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Count on Your Subordinates: Young Managers and Innovation Efficiency

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Abstract

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Comments

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COUNT ON YOUR SUBORDINATES: YOUNG MANAGERS AND INNOVATION EFFICIENCY[‡]

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ABSTRACT

We investigate the relationship between executives' horizons and firms' innovation efficiency. Motivated by Acharya, Myers, and Rajan's (2011, JF) theory, we devise a measure of internal governance based on the difference in expected horizons between a CEO and her subordinates. Consistent with our conjecture, we find robust evidence that subordinate managers with longer horizon compared to the CEO can improve firm's innovation efficiency. Internal governance has a stronger effect on innovation efficiency for firms with elder, generalist CEOs and when the number of subordinates on the board is higher. However, while the presence of powerful CEOs attenuates the effect, overconfident CEOs do not negate the internal governance effect. Our proposed internal governance mechanism seems to be able to address the managerial myopia issue in corporate settings.

JEL Classification: G30, O30, O31, O32, O34

Key Words: Innovation, Executives' Horizons, Internal Governance, Management of Long-term Goals.

1. Introduction

Innovation is the primary driver of economic growth and is "the fundamental impulse that keeps the capital engine in motion" (Schumpeter, 1934). It is also risky; firms may not realize profits from innovation in the short term. It sometimes even takes years for firms to obtain profits from innovative activities or it may not be profitable at all. Although public firms can take advantage of risk sharing across investors, they experience agency problems. Pressures to beat quarterly earnings targets given by analysts (Porter 1992; He and Tian 2013) and concerns of being fired owing to poor performance (Kaplan and Minton 2006) induce managerial short-termism. Previous studies suggest that monitoring from institutional investors (Aghion, Van Reenen, and Zingales 2013), and external predator pressure (Atanassov 2013), facilitate innovation, yet other studies (He and Tian 2013; Fang, Tian, and Tice 2014) show that excessive monitoring hinders firm's innovation. Thus, identifying effective monitoring mechanisms that reduce the agency problem and support long-term investments is critical in fostering innovation at the firm level. In this study, we examine the role of internal governance stemming from the difference in expected horizons between a CEO and his or her subordinates on innovation efficiency.

Generally, CEOs have short horizons in the firm, their personal interests are not always aligned with those of shareholders, and they may not act as faithful agents.[1] It is documented that CEOs may reduce firm's future investments (Stein 1988, 1989; Edmans, Fang, and Lewellen 2017), decrease investment quality (Pan, Wang, and Weisbach 2016), discourage risk-taking (Holmstrom 1982), or overinvest to signal investment opportunities to the market (Bebchuk and Stole, 1993). To restrain the negative impact of CEO's limited horizon on firm's long term goals, Acharya, Myers and Rajan (2011) propose a bottom-up governance mechanism through which subordinate managers with longer horizon can force the CEO to focus on the long-term future of the firm. This internal governance theory assumes that 1) subordinate managers are, generally, younger than the CEO, and 2) they are likely to succeed him or her. Under these conditions, subordinate managers could compel the CEO to extend his or her investment horizon to coincide with that of the firm to keep the managers motivated and preserve their contribution to the firm's cash flow.

[1] The average CEO tenure is only about 5 years. (Equilar, 2018)

Subordinate managers have the desire to allocate a firm's resources properly and invest in its future, especially if they see considerable scope for career development (Acharya, Myers and Rajan, 2011). They face a greater risk of finding a job with comparable compensation package (Cheng, Lee, and Shevlin 2016). With many more years of employment remaining, they have a lot at stake and they care about the long-term success of the firm. In addition, they are also the implementers of long-term investment as they possess firm-specific knowledge and experience. Their day-to-day contribution to firm's operations and decision-making, ample experience in the business, and superior insight about the industry compared to other external monitors such as independent directors, analysts, and institutional investors make them better suited to help the CEO allocate future investments efficiently.

Creativity may decline with age, though business skills increases with experience. (Liang, Wang, and Lazear (2018)). Statistics show that subordinate managers are, consistently, younger than the CEO with an average and median age difference of approximately four years.[2] In addition, both academic and professional studies provide strong evidence that approximately 70-80% of new CEOs are internally promoted (DeVaro and Morita, 2013; Eisfeldt and Kuhnan, 2013).[3] These results echo the key assumptions of the internal governance theory. Hence, following Acharya, Myers, and Rajan (2011), we use the difference between the CEO's age and the subordinate managers' average age, along with other alternative measures, to capture the difference in horizons inside the top management team.[4]

Our focus of difference in horizons differs from previous theoretical and empirical works on how executives' horizons affect firms' innovative activities.[5] While existing literature generates conflicting predictions and evidence on the relationship between executives' horizon and long-term investments, our conjecture is primarily based on the difference in horizons of these two group of players inside the top management team. In the presence of a principal-agent relationship, we hypothesize that teams comprised of multiple agents with different appropriation horizons may

[2] Table A.1 presents summary statistics for the age difference between the CEO and his or her immediate subordinates by year and firm quintiles.
[3] A recent report published by Chief executive magazine shows that 78% of firms have internally sourced CEOs.
[4] Section 3.3 provides detailed discussion of different measures of internal governance.
[5] Previous theoretical literature proposes two competing arguments on how executives' expected horizon can impact managerial decision-making in general. Market learning models developed by Holmström (1999) and Scharfstein and Stein (1990) predict that younger executives invest less aggressively, as they are more risk-averse. On the other hand, the managerial signaling model developed by Prendergast and Stole (1996) predicts that younger managers make more and bolder investments compared to their older counterparts.

help the firm to focus on long-term investments through internal monitoring executed by subordinate managers. When aspiring younger managers engage in firm-specific learning effort to generate cash flow and simultaneously provide checks and balances to an older CEO, we expect innovation efficiency to increase as a result.

An alternative argument might suggest that an innovative firm in need of a steady hand with operational experience could hire older managers that would increase firm's innovative efficiency by helping the young dreamers – CEOs – make rational decisions about allocation of R&D resources. Whether this organizational structure works depends on subordinates' motivation to contribute, the relative power and constraints which the two parties inside the firm's top executive team impose on each other. In sum, the impact of the difference in horizons on innovation efficiency is an empirical question that may vary with firm's characteristics and top management team composition.

In this research, we direct our attention to innovation efficiency to portray a complete picture of the innovation process. Most of the literature on innovation research focuses on the quantity of innovation or subsequent citation with limited or no attention devoted to the private value gained from innovative activities or of the resources devoted toward such activities (Hall, Jaffe, and Trajtenberg 2005; Nicholas 2008). Directing the attention toward innovation efficiency rather than the quantity of corporate innovation may avert the potential problem that results are driven by a huge number of minor scientific advances with limited impact on the firm's valuation and/or its competition. Our main measures of firm's innovation efficiency are the number of patents, citation-weighted patents, and the market value of granted patents scaled by R&D spending. To capture all aspects of a firm's quantity quality and market reaction innovative activities,

To answer our research questions, we assemble a rich panel dataset of Standard & Poor (S&P) 1500 major US firms from 1992 to 2010 containing time-varying information on firms' top management team, financial characteristics and innovation efficiency. We find a robust positive association between the difference in horizons, and innovation efficiency. We document that firms whose non-CEO executives' horizon exceeds the CEO's horizon have a higher number of patents, more citation-weighted patents, and greater market value for granted patents per R&D expenditure. To alleviate the spurious correlation concern and disentangle whether the association between difference in horizons and innovation efficiency is driven by younger managers vs. younger

dreamers CEOs, we split our sample into positive (i.e., CEO's age exceeds the average age of the non-CEO executives) and negative horizon subsamples. According to our prediction, this positive association should only manifest in the positive horizon subsample. Our results confirm this prediction. For the negative horizon subsample, the relationship between the difference in horizons and innovation efficiency is insignificant, which is consistent with the argument that limited-horizon older subordinates may lack the motivation to contribute to the innovation process and hence unable to help a younger CEO to make better R&D allocation decisions. Overall, our results are also consistent with the prediction that non-CEO executives with a longer horizon provide an effective governance mechanism to push the CEO to focus on long-term goals.

