The bright side of belief dispersion within TMTs

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Abstract

Prior research shows that firm innovation policies can be affected by the perceptional lens of their top executives. However, existing literature has exclusively focused on CEOs and ignored the interactional effect among CEO and non-CEO executives. In this study, I examine the effect of having different opinions within a firm's TMT and find that belief dispersion within the TMT is positively related to corporate innovative efficiency. This result still holds after considering potential endogeneity in the baseline regressions. Next, I use three subsample analyses to indicate that information sharing and bias reduction are potentially the channels of the positive effect of belief dispersion. The last section of this thesis provides evidence that illustrates a positive relationship between TMTs belief dispersion and firm performance, yielding further corporate implications.

Declaration

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1. Introduction

Why did some U.S. foreign-policy decisions such as the Bay of Pigs invasion, the Cuban missile crisis, and the escalation of the Vietnam War end disastrously? Janis (1972) identified a cluster of symptoms for what he coined the term "groupthink", which refers to a phenomenon that people in a decision-making cohort has similar beliefs, and argued that the decisions mentioned above that lead to adverse consequences are the victim of groupthink. Moreover, Bénabou (2013) argues that groupthink can lead to collective delusions in groups, organizations and markets, which thus cause a denial of bad news and information avoidance among decision-makers. Groupthink in senior management can also be a contributing factor for the failure of corporation, such as the collapse of Enron and Worldcom (Cohan 2002; Samuelson 2001). In contrast, different opinions and dispersed beliefs among a firm's top executives can improve the efficiency of the firm's decision-making. As argued by Nooyi, the former CEO of PepsiCo, constructive fights and constructive dialogues can lead to a better outcome[1]. This anecdotal evidence suggests that it is important to understand the implication of collective beliefs among decision makers.

Many decisions are made based on personal beliefs, considering the likelihood of success; however, these beliefs are subjected to behavioral biases (Tversky & Kahneman 1974). These biases can alter individuals' cognitive base, thereby affecting their beliefs about future uncertain outcomes (Einhorn & Hogarth 1978). One of the most prominent behavior biases is overconfidence (Plous 1993). Previous psychology literature has documented that overconfident individuals are prone to have irrational and optimistic beliefs (Alicke 1985; Einhorn & Hogarth 1978; Stone 1994; Svenson 1981). In the field of corporate finance, since the seminal work of Malmendier and Tate (2005), overconfidence has received growing

[1] See Clifford (2016).

attention. For instance, it has been shown that overconfidence has an explanatory power toward a firm's investment distortion (Malmendier & Tate 2005), valued-destroying mergers (Malmendier & Tate 2008), and the success of corporate innovation (Hirshleifer, Low & Teoh 2012).

While the existing literature highlights the relation between optimistic managerial belief and corporate decision, it has only focused on the belief of one single decision-maker, i.e., the CEO. In this study, I extend the literature by examining the beliefs held by the top management team (TMT) members regarding their firm's prospects. This extension is meaningful because firm decisions are not formulated and made solely by CEOs. Instead, firm decisions are often made by the firm's top management team (TMT), consisting of the firm's top executives, through multiple discussions and debates (Hambrick & Mason 1984; Murray 1989). This corporate decision-making practice highlights the importance of TMTs. Moreover, the "upper echelon" theory (Hambrick & Mason 1984), suggests that a firm's outcomes are the reflection of the value and cognitive bases of the firm's TMT, showing the importance of TMTs belief. However, how the distribution of TMTs belief (i.e., congruent or dispersed) can affect corporate decision-making is not clear. This study aims to fill in the gap and adds to our understanding of this critical question.

To be specific, this study examines the effect of TMTs belief dispersion on corporate innovation output. Innovation arguably is one of the most crucial corporate issues, as it matters a firm's long-run competitive advantage and even the survival of firms (Eisdorfer & Hsu 2011). The research of overconfidence in corporate content has found that overconfident CEOs are better innovators (Galasso & Simcoe 2011; Hirshleifer, Low & Teoh 2012). This effect of overconfidence arises from CEOs' belief about their firms. That is either overestimation of expected future outcomes or underestimation of risk (Hirshleifer, Low & Teoh 2012). Regarding other non-overconfident (potentially rational or risk-averse) executives in TMTs, they may hold a different belief. Such different belief can lead to the opinion that against the risky innovative investment favored by overconfident CEOs. Also, another stream of innovation literature finds that TMTs characteristics can influence the success of innovation activities (e.g., Alexiev et al. 2010; Daellenbach, McCarthy & Schoenecker 1999). These two strands of literature jointly suggest a link between TMTs belief dispersion and firm's innovative outcomes, which is the main focus of this thesis.[2]

From the bright-side perspective, belief dispersion may yield a high innovation efficiency in firms[3]. First, belief dispersion introduces a dissent among top executives, thereby reducing the biases in TMTs' decision-making process (Asch 1955; Landier, Sraer & Thesmar 2009). TMTs with belief dispersion thus can produce quality decisions and lead to higher innovation efficiency in their firms. Second, belief dispersion encourages knowledge and information sharing among TMTs' members (Che & Kartik 2009; Malenko 2014; Parks & Nelson 1999). This activity can prepare a better knowledge base for TMTs' decisions, especially for those information-intense decisions (e.g., innovative decisions). Lastly, TMTs with belief dispersion can imply that innovative decisions made by their TMT are less arbitrary and based on more objective information (Landier, Sraer & Thesmar 2009). It would encourage their subordinators such as the employees in research and development (R&D) division to put more effort into innovative activities since those employees will view innovation as having a higher chance of success if they observe belief dispersion in such a management team. Hence, more efforts will be spent during the implementation of innovation. Therefore, my first

[2] The term "belief" refers to each executive's opinion about their firm's future performance. I also use the words, "belief dispersion", to describe a dispersed belief within TMTs.

[3] I acknowledge that existing literature also suggests belief dispersion could have a dark side (Stasser, Taylor & Hanna 1989; Stasser & Titus 1987; Van Ginkel & Van Knippenberg 2009). For instance, Carnevale and Probst (1998) argue that disagreement within a team could lead to the team members' cognitive overload and thus obstruct cognitive flexibility and creative thinking, which is detrimental to innovation outcomes. However, the evidence does not support the alternative hypothesis.

hypothesis argues that there is a positive relation between TMTs belief dispersion and corporate innovation efficiency.

I test my hypothesis by examining whether TMTs belief dispersion can lead to high or low efficiency in the firm’s innovative activities. Firms with high efficiency in those activities should present an ability to generate more innovative outputs per dollar of R&D spending. Thus, I regress the TMTs belief dispersion (measured by the standard deviation of executives’ confidence levels in TMTs) on three standard innovation measures (i.e., the number of future citations received by each patent, the estimated market value for each patent, and the number of patents applied by a firm) and also control for firm’s R&D expense.

The results from the baseline regressions show a positive relationship between TMT belief dispersion and the firm’s ability to produce high-impact patents (measured by citation counts and patent value). These findings are consistent with the expected effects of belief dispersion, which are reducing biases in decision-making processes and arriving at a better knowledge base for decisions. Hence, the TMTs with belief dispersion can generate relatively more high-impact patents per R&D spending.

I acknowledge that the baseline results may be subject to endogeneity. Malmendier, Tate and Yan (2011) also illustrate that CEOs' early-life experience can affect the level of overconfidence that they are subjected to. Such an effect of personal experience on belief may not be limited to CEOs and also can be found in other TMTs members. Also, successful career achievement can provide a positive signal to each executive about their skill and ability. This signal would enhance their positive views about the firm (Camerer & Lovallo 1999). However, the enhancement in positive belief is likely to be different across the TMT members, which can increase belief dispersion in the TMT (i.e., reverse causality). Therefore, belief dispersion is likely to be endogenous. Three additional tests are thus performed to mitigate endogeneity concerns. Two of these tests make use of plausible exogenous in TMTs belief dispersion, and another one employs a two-stage least square (2SLS) approach with an instrumental variable (IV).

The first robustness test utilizes the events of the executive transition. Since executive turnovers will change the membership of TMTs, it may generate some exogenous variations in TMTs belief distribution. Following executive turnovers, firms that have experienced a significant amount of increase in TMTs belief dispersion are defined as treatment firms. The control group consists of the firms that have experienced a small increase or a decrease in TMTs belief dispersion after executive turnovers. Based on a matched sample, I estimate the baseline regressions by using the data around executive turnovers. The result indicates that treatment firms have higher innovation efficiency than the control firms after experiencing executive turnovers.

The second robustness test uses the dot-com bubble as a quasi-natural experiment. When the bubble burst, it is likely to cause an exogenous variation in TMTs belief distribution. Using a difference-in-difference (DiD) approach (the treatment group is the internet firms with high belief dispersion and the control group is other firms in the sample), I show that an exogenous decrease in TMTs belief dispersion leads to a significant reduction in firm's innovation efficiency.

In the last robustness test, I use as an IV, the lagged industry median belief dispersion, and run the 2SLS regression model. The result obtained from this test confirms the positive effect of belief dispersion on the effectiveness of corporate innovative investments. Overall, these three robustness tests suggest that my baseline results are robust.

If TMTs belief dispersion is beneficial for corporate innovation, one might wonder the underlying mechanism. Thus, I further perform three subsample analyses to identify the potential driving force for the effect of belief dispersion on innovation. The results indicate that the positive relationship between TMTs belief dispersion and corporate innovation efficiency is more pronounced in three types of firms. These are the firms with overconfident CEOs, the firms with a chief technology officer (CTO) in the TMT, and the firms in high-tech industries. These typical firms are likely to have a better information-sharing environment for innovation, suggested by previous literature (e.g., Adler & Ferdows 1990; Hirshleifer, Low & Teoh 2012). Thus, information sharing is possibly the underlying channel that belief dispersion goes through and yields high corporate innovation efficiency.

Since belief dispersion plausibly leads to a better decision-making process, this effect could have impacts beyond corporate innovation activities. Hence, the last section attempts to provide an implication about the relationship between TMTs belief dispersion and firm performance. By using OLS estimation, I find that TMTs belief dispersion is positively related to the two standard measures of firm performance, i.e., *Tobin's Q* and return on asset (ROA). To mitigate endogeneous concerns, I re-run the regression with firm-fixed effects and use a 2SLS approach. The estimated coefficients of belief dispersion are still positive and significant.

In summary, my empirical results show a positive causal effect of TMTs belief dispersion on their firm's innovation efficiency. This effect is more sound in firms where the initiative of innovation is greater. Moreover, belief dispersion is likely to yield better corporate performance.

This thesis can first contribute to the literature of TMTs on corporate performance and policies (Bantel & Jackson 1989; Bushman, Dai & Zhang 2016; Finkelstein & Hambrick 1990; Hambrick & Mason 1984; Wiersema & Bantel 1992). For instance, Hambrick and Mason (1984) argue that TMTs members are powerful actors in a firm, and their cognitive bases can affect the firm's strategic choices and performance levels. Furthermore, research on human relations in a team highlights that team characteristics can shape the behavior of people that performs jointly with others (Stewart 2003; Terrion & Ashforth 2002). As argued by Terrion and Ashforth (2002), individuals performing in team contexts often forego their own identities. Instead, there take the identity of their team (Terrion & Ashforth 2002). Regarding the results in this thesis, it shows that dispersion within TMTs, as a team attribute, is beneficial for the TMTs decision-making. Such an attribute can enlarge the knowledge base in TMTs and thus improve corporate innovation performance.

Secondly, this thesis can contribute to the literature of corporate innovation (Aghion, Van Reenen & Zingales 2013; Hirshleifer, Hsu & Li 2013; Hirshleifer, Low & Teoh 2012). Existing literature has shown that some TMT attributes can affect a firm’s innovation policy. For instance, Alexiev et al. (2010) show that TMTs advice-seeking behavior is an important determinant of firms’ exploratory innovation. Furthermore, the perceptual lens of top managers also has a significant impact on the firm’s commitment to innovation. Both studies from Galasso and Simcoe (2011) and Hirshleifer, Low and Teoh (2012) find that overconfident CEOs are more likely to pursue innovation. In this study, I identify a novel factor that contributes to innovation outcomes. I find that TMTs with dispersed beliefs can encourage information sharing among the members and improves the teams’ knowledge base for innovative decisions. Belief dispersion within TMTs can increase the effectiveness of corporate innovative activities. Thus, my thesis can provide some implications for innovative information gathering, screening, and processing within TMTs and firms.

Lastly, my findings contribute to the literature of behavioral corporate finance (Bolton, Scheinkman & Xiong 2006; Goel & Thakor 2008; Malmendier & Tate 2005) by highlighting the important role of the dispersion of executives’ cognitive biases (not limited to CEOs). Malmendier and Tate (2015) suggest that behavioral biases (e.g., CEO overconfidence) matter not only for the choices and outcomes of the agents who are subject to them. They also matter for the interaction between biased agents and potentially rational agents. Also, Campbell et al. (2011) show the importance of considering different levels of CEO optimism in research. My study follows these two suggestions. In this study, I focus on the deviation of executives' beliefs about their firm's future performance within TMTs. Thus, this thesis can consider multiple levels of overconfidence and also potentially catches the beliefs from rational and underconfident agents. To my knowledge, the present study is one of the few studies that examine the interactive effect among biased and rational executives.

The rest of the thesis is organized as follows. Section 2 discusses the related literature. Section 3 develops the hypotheses. Section 4 describes data, methodology and variable, and reports the summary statistics. Section 5 presents the baseline results and three robustness checks for endogeneity. Section 6 shows the results from three subsample analyses to discuss the underlying channel. Section 7 provides the implication of belief dispersion on overall firm performance. Section 8 concludes this study.

