t	-			0.014 (0.062)	
CEO relative incentive > 1_t	-				-0.134 (0.099)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,504	3,487	3,504	3,487
Wald chi2		43.82	42.67	43.66	63.15
Prob>chi2		0.000	0.000	0.000	0.000

Dependent variable: $Citation_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative $leverage_t$	-	-0.095 (0.099)			
Ln_defer relative $leverage_t$	-	-0.011 (0.051)			
Ln_pension relative $incentive_t$	-		-0.002 (0.060)		
Ln_defer relative $incentive_t$	-		-0.005 (0.050)		
Pension relative leverage > 1_t	-			-0.097 (0.075)	
Defer relative leverage > 1_t	-			-0.023 (0.064)	
Pension relative incentive > 1_t	-				-0.134 (0.104)
Defer relative incentive > 1_t	-				-0.155* (0.088)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,504	3,487	3,504	3,487
Wald chi2		42.61	43.05	46.77	60.16
Prob>chi2		0.000	0.000	0.000	0.000

Table A2.4 CEO inside debt compensation and innovative output (observations with negative net debts are dropped)

Table A2.4 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variables include $Patent_{t+1}$ (the number of patents in year t+1) and $Citation_{t+1}$ (the number of citations in year t+1). The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: Dependent variable is the number of patents

Dependent variable: $Patent_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative $leverage_t$	-	-0.026			
		(0.035)			
Ln_CEO relative $incentive_t$	-		-0.011		
			(0.032)		
CEO relative leverage > 1_t	-			0.085	
				(0.080)	
CEO relative incentive > 1_t	-				0.042
					(0.071)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,157	2,142	2,157	2,142
Wald chi2		29.07	28.57	29.05	28.87
Prob>chi2		0.006	0.008	0.006	0.007

Dependent variable: $Patent_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative $leverage_t$	-	-0.052			
		(0.061)			
Ln_defer relative $leverage_t$	-	0.010			
		(0.032)			
Ln_pension relative $incentive_t$	-		-0.047		
			(0.052)		
Ln_defer relative $incentive_t$	-		0.032		
			(0.039)		
Pension relative leverage > 1_t	-			0.027	
				(0.099)	
Defer relative leverage > 1_t	-			0.025	
				(0.034)	
Pension relative incentive > 1_t	-				-0.048
					(0.055)
Defer relative incentive > 1_t	-				0.067
					(0.055)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		2,157	2,142	2,157	2,142
Wald chi2		30.32	29.78	29.48	35.86
Prob>chi2		0.007	0.008	0.009	0.001

Table A2.4 CEO inside debt compensation and innovative output (observations with negative net debts are dropped) (cont.)

Table A2.4 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variables include $Patent_{t+1}$ (the number of patents in year t+1) and $Citation_{t+1}$ (the number of citations in year t+1). The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable is the number of citations

Dependent variable: $Citation_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative leverage$_t$	-	-0.200***			
		(0.064)			
Ln_CEO relative incentive$_t$	-		-0.142***		
			(0.052)		
CEO relative leverage > 1$_t$	-			-0.111	
				(0.086)	
CEO relative incentive > 1$_t$	-				-0.133*
					(0.075)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		1,864	1,852	1,864	1,852
Wald chi2		180	188.6	155	158.7
Prob>chi2		0.000	0.000	0.000	0.000

Dependent variable: $Citation_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative leverage$_t$	-	-0.143			
		(0.117)			
Ln_defer relative leverage$_t$	-	-0.139***			
		(0.053)			
Ln_pension relative incentive$_t$	-		-0.073		
			(0.089)		
Ln_defer relative incentive$_t$	-		-0.124**		
			(0.056)		
Pension relative leverage > 1$_t$	-			-0.074	
				(0.102)	
Defer relative leverage > 1$_t$	-			-0.069	
				(0.067)	
Pension relative incentive > 1$_t$	-				-0.098
					(0.078)
Defer relative incentive > 1$_t$	-				0.191
					(0.126)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		1,864	1,852	1,864	1,852
Wald chi2		176.2	177.9	162.6	172.9
Prob>chi2		0.000	0.000	0.000	0.000