Our results also suggest that internal governance is contingent upon the importance of subordinate managers and the distribution of power within the top management team. We further find that non-CEO monitoring is effective only when the CEO is close to retirement and if the CEO is a generalist, who most likely needs subordinate managers' (implementers) support and expertise to determine the best allocation of firms' investments. In addition, we find that the impact of internal governance is stronger when the number of non-CEO executives on the board increases. These results are consistent with previous literature that suggests that the presence of non-CEO executives on the board of directors increases their power and improving the monitoring role of the board (Raheja, 2005; Adams and Ferreira 2007; Harris and Raviv, 2008; Masulis and Mobbs, 2011).[6] On the other hand, the impact of internal governance is weaker for firms in which the CEO assumes greater power compared to his or her industry peers. Further, we find that the impact of internal governance on innovation efficiency is unaffected by the CEO's overconfidence.

To reaffirm the causal relationship between internal governance and innovation efficiency, we use *Research Quotient* (RQ) as an alternative measure of innovation efficiency. Previous literature has raised some concerns about the limitations of patent-based innovation data (Hall, Jaffe, and Trajtenberg 2001, 2005; Chen, Leung, and Evans 2016).[7] Hence, the use of RQ as an alternative measure can help alleviate concerns that our results are driven by patent and citation-based innovation. RQ is defined as the percentage increase in revenue from a 1% increase in R&D

[6] Masulis and Mobbs (2011) investigate the role of inside directors in the firm. They find that firms with inside directors holding outside directorship have better operating performance and market-to-book ratios, make better acquisition decisions, have greater cash holdings, and overstate earnings less often.

[7] In this study, we use newly collected patent data from Kogan et al. (2017). According to Dass, Nanda, and Xiao (2017) this patent data is truncation free and it overcomes the limitations of that NBER patent dataset that has been heavily used in innovation literature.

expenditure, and it captures the firm-specific output elasticity of R&D (Knott, 2008). Firm-level financial data are used to estimate RQ rather than patent data. Using RQ, we find that our results hold for both our main measure of the difference in horizons and alternative measure of non-CEO executives' horizon.

Although we argue that younger subordinate managers can improve firms' innovation efficiency through monitoring CEO's long-term investment allocation decisions, our results may be subject to potential endogeneity. This type of endogeneity can be viewed as a self-selection issue where younger executives with longer expected horizons might choose firms with longer horizon investments. Thus, the observed positive association could be related to omitted variables that affect both the managers-firm self-selection process and the ultimate innovation efficiency output. To address these concerns, we first use propensity score matching (PSM) to test the counterfactual using our observational data (Dehejia and Wahba, 2002). We match with replacement high-internal governance firms with low internal governance firms on all confounding control variables. Our results show positive and statistically significant average treatment effects (ATE), where firms with high internal governance experience greater innovation efficiency.

In addition, we use the instrumental variable approach as an alternative identification strategy to account for other sources of endogeneity, including unobservable heterogeneity and simultaneity. Following Serfling (2014), we use the ratio of the average consumer price index (CPI) in the birth year of subordinate managers divided by the CPI in the year when the CEO was born. A higher ratio corresponds to a larger age difference as CPI is expected to increase over the years. This instrument is likely to be valid and meets both relevance and exogeneity conditions. Our instrument is increasing with age difference, our main measure of the difference in the horizon. In addition, we expect no relation between a firm's innovation output in recent years and CPI in the birth years of its executives. Our results confirm that the predicted internal governance exercised by the non-CEO executives is effective in increasing firms' innovation efficiency. Furthermore, to address the potential omitted variables problem, we include a long list of control variables and various fixed effects. We additionally control for various CEO characteristics that are known to affect a firm's innovation activities, including age and compensation package. Our results hold and are consistent across various partitions of the data, which further help alleviate the endogeneity concern as it is less likely for omitted variables to explain our results in both the subsamples and the entire sample.

This research contributes to the literature of several fields. To the best of our knowledge, our study is the first to test the impacts of the senior executives' horizon and the difference in horizons within a management team on firm innovation efficiency. This study is closely related to the growing literature that studies managerial characteristics and their impact on firms' long-term investment and innovation activities (Hirshleifer, Low, and Teoh 2012; Custódio and Metzger 2014; Yim 2013; Custódio, Ferreira, and Matos 2017; Pan, Wang, and Weisbach 2016; Ederer and Manso 2013). However, the novelty of this study lies in focusing on the distinction between the CEO and his or her subordinates' horizons. More importantly, the horizon of the implementers or non-CEO executives is highly significant to a firm's innovation efficiency owing to their importance in the firm's innovation process. The in-depth knowledge of non-CEO executives along with their career and personal motivation to be the next CEO improves a firm's investment agenda, as shown in higher innovation quantity, quality, and market value generated for granted patents per R&D expenditure. Our findings regarding the horizon of the managers echo the theory prediction and the international evidence presented by Liang, Wang, and Lazear's (2018).

In addition, this study is related to the previous literature that examines how different governance mechanisms help improve firms' innovation (Aghion, Van Reenen, and Zingales 2013; Tian and Wang 2014; Atanassov 2013; O'Connor and Rafferty 2012; Sapra, Subramanian, and Subramanian 2014). However, our paper is different from previous studies that focus solely on the CEO, by providing empirical evidence that internal governance executed by inside managers matters. This study also differentiates itself from the tournament literature (Kini and Williams 2012; Bushman, Dai, and Zhang 2016; Shen and Zhang 2017) by focusing on the impact of divergence in expected horizons in the top management team rather than the pay gap. Although the pay gap is one of the most important incentives to senior executives, it would not be as important if the subordinates do not have a sufficiently long horizon in the firm.

Our research has strong implications for how corporate governance can improve a firm's innovation. An optimal structure of senior executives should be a good mixture of talents with diversified career horizons. A more dictatorial, entrenched CEO could use his or her power to discourage long-term investments that lead to more innovation. A more democratic CEO may listen to his or her subordinate colleagues and support the long-term goals for the company, and thus generate more innovation. Firms having senior executives with diversified horizons are expected to be more innovative and competitive over the long run. To this end, our findings are

closely related to the broad literature on whether centralized power or group decision-making leads to better firm performance (Adams, Almeida, Ferreira, 2005).

The remainder of the paper is structured as follows. Section 2 presents the literature review and develops hypotheses. Section 3 presents the data, sample, and construction of variables. Section 4 reports the empirical results and Section 5 concludes the study.

2. Literature Review and Hypotheses Development

Departing from the theoretical and empirical literature, which focuses on the CEO, recent theoretical research argues that the top management team includes diverse agents with divergent horizons and preferences (Landier, Sraer, and Thesmar 2009; Acharya, Myers, and Rajan 2011). Particularly, the immediate subordinates of CEOs are critical contributors, and they provide checks and balances in the firm and influence corporate decisions. Acharya, Myers, and Rajan (2011) conclude that "control need not be exerted just top-down, or from outside; it can also be asserted bottom-up." Therefore, a bottom-up governance mechanism exercised by subordinates who have an extended horizon in the firm compared with a short-term oriented CEO is a force in corporate governance that needs to be carefully studied. According to Acharya, Myers, and Rajan (2011), although the CEO is the highest-ranked executive within a firm's managerial hierarchy, he or she is not the sole productive asset in the firm. The CEO needs the cooperation of his or her subordinates to operate the business. An older CEO with a shorter career horizon than one's subordinates may extract rents from the firm at the cost of the shareholders and other stakeholders. However, younger subordinate managers, in turn, may have a long-term interest in the firms' prospects, especially if they see sufficient scope for career advancement within the firm (i.e., become the next CEO) (Prendergast 1999). If subordinate managers realize that CEO misuse firm's resources, leaving nothing behind, they will have no incentive to exert effort, and the firm's cash flow and the efficiency of future investment will fall significantly.

Landier, Sraer, and Thesmar (2009) derive a theoretical model in which the firm is organized as a two-agent hierarchy: a decision-maker and an implementer. Both have their own intrinsic preferences over potential projects. The model suggests that dissent between the two agents can be useful for organizational efficiency. It forces the decision-maker (CEO) to use objective information and give less preference to their own bias toward a specific project to keep implementers (subordinates) motivated. They further argue that dissent can be optimal, in

particular, when the exchange of information between the two agents is useful, and the uncertainty of projects is high. Along the same line, Fama and Jensen (1983) argue that internal managers are the most critical source of private and firm-specific information, which increase their power and ability in making corporate decisions. More recently, Masulis and Mobbs (2011) and Cheng, Lee, and Shevlin (2016) show empirically that non-CEO executives play an essential role in improving internal monitoring because of their firm-specific knowledge and experience.