2. Literature reviews

Overconfidence is one of the most influential behavior biases that has been documented by the psychology literature. For example, Plous (1993) stated in his book, "No problem in judgment and decision making is more prevalent and more potentially catastrophic than overconfidence" (Plous 1993, p. 217). In terms of its manifestation, Moore and Healy (2008) notice that three are faces of overconfidence. Overconfidence can first be defined as "*overestimation*", a manifestation for individuals that overestimates their ability, performance, or chance of success. The second definition of overconfidence is "*better-than-average*". It is a tendency that people believe themselves to be better than others. The last one is "*overprecision*". It occurs when people exhibit excessive certainty in their beliefs. All these manifestations of overconfidence have been examined in the previous psychology literature (e.g., Fischhoff, Slovic & Lichtenstein 1977; Larrick, Burson & Soll 2007; Soll & Klayman 2004).

The extensive literature has documented the importance of overconfidence in social science and psychology (e.g., Alicke 1985; Larwood & Whittaker 1977; Svenson 1981). Overconfidence is also considered as one of the important determinants of wars, entrepreneurial failures, and stock market bubbles (Camerer & Lovallo 1999; Howard & Howard 1984; Scheinkman & Xiong 2003).

However, in the field of corporate finance, overconfidence had received little attention prior to 2005. In a seminal paper of managerial overconfidence, Malmendier and Tate (2005) illustrate how it can affect corporate investment decisions. Since overconfident CEOs are prone to overestimate their ability and skills, they believe that the market underestimates the firm's stock price. Such biased beliefs yield severe consequences for corporate finance and investment decisions. First, overconfident CEOs will view external financing costly. Due to the optimistic beliefs on the firm's future performance, they believe that the firm's stock is undervalued. As a result, overconfident CEOs will hesitate to raise external funds by issuing equity, which can lead to an underinvestment problem when a firm's internal fund is insufficient. Second, overconfident CEOs tend to overestimate the investment outcomes, which leads to an overinvestment problem, especially when the internal fund is sufficient.

The empirical evidence in Malmendier and Tate (2005) is consistent with the above arguments. Firstly, CEOs are classified as overconfident CEOs when they fail to divest firm-specific risk in their stock and option holding accounts. One example is their late exercising behaviors of the vested stock options. This option-based measure of overconfidence was built on the theoretical framework of Hall and Murphy (2002). Rational executives are prone to exercise in-the-money stock options immediately after the vesting periods to diversify their exposures to the firm's specific risk. Only overconfident CEOs, induced by optimistic beliefs of the firm's future performance, would postpone exercising those vested options. Second, Malmendier and Tate (2005) investigate the relation between CEO overconfidence and the level of sensitivity of corporate investment to the firm's internal funds. They find that firms managed by overconfident CEOs have higher sensitivity of investment to internal funds than their rational peers.

Since the publication of Malmendier and Tate (2005), many researchers have started to investigate the impact of managerial overconfidence on a variety of corporate behaviors (e.g., Banerjee, Humphery-Jenner & Nanda 2015; Bolton, Scheinkman & Xiong 2006; Malmendier & Tate 2008). However, there is a debate on whether shareholders can benefit from hiring an overconfident CEO. In one strand of literature, managerial overconfidence is viewed as a value-destroying mechanism (e.g., Banerjee, Humphery-Jenner & Nanda 2015; Malmendier & Tate 2005, 2008). For instance, Malmendier and Tate (2008) illustrate that overconfident CEOs are prone to make value-destroying M&A decisions. But, another strand of literature documents the positive impacts from the presence of overconfident CEOs. For example, Hirshleifer, Low

& Teoh (2012) show that overconfident CEOs tend to engage more in innovative activities. Phua, Tham and Wei (2018) find that overconfident CEOs are better leaders than their peers. They can attract and maintain a stable relationship with suppliers and employees. Other studies also theoretically or empirically show some benefits of employing overconfident CEOs (e.g., Campbell et al. 2011; Galasso & Simcoe 2011; Hirshleifer, Low & Teoh 2012; Yu 2014).

Such mixed views on CEO overconfidence encourage further research on managerial behavior bias. For instance, little research on overconfidence has been extended in the setting of a top management team (i.e., TMT). One exception is Meissner, Schubert and Wulf (2017), which find that demographic diversity reduces team-level of overconfidence while the average tenure of the team increases it. Although Meissner, Schubert, and Wulf (2018) have considered the determinants of team-level of overconfidence, the consequence of such characteristic is unexplored. Moreover, no study has considered the dispersion of overconfidence in a team, especially in TMTs. Such a gap in the literature motivates my study, which aims to investigate how top executives with different levels of confidence will yield positive or negative impacts on firm value.

My study is also closely related to the literature on top management teams (i.e., TMTs), which adopts a multi-agent perspective (e.g., Bebchuk, Cremers & Peyer 2011; Bushman, Dai & Zhang 2016; Jayant, Ebru & Anand 2009). This perspective views top executives as a team rather than as individuals. Hambrick and Mason (1984) suggest that TMTs are powerful actors in many firms. The firm's performances are reflections of the values and cognitive bases of the TMTs. Many studies also highlight the importance of TMTs' characteristics (e.g., Bantel & Jackson 1989; Finkelstein & Hambrick 1990; Priem 1990). For example, Wiersema and Bantel (1992) find that firms managed by a TMT with lower average age, shorter tenure, or higher educational level are more likely to undergo strategic changes.

Another strand of TMT literature investigates the effects of TMT heterogeneity (e.g., Alexiev et al. 2010; Hambrick, Cho & Chen 1996; Knight et al. 1999; Murray 1989), but the impact of TMT heterogeneity on firm value is under-debate. From the value increasing perspective (Cox 1994), group diversity can bring some benefits to organizations. For example, gender diversity in boardroom can yield a positive effect on firm performance and corporate governance (Campbell & Mínguez-Vera 2008; Francoeur, Labelle & Sinclair-Desgagné 2008). In contrast to the value increasing view, some others consider "diversity as process loss" (e.g., Jehn, Northcraft & Neale 1999; Pelled 1996). The reason is that group diversity can lead to high potential costs and worse organizational performance.

Following the literature on TMTs, due to the uncertainty of a firm's future performance, members in the TMT may also hold different beliefs. For example, overconfident team members may hold optimistic beliefs (Moore & Healy 2008), but underconfident ones could have negative views. Furthermore, such dispersion in beliefs within the TMTs members may affect the firm's corporate decisions, as many decisions and opinions are rooted from personal beliefs (Tversky & Kahneman 1974). One prominent manifestation of heterogeneous beliefs within a group is disagreement. Many studies have discussed how different beliefs can lead to disagreement (e.g., Bolton, Scheinkman & Xiong 2006; Harrison & Kreps 1978; Thakor & Whited 2010). Scheinkman and Xiong (2003) argue that overconfidence is a significant source of disagreement in the stock market. This disagreement is introduced by the optimistic beliefs from overconfident investors and the realistic beliefs from rational investors. Moreover, Greitemeyer and Schulz-Hardt (2003) argue that individuals tend to view information as more credible if it is consistent with their own prior beliefs or preferences. As a result, each member within the TMTs may insist on the choices in their favor, resulting in disagreement during group decision-making processes.

Although the dispersion in beliefs leads to disagreement has been documented, how such a dispersion within the TMTs members can affect corporate decision-making and firm performance is still little known. For example, overconfident TMTs members may prefer risky investment, but rational and underconfident members may prefer an investment with low risk. Thus, these diverse beliefs and preferences can induce disagreement within TMTs and yield significant impacts on corporate decision-making, especially investment decisions with high uncertainty.

This study explores innovation as it is arguably one of the most crucial decisions for firms (Eisdorfer & Hsu 2011; Schumpeter 1950). Furthermore, innovative projects are highly risky and challenging, and the results of it take a long time to resolve (Hirshleifer, Low & Teoh 2012). Successful innovation can provide long-term competitive advantages and survival ability (Eisdorfer & Hsu 2011). Innovation is also the lifeblood of change because it can destroy or recreate a firm (Schumpeter 1950), and circumvent or raises market barriers (Porter 1985). Because of its importance and significance, many researchers have attempted to understand the key factors contributing to innovation success (e.g., Acharya & Subramanian 2009; Baranchuk, Kieschnick & Moussawi 2014; Gao & Chou 2015; He & Tian 2013; Hirshleifer, Hsu & Li 2013).

The positive impact of CEO overconfidence on corporate innovation has been documented. Hirshleifer, Low and Teoh (2012) show that overconfident CEOs are prone to invest heavily in innovative projects. This impact of overconfidence arises from either overestimation of expected future outcomes or underestimation of risk (Hirshleifer, Low & Teoh 2012). Overconfident CEOs are likely to take more risk, so they engage in more innovation activities than risk-averse peers. Similar results and conclusions also can be found in Galasso and Simcoe (2011). Another strand of innovation literature focuses on TMTs (e.g., Alexiev et al. 2010; Daellenbach, McCarthy & Schoenecker 1999; Nijstad, Berger-Selman &

De Dreu 2014; Young, Charns & Shortell 2001). They find that TMT's characteristics can influence the success of innovation activities. For example, Daellenbach, McCarthy and Schoenecker (1999) demonstrate that the presence of technical orientation managers in TMTs increases the commitment to innovation. Alexiev et al. (2010) examine the relation between TMT advice-seeking behavior and innovation activity. They show that TMT heterogeneity can improve the effectiveness of using internal advice to increase innovation.

The above two strands of literature show that both CEO overconfidence and the characteristics of TMTs have significant impacts on corporate innovation activities. However, no study has tried to combine these two strands. In this paper, I intend to fill the gap by showing how the belief dispersion within TMTs members can affect corporate innovation activities. Therefore, my study enhances our understanding of related important issues and contributes to the literature on behavioral finance, TMTs, and corporate innovation.

3. Hypothesis development

Overconfidence is the most prevalent and persistent behavior bias and is closely related to individual beliefs regarding the uncertain outcomes in the future (De Bondt & Thaler 1995). The TMT members may be subjected to different levels of overconfidence about the firm's prospect, implying a belief dispersion, which leads to a disagreement among top executives. As TMT members are the key decision-makers of firms, such disagreement within TMT is likely to yield a significant impact on the decision-making processes of corporate innovation. For example, overconfident managers who overestimate the returns of innovative investments are prone to invest in these risky projects (Galasso & Simcoe 2011; Hirshleifer, Low & Teoh 2012; Malmendier & Tate 2005). However, the likelihood of innovation success is low. Therefore, less optimistic members of the TMTs may disagree with the decisions proposed by overconfident executives.

The effectiveness of innovation activities depends on the quality of TMTs' decisions. Prior literature provides mixed views about group dissent on the quality of group decisions (e.g., Bénabou 2013; De Dreu & Weingart 2003). In this case, the dissent induced by belief dispersion within the TMT members can increase or decrease the efficiency of corporate innovation investment. On the one hand, from the bright-side perspective, disagreement within the TMTs can help reduce the biases in group decision-making processes. First, group members' biases can "cancel out each other" by negotiations (Landier, Sraer & Thesmar 2009). Less bias in the decision processes then yields better innovation outcomes. Second, the disagreement can restrain the social conformity biases (Asch 1956; Asch & Guetzkow 1951), which is also known as "groupthink" (Janis 1972). Prior research documents that disagreement may help to resist social conformity pressure (Asch 1955; Nemeth & Chiles 1988). This strand of the literature suggests that dissent can increase an individual's courage to be an independent thinker. When there is a group dissent, executives will be concerned that their private and public judgment coincide (Nemeth & Chiles 1988). Thus, disagreement promotes independent thinking and against social conformity biases, which also results in better idea creation and innovation outcomes.

Furthermore, dissent in TMTs can encourage knowledge and information sharing among the TMT members. Dispersed beliefs could also reflect different sources of information obtained by TMT members (Wiersema & Bantel 1992). When there are dissents or different preferences among the TMT members (Che & Kartik 2009; Malenko 2014; Parks & Nelson 1999), each executive can access other sources of information through discussion (Che & Kartik 2009; Malenko 2014; Parks & Nelson 1999). As a result, a broader knowledge base for decision making will be arrived, contributing to the quality of TMTs' innovation decisions.

The positive effect of belief dispersion on firm innovation can also be transmitted to the subordinators (Stewart 2003). For example, the employees, especially those from the R&D department, may put more effort into innovation projects because they understand the decision-making process being less arbitrary (Landier, Sraer & Thesmar 2009). Second, management disagreement can create a problem-solving culture within the firm. It encourages employees to propose different opinions and fosters creative thinking (Nemeth, Brown & Rogers 2001). Therefore, I hypothesize that:

Hypothesis 1: *Belief dispersion within TMTs increases firm innovation efficiency.*

Since bias reduction and information-sharing are the fundamental driving forces of the positive effect of belief dispersion on innovation, I also predict that the positive impact of TMT belief dispersion should be more pronounced when information-sharing and group discussion can mitigate the inefficiency induced by CEO's biased perception. For example, overconfident CEOs may overestimate the return of innovative investment and underestimate the related risk (Galasso & Simcoe 2011; Hirshleifer, Low & Teoh 2012). In this case, high belief dispersion within the TMTs can reduce the biased perception held by overconfident CEOs through group discussion and information-sharing about the innovation project selection, thereby improving the efficiency of innovation. Accordingly, I hypothesize that:

Hypothesis 1a: *The positive effect of belief dispersion within TMTs on firm innovation efficiency is more pronounced for firms that are managed by overconfident CEOs.*

Next, many large corporations have created a senior management position with the responsibility of taking care of the technology-related business, usually named as the Chief Technology Officer (CTO). They serve as technical experts within TMTs and play an important role in distributing the complex innovation information to the team members (Adler & Ferdows 1990). CTOs can facilitate tech-related communication during the group discussions process, and thus improve the innovative information sharing. Therefore, I also hypothesize that:

Hypothesis 1B: *The positive effect of TMT belief dispersion on firm innovation efficiency is more pronounced for firms with CTOs.*

Further, I also predict the benefit of belief dispersion and information-sharing depends on the firm's industry environment. The innovation activity and efficiency are more crucial for firms operating in the high-tech industries, as it determines the survival and long-term prospect of these firms (Suzuki & Kodama 2004). A diverse belief and discussion within the TMT members can improve the quality of selected innovation projects (Cohen & Levinthal 1990). Accordingly, I hypothesize that:

Hypothesis 1C: *The positive effect of TMT belief dispersion on firm innovation efficiency is more pronounced for firms operating in the high-tech industries.*

4. Data, Methodology, and Variables

4.1. Sample selection

The initial sample consists of all U.S. listed firms during the periods from 1992 to 2010. I exclude financial firms (SIC code: 6000 – 6999) and utility firms (SIC code: 4900-4999) because of their regulatory nature. I require firms to have accounting data from Compustat, executive compensation data from the Compustat ExecuComp database, stock price information from the Center for Research in Security Prices (CRSP), and patent-related information from Kogan et al. (2017) patent database. Following the literature (Bebchuk, Cremers & Peyer 2011; Bushman, Dai & Zhang 2016), I remove the firms that have reported less than five executives' compensation data in given years. If a firm has reported more than five executives' information, only the top five highest-paid executives' information is used. The final sample ends up with 9,098 firm-year observations.