Table A2.5 CEO inside debt compensation and innovative output (observations with negative net debts are kept)

Table A2.5 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variables include $Patent_{t+1}$ (the number of patents in year t+1) and $Citation_{t+1}$ (the number of citations in year t+1). The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Panel A: Dependent variable is the number of patents

Dependent variable: $Patent_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln CEO relative $leverage_t$	-	0.005 (0.022)			
Ln_CEO relative $incentive_t$	-		0.005 (0.019)		
CEO relative leverage > 1_t	-			0.046 (0.036)	
CEO relative incentive > 1_t	-				0.032 (0.040)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,811	3,789	3,811	3,789
Wald chi2		50.14	48.24	53	46.96
Prob>chi2		0.000	0.000	0.000	0.000

Dependent variable: $Patent_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln pension relative $leverage_t$	-	-0.004 (0.036)			
Ln_defer relative $leverage_t$	-	0.012 (0.024)			
Ln_pension relative $incentive_t$	-		0.008 (0.032)		
Ln_defer relative $incentive_t$	-		0.008 (0.025)		
Pension relative leverage > 1_t	-			0.083 (0.090)	
Defer relative leverage > 1_t	-			0.034 (0.031)	
Pension relative incentive > 1_t	-				0.033 (0.071)
Defer relative incentive > 1_t	-				0.052 (0.038)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,811	3,789	3,811	3,789
Wald chi2		51.34	50.63	54.54	49.98
Prob>chi2		0.000	0.000	0.000	0.000

Table A2.5 CEO inside debt compensation and innovative output (observations with negative net debts are kept) (cont.)

Table A2.5 presents the empirical results of the Poisson model with firm and year fixed effects. The standard errors (in parentheses) are clustered at the firm level. The dependent variables include $Patent_{t+1}$ (the number of patents in year t+1) and $Citation_{t+1}$ (the number of citations in year t+1). The description and definition of independent variables are provided in Table 2.1. ***, **, * represent the significance at the 1%, 5%, and 10% levels.

Dependent variable is the number of citations

Dependent variable: $Citation_{t+1}$	Expected sign	Model (1)	Model (2)	Model (3)	Model (4)
Ln_CEO relative $leverage_t$	-	**-0.087****			
		(0.044)			
Ln_CEO relative $incentive_t$	**-**		-0.060		
			(0.037)		
CEO relative leverage > 1_t	-			-0.034	
				(0.040)	
CEO relative incentive > 1_t	-				0.021
					(0.055)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,337	3,319	3,337	3,319
Wald chi2		44.24	43.74	40.69	38.54
Prob>chi2		0.000	0.000	0.000	0.000
Dependent variable: $Citation_{t+1}$	Expected sign	Model (5)	Model (6)	Model (7)	Model (8)
Ln_pension relative $leverage_t$	-	**-0.098***			
		(0.053)			
Ln_defer relative $leverage_t$	-	**-0.070***			
		(0.040)			
Ln_pension relative $incentive_t$	-		-0.054		
			(0.040)		
Ln_defer relative $incentive_t$	-		-0.062		
			(0.044)		
Pension relative leverage > 1_t	-			-0.091	
				(0.068)	
Defer relative leverage > 1_t	-			-0.041	
				(0.046)	
Pension relative incentive > 1_t	-				-0.033
					(0.058)
Defer relative incentive > 1_t	-				0.174*
					(0.096)
Control variables		Yes	Yes	Yes	Yes
Firm and year FE		Yes	Yes	Yes	Yes
Observations		3,337	3,319	3,337	3,319
Wald chi2		47.20	45.03	39.93	40.60
Prob>chi2		0.000	0.000	0.000	0.000

APPENDICES OF CHAPTER 3

Table A3.1 Summary statistics

Table A3.1 reports summary statistics of 8,568 firm-year observations during 2007-2016. The description and definition of variables are provided in Table 3.1.