The previous discussion suggests that the divergence of horizons or the dissent in top management team may bring about a new source of governance mechanism executed by non-CEO executives. The competing horizons inside the firm's top executives' team may impose a counterpressure on the CEO to avoid his or her short-termism behavior and focus on long-term goals. The importance of subordinate managers is not limited to contribution withdrawal but also associated with their firm-specific knowledge to elicit better decision-making from the CEO. Previous literature provides evidence that subordinate managers can enhance a firm's operational efficiency and financial transparency to effectively constrain value-destroying behavior on the part of the CEO (Cheng, Lee, and Shevlin 2016; Jain, Jiang, and Mekhaimer 2016).[8]

To demonstrate how the difference in horizons between the CEO and his or her immediate subordinates can enact internal governance mechanism to help the firm survive and invest for its future, Acharya, Myers, and Rajan (2011) consider a partnership between an older CEO and younger manager, who will be the future CEO. The incumbent CEO decides on firm's investment plan and accordingly, the manager decides how much he or she will engage in firm-specific learning effort to generate cash flow. In this setting, the CEO has the incentive to invest if, and only if, the investment motivates the manager to exert greater effort that will increase current cash flow and consequently CEO's compensation. The investment plan is also important to the manager because it affects the firm value that the manager inherits in the future. Hence, if subordinate managers' contribution is important to the CEO, the CEO investment horizon can effectively be lengthened to coincide with that of the firm to keep subordinate managers motivated.

To investigate the relationship between internal governance, primarily stemming from the difference in horizons, and innovation efficiency, we test the following hypothesis.

[8] In their theoretical model, Fama and Jensen (1983) suggest that one of the most important sources of firm-specific information to the board is the information that comes from non-CEO executives.

H1: Internal governance reflected in the difference in expected horizons within top executives is positively associated with firms' innovation.

Internal governance or bottom-up governance exercised by non-CEO executives depends on the composition of the top management team. Huffman, Maurer, and Mitchell (2016) show that an elderly population applies higher discounting rate toward future uncertain cash flows, and this pattern affects their social economic behavior. Gibbons and Murphy (1992) suggest that CEOs close to retirement lose appetites to invest in long-term investments. CEOs with a short-expected horizon may bypass investments with long-term payoffs or overinvest to deliver the message that they care about investment opportunities (Bebchuk and Stole 1993). Under such circumstances, when the CEO lacks long-term incentives, internal governance may be critical to a firm's future. The negative impact of CEO horizon on firm's long-term investments echoes the theory prediction and the international evidence presented by Liang, Wang, and Lazear's (2018), and calls for an efficient "cure" in the corporate setting. To understand the impact of the CEO's expected horizon on the internal governance effectiveness, we test the following hypothesis.

H2: The positive association between internal governance and firm's innovation efficiency is stronger when the CEO is close to retirement.

We further investigate the impact of CEO's power on the effectiveness of internal governance. As stated by Landier, Sraer, and Thesmar (2009), a CEO, the primary decision-maker, needs to provide sufficient motivation to her subordinates, the implementers, to support their investment agenda. Previous literature suggests that as the CEO's power increases, the monitoring incentive inside the firm decreases (Ryan and Wiggins 2004; Adams, Almeida and Ferreira 2005; Pan, Wang, and Weisbach 2016). Consistent with this argument, Acharya, Myers, and Rajan (2011) suggest that internal governance is most effective when both the CEO and the subordinates are important and contribute to a firm's cash flow. However, if the CEO dominates the firm, there is much less incentive for subordinate managers to monitor the incumbent CEO. To investigate the role of CEO's power on the effectiveness of internal governance, we create an indicator variable that takes the value of one if the CEO's total pay is above the median CEO's total pay in the same year and operating industry. To study this relationship, we test the following hypothesis.

H3: The positive association between internal governance and a firm's innovation efficiency is weaker when the firm is led by a powerful CEO.

The role of subordinate managers in monitoring the CEO can take several forms. The direct approach may involve the withdrawal of contribution to the firm (Acharya, Myers, and Rajan, 2011) or dissent in the top management team (Landier, Sraer, and Thesmar 2009; Landier et al. 2013). In contrast, the indirect approach involves improving the oversight role of the board of directors. For example, Raheja (2005) argues that the board of directors use CEO succession to motivate inside directors to share their superior information to help the board implement higher value projects. Further, Harris and Raviv (2008) also present a theoretical model of optimal boards of directors. The study suggests that shareholders may be better off by the insiders-controlled board because it helps better exploit private information and improves shareholders' value. From the empirical perspective, Masulis and Mobbs (2011) show that inside directors improve a firm's operating performance and growth, make better acquisition decisions, have greater cash holdings, and overstate earnings less often.

Given the previous literature, we argue that insiders on the board may have more room to exercise their power and influence over the CEO by helping the board to make informed decisions about the potential returns on long-term investments. We test the following hypothesis.

H4: The positive association between internal governance and a firm's innovation efficiency is stronger as the number of non-CEO inside directors increases.

CEO experience is a key to the innovation process in the firm. Custódio, Ferreira, and Matos (2017) argue that given their diverse industry experience, generalist CEOs are better innovators. They build their argument based on the notion that generalist CEOs have higher mobility and show tolerance for failure due to their exposure to different industries. On the other hand, a specialist CEO with a more technical background may have an advantage. Specialist CEOs equipped with managerial skills in specific industries may invest in innovation efficiently, as they are better able to gauge value-enhancing investments in R&D and innovations and the expected return of these projects. Therefore, which CEO skills (generalist or specialist) matter for innovation and innovation efficiency is ultimately an empirical question. Our focus here is on the governance role of subordinates in fostering innovation, and we believe that a generalist CEO may need the

help of subordinates to allocate future investments of the firm better. Hence, we argue that the importance of subordinate managers and internal governance is higher when the CEO is a generalist. To investigate this argument, we test the following hypothesis.

H5: The positive association between internal governance and a firm's innovation efficiency is stronger when the CEO is a generalist.

We also test the impact of CEO overconfidence on the relationship between internal governance and innovation efficiency. Previous literature suggests that overconfident CEOs may engage in unprofitable mergers or suboptimal investments because they routinely overestimate their abilities and underestimate the potential of failure (Malmendier and Tate 2005, 2008). On the other hand, theoretical models (Bernardo and Welch 2001; Goel and Thakor 2008) and empirical evidence (Galasso and Simcoe 2011; Hirshleifer, Low, and Teoh 2012) suggest that overconfident CEOs are better innovators because they are determined to explore more and take greater risk. However, the impact of CEO overconfidence on internal governance exercised by non-CEO executives remains unclear

Moore and Healy (2008) and Moore and Schatz (2017) argue that overconfidence has three facets: (1) overestimation of one's actual performance; (2) overplacement of one's performance relative to others; and (3) excessive precision in one's belief. The latter two facets may negatively affect internal governance or subordinates' incentive to contribute to the firm. If a CEO overplaces his or her contribution, preference, or abilities, then we should expect internal governance exercised by non-CEO executives to be less effective. The same applies to excessive precision in CEO's belief. Hence, in this study, we argue that the existence of overconfident CEO may be disadvantageous or at least unsupportive to the effort of non-CEO executives to improve the firm's innovation efficiency. To test this empirically, we have the following hypothesis:

H6: Overconfident CEO would be unsupportive to internal governance efforts led by non-CEO executives to improve a firm's innovation efficiency.

3. Data and Variable Definitions

To construct our sample, we use several databases. Our sample covers the period from 1992 to 2010. We use Standard & Poor's ExecuComp database to collect executive information including age, compensation package, and other executive characteristics for the S&P 1500 firms.