4.2 Baseline regression specification and variable measurement

The purpose of the analysis in this section is twofold. First, it illustrates the econometric models that are used in empirical tests. Second, it explains why the variables are employed in empirical tests and how they are calculated.

The main objective of this paper is to examine the effect of TMT belief dispersion on a firm's innovation efficiency. Ordinary Least Squares (OLS) regression is employed to serve this objective. I also control for other important determinants of innovation and include year-fixed and industry-fixed effects to control for unobservable time and industry factors that may affect firm innovation. The reason for controlling industry-fixed effects is because of its significant explanatory power toward innovation. Cohen, Levin and Mowery (1987) document that industry-related factors can explain around 50% of the variance in R&D intensity, while the business unit only explains less than 1% of the variance. Thus, the baseline regression is designed as:

$$Innovation\ outcomes_{i,t+n} = \alpha + \beta_1 \times BD_{i,t} + \delta \boldsymbol{X}_{i,t} + YearFE + IndustryFE + \varepsilon_{i,t} \quad (1)$$

$Innovation\ outcomes_{i,t+n}$ is the dependent variable, which measures a firm's innovation performance from year t+1 to t+5. $BD_{i,t}$ is the key independent variable that measures the belief dispersion within TMTs. $\boldsymbol{X}_{i,t}$ contains a set of controls, while $YearFE$ and $IndustryFE$ are the two controls for year-fixed and industry-fixed effects. α is the intercept, and $\varepsilon_{i,t}$ is the error term.

There are three measures for a firm's innovation performance in this study. These variables are: (1) the patent count; (2) the patent citation; (3) the patent economic value. Patent-related data is from Kogan et al. (2017). This dataset contains information about patents granted by the US Patent and Trademark Office (USPTO) from 1926 to 2010. It also provides detailed information about each patent (see Kogan et al. 2017 for more details). Based on this database, I construct the three measures of a firm's innovation outcome in the following way.

The patent count is the total number of patents that are applied by a firm in a given fiscal year. This proxy gauges the productivity of a firm's innovation activity. However, it cannot reflect the success of these activities because each patent has different importance regarding the scientific value and economic value (Hirshleifer, Low & Teoh 2012). Hence, I employ the patent citation and the patent economic value as two additional measures. The patent citation is the total number of forwarding citations received by each patent. It measures the impact of each patent in the field of science. The patent economic value is an estimated value from the stock market reaction to the news about each patent (see more detailed in Kogan et al. 2017). Furthermore, I aggregate the innovation measures to firms by each patent's application year. The reason for using this time placer is because it can capture the actual time of innovation precisely (Griliches, Pakes & Hall 1986; He & Tian 2013). I also only include those eventually granted patents when measuring a firm's innovation performance to minimize the survivorship bias (He & Tian 2013).

Some data problems in the innovation measures, such as missing value and the right skewness, may affect the results. Following the innovation literature (He & Tian 2013; Hirshleifer, Low & Teoh 2012; Shen & Zhang 2018), I minimize the influence of these problems by taking some data transformation. Firstly, firm-year observations with missing value in the innovation proxies are assigned a zero value. Next, I apply the natural logarithm transformation to handle the right skewness. Specifically, I add one to the actual value of the innovation measures and then take the natural logarithm of them. The reason for that is to avoid losing observations with zero value in the innovation measures. Lastly, these variables are winsorized at 1% level.

The coefficient β_1 is the main interest of this study as it measures the effect of TMT's belief dispersion on innovation outcomes. Hypothesis 1 predictsβ_1 to be positive. That is, the higher the TMT belief dispersion, the higher the effectiveness in the firm's innovation activities. On the other hand, it is also possible that higher TMT belief dispersion leads to lower efficiency of firm innovation. Thus, it is a critical empirical question to examine whether belief dispersion is beneficial or detrimental from empirical tests.

$BD_{i,t}$ is a TMT-based measure. In the setting of this study, each TMT contains five top-paid executives for a firm-year observation. Also, all the members of a TMT are required to have vested stock options on hand, and at least one of these options is in the money. Based on these selected TMTs, $BD_{i,t}$ is calculated by the standard deviation of each executive's confidence levels within a TMT. Prior literature on CEO overconfidence suggests that stock option exercising behaviour can show executives' confidence levels in their firm's performance (Campbell et al. 2011; Humphery-Jenner et al. 2016; Malmendier & Tate 2005). Following these prior studies, I use the confidence levels of each executive to proxy their beliefs in the firm they manage. To be specific, I compute the confidence levels as:

$$Confidence = \frac{Average\ value\ per\ vested\ option}{Average\ strike\ price}$$

where,

$$Average\ value\ per\ vested\ option = \frac{Total\ value\ of\ veseted\ unexercised\ options}{Total\ numbers\ of\ vested\ unexercised\ options}$$

$$Average\ strike\ price = stock\ price\ at\ the\ fiscal\ year\ ending\ date - Average\ value\ pervested\ option$$

$\boldsymbol{X}_{i,t}$ denotes a vector of other explanatory variables that are suggested by prior literature (e.g., Hirshleifer, Low & Teoh 2012). It includes the controls for firm-specified factors, stock market performance, and CEO characteristics.

Each firm-level characteristic is computed as the following: firm size is the natural logarithm of one plus annual sales of a firm scaled by its total book asset; capital intensity is the natural logarithm of a firm's net property, plant, and equipment over the number of its employees; institutional holdings is the ratio of the shares held by intuitional investors to the number of outstanding shares; leverage is the sum of a firm's debt scaled by its total book asset; the cost of innovation activities is the natural logarithm of one plus a firm's R&D expenditure scaled by its total book asset. Following the literature (e.g., Hirshleifer, Hsu & Li 2013), any missing R&D value is assigned to 0.

Many previous studies have documented the important impact of these firm-specific factors on innovations. The classic hypothesis between firm size and innovation suggests that large firms can generate more technological advantages than small firms (Schumpeter 2010). Also, Aghion, Van Reenen and Zingales (2013) document that higher institutional ownership is associated with more innovative activities in publicly traded firms. Next, Hall and Ziedonis (2001) illustrate that capital-intensive firms are prone to innovative investment. Furthermore, leverage is likely to impact innovation by affecting each firm's availability of investment funds and stability of operation. Lastly, controlling the cost of each firm's innovation activities is required by the objectives of this study. This research aims to discover the determinants of firms' innovation efficiency. Using output-oriented innovation measures alone cannot serve this purpose. Inspired by Hirshleifer, Low and Teoh (2012) and He and Tian (2013), I control for firms' R&D expenditure in year *t* to consider the input of firms' innovation activities. Thus, the innovation outputs in each firm can show the effectiveness of those innovative activities.

I also include the controls for past stock price performance to address a potentially spurious relationship between the primary dependent variable and innovation activities. The measure of belief dispersion used in this study is based on the confidence levels of each top executive, estimated by their option holding profiles. However, this measure of confidence may associate with the past stock returns (Hirshleifer, Low & Teoh 2012). High returns can increase the moneyness of stock options, which is perceived as high individual confidence levels. Hence, in addition to reflecting executives' beliefs in their firm, the measure may reflect stock price performance consequent to the option grant date. This conjecture implies a potential error in the results of this study if better stock performance is also associated with more firm innovation. Following the literature (Hirshleifer, Low & Teoh 2012; Malmendier & Tate 2015), I address this concern by adding two controls to all regression models. The first one is the past 12 months' buy-and-hold stock return before the ending fiscal month of each firm. I also adjust this measure yearly by the industry median value of stock return to mitigate the industry effects on a firm's stock performance, based on the firm's two-digit SIC code. The second one is the volatility of the stock returns over the past 5 fiscal years.

Given that the CEO bears responsibility for the entire firm (Shen & Zhang 2018), I also take into account some CEO characteristics in this study. Sheikh (2012) finds that CEO delta is positively related to investment in innovative projects. Regarding CEO vega, it provides the incentives to take risky investment (Coles, Daniel & Naveen 2006), which can also relate to innovative investment. I obtain the data for CEO delta and CEO vega from Coles, Daniel and Naveen (2006). In their study, the two variables are calculated as the dollar change in the CEO's wealth in respective to a 1% change in stock price (CEO delta), and 1% change in the standard deviation of stock return (CEO vega). Moreover, CEO tenure may also relate to firm innovation, as it can affect the level of risk aversion associated with CEOs. Berger, Ofek and Yermack (1997) argue that CEOs with longer tenures and high cash compensation are likely to be entrenched and will seek to avoid risk. I compute CEO tenure as the natural logarithm of one plus the number of years since an executive became the CEO. Lastly, Hirshleifer, Low and Teoh (2012) have documented that overconfident CEOs are prone to innovative investment. I also control for the effects of CEO overconfidence in this study. Due to the lack of detailed data about CEO holding options, I use the method in Campbell et al. (2011) to compute the dummy indicator for CEO overconfidence. It equals to 1 if a CEO has least held over 67% in-the-money options twice during the sample periods.

4.3 Econometric model to solve the endogeneity problems

Although many factors have been considered in the baseline regression model (1), endogeneity still may be a concern. In this section, I explain where the endogeneity concerns may arise from and what identification strategies have been used to mitigate these concerns.

There may be some firm-specific characteristics that can influence both innovation and TMT's belief dispersion in firms. This argument suggests that the belief dispersion is endogenous. Also, successful innovation is likely to provide a positive signal to each executive about their skill and ability, which can enhance their optimism (Camerer & Lovallo 1999). However, the enhancement may be different regarding each individual. This causality suggests a plausible feedback effect (i.e., reverse causality) from successful innovation performance to TMT's belief dispersion.

To mitigate the endogeneity concerns, I first investigate the lead-lag relation between the dependent and the independent variables in the baseline model (1). Specifically, all the explanatory variables are at least lagged 1-year in relation to the measures of innovation outcomes. Second, I employ three different identification strategies in this research to further address the endogeneity problem.

The first strategy relies on the events of executive turnover. TMT's belief dispersion is a team-based behavioral trait. Such behavioral trait may be different when the member of TMTs has been replaced. Thus, the events of executive transition provide a window to identify the relationship between TMT's belief dispersion and firm's innovation efficiency. If TMT's belief dispersion indeed yields better innovation efficiency, it should be discovered when the dispersion increases mainly due to a new joining executive.

Based on the above idea, I start by examining executive turnover events in the sample. When the executive leaves the current firm and joins a new company, we define the first year of the executive is reported by the new company as the turnover happening year. I further require that this executive is not joining other companies in the following year. Any turnover events that cannot satisfy this requirement is excluded.

Next, turnover-related firms are divided into two groups: the treatment and the control. The treatment group consists of the firms with increased TMT's belief dispersion due to a new joining executive. Firstly, I calculate the five-year average of each TMT's belief dispersion in pre- and post- turnover periods for the turnover-related firms. Secondly, I calculate the increasing rate by using the post-turnover average minus the pre-turnover average. Lastly, I select the firms with the top 25% of the increasing rate as the treatment group, and the remaining firms belong to the control group.

Further, I perform a propensity score matching (PSM) approach by including all other control variables in the baseline model (1). This matching process ensures that the treatment and the control groups are similar in terms of other important determinants of innovation. The final matched sample consists of 207 pairs of treatment-control observations. With this sample, I run the following regression using the matched sample:

$$Innovation\ outcomes_{i,t+3/t+4/t+5} = \alpha + \beta_1 \times Treat_{i,t} + \delta \boldsymbol{X}_{i,t} + YearFE + IndustryFE + \varepsilon_{i,t} \qquad (2)$$

α is the intercept and $\varepsilon_{i,t}$ is the error term. Since firm's innovation results take a long time to resolve (Hirshleifer, Low & Teoh 2012), we examine the *innovation outcomes* at 3 years and 5 years after the executive joining the company. *Treat* is the dummy indicator, which is equal to 1 for the treatment group and 0 for the control. I also include, $\boldsymbol{X}_{i,t}$, the same set of controls as the baseline model. This regression model also includes year-fixed effects and industry-fixed effects to account for the time- and industry- invariant factors. If an increasing in belief dispersion improves the innovation efficiency, the estimated coefficient on the dummy variable (*Treat*) is expected to be positive.

The second identification strategy is using the burst of dot-com bubble as an exogenous shock to TMTs' belief dispersion. During the periods of 1999 to early 2000, there are many initial public offerings (IPOs) from the dot-com related industries. More importantly, the first-day returns on these IPOs are incredibly high. Ljungqvist and Wilhelm Jr. (2003) emphasize the fact that the first-day returns are around 73 percent in 1999 but only be 17 percent in 1996. Since personal life experience may affect personal belief (Malmendier, Tate & Yan 2011), the booming and the burst dot-com bubble around 1999 provide an exogenous variation in the life experience of executives from the dot-com related industries and thus affect the TMTs' belief dispersion. A firm's executives could learn from the failures of their peers and change their beliefs, which can reduce the dispersion of the TMTs caused by the unrealistic beliefs of the TMT members. Secondly, the market crisis may require quicker responses to gain competitive advantages (Hambrick, Cho & Chen 1996). Such requirement further induces homogenous belief among the firm's top managers to generate quicker management consensus.