Variable	N	mean	median	25th quartile	75th quartile	Std. Dev
Panel A: CEO pay incentives						
CEO vega (1000$)	8,568	167	64	17	187	379
Ln_vega	8,568	4	4	3	5	2
CEO vega of options (1000$)	8,295	163	63	14	189	332
Ln_vega_options	8,295	4	4	3	5	2
CEO equity (1000$)	8,568	140,000	17,483	7,021	46,219	1,690,000
CEO inside debt (1000$)	8,568	5,546	597	0	4,802	13,899
CEO deferred compensation (1000$)	8,568	2,620	93	0	1,706	9,487
CEO pension compensation (1000$)	8,568	2,926	0	0	1,266	7,882
Salary (1000$)	8,568	846	800	593	1,000	409
Bonus (1000$)	8,568	139	0	0	0	1,030
CEO relative leverage	7,299	16.27	0.30	0.00	1.55	271.72
Ln_CEO relative leverage	7,299	0.65	0.26	0.00	0.94	1.00
CEO relative incentive	7,110	20.73	0.33	0.00	1.63	339.27
Ln_CEO relative incentive	7,110	0.68	0.28	0.00	0.97	1.03
Panel B: Diversity (non-standardised)						
Edu_hhi	8,568	0.16	0.14	0.11	0.17	0.08
Ethnicity_hhi	8,568	0.87	0.85	0.78	1.00	0.14
Finexpert_hhi	8,568	0.64	0.58	0.52	0.72	0.15
Gender_diversity	8,568	0.13	0.13	0.00	0.20	0.10
Age_diversity	8,568	7.68	7.39	6.04	9.10	2.32
Boardexp_diversity	8,568	0.84	0.80	0.50	1.17	0.47
Panel C: Other variables						
Firm_size	8,568	7.73	7.57	6.59	8.70	1.54
Lagged RD_intensity	8,568	0.03	0.01	0.00	0.04	0.05
ROA	8,568	0.05	0.06	0.02	0.09	0.10
Lagged ROA	8,568	0.06	0.06	0.03	0.10	0.10
Lagged MB	8,568	3.49	2.40	1.59	3.74	15.41
Lagged leverage	8,568	0.19	0.18	0.04	0.30	0.16
Stock return	8,568	0.15	0.11	-0.12	0.34	0.47
Lagged stock return	8,568	0.15	0.10	-0.13	0.34	0.49
Lagged cash flow volatility	8,568	0.04	0.03	0.02	0.05	0.04
Lagged sales growth	8,568	0.09	0.07	-0.01	0.15	0.26
Lagged capital expenditure	8,568	0.05	0.03	0.02	0.06	0.05
Lagged tangibility	8,568	0.24	0.17	0.09	0.33	0.21
Firm age	8,568	27.60	22.00	14.00	39.00	19.85
Tax loss indicator	8,568	0.76	1.00	1.00	1.00	0.43
HHI	8,568	0.19	0.14	0.07	0.23	0.18
Liquidity constraint	8,568	0.03	0.00	0.00	0.00	0.18
CEO chair	8,568	0.53	1.00	0.00	1.00	0.50
CEO age	8,568	56.28	56.00	52.00	61.00	6.93
CEO tenture	8,568	8.43	6.32	3.00	11.23	7.46
Ln_cash_compensation	8,568	6.69	6.75	6.44	7.00	0.82
Ratio of independent directors	8,568	0.79	0.82	0.71	0.88	0.11
Boardsize	8,568	9.02	9.00	8.00	10.00	2.06

Table A3.2 Correlation matrix

Table A3.2 reports the correlation matrix of variables. The description and definition of variables are provided in Table 3.1. * p< 0.05, ** p<0.01, *** p<0.001