Data on the CEO General Ability Index (GAI) are collected from Miguel Ferreira's website (Custódio, Ferreira, and Matos 2013).[9] Financial and accounting data, including R&D expenditure, total sales, leverage, cash, and capital expenditure, are extracted from the Compustat database. Analyst coverage data are collected from the Institutional Brokers' Estimate System (I/B/E/S) dataset, while data on institutional holding are obtained from the Thomson Reuters 13F database. The variable definitions and their sources are summarized in Appendix A.

3.1. Innovation Data

Ever since Schumpeter's (1934) study, technological innovation has been considered as a key driver of future economic growth (Solow 1957; Aghion and Howitt 1992; Grossman and Helpman 1990; Romer 1990; Kogan et al. 2017). Corporate innovation measures the realization of firms' long-term R&D investments and determines firms' competitiveness (Cho et al. 2016; Porter 1990; Porter 1992). Despite the growing body of innovation literature, quantifying and assessing the economic significance of firms' innovation is an extremely challenging task. To measure innovation activities, previous literature has used the number of patents applied and issued (as a proxy for innovation quantity) and the subsequent number of citations (as a proxy for innovations scientific value). We focus on the efficiency by considering the resources devoted to innovations, R&D investments (input), and output variables of innovation such as the quantity, scientific value, and economic value of firms' innovation activities.

Our analyses use newly collected patent data from Kogan et al. (2017) (KPSS). The advantage of using KPSS is twofold. First, in addition to providing the number of patents and citations of innovation activities, KPSS uses financial data to estimate the economic value of each patent granted. Such a measure will help us distinguish between the economic value of the patent and the quantity and scientific value of innovation. The private economic value does not necessarily match the scientific value. For example, a patent may provide scientific advancement that may or may not restrict competition or generate large profits for the firm. More importantly, an innovation measure based on financial data is free of truncation problem often observed in reported innovation measures based on patent and citation data. When aggregated at the firm level,

[9] GAI is constructed to reflect the generality of CEO skills. The index considers five aspects of a CEO's professional career: the number of (1) positions, (2) firms, and (3) industries in which a CEO worked; (4) whether the CEO held a CEO position at a different company; and (5) whether the CEO worked for a conglomerate. The data are available from 1992–2007.

we can highlight the value creation generated from the top management team's efforts in investing in innovative projects. Second, KPSS data extend the innovation data to 2010 compared to NBER, which covers the period between 1975 and 2006. A comparison of NBER innovation data and KPSS data shows that 27% of KPSS's collected data are not included in NBER. Furthermore, the NBER dataset has several limitations due to the time delay for a patent to be granted and cited (Hall, Jaffe, and Trajtenberg 2001, 2005; Chen, Leung, and Evans 2016). However, Dass, Nanda, and Xiao (2017) suggest that KPSS data are truncation-free and show that adjustments used in earlier works do not work well for NBER data. Our study uses the KPSS data to focus on the impact of internal governance on innovation efficiency.

3.2. Innovation Efficiency

R&D conducted by firms is viewed as a long-term investment activity that may or may not contribute positively to the firms' net cash flows and overall market value. In this study, our focus is to assess a firm's innovation efficiency or the private return to R&D spending of the firm. We merge our patent data with the CRSP/Compustat merged database. We also omit firms in industries that never patent in our sample. In addition, we omit financial firms (SIC codes 6000 to 6799) and utilities (SIC codes 4900 to 4949). To minimize the impact of outliers, we winsorize all variables at the 1% level.

In measuring the innovation efficiency, we focus on three facets of innovation: quantity measured by the number of patents, the scientific value measured by subsequent citation of patents, and the market value of innovation measured by the change in a firm's valuation when the patent is granted.

3.2.1. Patents

Previous literature has used patent data to measure the quantity of innovation produced by a firm. To measure patent efficiency, we aggregate patents at the firm level and divide the total number of patents in the year $t+n$ by R&D expenses in year t, as shown in equation (1).

$$PAT\ EFF_{f,t} = Log\left(\frac{PAT_{f,t+n}}{R\&D_{f,t}} + 1\right) \quad (1)$$

where $PAT_{f,t+n}$ is the lead total number of patents applied for in the year $t+n$ (where n =1 or 2) and R&D is the research and development expenditure in firm *f*, year *t*. Previous literature suggests that using patent numbers as the sole measure of innovation may not capture the impact of a firm's innovation activities. The number of patents is noisy because it can include many risky innovations that might be of no value or even hurt firm valuation.[10] Hence, we use alternative measures to proxy innovation efficiency.

3.2.2. Scientific Value of Innovation

The citation is perceived as the scientific value of innovation. It is still under debate how citations of patents are related to firm valuation. For example, Hall, Jaffe, and Trajtenberg (2005) and (Nicholas 2008) show that firms with high cited patents are valued higher in stock markets. However, Abrams, Akcigit, and Popadak (2013) document that the relationship between patent citations and valuation is non-monotonic. A highly popular measure of the output of innovation produced by a firm is the number of citation-weighted (*cw*) patents. We use an analogous measure of this metric. The scientific value, citation-weighted patents ($\Theta_{f,t}^{cw}$), is defined in equation (2):

$$\Theta_{f,t}^{cw} = \sum_{j \in P_{f,t}} \left(1 + \frac{C_j}{\overline{C_j}}\right) \tag{2}$$

where C_j is the number of forward citations for patent *j*, $\overline{C_j}$ is the average number of citations received by all patents granted in the same year as patent *j*, and $P_{f,t}$ denotes the patent set of firm *j* in year *t*. This scaling is used to adjust for citation truncation lags (Hall, Jaffe, and Trajtenberg 2005).

To measure the efficiency of firm *f* citation-weighted patents per R&D expenditure, we calculate per dollar investment citation-weighted patents yield as shown in equation (3):

$$TCW\ EFF_{f,t} = Log\left(\frac{\Theta_{f,t+n}^{cw}}{R\&D_{f,t}} + 1\right) \tag{3}$$

3.2.3. Stock Market Value of Innovation

The ultimate objective of a firm's innovation is to improve the firm's growth opportunities and valuation. The importance of a new patent can be assessed through the change in the market

[10] See e.g., Forbes (2013) "For Most Small Companies Patents Are Just About Worthless."

values of the firm. According to the KPSS model, on the patent issue date, the market reacts to the news by adjusting the value of the firm ΔV as follows:

$$\Delta V_j = (1 - \pi_j)\xi_j \tag{4}$$

where π_j is the market's ex-ante probability assessment that the patent application is successful and ξ_j is the dollar value of patent *j*. The market reaction to the patent granted described in equation (4) may understate the total impact of the patent on firm value, since the information about the probability that a patent will be granted is known to the market before the uncertainty about patent application is resolved. The second step in determining the market value of the patent is to isolate the component of the return around patent issuance events that are related to the value of the patent. In particular, the stock price of innovating firms may fluctuate during the announcement window around patent issuance for reasons unrelated to innovation. Hence, it is important to account for measurement error in stock returns. To eliminate any unrelated market movements, KPSS focuses on the firm's idiosyncratic return defined as the firm's return minus the return on the market portfolio. The idiosyncratic stock return *R* for a given firm around the time that its patent *j* is issued is described in equation (5).

$$R_j = \upsilon_j + \varepsilon_j \tag{5}$$

where υ_j denotes the value of patent *j*—as a fraction of the firm's market capitalization—and ε_j denotes the component of the firm's stock return that is unrelated to the patent. KPSS constructs the estimate of the economic value of patent, ξ, as the product of the estimate of the stock return due to the value of the patent and M, the market capitalization of the firm that issued patent *j* on the day prior to the announcement of the patent issuance. The computation is shown in equation (6).

$$\xi_j = (1 - \bar{\pi})^{-1} \frac{1}{\mathrm{N}_j} E[\upsilon_j | R_j] M_j \tag{6}$$

where $\bar{\pi}$ is the unconditional probability of a successful patent application; N_j is the total number of patents issued to the same firm on the same day as patent *j*; and ν_j denotes the value of patent *j*. The stock market value of patents for a firm ($\Theta_{f,t}^{sm}$) is thus the sum of the economic value of all patents by a given firm *j* in year *t* as shown in equation (7).

$$\Theta_{f,t}^{sm} = \sum_{j \in P_{f,t}} \xi_j \tag{7}$$

where $P_{f,t}$ denotes the patent set of firm *j* in year *t*.