Internet firms are more likely to be affected by the burst of dot-com bubble. Thus, I define the treatment group and control group based on the value of TMT's belief dispersion of Internet firms in 1999 right before the burst of dot-com bubble. The Internet firms with top 50% high belief dispersion in the TMTs are considered as the treatment firms. The other Internet firms and firms in other industries are defined as control firms. Next, I use the difference in difference (DiD) approach to address the endogeneity issues in the baseline regression (1). The DID regression takes the following form:

$$\begin{aligned} Innovation\ outcomes_{i,t+1} &= \alpha + \beta_1 \times Treat_i + \beta_2 \times Post_t + \beta_3 \times Treat_i \times Post_t + \delta \boldsymbol{X}_{i,t} \\ &+ IndustryFE + \varepsilon_{i,t} \end{aligned} \quad (3)$$

α and $\varepsilon_{i,t}$ are the intercept and the disturbance term, respectively. $Treat_i$ is the dummy indicator to distinguish the treatment and control firms. $Post_t$ is a time indicator, which equal to 1 for the period from 2000 to 2002 and 0 otherwise. I also include the same set of controls as the baseline. This model also includes industry-fixed effects. β_3 is expected to be negative because of the decreasing in TMTs' belief dispersion of the treatment group after the burst of dot-com bubble.

The last identification strategy relies on an instrumental variable (IV) with a two-stage least square (2SLS) regression (Wooldridge 2016). I use the industry median level of TMT's belief dispersion in a given year as an instrument variable. This IV is likely to satisfy both relevance and exclusion restrictions for a valid IV. Firstly, it is likely that the firms in the same industry are having similar recruitment policies, which can lead to similar TMT's belief dispersion in those firms. Secondly, it is unlikely that a firm's innovation efficiency can be affected by the industry-level of TMT's belief dispersion.

I calculate the instrumental variable for each firm-year observation based on their industry classification, and then run the 2SLS regressions shown as below:

First stage:

$$BD_{i,t} = \alpha + \beta_1 \times BD(Industry\ median)_{i,t-1} + \delta \boldsymbol{X}_{i,t} + YearFE + IndustryFE + \varepsilon_{i,t} \quad (4)$$

Second stage:

$$Innovation\ outcome_{i,t+n} = \alpha + \beta_1 \times \widehat{BD_{i,t}} + \delta \boldsymbol{X}_{i,t} + YearFE + IndustryFE + \varepsilon_{i,t} \quad (5)$$

From model (4), the significance of the estimated coefficient on $BD(Industry\ median)_{i,t}$ can indicate whether the IV is satisfying the relevance condition. Also, the F-statistic from the model (4) can show whether the relationship between the IV and the endogenous variable is strong or weak (Staiger & Stock 1994; Stock & Yogo 2002). In the second stage regression, the coefficient on $\widehat{BD_{i,t}}$ is also expected to be significantly positive.

4.4. Summary statistics

[Insert Table 1]

Table 1 presents descriptive statistics for the final sample. On average, each firm applies 25 patents per year. Concerning the quality, these patents on average would receive 216 forward citations and worth $544 million. However, there are some extreme values in these innovation measures, which is shown by the maximum value of each variable. Thus, I use the logarithm transformation of these variables to mitigate the effect of outliers. On average, belief dispersion within TMTs is 0.31. The median value and standard deviation of belief dispersion are 0.15 and 0.46, respectively.

Table 1 also shows the descriptive statistics of CEO and firm characteristics. 73% of CEOs are defined as overconfident CEOs, and CEO tenure on average is 7 years. The mean of CEO delta and CEO vega equal to $0.55 million and $0.14 million, respectively. Regarding other variables, an average firm has annual sales of $5.5 billion, PPE per employee of $289.31 thousand, leverage of 22%, the pay gap between CEO and the next layer of senior executives of $6.46 thousand, and R&D expenditure of $0.04 million. Moreover, on average, 58% of the firm's share is held by institutional investors, and the annual return and the annual return volatility of the share are 13% and 41%, respectively[4].

[Insert Table 2]

The correlation matrix of the key variables is reported in table 2 panel A and B. Panel A shows that belief dispersion is negatively related to firm size, capital intensity, and leverage ratio, but it is positively related to past stock performance, past stock return volatility, and R&D expenditure. Panel B indicates that some CEO characteristics are related to belief dispersion. CEOs being overconfident, having long tenure or high delta is likely to link with high belief

[4] The summary statistics that are shown in Table 1 are mostly consistent with previous literature (e.g., Hirshleifer, Low & Teoh 2012; Shen & Zhang 2018)

dispersion. In contrast, having high CEO vega is negatively related to the levels of the dispersion.

5. Main results

5.1. Baseline Results

[Insert Table 3]

Table 3 shows the regression results for empirical analysis by taking the baseline model (1). The primary independent variable is *Dispersion*, and the dependent variable is innovation output. There are three different innovation output measures, and each of them is calculated from year t+1 to year t+5 to account for the implementing time of any innovation policy. In Panel A, the dependent variables are *Ln(1+citation count)* for Column 1-5 and *Ln(1+patent value)* for Column 6-10. These two measures aim to capture the scientific and economic importance of corporate innovation output. They focus on the impact of belief dispersion on innovation quality. The dependent variable is *Ln(1+patent count)* for all regressions in Panel B. This variable shows a firm's overall innovation productivity. Therefore, the regression results indicate how belief dispersion can affect corporate innovation in quantity. Further, all the regressions have controlled for R&D expenditure. In this case, the estimated coefficients of belief dispersion present their influence on a firm's innovation efficiency. I also cluster standard errors at the firm.

The results in Table 3 are consistent with the main hypothesis. The coefficients of *Dispersion* are positive and significant at 1% or 5% level across all regressions in Panel A of Table 3. These findings support the argument that belief dispersion can contribute to a firm's efficiency in producing higher-impact patents. Regarding the economic significance, from the results in columns 1 and 3 of Panel A, one standard deviation increase in *Dispersion* can raise *citation count* by 5.24% in year t+1 and 6.99% in year t+3. Similarly, from columns 6 and 8 of Panel A, *patent value* would be increased by 7.25% in year t+1 and 9.15% in year t+3 if *dispersion* is increased by one standard deviation. These increases are economically significant.

According to the sample average, the increase in future one year citations is about 11 and $39.58 million in patent value. However, the coefficients of *Dispersion* are all insignificant for the regressions at Panel B of Table 3, which means belief dispersion is not related to the quantity of corporate innovation.

In sum, the findings in panel A and B of Table 3 are more consistent with the expected effects of belief dispersion, which include reducing the biases in group decision-making processes and sharing knowledge among TMTs' members. From these two channels, belief dispersion is likely to yield high-quality innovation, not a large quantity of innovation, thereby affecting the efficiency of generating high-cited and high-value patents.

The estimated coefficients of the control variables in Table 3 are consistent with existing literature (e.g., He & Tian 2013; Hirshleifer, Hsu & Li 2013; Shen & Zhang 2018). For example, the coefficients on *Ln(1+Sale), Ln(1+PPE/EMP),* and *Ln(1+R&D exp.)* are positive and significant, which indicate that a firm is likely to be innovation efficient if it is large, with more tangible assets, or spending more on R&D. Further, institutional ownership, tournament incentives in TMTs (*Ln (Pay Gap)*), and past stock return volatility are positively related to corporate innovation efficiency. Increasing in debt financing will reduce the effectiveness of corporate innovation, supported by the negative and significant coefficients of *Leverage*.

Although Hirshleifer, Low and Teoh (2012) and Galasso and Simcoe (2011) find positively significant effects of CEO overconfidence on corporate innovation, I cannot find a similar result. The coefficients on CEO overconfidence are insignificant. The setting of this study may explain the inconsistency. By applying a team concept, this study considers not only CEOs' but also other TMT members' behavior biases, which shows the importance of viewing top executives jointly as a team, rather than focusing on one single agent (i.e., CEOs). Other

CEO characteristics, such as CEO tenure and CEO delta, show an insignificant impact on firms' innovation efficiency. Only CEO vega appears to have a positive influence. It is not surprising that CEO risk-taking incentives are related to one of the risky corporate investments, i.e., innovation.

5.2. Robustness

So far, the results from the baseline regression (1) are consistent with Hypothesis 1. However, there are potential endogeneity concerns, as discussed in section 3.3. These concerns can prevent the current study to draw a causal relationship between belief dispersion and corporate innovation efficiency. To alleviate endogeneity concerns, I have performed three additional tests and the results are presented in the following subsection.

5.2.1 The effects of belief dispersion around executive turnovers

[Insert Table 4]

The first identification approach relies on the events of executive turnover. Firms that have a sharp increase in belief dispersion after executive turnovers are defined as treatment firms. This increase is likely due to the change of their TMT members, rather than firm-specific factors. Thus, the result from this approach can mitigate the omitted variable bias. If consistent with the main result in OLS estimation, treatment firms should present better innovation performance than control firms because of the significant increase in belief dispersion.

Table 4 reports the results. Panel A presents that there is a significant difference between the treatment and the control in the change of belief dispersion after executive turnovers. On average, the change is 0.31 (in Column 1) for treatment firms, and it is -0.32 (in Column 2) for control firms. The difference in differences on average is 0.628, and it is significant at 1% level (in Column 3). Panel B shows the regression results on a matched sample. The controls in this regression are the same as the baseline model. The matched sample is created by a PSM approach[5]. Since the corporate innovation activities need more than one year to generate the outcomes, the dependent variables are calculated at three- to five-year after executive transition events. *Treat* is a dummy indicator, which equals to 1 for treatment firms and 0 for control firms. The difference between the treatment and the control group is the change in TMT belief dispersion, caused by executive turnovers. In Panel B of Table 4, the coefficients of *Treat* are all positive and significant. This result indicates that exogenous increases in belief dispersion indeed yield higher innovation efficiencies, suggesting a positive relationship between belief dispersion and corporate innovation efficiency.

5.2.2 DiD approach

The second identification strategy is to rely on a natural experiment. The dot-com bubble burst around 1999 is employed as an exogenous shock. As explained in Section 3.3, this shock is suitable for identification purposes. It generates some exogenous variations in the belief dispersion of treatment firms. Internet firms with high dispersion before the burst of dot-com bubble are defined as the treatment firms, and the other in the sample are selected as the control. The pre- and the post-bubble periods are 1996 to 1998 and 2000 to 2002, respectively. Therefore, *Treat* indicator equals 1 for treatment firms and 0 for control firms. *Post* equals 1 for post-bubble period and 0 otherwise.

Before starting the DiD analysis, I check whether the parallel trend assumption is satisfied. Figure 1 provides the first piece of evidence that the parallel trend assumption is satisfied. Panels A-C shows the patterns of different innovation measures for the two groups of firms over a seven-year event window [-3, +3]. Overall, the differences between the two groups are similar before the exogenous shock. In addition, panel B of Table 5 shows that the coefficients of *Treat* are statistically insignificant. This result indicates that there is no

[5] I include all other control variables in the baseline model as the matching variables.

statistical difference in innovation efficiency between the treatment and the control group, suggesting that the parallel trend assumption is satisfied.

[Insert Figure 1 & Table 5]

Table 5 provides the main results from the DiD analysis. Panel A shows the mean difference (after-before) in belief dispersion for the treatment and the control. The mean difference is -0.463 for treatment firms (in Column 1) and -0.098 for control firms (in Column 2). Column 3 shows the difference in differences, which is -0.364 and significant at 1% level. Thus, there is a more significant decrease in belief dispersion in treatment firms than control firms, surrounding the event of the dot-com bubble burst.

Further, Panel B of Table 5 presents the results from three DiD regressions. The coefficients of *Post* are negative and significant. This result indicates that the burst of the dot-com bubble causes a significant decrease in firms' innovation efficiency. The critical variable for identification purposes is the interaction between the two dummy variables, *Treat*Post*. The estimated coefficient of this variable is negative and significant. This result suggests that the decrease in innovation efficiency in treatment firms is more substantial than in control firms. Thus, the DiD estimation yields a consistent result as the main regression, supporting hypothesis 1, that is, the higher the dispersion, the better corporate innovation efficiency.

5.2.3. Instrumental Variable Approach

The last identification strategy is to use a 2SLS regression. In a similar spirit with Shen and Zhang (2018), I use the lagged industry-level median dispersion as an instrument variable. This instrument is likely to be valid, that is, correlated with the endogenous variable and not directly related to the dependent variable. The results from the first-stage regression show the satisfaction of the relevance requirement. However, the satisfaction of the exclusion restriction cannot be directly tested. I find no prior study that has indicated a direct link between an industry-level dispersion and firm-level innovative performance. Thus, the IV is likely to satisfy the requirement of exclusion.

[Insert Table 6]

Table 6 presents the 2SLS regression results. The first column in each panel shows the first-stage regression results. In the first stage, I regress *dispersion* on the IV, *Industry median dispersion*, and all other control variables in the second-stage regression. Consistent with the expectation, the coefficient of the IV is significant at 1% level. This result suggests a strong relevance between the IV and the endogenous variable. Also, the IV is not a weak-instrument according to the F-statistic from the first-stage regression. The F-statistic is greater than 10, which will reject the null hypothesis that the IV is weak (Staiger & Stock 1994).

In the first-stage regression, the estimated coefficients of CEO characteristics are statistically significant. CEO overconfidence and CEO delta are positively related to belief dispersion, while CEO tenure and CEO vega are negatively related to it. This result confirms the argument from many previous studies (e.g. Shen & Zhang 2018), that is, CEOs, as the leader of TMTs, having a notable influence on TMTs' characteristics. Furthermore, higher belief dispersion is likely to be observed at larger firms, firms with higher leverage and with higher R&D expenditure. Larger belief dispersion is also more likely to exist at firms with better past stock performance, higher past stock return volatility, and greater CEO pay gap.