	1	2	3	4	5	6	7	8	9	10	11
1. ln vega	1										
2. ln vega options	0.973***	1									
3. ln CEO relative leverage	0.0449***	0.0659***	1								
4. ln CEO relative incentive	0.0242*	0.0484***	0.987***	1							
5. diversity index	0.290***	0.286***	0.110***	0.0929***	1						
6. edu hhi	-0.246***	-0.255***	-0.0867***	-0.0748***	-0.606***	1					
7. ethnicity hhi	-0.185***	-0.174***	-0.0525***	-0.0337**	-0.546***	0.196***	1				
8. finexpert hhi	-0.0930***	-0.100***	-0.0701***	-0.0683***	-0.471***	0.128***	0.0417***	1			
9. gender diversity	0.176***	0.177***	0.120***	0.106***	0.545***	-0.223***	-0.195***	-0.0704***	1		
10. age diversity	-0.118***	-0.132***	-0.0947***	-0.0847***	0.154***	0.0770***	0.0742***	0.0404***	-0.116***	1	
11. boardexp diversity	0.257***	0.254***	0.0825***	0.0691***	0.564***	-0.317***	-0.205***	-0.131***	0.199***	-0.235***	1
12. firm size	0.460***	0.433***	0.100***	0.0570***	0.464***	-0.378***	-0.255***	-0.125***	0.298***	-0.149***	0.435***
13. lagged rd intensity	0.0942***	0.0970***	-0.00578	-0.00275	0.0261*	-0.0321**	-0.0541***	0.0163	-0.0956***	0.0372**	0.0645***
14. roa	0.187***	0.182***	0.119***	0.0982***	0.0671***	-0.0148	-0.0884***	-0.0321**	0.0801***	-0.0207	-0.00307
15. lagged roa	0.142***	0.142***	0.117***	0.0927***	0.0358**	-0.00648	-0.0838***	-0.00617	0.0428***	-0.0390**	0.00152
16. lagged mb	0.0299*	0.0305*	0.0249*	0.00941	0.0250*	-0.0244*	-0.0262*	0.0154	0.0422***	-0.0128	0.00849
17. lagged leverage	0.0440***	0.0411***	-0.241***	-0.245***	0.116***	-0.0934***	-0.0160	-0.0531***	0.0899***	-0.0105	0.0938***
18. stock return	0.0263*	0.0212	-0.00372	-0.00687	0.00942	-0.000237	-0.00202	-0.0127	0.00258	0.0264*	-0.0166
19. lagged stock return	0.0144	0.00876	0.00121	-0.00153	0.00348	0.00723	-0.00449	-0.00442	-0.00718	0.0331**	-0.0176
20. lagged cash flow volatility	-0.0910***	-0.102***	-0.0248*	-0.0155	-0.145***	0.0822***	0.0539***	0.0615***	-0.158***	0.0322**	-0.0936***
21. lagged sales growth	-0.0239*	-0.0288*	-0.0441***	-0.0451***	-0.0812***	0.0444***	0.0295*	0.0383**	-0.0887***	0.0279*	-0.0605***
22. lagged capital expenditure	-0.0851***	-0.101***	-0.0588***	-0.0614***	-0.126***	0.0779***	0.107***	0.0189	-0.0924***	0.0107	-0.0780***
23. lagged tangibility	-0.0721***	-0.0816***	-0.0407***	-0.0426***	-0.0816***	0.0296*	0.0662***	0.0122	-0.0460***	-0.0400***	-0.0410***
24. firm age	0.216***	0.217***	0.204***	0.176***	0.256***	-0.200***	-0.201***	-0.0692***	0.209***	-0.185***	0.244***
25. tax loss indicator	-0.0621***	-0.0656***	-0.0599***	-0.0567***	-0.0149	0.0613***	0.00212	0.00781	0.0223	0.0443***	-0.0404***
26. HHI	-0.0368**	-0.0352**	0.0484***	0.0452***	0.0580***	-0.0141	-0.000657	-0.0295*	0.0881***	0.00851	0.0258*
27. constraint	-0.0903***	-0.0950***	-0.0431***	-0.0378**	-0.0352**	0.0256*	0.0218	0.0160	-0.0498***	0.0389**	-0.0269*
28. ceo chair	0.188***	0.142***	0.110***	0.0944***	0.0833***	-0.0459***	-0.0825***	-0.0283*	0.0929***	-0.125***	0.113***
29. ln age	0.0673***	0.0406***	0.130***	0.121***	-0.0563***	0.00823	0.00667	-0.0145	0.0289*	-0.182***	-0.0110
30. ln tenure	0.114***	0.0516***	0.00487	0.00608	-0.146***	0.131***	0.0375**	0.0405***	-0.124***	0.0428***	-0.133***
31. ln cash compensation	0.240***	0.230***	0.111***	0.0905***	0.246***	-0.195***	-0.125***	-0.0688***	0.185***	-0.0681***	0.207***
32. ln in dir	0.158***	0.175***	0.0812***	0.0711***	0.251***	-0.245***	-0.156***	-0.0978***	0.196***	-0.298***	0.326***
33. ln boardsize	0.282***	0.284***	0.134***	0.110***	0.522***	-0.543***	-0.244***	-0.153***	0.315***	-0.0421***	0.307***

Table A3.2 Correlation matrix (cont.)