To measure the efficiency of the market value of firm *j* innovation with respect to investments in *R&D*, we calculate per dollar investment innovation yield as shown in equation (8) for firm *j* in year *t*:

$$eff_{f,t}^{sm} = \frac{\Theta_{f,t}^{sm}}{R\&D_{f,t}} \tag{8}$$

3.3. Internal Governance

3.3.1. The Difference in Horizons Measured by Age Difference

The strength of internal governance is expected to increase with key subordinates' incentives and ability to monitor the CEO and to make contributions to the firm's decision-making. In this study, we measure internal governance based on the relative horizons of the CEO versus the key subordinates. Executive age has been used as a proxy for horizons (Brickley, Linck, and Coles 1999; Gibbons and Murphy 1992; Dechow and Sloan 1991; Matějka, Merchant, and van der Stede 2009). Age captures the accumulation of individual attributes, experience, and aspiration for the future. It has proven to be an important determinant of executives' decision-making (Serfling 2014; Yim 2013). Our measure is based on Acharya, Myers, and Rajan (2011), who suggest that the age difference can capture the difference in horizons between the CEO and other subordinate managers. Our primary measure of internal governance or difference of horizons is calculated as follows.

$$\begin{aligned} &Difference\ in\ horizons\ \left(Age\ Gap_{f,t}\right) \\ &\quad = CEO's\ Age_{f.t} - Non\_CEO\ Executives' Age_{f,t} \end{aligned} \tag{9}$$

where $CEO's\ Age_{f.t}$ is the age of the CEO and $Non\_CEO\ Executives'\ Age_{f,t}$ is the average age of the top four subordinate managers for firm *f* at year *t*. Our measure provides a simple yet effective proxy to capture the difference in horizons within the top management team

for a firm. It also alleviates the problem of using raw age as a measure of the horizon as it may reflect executive attributes including sophistication, risk-taking, education, or experience.[11]

To better understand our main measure of internal governance, we plot the mean and median age difference over our sample period of 1992-2010 in Figure A1. The median age difference is the smallest in 1992 with about 2.5 years difference between the CEO and his or her subordinates and reaches a maximum value of 4.5 around 2001-2003. The mean and median of difference in horizons are quite similar throughout the sample. Table A1 panel A provides annual summary statistics of the difference in horizons over the same sample period, while, panel B presents the descriptive statistics across firm size quintiles. We find that the mean age difference is monotonically decreasing as the firm size increases. Further, figure A2 shows that the difference in horizons is not entirely driven by one side of the top management team as both CEO age and average age of subordinates vary over time.

Alternative Measures of Internal Governance: Non-CEO Executives' Horizon

To further examine the relationship between the horizon of non-CEO executives and a firm's innovation efficiency, we use four alternative measures of executives' horizon. We use the difference in horizon scaled by CEO's age; non-CEO executives' age, expected remaining horizon and their industry-adjusted horizon. Scaled difference in the horizon is defined as the age gap between the CEO and his or her subordinates scaled by CEO's age. Executive age is defined as the average non-CEO executives' age in firm *i* in year *t*. We expect that as the non-CEOs age, they would have less incentive to monitor the CEO and help direct a firm's investment in high impact innovative activities. In other words, as non-CEO executives' age increases, their expected remaining horizon in the firm decreases.

To circumvent problems associated with using executives' raw age, we also use the difference between the expected retirement age of 65 and the average non-CEO executives' age for firm *i* in year *t* to proxy their expected remaining horizon.[12] Cheng, Lee, and Shevlin (2016) use this measure to proxy internal governance executed by non-CEO executives and its impact on

[11] Raw age may be directly correlated to risk aversion, experience, or education, but the age difference between the CEO and the subordinates controls for the individual attributes (see, Ang, Cole and Lawson 2010; Lundstrom 2002; Wiersema and Bantel 1992; Bantel and Jackson 1989).

[12] In unreported results, we show that our results are not sensitive to specific cutoffs. Our results are consistent when we use 67 as the expected retirement age.

real earnings management. This measure reflects the average remaining years of employment of non-CEO executives, considering a retirement age of 65 years. In addition, we use non-CEO executives' industry-adjusted expected horizon, defined as the difference between the average executives' age in the firm's operating industry and the firm's average of non-CEO executives' age. A positive (negative) value indicates that, on average, non-CEO executives are younger (older) than their operating industry peers, and hence have higher (lower) expected employment horizon.

3.3.2. Control Variables

Following the previous literature, we control for firm and industry characteristics that are known to affect a firm's innovation. We control for firm size (measured by the log of sales), profitability (measured by ROA), tangible assets (measured by property, plant, and equipment deflated by book value of total assets), growth opportunities (measured by Tobin's Q), financial constraints (measured by Z-Score), cash holding (measured by cash deflated by total assets), interest coverage (measured by interest expenditure divided by operating income), investment expenditure (measured by capital expenditure divided by total assets), leverage ratio (book value of debt divided by book value of total assets), and buy-and-hold returns over the fiscal year. In addition to firm-specific characteristics, we control for industry concentration (measured by Herfindahl index- HHI). We also control for other external governance mechanisms that may affect a firm's innovation. For example, Aghion, Van Reenen, and Zingales (2013) suggest that higher institutional ownership is associated with higher innovation output. Moreover, He and Tian (2013) suggest that analyst pressure on managers impedes a firm's investments in long-term innovative projects. Thus, we control for both institutional holdings and analyst coverage in all regression models.

4. Empirical Results

4.1. Summary Statistics

Table 1 reports sample summary statistics. We find that the mean and median of the number of *PAT* are 42.73 and 7, respectively. Citation-weighted patent *TCW* has a mean and median value of 99.03 and 16.56, respectively. We also find that the market reaction to granted patents *TSM* has a mean of $740.52 million and $34.76 million median value. In this study, we focus on return on R&D expenditure by computing the number of patents, citation-weighted patents, and market

value of innovation per dollars of R&D expenditure. Every million dollar invested in R&D generates on average 0.28 patents, 0.99 weighted citations, and $2.49 million increase in market valuation. These statistics are consistent with previous findings. For example, Shen and Zhang (2017) report the average number of patents of 43.4 and the median value of 6, while patents generated for every million dollars invested in R&D is equal to 0.234. The statistics suggest that our sample is skewed and hence we use the logarithmic transformation to account for extreme values.

Our sample also shows that the mean CEO's age is 53.71 and the median is 54 years. As expected and suggested by Acharya, Myers, and Rajan (2011), our sample shows that there is a difference of about four years between the CEO's age and non-CEO executives' ages. We find that non-CEO executives' age has a mean and median value of 49.91 and 50 years, respectively.[13] These results confirm that non-CEO executives on average have a longer expected horizon on the firm compared to the incumbent CEO. The age difference between the CEO and the subordinates ranges from -13.5 years to 23 years. The average age difference is 3.86 years, and the median value is 3.75 years. Moreover, Table 1 shows that on average non-CEO executives have about 15 years as expected remaining employment horizon, based on the retirement age of 65 years. On average, we find that the CEO compensation package is about 2.64 times that of subordinates' average package. Additionally, following Core and Guay (2002), we include the delta and vega of CEO compensation portfolios (*CEO Delta* and *CEO Vega*). *CEO Delta* is the dollar change (in millions) in a CEO's compensation portfolio if the stock price increases by 1%. *CEO Vega* captures the dollar change (in millions) in a CEO's compensation portfolio if the stock return volatility increases by 1%. The mean values of *CEO Delta* and *CEO Vega* are $1.202 million and $0.102 million, respectively. Descriptive statistics for external governance measures, including analyst followings, institutional ownership, and other control variables, are also reported in Table 1.

[Insert Table 1]

4.2. Baseline Regressions

In this section, we test the relationship between the internal governance proxied by the difference in horizons between the CEO and his or her subordinates on innovation efficiency.

[13] The summary statistics of the age difference are comparable to those reported by Acharya, Myers and Rajan (2011). They show that across 1992–2008 the mean CEO age is 55.6 years and the mean non-CEO executive age is 51.6 years.