Other columns in each panel of Table 6 report the results from the second-stage regressions. Specifically, the regressions in Panel A and B use *Ln(1+citation)* and *Ln(1+value)* as the dependent variable, respectively. In Panel C, the dependent variable is *Ln(1+patent)*. Consistent with the findings from the baseline model, the coefficients of instrumented *Dispersion* are mostly positive and significant in year t+3 to t+5, but they are positive and insignificant in year t+1 and t+2.

In summary, according to different identification strategies, the results are consistent with those from the baseline model, which suggests that there is a positive causal relationship between belief dispersion and firm innovation efficiency.

6. Subsample analysis

In this section, I further examine whether the positive effect of belief dispersion on innovation efficiency varies across firms with different characteristics. According to hypotheses 1A-1C, if information sharing is the underlying channel, such a positive effect should be more pronounced when the value of information is greater. To test this conjecture, I perform three different subsample analysis and present the results in table 7.

[Insert Table 7]

The first subsample analysis is based on whether or not a firm is managed by an overconfident CEO. Overconfident CEOs are prone to invest in innovative projects (Galasso & Simcoe 2011; Hirshleifer, Low & Teoh 2012). These typical CEOs are likely to discuss more innovation with other the TMTs' members, which contributes to setting up an environment with more significant initiative of innovation. Columns 1-3 of Table 7 report the results of the first subsample analysis. The coefficients on the interaction variable, *CEO overconfidence * Dispersion*, are all positive and statistically significant. This result supports the hypothesis 1A; the positive relationship between belief dispersion and corporate innovation efficiency should be more pronounced when CEOs are overconfident.

The second subsample analysis is based on the composition of TMTs. The CTO sitting in a TMT facilitates innovative information sharing among the team, and thus a more pronounced positive effect of belief dispersion on innovation efficiency should be found. I identify CTOs according to executives' annual title. An executive is a CTO if he or she annual title contains the words "tech.", "technology", or "technical". There are 977 CTOs in the sample. The *CTO indicator* equals to 1 for the TMTs with a CTO member, and 0 otherwise. Then, I estimate the baseline model with two additional variables, the *CTO* indicator and the interaction variable between CTO and belief dispersion. Columns 4-6 of Table 7 show the result. The coefficients of the interaction variable are positive and significant. This result supports hypothesis 1B, suggesting that the positive effect of belief dispersion on innovation efficiency is stronger when firms have a CTO in their TMTs.

The last subsample analysis examines the positive effect of belief dispersion across different industries. To be survived in an innovative industry, firms are required to produce a steady stream of innovations. Thus, the positive effect of belief dispersion on corporate innovation efficiency is expected to be stronger for those firms. The classification of the innovative industry follows Ljungqvist and Wilhelm Jr. (2003), which uses a firm’s four-digit SIC code. I generate an indicator, *HT*, which equals 1 for firms belong to the innovative industry, and 0 otherwise. Next, I estimate the baseline regression with two additional variables, the *HT* indicator and the interaction variable, *HT*Dispersion*. Columns 7-9 of Table 7 shows the results. In all these columns, the coefficients of the interaction term are all positive and significant, supporting Hypothesis 1C.

The results from subsample analysis show that the effect of belief dispersion on firm innovation efficiency is more pronounced in the firms with an information-sharing environment. This result implies that such a positive effect from belief dispersion is likely through the channel of information sharing.

7. Firm Performance Implication

Since innovation is the engine of firm growth, better efficiency in innovative investments may yield higher firm performance. Thus, I test the effect of the dispersion on firm performance and show the results in this section. Specifically, I estimate the same regression as the baseline model but replace the dependent variable by two measures of firm performance. The two measures are *Tobin's Q* and return on assets (ROA), which are standard measures of firm performance that can be found in previous studies (e.g., Bushman, Dai & Zhang 2016).

[Insert Table 8]

Table 8 shows the results. Both regressions in columns 1-2 find a positive coefficient of *Dispersion*, and it is statistically significant at 1% level. This positive effect of belief dispersion on firm performance is economically significant. One standard deviation increase in the belief dispersion will yield a 6.85% increase for *Tobin's Q* and an 18.17% increase for the ROA from the sample mean. Moreover, previous studies have documented that the board is an important determinant of firm performance. For example, Guest (2009) finds that board size is negatively related to firm performance among UK listed firms. Liu et al. (2015) show that board independence has a positive impact on Chinese firms' performance. Therefore, in Columns 3-4, I add board size and board independence to the set of controls. The estimated coefficients of *Dispersion* are still positive and statistically significant at 1% level after controlling for board information.

However, endogeneity issue is still a concern. It is likely to exist an omitted variable that can affect both belief dispersion and firm performance. For example, some firms may encourage employees to hold different opinions. This corporate culture may also foster creative thinking and then lead to better performance. Thereby, belief dispersion is an endogenous variable, and the result of the OLS regression is biased. I first mitigate endogeneous concerns by estimating the OLS regressions with firm-fixed effects. This method may remove the biases from time-invariant omitted firm characteristics (e.g., corporate culture). Second, I construct an instrument for belief dispersion (the industry median value of belief dispersion) and use a 2SLS approach to correct for the potential bias.

[Insert Table 9]

Panel A of Table 9 shows the regression results with firm-fixed effects. The dependent variable is Tobin's Q in Column 1, and it is ROA in Column 2. The two regressions find positive and significant coefficients of *Dispersion*. This result suggests that the findings from OLS estimation are robust after controlling for time-invariant firm factors. Panel B of Table 9 shows the result from 2SLS regressions. Column 1 presents the first-stage regression result. The coefficient of the IV is significant at 1% level, which indicates that the IV satisfies the relevance requirement. Also, the F-statistic from the first-stage regression exceeds the rule of thumb of a strong IV(i.e., F-statistic >10). Columns 2-3 present the results from the second-stage regression. Column 2 reports the results with Tobin's Q as the dependent variable, while Column 3 shows the results on ROA. From both regressions, the coefficient estimates of *Dispersion(instrumented)* are positive and significant, reinforcing the findings from OLS regressions.

8. Limitation and Conclusion

In this thesis, I examine the effect of TMTs belief distribution on firm innovation. The belief distribution is measured by the deviation of TMTs members' belief about their firm's future performance. The term, "Belief dispersion", refers to having dispersed beliefs within a firm's TMT. The baseline results show a positive relationship between TMTs belief dispersion and corporate innovation efficiency. I further perform three robustness tests to consider potentially endogeneity in belief dispersion. The first test utilizes the events of the executive transition, and the second one uses the dotcom bubble as a quasi-natural experiment. I employ a 2SLS approach in the last test. The results from all three approaches are consistent with the baseline model.

In the subsample analysis section, I test possible underlying mechanisms through which TMTs belief dispersion can enhance corporate innovative efficiency. I find a more evident effect of TMTs belief dispersion on innovation for the firms with overconfident CEOs or a CTO in the TMT, and the firms from high-tech industries. This result is consistent with the view that belief dispersion encourages information sharing within TMTs and thus leads to better innovation efficiency. I further provide implications about the relation of TMTs belief dispersion and firm performance in the last section of this thesis. Both results from baseline regression and robustness tests indicate that TMTs belief dispersion is positively related to firms' Tobin's Q and ROA. Thus, shareholders indeed benefit from the belief dispersion within the TMT.

My thesis contributes to three streams of literature. First, it identifies an important TMT attribute, belief dispersion, contributing to the literature of TMT. Second, it finds that TMTs belief dispersion is beneficial for innovation efficiency, contributing to the literature of corporate innovation. Finally, it sheds light on the interactional effect among the members of a firm's TMT, which is likely driven by each member's behavioral bias, contributing to the literature of behavioral finance.

I also acknowledge some limitations in this thesis. First, although my results suggest that belief dispersion within TMTs can enlarge the knowledge base in TMTs, such a relation cannot be tested directly as TMTs knowledge base is unobservable. Further, based on the current measure of TMTs belief dispersion, my study can only capture the belief of executives, who has a non-zero exercisable stock option. Future research could extend this measure by using texture analysis. Such method might provide a non-stock-based measure of TMTs belief dispersion. Finally, although the empirical results in my study show the benefit of belief dispersion, it does not exclude the alternative that belief dispersion may also have a dark-side effect on firm performance.

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Tables

Table 1. Summary statistics

This table presents the summary statistics of the variables that is used in the current study. The sample covers nonfinancial and nonutility firms in Execucomp from 1993 to 2010. After merging with Compustat, CRSP and Kogan et al. (2017) patent data, the final sample consists of 9,098 firm-year observations. Variable definitions are provided in the Appendix. All continuous variables are winsorized at 1% levels.

VARIABLES	Obs	Mean	Median	Std. Dev.	Min	Max
N patent	9,098	25.21	1.00	74.33	0.00	485.00
Ln(1+patent)	9,098	1.35	0.69	1.73	0.00	6.19
N Citation	9,098	215.95	0.00	750.93	0.00	5104.00
Ln(1+citation)	9,098	1.92	0.00	2.56	0.00	8.54
Patent Value	9,098	544.40	0.00	1932.99	0.00	12595.56
Ln(1+value)	9,098	2.29	0.00	2.86	0.00	9.44
Dispersion	9,098	0.31	0.15	0.46	0.00	2.86
CEO Overconfidence	9,098	0.73	1.00	0.45	0.00	1.00
CEO Tenure	9,098	7.36	5.00	7.10	0.00	35.00
Ln(1+CEO Tenure)	9,098	1.79	1.79	0.85	0.00	3.58
CEO Delta	9,098	0.55	0.24	0.79	0.01	3.57
Ln(1+ CEO Delta)	9,098	0.36	0.22	0.37	0.01	1.52
CEO Vega	9,098	0.14	0.07	0.16	0.00	0.60
Ln(1+CEO Vega)	9,098	0.12	0.07	0.13	0.00	0.47
Sale	9,098	5535.12	1516.93	11030.49	23.06	65052.48
Ln (1+Sale)	9,098	7.41	7.33	1.59	3.18	11.08
PPE/EMP	9,098	289.31	87.07	818.73	7.02	6063.36
Ln(PPE/emp)	9,098	4.65	4.48	1.16	2.08	8.71
Leverage	9,098	0.22	0.21	0.18	0.00	3.47
CEO paygap	9,098	6.46	6.47	1.18	3.29	9.17
Ln(CEO paygap)	9,098	2.00	2.01	0.17	1.46	2.32

R&D exp.	9,098	0.04	0.01	0.06	0.00	0.30
Ln (1+R&D exp.)	9,098	0.03	0.01	0.05	0.00	0.26
Institutional ownership	9,098	0.58	0.67	0.31	0.00	1.04
Stock Return	9,098	0.13	0.07	0.44	-1.26	3.21
Stock volatility	9,098	0.41	0.36	0.19	0.11	1.16

Table 2. Correlation matrix

This table presents the correlation coefficient among the main variables of the study. *Dispersion* is the proxy for belief dispersion. It is calculated by taking the standard deviation of the confidence levels among a firm's top-five executives. Individual confidence levels are calculated by following Campbell et al. (2011) overconfidence measure. Panel A reports the correlation coefficient among firm characteristics with belief dispersion. Panel B shows the correlation among CEO characteristics with belief dispersion. Variable definitions are provided in Appendix. ***, **, and * denote significant level at 1%, 5% and 10%, respectively.

Panel A. Correlations with firm characteristics (N= 9,098)

	Dispersion	Ln (1+sale)	Ln(PPE/Emp)	Institutional ownership	Leverage	Stock Return	Stock volatility	Ln (1+R&D exp.)	Ln(CEO paygap)
Dispersion	1.0000								
Ln (1+sale)	-0.1333***	1.0000							
Ln(PPE/Emp)	-0.1035***	0.0880***	1.0000						
Institutional ownership	-0.0098	0.0207**	0.0067	1.0000					
Leverage	-0.1190***	0.1791***	0.1925***	-0.0559***	1.0000				
Stock Return	0.1833***	-0.0790***	-0.0425***	-0.0191	-0.0264***	1.0000			
Stock volatility	0.1849***	-0.4954***	-0.0885***	0.0052	-0.1194***	0.1016***	1.0000		
Ln (1+R&D exp.)	0.0849***	-0.3378***	0.0080	0.0486***	-0.2183***	0.0758***	0.3864***	1.0000	
Ln(CEO paygap)	-0.0058	0.5509***	0.1143***	0.1167***	0.0779***	0.0136	-0.1786***	-0.0456***	1.0000

Panel B. Correlations with CEO characteristics (N=9,098)

	Dispersion	CEO Overconfidence	Ln(1+CEO Tenure)	Ln(1+ CEO Delta)	Ln(1+CEO Vega)
Dispersion	1.0000				
CEO Overconfidence	0.1656***	1.0000			
Ln(1+CEO Tenure)	0.0687***	0.1165***	1.0000		
Ln(1+ CEO Delta)	0.1686***	0.2267***	0.2875***	1.0000	
Ln(1+CEO Vega)	-0.0694**	0.1203**	0.0442**	0.6298**	1.0000

Table 3. The effect of belief dispersion to firm's innovative efficiency

This table presents the baseline regressions of firm innovative efficiency on the belief dispersion within TMTs. The dependent variables are firm's innovative outputs, which is calculated by citation count, patent value and patent count from year t+1 to year t+5. Also, innovative outcomes are aggregated at the application year of a patent for each firm-year observation. Following Hirshleifer, Low and Teoh (2012), innovative efficiency is measured at innovative outcomes on a given levels of innovative inputs. Specifically, each regression of innovation outcome in future [t+1, t+5] has controlled for firm R&D expense in current. Dispersion is the standard deviation of the confidence levels among a firm's top-five executives. Variable definitions are provided in the Appendix. All regressions control for the two-digit SIC code industry effect, and year effect. t-Statistics are calculated based on robust standard errors (within parentheses) and clustered at the firm level. ***, **, and * denote significant level at 1%, 5% and 10%, respectively.