Table A3.2 reports the correlation matrix of variables. The description and definition of variables are provided in Table 3.1. * p< 0.05, ** p<0.01, *** p<0.001

	12	13	14	15	16	17	18	19	20	21	22
1. ln vega											
2. ln vega options											
3. ln CEO relative leverage											
4. ln CEO relative incentive											
5. diversity index											
6. edu hhi											
7. ethnicity hhi											
8. finexpert hhi											
9. gender diversity											
10. age diversity											
11. boardexp diversity											
12. firm size	1										
13. lagged rd intensity	-0.113***	1									
14. roa	0.0952***	-0.0315**	1								
15. lagged roa	0.0811***	-0.0868***	0.452***	1							
16. lagged mb	0.00895	0.0551***	0.0672***	0.0627***	1						
17. lagged leverage	0.208***	-0.165***	-0.0931***	-0.178***	0.0392**	1					
18. stock return	-0.00402	0.0333**	0.0867***	-0.0964***	-0.00373	0.0464***	1				
19. lagged stock return	-0.00341	0.0257*	0.227***	0.0744***	0.0188	-0.0397***	-0.101***	1			
20. lagged cash flow volatility	-0.180***	0.184***	-0.0355**	-0.0669***	0.0350**	-0.0826***	0.0244*	0.0426***	1		
21. lagged sales growth	-0.0493***	0.0878***	0.0688***	0.194***	0.0174	-0.0319**	-0.0635***	0.00813	0.192***	1	
22. lagged capital expenditure	0.0328**	-0.173***	-0.0560***	-0.00374	-0.0167	0.0459***	-0.0319**	-0.0813***	0.222***	0.0642***	1
23. lagged tangibility	0.117***	-0.287***	-0.0720***	-0.0679***	-0.0309**	0.174***	-0.00953	-0.0385**	0.110***	-0.0480***	0.743***
24. firm age	0.428***	-0.0752***	0.0690***	0.0488***	0.0139	0.0242*	-0.0121	-0.0246*	-0.156***	-0.128***	-0.0549***
25. tax loss indicator	-0.0825***	0.0251*	0.00992	0.0149	0.00939	-0.00415	0.000374	0.00501	0.0109	0.0447***	-0.00379
26. HHI	0.000265	-0.210***	0.0426***	0.0221	0.0244*	0.0243*	0.0187	0.0132	-0.0797***	-0.0469***	-0.0873***
27. constraint	-0.111***	0.129***	-0.246***	-0.172***	0.0114	-0.0123	-0.0681***	-0.00896	0.115***	-0.0489***	-0.0469***
28. ceo chair	0.164***	-0.0882***	0.0545***	0.0470***	-0.0179	0.00595	0.00876	-0.0232	-0.0505***	-0.0586***	0.0186
29. ln age	0.0954***	-0.0809***	0.0224	0.0220	-0.0223	0.00487	0.0234	-0.00373	-0.0170	-0.0315**	-0.0297*
30. ln tenure	-0.0810***	0.0214	0.0521***	0.0600***	-0.0237*	-0.0253*	0.0179	0.0419***	0.0256*	0.0579***	0.0233
31. ln cash compensation	0.439***	-0.0807***	0.0629***	0.0454***	0.00479	0.0929***	0.00926	0.0120	-0.0554***	-0.0377**	-0.000547
32. ln in dir	0.218***	0.0239*	0.0175	0.0167	-0.00382	0.0870***	-0.0296*	-0.0196	-0.0470***	-0.0573***	-0.0326**
33. ln boardsize	0.578***	-0.116***	0.0877***	0.0609***	0.0235	0.150***	0.00963	-0.0126	-0.183***	-0.0803***	-0.0693***

Table A3.2 Correlation matrix (cont.)