Table 2 presents our baseline regression results; panel A reports the regression results for the first two measures and Panel B reports the results for the market value of innovation. Model (1) provides baseline regression results by including only difference in the horizon and control variables; Model (2) controls for CEO's age; and Model (3) adds *CEO Delta and CEO Vega* as additional explanatory variables. In all models, we include industry and year fixed effects. Our results show that the coefficients of age difference are positive and statistically significant. We find that as the difference in horizon measured by age difference increases, the quality, scientific value, and market value of innovation increases. These results are robust to the inclusion of conventional determinants of innovation, CEO age, *CEO Delta*, and *CEO Vega*. Our results are consistent with hypothesis 1 that internal governance, executed by non-CEO executives, helps firms better allocate their resources toward innovative activities that have the highest impact in scientific and monetary terms. We also find the coefficients of CEO's age are negative and statistically significant for the three measures of innovation efficiency. These results are also consistent with previous literature that CEO aging and career concerns affect future investment strategies and the quality of such investments (Serfling 2014; Pan, Wang, and Weisbach 2016). The results also echo the findings of Gonzalez-Uribe and Groen-Xu (2017), that CEO's horizon negatively affects R&D expenditure and innovation activities of the firm.

[Insert Table 2]

To further understand the relationship between the difference in horizons within the top management team and a firm's innovation efficiency, we split our sample into a positive horizon and negative horizon subsamples. A positive (negative) difference in horizons is defined as a positive (negative) age difference between the CEO and his or her subordinates: that is, the CEO is older (younger) than his or her subordinates. In essence, we should expect the improvement in innovation efficiency to be exclusive to firms with non-CEO executives who are younger than the current CEO. Panel A (Panel B) of Table 3 reports the regression results for the positive (negative) age difference group. The regression results confirm our conjecture that internal governance is effective only when the non-CEO executives have a longer horizon than the CEO. We find that the coefficients of age difference are positive and statistically significant exclusively for firms with positive age difference; however, it is insignificant for the negative age difference. These results

provide strong evidence that our measure, age difference, can capture the difference in horizons within the top management team.

[Insert Table 3]

These results are consistent with the previous literature that argues that bottom-up governance executed by insider non-CEO executives may help allocate a firm's resources to projects that have a higher impact on the firm's valuation and competitiveness (Acharya, Myers, and Rajan 2011; Landier, Sraer, and Thesmar 2009; Landier et al. 2013). Our results suggest that firms might benefit from divergence in horizons inside the top management team. Internal governance can work even if the CEO has a limited remaining horizon or short-term interest in the firm's future. The existence of insider stakeholders with extended horizons helps the top management team to stay focused on investments that are expected to provide higher returns in the future.

4.3. Addressing Endogeneity

One potential concern of our results is potential endogeneity. A firm's internal governance or difference in horizons may also be related to unobservable variables that affect the firm's innovation activities, leading to the observed positive association between internal governance and innovation efficiency. Although our baseline regressions and other tests control for variables that are known to affect a firm's innovation along with controlling for industry and year variations, we may still spuriously capture the association between internal governance and innovation efficiency. To rule out this possibility, we employ two different tests. We use propensity score matching to compute the average treatment effect and the instrumental variable approach to account for other sources of endogeneity.

4.3.1. Propensity Score Matching

A possible explanation of the positive association between internal governance and innovation efficiency is the self-selection of younger non-CEO executives to work in a firm with higher innovation efficiency. To overcome sample selection bias, we use propensity score matching to match firms with above median internal governance with those below the median of internal governance on all the control variables from our baseline regression (Ghaly, Dang and Stathopoulos, 2017). Our matching procedure uses a nearest neighbor matching algorithm with replacement and common support. This approach can help us isolate unobserved heterogeneity

that may be correlated with our measure of internal governance and help us establish the causal relationship between internal governance and innovation efficiency. Panel A of Table 4 shows the average treatment effect, which is defined as the average causal effect of treatment (high internal governance) on innovation efficiency. We find that, for all our outcome variables, the average treatment effect is positive and statistically significant. These results are consistent with our previous results that internal governance can help improve innovation efficiency.

4.3.2. *Instrumental Variable (2SLS)*

To further address the potential endogeneity, we estimate 2SLS regression using the ratio of average CPI in the birth years of subordinate managers divided by the CPI in the year when the CEO was born. Although we acknowledge the difficulty of finding a valid instrument for the age difference, the CPI ratio presents a strong candidate that meets both relevance and exogeneity conditions. Serfling (2014) used the CPI in the CEO birth year as an instrumental variable to study the impact of CEO's age on a firm's policies. Our instrument variable CPI (Sub)/CPI(CEO) is increasing with the age difference measure as we expect a higher CPI to correspond with a younger subordinate's birth year compared to that of an older CEO, who probably would have lower CPI in his or her birth year. According to our descriptive statistics, we should have about 54 (50) years lag between a firm's innovation efficiency at the current period and the CPI in the CEO's (subordinates) birth year. Such extended lag will help our instrument to meet the exogeneity condition as the CPI levels do not affect current innovation. In addition, the results reported in Panel B of Table 4 shows that our instrument meets the relevance condition, where the first-stage F-statistic is highly significant. Our results confirm the positive association between the predicted variable of the difference in horizons between a CEO and his or her non-CEO executives and different measures of innovation efficiency. We find that the coefficients of the predicted value of the difference in the horizon are positive and statistically significant across all measures of innovation efficiency. Our results further alleviate the concern that potential endogeneity may drive our main results.

[Insert Table 4]

4.4. Alternative Measures of Internal Governance: Non-CEO Executives' Horizon

Recognizing the inherent limitation of a multidimensional and broadly defined measure of horizons, such as the relative age difference, we use several alternative internal governance measures that capture the incentive of subordinates to monitor CEOs and contribute as implementers. In this section, we use alternative measures of internal governance based on non-CEO executives' horizon as robustness check to our previous results. We use the scaled difference in horizons, average subordinate managers' age, remaining horizon, and industry-adjusted horizon to investigate the relationship between subordinate managers' horizon and a firm's innovation efficiency. Table 5 reports the regression results. Our results suggest that non-CEO executives' horizon is important determinant to innovation efficiency. We find that scaled difference in horizons, remaining horizon and industry-adjusted horizon of non-CEO subordinate managers are positively associated with innovation efficiency. We also show that innovation efficiency decreases along with the average age of non-CEO executives. Our results confirm that non-CEO executive career horizon is very important in improving all aspects of innovation efficiency (quantity, quality and economic value). These results confirm our previous findings and highlight the importance of singling out the horizon of non-CEO executives from that of the CEO.

[Insert Table 5]

4.5. Alternative Measures of Innovation Efficiency: Research Quotient (RQ)

In the previous sections, we use the patent data collected by KPSS to measure firms' innovation efficiency. Although previous literature suggests that KPSS is free of measurement errors and truncation bias (Dass, Nanda, and Xiao (2017), we reassess our results using an alternative measure of innovation efficiency - *Research Quotient.* Research Quotient (RQ) is defined as the percentage increase in revenue from a 1% increase in R&D. RQ is the firm-specific output elasticity of R&D (Knott, 2008) estimated from financial data. In addition, it is a universal and unitless measure; thus, the interpretation of the results is uniform across different firms and industries.

The regression results in table 6 confirm our previous findings. We find that the coefficients of internal governance proxied by the age difference are positive and statistically significant, while the CEO age coefficients are negative and statistically significant. These results confirm that internal governance exercised by non-CEO executives can improve R&D productivity or innovation efficiency. To further strengthen our inference, we use alternative measures of non-

CEO executives' horizon and find that our previous results still hold. These results rule out the possibility that our results are data-driven or hold only for patent-based measures of innovation efficiency.

[Insert Table 6]

4.6. When is Internal Governance Effective?

In the previous section, we showed that internal governance is effective in improving a firm's innovation efficiency. However, the dynamic of this bottom-up governance mechanism depends heavily on the distribution of power and the importance of different players inside the top management team. For example, if a CEO is young or has extensive power relative to other members of the top management team, he or she may dominate the contribution to the firm, and hence, internal governance may have little or no impact on CEO behavior. To investigate the effectiveness of internal governance, we further study this relationship under different scenarios, including when the CEO is close to retirement, possess more power relative his or her subordinates, or he or she is classified as a generalist CEO.