Panel A. Belief dispersion with citation count and patent value

	Ln(1+Citation count)					Ln(1+Patent value)				
VARIABLES	t+1	t+2	t+3	t+4	t+5	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dispersion	0.114**	0.138**	0.152***	0.148**	0.134**	0.158**	0.181***	0.199***	0.198***	0.177**
	(0.057)	(0.058)	(0.059)	(0.060)	(0.063)	(0.066)	(0.069)	(0.072)	(0.073)	(0.077)
CEO Overconfidence	-0.027	-0.011	-0.005	0.037	0.004	0.027	0.063	0.084	0.149	0.111
	(0.083)	(0.087)	(0.090)	(0.094)	(0.097)	(0.087)	(0.094)	(0.100)	(0.106)	(0.111)
Ln(1+CEO Tenure)	-0.017	0.003	0.020	0.032	0.038	-0.066*	-0.042	-0.027	-0.000	0.005
	(0.035)	(0.036)	(0.038)	(0.040)	(0.040)	(0.039)	(0.041)	(0.043)	(0.046)	(0.048)
Ln(1+ CEO Delta)	-0.227	-0.231	-0.194	-0.195	-0.189	-0.086	-0.115	-0.152	-0.130	-0.074
	(0.145)	(0.147)	(0.147)	(0.152)	(0.151)	(0.171)	(0.178)	(0.185)	(0.196)	(0.198)
Ln(1+CEO Vega)	1.041***	0.837**	0.446	-0.017	-0.512	2.260***	2.027***	1.812***	1.147**	0.332
	(0.391)	(0.398)	(0.398)	(0.410)	(0.422)	(0.463)	(0.482)	(0.497)	(0.525)	(0.546)
Ln (1+Sale)	0.640***	0.653***	0.641***	0.651***	0.649***	0.907***	0.934***	0.936***	0.959***	0.964***
	(0.044)	(0.045)	(0.046)	(0.047)	(0.048)	(0.049)	(0.051)	(0.052)	(0.054)	(0.056)

Ln(PPE/Emp)	0.190***	0.180***	0.155**	0.145**	0.129*	0.264***	0.253***	0.227***	0.202**	0.181**
	(0.067)	(0.069)	(0.069)	(0.072)	(0.074)	(0.074)	(0.078)	(0.079)	(0.081)	(0.087)
Institutional ownership	0.322**	0.371***	0.377***	0.340**	0.384***	0.235	0.290*	0.335**	0.319*	0.372**
	(0.127)	(0.128)	(0.132)	(0.138)	(0.145)	(0.150)	(0.157)	(0.162)	(0.175)	(0.185)
Ln(pay gap)	0.435**	0.343	0.398*	0.514**	0.685***	0.577**	0.472**	0.450*	0.591**	0.840***
	(0.213)	(0.213)	(0.217)	(0.225)	(0.235)	(0.225)	(0.230)	(0.240)	(0.258)	(0.279)
Leverage	-0.903***	-0.960***	-0.958***	-0.913***	-0.962***	-1.081***	-1.107***	-1.124***	-1.126***	-1.146***
	(0.203)	(0.207)	(0.216)	(0.229)	(0.243)	(0.242)	(0.251)	(0.263)	(0.291)	(0.311)
Stock Return	-0.001	0.046	0.067	0.050	0.142***	0.117***	0.134***	0.116**	0.071	0.178***
	(0.041)	(0.042)	(0.044)	(0.048)	(0.049)	(0.044)	(0.048)	(0.052)	(0.057)	(0.058)
Stock volatility	1.023***	0.908***	0.651**	0.411	0.249	1.095***	1.053***	0.920***	0.719**	0.487
	(0.268)	(0.277)	(0.272)	(0.276)	(0.287)	(0.297)	(0.320)	(0.329)	(0.338)	(0.352)
Ln (1+R&D exp.)	7.726***	7.469***	7.604***	7.649***	7.776***	9.207***	9.151***	9.326***	9.678***	10.160***
	(0.986)	(1.061)	(1.123)	(1.224)	(1.370)	(1.093)	(1.215)	(1.316)	(1.503)	(1.741)
Constant	-4.414***	-4.785***	-4.537***	-5.487***	-5.390***	-7.558***	-7.932***	-7.353***	-8.532***	-8.585***
	(0.871)	(0.814)	(0.763)	(0.725)	(0.812)	(1.006)	(0.976)	(0.969)	(0.848)	(0.933)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,098	8,047	7,131	6,184	5,366	9,098	8,047	7,131	6,184	5,366
R-squared	0.533	0.539	0.536	0.544	0.545	0.568	0.571	0.568	0.573	0.576

Panel B. Belief-dispersion with patent counts

VARIABLES	Ln(1+Patent count)				
	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)
Dispersion	0.035	0.045	0.056	0.062	0.068
	(0.035)	(0.038)	(0.039)	(0.041)	(0.044)
Industry FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Control	Yes	Yes	Yes	Yes	Yes
Observations	9,098	8,047	7,131	6,184	5,366
R-squared	0.563	0.570	0.569	0.575	0.577

Table 4. The effect of belief dispersion around executive turnovers

This table shows the effect of belief dispersion on firm's innovative efficiency, surrounding executive turnovers. The indicator, treat, equals to 1 if a new joining executive sharply increases (top 25 percentile) the belief dispersion in the joining firm, and 0 otherwise. Firm-year observations are matched by the set of controls in the baseline regression (1) at the years when executive turnovers are happened. Variable definitions are provided in Appendix. All regressions control for the two-digit SIC code industry effects and year effects. t-Statistics are calculated based on robust standard errors (within parentheses) and clustered at the firm level. ***, **, and * denote significant level at 1%, 5% and 10%, respectively.

Panel A: The difference in *Dispersion* (after 5 yrs. – before 5 yrs.)

	The treatment group	The control group	Difference (treat – control)
	(1)	(2)	(3)
Dispersion	0.311	-0.317	0.628***
	(0.049)	(0.032)	(0.061)

Panel B: Regression results

	Ln(1+Citation count)			Ln(1+Patent value)			Ln(1+Patent count)		
VARIABLES	t+3	t+4	t+5	t+3	t+4	t+5	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treat	0.394*	0.610**	0.513**	0.569*	0.622*	0.770**	0.387**	0.421**	0.474**
	(0.238)	(0.252)	(0.255)	(0.313)	(0.354)	(0.352)	(0.170)	(0.196)	(0.200)
CEO	-0.152	-0.184	-0.603*	0.038	-0.296	-0.450	-0.084	-0.297	-0.373
Overconfidence	(0.245)	(0.267)	(0.328)	(0.297)	(0.348)	(0.372)	(0.186)	(0.220)	(0.244)
Ln(1+CEO	0.092	0.033	-0.166	0.112	0.032	-0.027	-0.263	-0.163	-0.257
Tenure)	(0.142)	(0.159)	(0.596)	(0.181)	(0.212)	(0.682)	(0.342)	(0.378)	(0.445)
Ln(1+ CEO	0.115	-0.059	0.680	-0.330	-0.019	2.549	1.296	2.182*	1.919
Delta)	(0.438)	(0.475)	(2.057)	(0.547)	(0.628)	(2.446)	(0.991)	(1.226)	(1.662)

Ln(1+CEO	-0.439	1.034	0.104	0.934	2.272	-0.043	0.073	0.014	0.000
Vega)	(1.455)	(1.700)	(0.167)	(1.766)	(2.046)	(0.195)	(0.112)	(0.132)	(0.139)
Ln (1+sale)	0.585***	0.505***	0.527***	0.854***	0.711***	0.713***	0.440***	0.367***	0.400***
	(0.150)	(0.173)	(0.167)	(0.173)	(0.213)	(0.192)	(0.108)	(0.138)	(0.130)
Ln(PPE/Emp)	-0.036	-0.155	-0.197	-0.143	-0.130	-0.158	-0.080	-0.075	-0.095
	(0.233)	(0.215)	(0.184)	(0.261)	(0.289)	(0.222)	(0.168)	(0.182)	(0.147)
Institutional	1.050**	1.631***	1.610***	0.799	1.377*	2.080***	0.356	0.715	0.985**
ownership	(0.485)	(0.523)	(0.548)	(0.625)	(0.817)	(0.701)	(0.350)	(0.470)	(0.473)
Ln(pay gap)	0.228	0.113	-0.207	0.613	1.373	0.789	0.363	0.670	0.795
	(0.758)	(0.897)	(0.985)	(0.951)	(1.261)	(1.244)	(0.573)	(0.732)	(0.783)
Leverage	-2.136***	-1.349*	-1.081	-2.848***	-2.478**	-2.218**	-1.721***	-1.414**	-1.366*
	(0.744)	(0.768)	(0.752)	(1.066)	(1.052)	(1.053)	(0.638)	(0.672)	(0.698)
Stock Return	0.236	0.193	-0.090	0.304	0.245	0.043	0.288	0.268	0.118
	(0.273)	(0.280)	(0.316)	(0.337)	(0.354)	(0.335)	(0.211)	(0.217)	(0.231)
Stock volatility	0.409	0.620	-0.576	1.187	2.022	1.487	0.285	0.549	-0.097
	(0.915)	(1.004)	(0.980)	(1.223)	(1.419)	(1.429)	(0.723)	(0.875)	(0.900)
Ln (1+RD exp.)	8.291***	8.462**	8.742**	9.673***	7.786*	7.718*	6.581***	6.467**	6.991***
	(3.126)	(3.508)	(3.621)	(3.700)	(4.456)	(3.999)	(2.401)	(2.875)	(2.605)
Constant	-5.144**	-5.566**	-3.162	-7.060***	-9.317***	-8.774***	-3.031**	-4.107**	-4.524**
	(2.074)	(2.296)	(2.622)	(2.657)	(3.046)	(3.060)	(1.483)	(1.817)	(1.956)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	270	218	188	270	218	188	270	218	188
R-squared	0.572	0.591	0.563	0.580	0.585	0.629	0.612	0.610	0.618

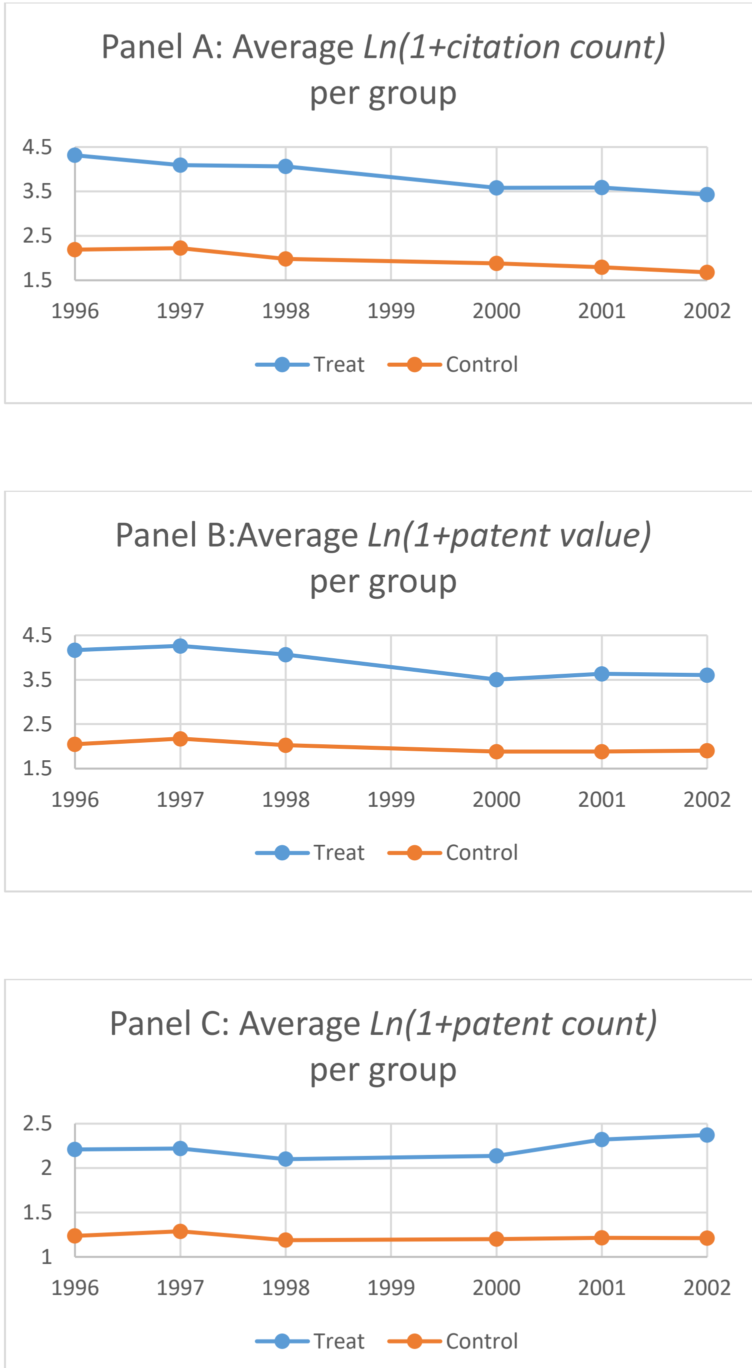

Figure 1. innovation outcomes during dotcom bubble periods.

Figure 1 presents the innovation outcomes for treatment group and control group over dotcom bubble periods. Innovation outcome measures by average citation and average patent value per year for the applied patents. The treatment group contains the high-tech firms with high belief dispersion in their TMTs. The control group includes firms in other industries or high-tech firms with low belief dispersion in their TMTs.