Table A3.2 reports the correlation matrix of variables. The description and definition of variables are provided in Table 3.1. * p< 0.05, ** p<0.01, *** p<0.001

	23	24	25	26	27	28	29	30	31	32	33
1. ln vega											
2. ln vega options											
3. ln CEO relative leverage											
4. ln CEO relative incentive											
5. diversity index											
6. edu hhi											
7. ethnicity hhi											
8. finexpert hhi											
9. gender diversity											
10. age diversity											
11. boardexp diversity											
12. firm size											
13. lagged rd intensity											
14. roa											
15. lagged roa											
16. lagged mb											
17. lagged leverage											
18. stock return											
19. lagged stock return											
20. lagged cash flow volatility											
21. lagged sales growth											
22. lagged capital expenditure											
23. lagged tangibility	1										
24. firm age	0.0378**	1									
25. tax loss indicator	-0.0393**	-0.0725***	1								
26. HHI	-0.0551***	0.0644***	-0.0280*	1							
27. constraint	-0.0476***	-0.0350**	0.0131	0.0238*	1						
28. ceo chair	0.0668***	0.145***	-0.0365**	0.0502***	-0.0202	1					
29. ln age	0.0293*	0.108***	-0.00272	0.0670***	0.00156	0.244***	1				
30. ln tenure	0.00946	-0.0762***	0.00219	-0.0235	-0.00102	0.319***	0.397***	1			
31. ln cash compensation	0.0421***	0.253***	-0.0350**	0.0608***	-0.0394**	0.162***	0.129***	0.0534***	1		
32. ln in dir	0.00378	0.226***	-0.0196	-0.0419***	-0.0342**	0.161***	-0.0285*	-0.0659***	0.109***	1	
33. ln boardsize	0.0421***	0.394***	-0.0652***	0.0596***	-0.0680***	0.0611***	0.0569***	-0.137***	0.281***	0.194***	1

APPENDICES OF CHAPTER 4

Table A4.1 Summary statistics

Table A4.1 reports summary statistics of 8,338 firm-year observations during 2007-2016. The description and definition of variables are provided in Table 4.1.

Variable	N	mean	median	25th quartile	75th quartile	Std. Dev
Panel A: Volatility						
Monthly annualised volatility (%)	8,338	35.30	31.07	22.73	42.64	19.09
Panel B: Faultlines						
Fau_strength	8,338	0.65	0.66	0.49	0.82	0.21
Fau_distance	8,338	2.39	2.28	2.01	2.61	0.60
Panel C: Diversity (non-standardised)						
Gender_diversity	8,338	0.13	0.13	0.00	0.20	0.10
Age_diversity	8,338	7.71	7.42	6.07	9.13	2.33
Boardexp_diversity	8,338	0.84	0.80	0.50	1.17	0.47
Edu_hhi	8,338	0.16	0.14	0.11	0.17	0.08
Ethnicity_hhi	8,338	0.88	0.86	0.78	1.00	0.14
Finexpert_hhi	8,338	0.64	0.59	0.53	0.72	0.15
Panel D: Other variables						
Firm_size	8,338	7.72	7.56	6.59	8.67	1.53
MB	8,338	4.42	2.38	1.57	3.76	24.00
Leverage	8,338	0.20	0.19	0.05	0.31	0.16
Tangibility	8,338	0.24	0.17	0.09	0.33	0.22
Cash	8,338	0.16	0.11	0.04	0.24	0.16
Dividend_pay	8,338	0.57	1.00	0.00	1.00	0.50
ROA	8,338	0.05	0.06	0.02	0.09	0.10
RD_expense	8,338	0.03	0.01	0.00	0.05	0.05
Firm age	8,338	27.77	22.00	14.00	39.00	19.85
Size of board of directors	8,338	9.01	9.00	8.00	10.00	2.07
Board age	8,338	62.19	62.30	59.86	64.56	3.70
Tenure	8,338	8.51	6.50	3.01	11.34	7.47
Ceo chair	8,338	0.53	1.00	0.00	1.00	0.50
Ln_population	8,338	9.92	9.02	10.32	1.18	9.92
Population_growth	8,338	0.01	0.00	0.02	74.42	0.01
Ln_income	8,338	9.98	9.79	10.07	1.41	9.98
Income_growth	8,338	0.02	0.00	0.05	367.25	0.02