4.6.1. CEO Horizon

At different stages of the CEO's career, he or she may use R&D expenditure for different purposes. For example, Bebchuk and Stole (1993) and Pan, Wang, and Weisbach (2016) suggest that CEOs with shorter career horizon may choose to overinvest to signal the presence of investment opportunities, without much emphasis on the quality of investment. Along the same line, Gibbons and Murphy (1992) suggest that CEOs close to retirement lose incentives to focus on long-term investments. When the CEO's horizon decreases, the chance that the immediate subordinates will succeed him or her is much higher. This may incentivize non-CEO executives to exert more effort to keep the firm investment activities as efficient as possible. To test this argument, we create an indicator variable, Old CEO, which takes the value of 1 if a CEO's age exceeds the sample median CEO age, and 0 otherwise.

[Insert Table 7]

Table 7 presents the results. We find that the presence of older CEOs with a shorter expected horizon decreases firms' innovation efficiency. The coefficients of Old CEO are negative and statistically significant for different measures of innovation efficiency. We also find that the

coefficients of the interaction term between the internal governance measured by the difference in horizons and the Old CEO indicator variable are positive and statistically significant. These results are consistent with hypothesis 2 and our prediction that, as a CEO ages and the second line managers become closer to replace him or her, internal governance is more effective in efficiently allocating a firm's investments. The results also show that internal governance is only effective when the subordinates are close to replacing the incumbent CEO. The coefficients of difference in horizons are not statistically significant for all measures of innovation efficiency.

4.6.2. CEO Power

Another dimension that may affect the strength of internal governance influence on innovation efficiency is the CEO power. As suggested by Acharya, Myers, and Rajan (2011) that internal governance is based on the concept of a rolling partnership between CEOs and their subordinates. For this partnership to succeed, both CEOs' and their subordinates' contributions must be important to the firm. If one party dominates the contribution, the other party does not have enough incentive to contribute to or monitor firms' investments. Bebchuk, Cremers, and Peyer (2011) find that CEO dominance is associated with a significant decrease in firm performance. We use total pay of the CEO relative to his or her median industry peers. We create an indicator variable, CEO Power, which takes the value of 1 if the CEO total pay is greater than the median pay of other CEOs in the same operating industry during the same year and 0 otherwise.

[Insert Table 8]

Our results indicate that internal governance may lose its effectiveness in increasing a firm's innovation efficiency if a powerful CEO leads the firm. Table 8 shows the regression results. We find that the coefficients of internal governance measured by the difference in horizons are positive and statistically significant. However, the interaction term between CEO Power and the difference in horizons is negative and statistically significant. These results confirm hypothesis 3 is valid: the effectiveness of internal governance depends on CEO power. The results confirm previous findings that as the CEO's power increases, the monitoring incentives of insiders decrease (Ryan and Wiggins 2004; Adams, Almeida and Ferreira 2005; Pan, Wang, and Weisbach 2016).

4.6.3. Subordinates' power: Inside Directors

An alternative channel through which non-CEO executives can exercise their power is improving the oversight role of the board. Non-CEO executives possess a wealth of information

about a firm's long-term investments and its prospects. If non-CEO executives have an extended horizon in the firm compared to the CEO, they would have the ability and incentive to improve the monitoring role of the board through providing an accurate and reliable assessment of the firm's future investments. Consistent with this argument, previous theoretical (Raheja, 2005; Adams and Ferreira, 2007; Harris and Raviv 2008) and empirical works (Duchin et al., 2010, Masulis and Mobbs, 2011) suggest that non-CEO inside directors improve board performance. To investigate the impact of non-CEO executives serving as inside directors and their ability to enforce internal governance, we use the number of non-CEO directors on the board, extracted from the ExecuComp dataset, as an indirect proxy of non-CEOs power.

[Insert Table 9]

Table 9 reports the regression results. We find that non-CEO inside directors can help improve the internal governance to increase innovation efficiency. We find that the interaction terms between the difference in horizons and non-CEO inside directors are positive and statistically significant for the quantity and scientific value of innovation. On the other hand, we find that the coefficients of inside directors are positive and statistically significant for the stock market value of innovation measure. However, the interaction terms between inside directors and the difference in the horizon are positive, they are statistically insignificant for the market value measure. Our results suggest that the role of subordinate managers to improve the oversight role of the board may work as a complementary force to the difference in horizons inside the top management team to improve the private value generated from firms' innovative activities and investments in R&D.

4.6.4. Generalist CEO

In this section, we scrutinize the influence of a CEO's experience on the effectiveness of internal governance in improving innovation efficiency. Previous literature suggests that CEOs with greater tolerance for failure and higher risk exposure due to their diverse work experience may spur a firm's innovation. Custódio, Ferreira, and Matos (2017) suggest that a generalist CEO improves a firm's innovation efficiency because they acquire knowledge beyond the firm's current technological domain and they can use their skills bank to target different innovative projects. Although this argument is valid, using the firm's resources efficiently might be harder for a generalist CEO without the help of subordinates. To stimulate innovation efforts, the firm requires

the general skills of the CEO as well as firm-level skills of the subordinate managers. Hence, we argue that to achieve an efficient innovative investment, the firm would require general and firm-specific knowledge of both parties within the top management team.

To investigate this relation, we use CEO General Ability Index created by Custódio, Ferreira, and Matos (2013) to classify our sample of CEOs into generalists versus specialists. We create an indicator variable, GAI, which takes the value of 1 if the CEO scores above the median GAI and 0 otherwise. Our results interestingly suggest that internal governance is exclusively effective in improving firms' innovation efficiency when the CEO is a generalist. We find that the interaction terms between GAI and difference in horizons to be positive and statistically significant indicating that internal governance helps to increase the quantity, scientific values, and market reaction of granted patents for every dollar invested in R&D only when the CEO is a generalist. These results echo our previous results that internal governance is effective only when both parties inside the top management contribute to a firm's cash flow and innovation process. We also find that generalist CEOs have a negative impact on innovation efficiency. These results emphasize the importance of generalist CEOs in the innovation process and whether they may spur the investment of the firm at the expense of inefficient use of a firm's resources. Our results suggest that to achieve efficient investment, the top management team needs to include both general and firm-specific expertise.

[Insert Table 10]

4.6.5. Overconfident CEO

We also test the impact of CEO overconfidence on the relationship between internal governance and innovation efficiency. Following previous literature (Malmendier and Tate 2005, 2008; Banerjee, Humphery-Jenner, and Nanda 2015), we use the option-based measure to proxy CEO's overconfidence. The intuition of this measure is to capture the extent to which the CEO of the firm retains in-the-money options that are vested. Retaining such options voluntarily after the vesting period in which exercise becomes permissible is viewed as being overconfident (Malmendier and Tate 2005; Banerjee, Humphery-Jenner, and Nanda 2015). To construct this measure, we collect options grant information from Execucomp. Next, for every CEO in our sample, we divide the value of all unexercised exercisable options by the number of options vested

and scale it by the price at the end of the fiscal year as reported in Compustat. To classify a CEO as overconfident, a CEO should score above the median value of our overconfidence measure.

Table 11 reports the regression analysis. We find that internal governance is not effective in improving a firm's innovation when the CEO is overconfident. We find that the interaction terms between the overconfidence indicator variable and difference in horizons are insignificant for all different measures of innovation. However, the coefficients of internal governance are still positive and statistically significant for quantity and the scientific value. These results are to some degree aligned with hypothesis 6. Overconfident CEOs may be unsupportive to internal governance efforts inside the firm as indicated by the negative coefficients, but the impact is not statistically significant. Thus, it is important to highlight that our results suggest that overconfident CEOs are limited in their ability to weaken or undermine the effort of internal governance inside the firm. Interestingly, internal governance is only marginally significant for the stock market value of innovation variable, while overconfident CEOs can bring value creation to the firm for their innovations.