Table 5. Dotcom bubble

This table shows the effect of the belief dispersion on firm innovation surrounding the dotcom bubble in 1999. Sample periods cover from 1996 to 2002, and 1999 is defined as the year when the bubble burst. The treatment group contains high-tech firms with high belief dispersion in pre-bubble burst periods. The control group includes other firms in the sample. The definitions of other variables are provided in Appendix. All regressions control for the two-digit SIC code industry effect. . t-Statistics are calculated based on robust standard errors (within parentheses) and clustered at the firm level. ***, **, and * denote significant level at 1%, 5% and 10%, respectively.

Panel A: Difference in the differences of *Dispersion* (after – before)

	Mean treatment difference	Mean control difference	Mean DiDs (treat – control)
	(1)	(2)	(3)
Dispersion	-0.463	-0.098	-0.365***
	(0.101)	(0.021)	(0.084)

Panel B: DiD regressions result

VARIABLES	(1) Ln(1+citation count$_{t+1}$)	(2) Ln(1+patent value$_{t+1}$)	(3) Ln(1+patent count$_{t+1}$)
Treat	0.345	0.414	-0.057
	(0.355)	(0.364)	(0.239)
Treat*Post	-0.709***	-0.824***	-0.213
	(0.271)	(0.282)	(0.193)
Post	-0.809***	-0.615***	-0.281***
	(0.090)	(0.098)	(0.055)
CEO Overconfidence	-0.004	0.096	-0.028
	(0.111)	(0.112)	(0.072)
Ln(1+CEO Tenure)	-0.030	-0.059	-0.043
	(0.049)	(0.052)	(0.032)
Ln(1+ CEO Delta)	-0.126	0.090	-0.115
	(0.192)	(0.219)	(0.128)
Ln(1+CEO Vega)	1.906***	2.833***	1.839***
	(0.577)	(0.656)	(0.389)
Ln (1+sale)	0.734***	1.003***	0.558***
	(0.060)	(0.059)	(0.040)
Ln(PPE/Emp)	0.169*	0.244***	0.148**
	(0.094)	(0.092)	(0.060)
Institutional ownership	0.273	0.177	0.039
	(0.189)	(0.209)	(0.121)
Ln(pay gap)	0.255	0.409	0.153
	(0.308)	(0.302)	(0.191)
Leverage	-1.093***	-1.214***	-0.820***
	(0.271)	(0.286)	(0.178)
Stock Return	0.081	0.163**	0.065
	(0.067)	(0.069)	(0.040)
Stock volatility	0.212	0.345	0.211
	(0.361)	(0.372)	(0.232)
Ln (1+R&D exp.)	12.531***	14.360***	9.054***
	(1.330)	(1.403)	(0.898)
Constant	-6.033***	-8.853***	-4.054***
	(0.803)	(1.065)	(0.803)
Industry FE	Yes	Yes	Yes
Year FE	No	No	No
Observations	3,334	3,334	3,334
R-squared	0.559	0.620	0.618

Table 6: Instrumental-variable regressions

This table presents the results of the instrumental-variable regressions. Belief dispersion is the endogenous variable. Lagged industry median value of this variable is the instrument. Industries are classified by the firm's three-digit SIC code. In each Panel, Column 1 presents the first stage regression, and Columns 2-6 present the second-stage regressions. All regressions control for the two-digit SIC code industry effects and year effects. t-Statistics are calculated based on robust standard errors (within parentheses) and clustered at the firm level. ***, **, and * denote significant level at 1%, 5% and 10%, respectively.

Panel A: Citation count

	First-stage	Ln(1+Citation count)				
VARIABLES	Dispersion	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)	(6)
Dispersion (instrumented)		0.746**	0.839**	0.923**	0.798**	0.561
		(0.348)	(0.349)	(0.361)	(0.377)	(0.355)
Lagged IV	0.391***					
	(0.068)					
CEO Overconfidence	0.103***	-0.117	-0.094	-0.081	-0.068	-0.097
	(0.017	(0.095)	(0.098)	(0.103)	(0.106)	(0.109)
Ln(1+CEO Tenure)	-0.020**	0.018	0.030	0.048	0.059	0.049
	(0.010)	(0.038)	(0.039)	(0.041)	(0.042)	(0.042)
Ln(1+ CEO Delta)	0.365***	-0.465**	-0.497**	-0.499**	-0.463**	-0.344*
	(0.044)	(0.201)	(0.204)	(0.207)	(0.213)	(0.206)
Ln(1+CEO Vega)	-0.530***	1.111**	0.962**	0.617	0.029	-0.559
	(0.119)	(0.468)	(0.467)	(0.468)	(0.476)	(0.472)
Ln (1+Sale)	-0.031***	0.677***	0.688***	0.670***	0.671***	0.652***
	(0.009)	(0.050)	(0.050)	(0.052)	(0.052)	(0.053)
Ln(PPE/Emp)	-0.016	0.179**	0.168**	0.142*	0.135*	0.117
	(0.011)	(0.071)	(0.074)	(0.074)	(0.076)	(0.078)
Institutional ownership	0.073**	0.285**	0.320**	0.318**	0.280*	0.344**
	(0.031)	(0.132)	(0.133)	(0.138)	(0.144)	(0.149)
Ln(pay gap)	0.170**	0.402*	0.265	0.341	0.513**	0.708***
	(0.066)	(0.241)	(0.239)	(0.243)	(0.246)	(0.252)
Leverage	-0.160**	-0.644***	-0.607***	-0.554**	-0.550**	-0.566**
	(0.070)	(0.212)	(0.220)	(0.231)	(0.233)	(0.233)
Stock Return	0.100***	-0.091	-0.047	-0.049	-0.034	0.069
	(0.020)	(0.056)	(0.059)	(0.061)	(0.066)	(0.062)
Stock volatility	0.370***	0.721**	0.475	0.113	-0.140	-0.285

	(0.073)	(0.297)	(0.308)	(0.306)	(0.314)	(0.320)
Ln (1+R&D exp.)	-0.348	10.920***	10.950***	11.146***	11.512***	11.594***
	(0.291)	(1.074)	(1.143)	(1.168)	(1.248)	(1.293)
Constant	-0.434	-9.213***	-9.317***	-9.216***	-9.334***	-9.081***
	(0.326)	(0.639)	(0.608)	(0.628)	(0.660)	(0.751)
F-statistic	166.21					
Observations	8,064	8,064	7,131	6,283	5,457	4,711
R-squared	0.200	0.539	0.540	0.534	0.546	0.554

Panel B: Patent value

	First-stage	Ln(1+Patent value)				
	Dispersion	t+1	t+2	t+3	t+4	t+5
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Dispersion (instrumented)		0.356	0.492	0.862**	0.998**	0.855**
		(0.377)	(0.386)	(0.413)	(0.458)	(0.427)
Lagged IV	0.391***					
	(0.068)					
CEO Overconfidence	0.103***	-0.009	0.027	0.018	0.015	-0.029
	(0.017	(0.101)	(0.108)	(0.115)	(0.123)	(0.128)
Ln(1+CEO Tenure)	-0.020**	-0.042	-0.020	0.008	0.041	0.029
	(0.010)	(0.042)	(0.044)	(0.046)	(0.050)	(0.050)
Ln(1+ CEO Delta)	0.365***	-0.170	-0.238	-0.443*	-0.483*	-0.338
	(0.044)	(0.231)	(0.242)	(0.250)	(0.267)	(0.259)
Ln(1+CEO Vega)	-0.530***	1.957***	1.806***	1.832***	1.269**	0.365
	(0.119)	(0.540)	(0.552)	(0.570)	(0.598)	(0.604)
Ln (1+Sale)	-0.031***	0.933***	0.965***	0.977***	0.992***	0.979***
	(0.009)	(0.053)	(0.054)	(0.056)	(0.058)	(0.060)
Ln(PPE/Emp)	-0.016	0.233***	0.219***	0.199**	0.188**	0.154*
	(0.011)	(0.079)	(0.082)	(0.083)	(0.085)	(0.090)
Institutional ownership	0.073**	0.212	0.253	0.285*	0.244	0.310
	(0.031)	(0.157)	(0.162)	(0.169)	(0.182)	(0.191)
Ln(pay gap)	0.170**	0.668***	0.516**	0.411	0.568**	0.834***
	(0.066)	(0.250)	(0.255)	(0.266)	(0.282)	(0.302)
Leverage	-0.160**	-0.896***	-0.785***	-0.719***	-0.700**	-0.598**
	(0.070)	(0.248)	(0.258)	(0.276)	(0.294)	(0.299)
Stock Return	0.100***	0.082	0.091	0.026	-0.011	0.082
	(0.020)	(0.059)	(0.064)	(0.069)	(0.078)	(0.074)
Stock volatility	0.370***	0.779**	0.632*	0.342	0.012	-0.301
	(0.073)	(0.336)	(0.362)	(0.375)	(0.388)	(0.393)
Ln (1+R&D exp.)	-0.348	13.534***	13.895***	14.134***	14.815***	15.722***
	(0.291)	(1.147)	(1.221)	(1.290)	(1.409)	(1.502)
Constant	-0.434	-12.133***	-12.810***	-12.606***	-12.890***	-12.815***
	(0.326)	(0.856)	(0.755)	(0.749)	(0.767)	(0.844)
F-statistic	166.21					
Observations	8,064	8,064	7,131	6,283	5,457	4,711
R-squared	0.200	0.584	0.586	0.579	0.579	0.587

Panel C: Patent Count

	First-stage	Ln(1+Patent count)				
	Dispersion	t+1	t+2	t+3	t+4	t+5
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Dispersion (instrumented)		0.234	0.316	0.516**	0.671**	0.595**
		(0.216)	(0.222)	(0.238)	(0.282)	(0.280)
Lagged IV	0.391***					
	(0.068)					
CEO Overconfidence	0.103***	-0.083	-0.070	-0.086	-0.098	-0.106
	(0.017	(0.065)	(0.069)	(0.075)	(0.082)	(0.087)
Ln(1+CEO Tenure)	-0.020**	-0.015	-0.011	-0.002	0.016	0.012
	(0.010)	(0.026)	(0.028)	(0.029)	(0.031)	(0.032)
Ln(1+ CEO Delta)	0.365***	-0.260*	-0.262*	-0.319**	-0.374**	-0.309**
	(0.044)	(0.136)	(0.141)	(0.145)	(0.158)	(0.157)
Ln(1+CEO Vega)	-0.530***	1.362***	1.277***	1.194***	0.906**	0.446
	(0.119)	(0.331)	(0.336)	(0.345)	(0.363)	(0.364)
Ln (1+Sale)	-0.031***	0.535***	0.555***	0.557***	0.573***	0.570***
	(0.009)	(0.038)	(0.040)	(0.041)	(0.043)	(0.044)
Ln(PPE/Emp)	-0.016	0.157***	0.153***	0.142**	0.135**	0.124**
	(0.011)	(0.052)	(0.055)	(0.056)	(0.059)	(0.062)
Institutional ownership	0.073**	0.068	0.108	0.121	0.096	0.150
	(0.031)	(0.096)	(0.100)	(0.104)	(0.114)	(0.122)
Ln(pay gap)	0.170**	0.259	0.181	0.226	0.306	0.454**
	(0.066)	(0.161)	(0.167)	(0.176)	(0.187)	(0.197)
Leverage	-0.160**	-0.542***	-0.523***	-0.510***	-0.531***	-0.497***
	(0.070)	(0.155)	(0.164)	(0.174)	(0.189)	(0.193)
Stock Return	0.100***	-0.005	-0.010	-0.046	-0.048	0.032
	(0.020)	(0.035)	(0.038)	(0.041)	(0.048)	(0.048)
Stock volatility	0.370***	0.641***	0.584**	0.375	0.064	-0.154
	(0.073)	(0.210)	(0.228)	(0.235)	(0.247)	(0.255)
Ln (1+R&D exp.)	-0.348	8.445***	8.691***	8.736***	9.403***	10.039***
	(0.291)	(0.766)	(0.827)	(0.893)	(0.982)	(1.048)
Constant	-0.434	-6.389***	-6.937***	-7.147***	-7.336***	-7.336***
	(0.326)	(0.652)	(0.560)	(0.476)	(0.506)	(0.536)
F-statistic	166.21					
Observations	8,064	8,064	7,131	6,283	5,457	4,711
R-squared	0.200	0.575	0.580	0.572	0.569	0.577

Table 7. Subsample analyses

This table shows the differential effects of TMT's belief dispersion across subsamples. CEO overconfidence is a dummy indicator, which equals to 1 if a CEO is overconfident, and 0 otherwise. CTO is a dummy variable, which equals to 1 if a TMT with at least one technology-related executive and 0 otherwise. HT is a dummy indicator and equals to 1 if a firm belongs to high-tech industry, and 0 otherwise. See Appendix for more detail of each used variable. All regressions control for the two-digit SIC code industry effects and year effects. t-Statistics are calculated based on robust standard errors (within parentheses) and clustered at the firm level. ***, **, and * denote significant level at 1%, 5% and 10%, respectively.