Table A4.2 Correlation matrix

Table A4.2 reports the correlation matrix of variables. The description and definition of variables are provided in Table 4.1. * p< 0.05, ** p<0.01, *** p<0.001

	1	2	3	4	5	6	7	8	9
1. ln_monthly_volatility	1								
2. diversity_index	-0.193***	1							
3. gender_diversity	-0.182***	0.550***	1						
4. age_diversity	0.0607***	0.144***	-0.127***	1					
5. boardexp_diversity	-0.110***	0.573***	0.206***	-0.227***	1				
6. edu_hhi	0.121***	-0.624***	-0.241***	0.0897***	-0.339***	1			
7. ethnicity_hhi	0.149***	-0.515***	-0.165***	0.0801***	-0.188***	0.164***	1		
8. finexpert_hhi	0.0538***	-0.478***	-0.101***	0.0613***	-0.148***	0.145***	0.0475***	1	
9. fau_strength	-0.00621	-0.00496	-0.0145	-0.0649***	0.0437***	-0.0136	-0.0277*	0.0200	1
10. fau_distance	-0.0184	0.0368***	0.0627***	0.0355**	-0.0159	0.00295	-0.0422***	0.0155	0.190***
11. firm_size	-0.356***	0.465***	0.306***	-0.162***	0.460***	-0.369***	-0.229***	-0.139***	0.0294**
12. mb	-0.0505***	0.0531***	0.0365***	0.00429	0.0312**	-0.0222*	-0.0429***	-0.0161	0.0137
13. leverage	-0.0331**	0.176***	0.128***	-0.0657***	0.187***	-0.157***	-0.0336**	-0.0686***	0.0263*
14. tangibility	0.102***	-0.0617***	-0.0152	-0.0468***	-0.0199	0.0211	0.0759***	-0.000944	0.00249
15. cash	0.0763***	-0.0901***	-0.109***	0.0835***	-0.113***	0.0978***	-0.0696***	0.0938***	-0.0130
16. dividend_pay	-0.281***	0.173***	0.189***	-0.104***	0.143***	-0.120***	-0.0846***	-0.0678***	0.00520
17. roa	-0.300***	0.0308**	0.0573***	0.00441	-0.0300**	0.0143	-0.0586***	-0.0129	-0.00997
18. rd_expense	0.0760***	0.00965	-0.119***	0.0301**	0.0252*	-0.0212	-0.0910***	0.0206	0.00583
19. ln_firmage	-0.233***	0.174***	0.149***	-0.132***	0.171***	-0.128***	-0.129***	-0.0559***	0.00484
20. ln_boardsize	-0.242***	0.514***	0.333***	-0.0618***	0.328***	-0.524***	-0.201***	-0.159***	-0.0164
21. ln_boardage	-0.133***	-0.0787***	-0.119***	-0.0527***	0.0359**	0.0296**	0.0643***	-0.00279	-0.0384***
22. ln_tenure	-0.0166	-0.164***	-0.134***	0.0429***	-0.162***	0.141***	0.0270*	0.0532***	0.0680***
23. ceo chair	-0.0467***	0.0494***	0.0633***	-0.0989***	0.0786***	-0.0160	-0.0677***	-0.0157	0.0910***
24. ln_population	0.0128	0.00192	-0.0269*	-0.00869	0.0733***	-0.0336**	0.0476***	0.0182	0.00680
25. population_growth	-0.00745	-0.00822	-0.0109	-0.00959	-0.00754	-0.00580	-0.00307	0.00453	0.00786
26. ln_income	-0.00399	-0.125***	-0.136***	-0.0755***	-0.0357**	0.0461***	0.0680***	-0.00110	-0.00106
27. income_growth	0.0322**	0.0146	0.00893	0.00525	0.0187	0.00370	0.00256	-0.0155	0.00356

Table A4.2 Correlation matrix (cont.)