VARIABLES	(1) Ln(1+citation$_{t+1}$)	(2) Ln(1+value$_{t+1}$)	(3) Ln(1+patent$_{t+1}$)	(4) Ln(1+citation$_{t+1}$)	(5) Ln(1+value$_{t+1}$)	(6) Ln(1+patent$_{t+1}$)	(7) Ln(1+citation$_{t+1}$)	(8) Ln(1+value$_{t+1}$)	(9) Ln(1+patent$_{t+1}$)
Dispersion	-0.114	-0.066	-0.114**	0.062	0.097	0.005	-0.037	0.002	-0.017
	(0.097)	(0.095)	(0.057)	(0.059)	(0.068)	(0.037)	(0.062)	(0.073)	(0.039)
CEO Overconfidence	-0.086	-0.032	-0.097	-0.029	0.021	-0.060	-0.026	0.027	-0.058
	(0.090)	(0.095)	(0.061)	(0.082)	(0.086)	(0.055)	(0.082)	(0.086)	(0.055)
CEO Overconfidence x Dispersion	0.267**	0.261**	0.175**						
	(0.117)	(0.121)	(0.069)						
CTO				-0.091	0.050	-0.027			
				(0.098)	(0.109)	(0.073)			
CTO x Dispersion				0.371**	0.427**	0.214**			
				(0.163)	(0.167)	(0.100)			
HT							0.041	0.097	0.158
							(0.153)	(0.170)	(0.106)
HT x Dispersion							0.482***	0.495***	0.161*
							(0.131)	(0.147)	(0.083)
Ln(1+CEO Tenure)	-0.011	-0.058	-0.025	-0.009	-0.055	-0.024	-0.011	-0.059	-0.025
	(0.035)	(0.038)	(0.023)	(0.035)	(0.038)	(0.023)	(0.035)	(0.038)	(0.023)
Ln(1+ CEO Delta)	-0.245*	-0.108	-0.179*	-0.242*	-0.104	-0.177*	-0.253*	-0.117	-0.182*
	(0.144)	(0.170)	(0.101)	(0.145)	(0.172)	(0.102)	(0.145)	(0.171)	(0.102)

Ln(1+CEO Vega)	0.819**	1.967***	1.236***	0.780**	1.905***	1.208***	0.764*	1.913***	1.208***
	(0.390)	(0.461)	(0.282)	(0.391)	(0.462)	(0.283)	(0.391)	(0.459)	(0.281)
Ln (1+sale)	0.633***	0.901***	0.500***	0.636***	0.906***	0.502***	0.632***	0.899***	0.498***
	(0.043)	(0.047)	(0.032)	(0.043)	(0.047)	(0.032)	(0.043)	(0.047)	(0.032)
Ln(PPE/Emp)	0.165**	0.233***	0.143***	0.164**	0.231***	0.142***	0.157**	0.223***	0.136***
	(0.066)	(0.073)	(0.047)	(0.066)	(0.073)	(0.047)	(0.066)	(0.073)	(0.047)
Institutional ownership	0.294**	0.200	0.077	0.293**	0.197	0.077	0.279**	0.181	0.062
	(0.124)	(0.146)	(0.087)	(0.124)	(0.145)	(0.087)	(0.123)	(0.145)	(0.086)
Ln(pay gap)	0.455**	0.598***	0.290**	0.457**	0.602***	0.291**	0.444**	0.586***	0.283**
	(0.211)	(0.223)	(0.140)	(0.213)	(0.224)	(0.141)	(0.213)	(0.224)	(0.141)
Leverage	-0.745***	-0.885***	-0.551***	-0.746***	-0.874***	-0.549***	-0.725***	-0.858***	-0.527***
	(0.188)	(0.224)	(0.137)	(0.189)	(0.224)	(0.137)	(0.187)	(0.224)	(0.137)
Stock Return	0.002	0.121***	0.032	-0.001	0.118***	0.030	0.003	0.123***	0.033
	(0.040)	(0.044)	(0.026)	(0.040)	(0.044)	(0.026)	(0.040)	(0.044)	(0.026)
Stock volatility	0.795***	0.792***	0.614***	0.775***	0.755***	0.600***	0.758***	0.744**	0.571***
	(0.265)	(0.292)	(0.186)	(0.264)	(0.290)	(0.185)	(0.263)	(0.292)	(0.185)
Ln (1+R&D exp.)	10.827***	13.227***	8.195***	10.839***	13.163***	8.189***	10.559***	12.873***	7.895***
	(0.984)	(1.076)	(0.705)	(0.985)	(1.072)	(0.704)	(1.003)	(1.102)	(0.721)
Constant	-4.373***	-7.535***	-3.362***	-4.406***	-7.607***	-3.393***	-4.282***	-7.415***	-3.286***
	(0.825)	(0.945)	(0.722)	(0.837)	(0.947)	(0.727)	(0.839)	(0.961)	(0.733)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,098	9,098	9,098	9,098	9,098	9,098	9,098	9,098	9,098
R-squared	0.541	0.578	0.574	0.542	0.579	0.575	0.543	0.580	0.576

Table 8. Belief dispersion with firm performance

This table presents the regression of firm performance on belief dispersion. Firm performance is measured by Tobin's Q, the ratio if market value to book asset, and ROA, the ratio of net income to book assets. *Dispersion* is the standard deviation of the confidence levels among firm's top-five paid executives. Variable definitions are provided in the Appendix. All regressions control for the two-digit SIC code industry effect and year effect. t-Statistics are calculated based on robust standard errors (within parentheses) and clustered at the firm level. ***, **, and * denote significant level at 1%, 5% and 10%, respectively.

VARIABLES	(1) Q_{t+1}	(2) ROA_{t+1}	(3) Q_{t+1}	(4) ROA_{t+1}
Dispersion	0.330***	0.019***	0.380***	0.017***
	(0.065)	(0.006)	(0.060)	(0.004)
CEO Overconfidence	0.155**	0.013**	0.156**	0.014***
	(0.074)	(0.005)	(0.074)	(0.005)
Ln(1+CEO Tenure)	-0.126***	0.000	-0.144***	-0.001
	(0.038)	(0.002)	(0.041)	(0.002)
Ln(1+ CEO Delta)	0.911***	0.017*	0.938***	0.022***
	(0.151)	(0.009)	(0.145)	(0.007)
Ln(1+CEO Vega)	-0.080	-0.032	-0.273	-0.006
	(0.270)	(0.021)	(0.287)	(0.019)
Ln (1+Sale)	-0.182***	0.008***	-0.168***	0.007**
	(0.041)	(0.003)	(0.038)	(0.003)
Ln(PPE/Emp)	-0.073*	0.001	-0.057	-0.002
	(0.041)	(0.003)	(0.040)	(0.003)
Institutional ownership	-0.075	0.041***	-0.049	0.041***
	(0.128)	(0.009)	(0.199)	(0.012)
Ln(pay gap)	0.617***	0.016	0.637***	0.006
	(0.166)	(0.012)	(0.144)	(0.013)
Leverage	0.745	-0.118***	0.768	-0.112**
	(0.996)	(0.043)	(1.162)	(0.047)
Stock Return	0.461***	0.030***	0.428***	0.037***
	(0.090)	(0.009)	(0.058)	(0.005)
Stock volatility	-1.037***	-0.192***	-1.227***	-0.183***
	(0.173)	(0.020)	(0.192)	(0.018)
Ln (1+R&D exp.)	10.932***	-0.466***	10.382***	-0.422***
	(2.111)	(0.128)	(2.359)	(0.127)
Board Size			-0.010	-0.002**
			(0.014)	(0.001)
Board Independence			-0.254	0.005
			(0.248)	(0.014)
Constant	1.532***	-0.037	2.206***	0.026
	(0.590)	(0.044)	(0.641)	(0.062)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	9,089	9,089	9,089	9,089
R-squared	0.199	0.174	0.117	0.045

Table 9. Endogeneity

This table presents the results for mitigating endogeneity concerns. The regressions in Panel A use firm-fixed effects to control for firm specific time-invariant factors. Panel B presents the result by using 2SLS approach. Variable definitions are provided in the Appendix. t-Statistics are calculated based on robust standard errors (within parentheses) and clustered at the firm level. ***, **, and * denote significant level at 1%, 5% and 10%, respectively.

Panel A: firm fixed effects regressions

VARIABLES	Q_{t+1} (1)	ROA_{t+1} (2)
Dispersion	0.208***	0.007*
	(0.038)	(0.003)
CEO Overconfidence	0.071	0.019***
	(0.050)	(0.004)
Ln(1+CEO Tenure)	-0.045**	-0.002
	(0.022)	(0.002)
Ln(1+ CEO Delta)	0.775***	0.012
	(0.082)	(0.007)
Ln(1+CEO Vega)	-1.945***	0.008
	(0.223)	(0.020)
Ln (1+Sale)	-0.398***	0.006
	(0.045)	(0.004)
Ln(PPE/Emp)	-0.157***	-0.010*
	(0.060)	(0.005)
Institutional ownership	0.094	0.015
	(0.105)	(0.009)
Ln(pay gap)	0.367***	0.013
	(0.134)	(0.012)
Leverage	0.725***	-0.068***
	(0.145)	(0.013)
Stock Return	0.206***	0.035***
	(0.033)	(0.003)
Stock volatility	-0.184	-0.023
	(0.181)	(0.016)
Ln (1+R&D exp.)	6.717***	0.133*
	(0.796)	(0.072)
Board Size	-0.077	-0.011
	(0.150)	(0.014)
Board Independence	-0.031***	-0.002*
	(0.012)	(0.001)
Constant	4.484***	0.029
	(0.528)	(0.047)
Observations	7,877	7,877

Industry	No	No
Firm FE	Yes	Yes
Year FE	Yes	Yes
R-squared	0.121	0.072

Panel B: 2SLS regression

VARIABLES	First-stage Dispersion (1)	Q_{t+1} (2)	ROA_{t+1} (3)
Dispersion(Instrumented)		0.475***	0.026***
		(0.168)	(0.009)
Industry median (Dispersion)	0.795***		
	(0.046)		
CEO Overconfidence	0.086***	0.146**	0.013**
	(0.012)	(0.070)	(0.005)
Ln(1+CEO Tenure)	-0.020***	-0.141***	-0.000
	(0.007)	(0.042)	(0.002)
Ln(1+ CEO Delta)	0.298***	0.902***	0.019**
	(0.032)	(0.171)	(0.007)
Ln(1+CEO Vega)	-0.498***	-0.211	0.000
	(0.079)	(0.318)	(0.019)
Ln (1+Sale)	-0.024***	-0.166***	0.007**
	(0.007)	(0.039)	(0.003)
Ln(PPE/Emp)	-0.006	-0.055	-0.002
	(0.009)	(0.040)	(0.003)
Institutional ownership	0.056	-0.054	0.040***
	(0.029)	(0.196)	(0.012)
Ln(pay gap)	0.149***	0.615***	0.004
	(0.050)	(0.151)	(0.013)
Leverage	-0.137***	0.786	-0.110**
	(0.037)	(1.144)	(0.047)
Stock Return	0.090***	0.418***	0.036***
	(0.014)	(0.060)	(0.005)
Stock volatility	0.286***	-1.261***	-0.186***
	(0.058)	(0.195)	(0.018)
Ln (1+R&D exp.)	-0.289	10.391***	-0.421***
	(0.209)	(2.340)	(0.127)
Board Size	-0.021	-0.253	0.005
	(0.053)	(0.247)	(0.014)
Board Independence	-0.014***	-0.009	-0.002*
	(0.004)	(0.014)	(0.001)
Constant	0.087***	2.186***	0.024
	(0.011)	(0.649)	(0.061)
F-statistic	224.63		
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	7,877	7,877	7,877
R-squared	0.288	0.232	0.186
Number of gvkey			

Appendix

This appendix defines the variables used in the study. Accounting data are from Compustat, stock return data from CRSP, patent data from Kogan et al. (2017), CEO incentives data from Coles, Daniel and Naveen (2006), and compensation data from ExecuComp. Patent data are aggregated at its application year for each firm-year observation.

Variable	Description
Dependent variable	
Log(1+patent)	The natural logarithm of one plus the number of patents applied.
Log(1+citation)	The natural logarithm of one plus the number of future citation of a patent.
Log(1+value)	The natural logarithm of one plus a patent's three-day announcement return, [t, t+2], around the patent issuance event.
Tobin's Q	Ratio of market value to book assets.
ROA	Ratio of net income to book assets.
Main independent variable	
Dispersion	Dispersion is the standard deviation of the confidence levels among a firm's top-five executives, and executive confidence levels are calculated by following Campbell et al. (2011) overconfidence measure.
Firm characteristics	
Log (1+Sale)	The natural logarithm of one plus Firm sales scaled by total book asset at the end of fiscal year.
Log(PPE/emp)	The natural logarithm of a firm's net property, plant, and equipment per employee
Institutional ownership	The percentage of firm shares outstanding held by institutional investors.
Leverage	Sum of a firm's total long-term debt and short-term debt scaled by total book assets at the end of fiscal year.
Stock return	Buy-and-hold return of a firm shares over the fiscal year, adjusted by industry median.
Stock volatility	The standard deviation of a firm shares monthly returns over the last five fiscal years.
Log (1+R&D exp.)	The natural logarithm of one plus a firm's R&D expenditure, scaled by total book asset. Missing R&D values are set as zero.
Log(pay gap)	The natural logarithm of Pay gap, which is defined as the distance between CEO pay to the median pay of a VP in the firm.
CEO characteristics	
CEO Overconfidence	A dummy variable equals 1 for the CEOs holding over 67% deep in-the-money options at least twice during the sample periods, and 0 otherwise.
Log(1+CEO Tenure)	The natural logarithm of one plus a firm's CEO tenure, defined as the number of years since the executive became a CEO.

Log(1+ CEO Delta)	The natural logarithm of one plus a firm's CEO delta, defined as the dollar change in the CEO's wealth for a 1% change in stock price; see Coles, Daniel and Naveen (2006).
Log(1+CEO Vega)	The natural logarithm of one plus a firm's CEO vega, defined as the dollar change in the CEO's wealth for a 0.01 change in standard deviation of returns; see Coles, Daniel and Naveen (2006).
Other control variables	
High Tech industry	A dummy indicator equals to 1 if a firm belonged to High-tech industry, and 0 otherwise. Following Ljungqvist and Wilhelm Jr. (2003), high-tech industry includes firms in SIC codes 3571, 3572, 2575, 3578 (computer hardware), 3661, 3663, 3669 (communications equipment), 3674 (electronics), 3812 (navigation equipment), 3823, 3825, 3826, 3827, 3829 (measuring and controlling devices), 4899 (communication services), and 7370, 7371, 7372, 7373, 7374, 7375, 7378, and 7379 (software).
CTO	A dummy indicator equals to 1 if a TMT with at least one technology-related executive, and 0 otherwise. If an executive's annual title contains words "technology," "technical," or "information", the executive is defined as technology-related executive.