Table A4.2 reports the correlation matrix of variables. The description and definition of variables are provided in Table 4.1. * p< 0.05, ** p<0.01, *** p<0.001

	10	11	12	13	14	15	16	17	18
1. ln_monthly_volatility									
2. diversity_index									
3. gender_diversity									
4. age_diversity									
5. boardexp_diversity									
6. edu_hhi									
7. ethnicity_hhi									
8. finexpert_hhi									
9. fau_strength									
10. fau_distance	1								
11. firm_size	0.0437***	1							
12. mb	0.0156	0.0341**	1						
13. leverage	-0.0254*	0.366***	0.115***	1					
14. tangibility	-0.0117	0.146***	-0.0194	0.208***	1				
15. cash	0.0337**	-0.296***	0.0187	-0.418***	-0.346***	1			
16. dividend_pay	0.0473***	0.324***	0.0277*	0.116***	0.137***	-0.249***	1		
17. roa	-0.00604	0.0717***	0.0546***	-0.156***	-0.0761***	0.0628***	0.137***	1	
18. rd_expense	0.0153	-0.182***	0.0201	-0.237***	-0.307***	0.503***	-0.259***	-0.146***	1
19. ln_firmage	0.0675***	0.362***	0.00346	0.0842***	0.0359**	-0.184***	0.399***	0.0356**	-0.0715***
20. ln_boardsize	-0.00340	0.588***	0.0324**	0.245***	0.0851***	-0.258***	0.337***	0.0502***	-0.168***
21. ln_boardage	0.0321**	0.0975***	0.00728	0.0373***	0.0414***	-0.108***	0.160***	0.00998	-0.0667***
22. ln_tenure	0.118***	-0.110***	0.00772	-0.0707***	-0.0127	0.0767***	-0.0493***	0.0556***	0.0477***
23. ceo chair	0.0142	0.136***	0.0153	0.0207	0.0598***	-	0.124***	0.0439***	-0.0919***
24. ln_population	-0.0176	0.0287**	-0.0240*	0.0324**	0.0678***	-0.0327**	0.0120	0.000333	-0.0370***
25. population_growth	-0.00160	0.00991	0.000396	0.0178	-0.0133	-0.00549	-0.00609	0.00822	-0.0211
26. ln_income	-0.0313**	-0.0801***	-0.0248*	-0.0203	0.0497***	-0.0112	-0.0676***	-0.0149	0.0533***
27. income_growth	0.00852	-0.00595	0.0392***	0.0158	-0.00377	-0.000672	0.0219*	-0.00565	-0.0130

Table A4.2 Correlation matrix (cont.)

Table A4.2 reports the correlation matrix of variables. The description and definition of variables are provided in Table 4.1. * p< 0.05, ** p<0.01, *** p<0.001

	19	20	21	22	23	24	25	26	27
1. ln_monthly_volatility									
2. diversity_index									
3. gender_diversity									
4. age_diversity									
5. boardexp_diversity									
6. edu_hhi									
7. ethnicity_hhi									
8. finexpert_hhi									
9. fau_strength									
10. fau_distance									
11. firm_size									
12. mb									
13. leverage									
14. tangibility									
15. cash									
16. dividend_pay									
17. roa									
18. rd_expense									
19. ln_firmage	1								
20. ln_boardsize	0.339***	1							
21. ln_boardage	0.236***	0.106***	1						
22. ln_tenure	-0.0470***	-0.156***	0.170***	1					
23. ceo chair	0.0842***	0.0446***	0.0446***	0.342***	1				
24. ln_population	-0.00117	0.0398***	0.0259*	-0.0293**	-0.0127	1			
25. population_growth	0.00307	0.00678	0.00736	-0.0235*	0.0123	0.0397***	1		
26. ln_income	-0.0245*	-0.101***	0.00985	-0.0290**	-0.0280*	0.00232	0.0158	1	
27. income_growth	-0.0000928	0.00992	0.00447	0.00953	0.0123	0.0416***	-0.00245	0.0190	1

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