[Insert Table 11]

4.6.6. *Other Results*

a. Family Firms

In addition to previous results, we investigate the impact of family firms on the effectiveness of internal governance. Previous studies show that family firms tend to be less innovative firms. Chen and Hsu (2009), Chrisman and Patel (2012), and Munari, Oriani, and Sobrero (2010) show that family firms tend to invest less in R&D. Duran, Kammerlander, van Essen and Zellweger (2015) find that the innovativeness of family firms depends on the level of control, wealth concentration, and the importance of non-financial goals. To test this relationship, we use a family firm dataset collected from Anderson, Duru, and Reeb (2009) and Anderson, Reeb, and Zhao (2012). Consistent with the previous literature, our untabulated results (for brevity) find that family firms tend to be less efficient in generating patents, citations, and market value from their R&D investments. Further, we find internal governance is not effective in reversing the negative effect of family firms on innovation efficiency. We find that the interaction terms between the family firm indicator variable and the difference in horizons measured by age difference are always statistically insignificant.

b. High-tech Industries

Innovation process differs from one industry to another. For example, the innovation process in high-tech industries is critical to firm growth and survival. The demand for innovation in high-tech industries may have a positive or negative impact on firm's innovation efficiency. As high-tech industries tend to produce more innovative products, they may build the know-how of innovation. Building on their previous success, firms in high-tech industries may become more efficient in allocating investment in high-rewarding projects. On the other hand, these firms may face pressure from the market to invest more in innovative activities. Such pressure may lead to inefficient allocation of firms' R&D to chase innovation. To test this relationship and its impact on the relationship between internal governance and innovation efficiency, we follow Shen and Zhang (2017) and create an indicator variable that takes the value of 1 if the firm is part of the seven industry classifications (industries with three-digit SIC codes 283, 357, 366, 367, 382, 384, and 737).[14]

Our results (untabulated for brevity) suggest that high-tech industries are less efficient in allocating firms' investments. Or it might be mechanical because high-tech industries have much higher R&D investments, and the firms in the industry might be reluctant to apply for patents to avoid severe competition. We find that the coefficients of the high-tech indicator variable are negative and statistically significant for all measures of innovation efficiency. We also find that internal governance coefficients are still positive and statistically significant. The interaction term between the age difference and high-tech indicator variable is statistically insignificant for all measures of innovation efficiency, suggesting that the effectiveness of internal governance is indifferent between high-tech industries and other industries. Our results are consistent with previous studies (He and Tian 2013; Fang, Tian, and Tice 2014) that argue that excessive monitoring from the market may hinder innovation.

5. Conclusion

Previous theoretical (Acharya, Myers, and Rajan 2011; Landier, Sraer, and Thesmar 2009) and empirical evidence (Masulis and Mobbs 2011; Landier et al. 2013) suggest that internal

[14] SIC codes 283, 357, 366, 367, 382, 384, and 737 represent firms operating in Drugs, Computer and Office Equipment, Communication Equipment, Electronic Components and Accessories, Laboratory, Optic, Measure, Control Instruments, and Computer Programming and Data Processing, respectively.

governance exercised by senior non-CEO executives can form a counterpower to myopic CEO behavior. In this study, we investigate the relationship between internal governance exercised by senior non-CEO executives and innovation efficiency. Our study provides empirical evidence that subordinated managers' expected employment horizon relative to that of CEO, is an important determinant of innovation efficiency. Using a rich original panel dataset of major US firms included in S&P 1500 from 1992 to 2010, we find a strong positive association between the difference in horizons within the top management team and innovation efficiency. Our results are robust to alternative measures of horizon, and measures of innovation efficiency.

Our results indicate that the internal governance is contingent on the composition of the top management team. We find that internal governance is effective when the subordinate managers' expected horizon exceeds the CEO's horizon. Moreover, internal governance is effective only when an elder or generalist CEO lead the firm. On the other hand, the presence of powerful CEOs attenuates the effect of internal governance on innovation efficiency. In addition, even firms led by overconfident CEOs still benefit from internal governance in improving the quantity and scientific value of the innovation. Thus, overconfident CEOs have limited ability to weaken or undermine the effort of internal governance inside the firm on innovation. To rule out the alternative explanation that our results are driven by self-selection of young non-CEO executives, who choose to work in an efficient, innovative firm, we conduct propensity score matching and 2SLS regression analysis using the ratio of average consumer price index (CPI) in the birth year of subordinate managers divided by the CPI in the year when the CEO was born, as an instrument. The additional tests suggest that self-selection of non-CEO executives does not drive our results.

Our study contributes to the literature by examining the impact of internal governance on innovation efficiency. Our findings shed light on how the top management team can work together and shape the corporate strategy that boosts the long-term growth and competitiveness of a firm. Departing from previous research that usually emphasizes CEOs or views executives as a unified team, we provide evidence that subordinate managers play an important monitoring role on the CEOs from the bottom up and that effective internal governance can positively impact firms' innovation efficiency.

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Table1: Descriptive Statistics

This table presents descriptive statistics of S&P 1500 firms available on ExecuComp during 1992–2010. All variables are winsorized at 1% and 99% values. Variable definitions are provided in the Appendix.

Variable	Min	25th	Mean	Median	S.D.	75th	Max
Innovation							
PAT	1.00	2.00	42.73	7.00	109.52	27.00	746.00
TCW	1.00	4.86	99.03	16.56	258.62	63.19	1780.99
TSM	0.51	7.09	740.52	34.76	2339.14	245.39	16034.39
R&D	0.00	3.12	143.49	20.65	439.94	72.69	3348.00
$PAT/R\&D$	0.00	0.09	0.28	0.20	0.28	0.38	5.34
$TCW/R\&D$	0.00	0.20	0.99	0.48	4.88	1.02	343.58
$TSM/R\&D$	0.01	0.37	2.49	1.04	5.46	2.59	239.50
Top Management Team Characteristics							
CEO's Age	39.00	49.00	53.71	54.00	6.57	58.00	72.00
CEO's Delta	0	67.66	1202.20	177.76	12675.23	479.13	515556
CEO's Vega	0	10.87	101.63	34.65	244.45	96.85	11262
CEO's GAI	-1.50	-0.71	0.02	-0.16	1.00	0.54	6.87
Non-CEO Age	37.29	46.25	49.91	50.00	5.39	53.50	63.67
Difference in Horizons	-13.50	-1.00	3.86	3.75	7.17	8.33	23.00
Rem. Horizon	1.33	11.50	15.09	15.00	5.39	18.75	27.71
Ind. Adj. Sub Age	-14.00	-3.50	-0.16	0.00	5.40	3.50	12.50
Pay ratio	0.36	1.65	2.64	2.28	1.66	3.11	11.07
External Governance							
Analyst Coverage	1.00	4.00	9.84	8.00	7.36	14.00	48.00
Institutional Ownership	0.00	0.50	0.64	0.67	0.22	0.81	1.00
Control Variables							
HHI	0.04	0.13	0.27	0.20	0.20	0.35	1.00
Stk. Ret	-0.79	-0.16	0.18	0.10	0.58	0.39	2.66
Ln(Sales)	14.39	17.37	18.45	18.40	1.64	19.51	22.53
Leverage	0.00	0.05	0.22	0.20	0.19	0.33	0.89
Tobin Q	0.70	1.20	2.07	1.60	1.45	2.36	8.78
ROA	-0.35	0.05	0.09	0.09	0.11	0.15	0.37
Tangibles	0.00	0.12	0.29	0.23	0.22	0.41	0.88
Z- Score	-4.63	2.23	5.16	3.61	5.85	5.91	35.78
Interest Coverage	-0.80	0.02	0.13	0.09	0.23	0.18	1.35
Cash	0.00	0.02	0.15	0.08	0.18	0.22	0.76
Invest	0.00	0.02	0.06	0.04	0.06	0.08	0.30

Table 2: Difference in Horizons

This table reports the regression results for the relationship between executives' horizon and firms' innovation efficiency. The difference in horizons is measured by the age difference between the CEO and his or her immediate non-CEO executives. Panel A presents the quantity and scientific value of innovation efficiency measured by the log of number of patents in t+1 and t+2 deflated by R&D expenses in year t and citation-weighted patents in t+1 and t+2 deflated by R&D expenses in year t. Panel B presents the regression results for the market value of innovation efficiency measured by the log of the stock market reaction of the granted patent in t+1 and t+2 deflated by R&D expenses in year t. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% levels respectively. Variable definitions are provided in the Appendix.

Panel A: Quantity and Quality of Innovation

	$PAT\ EFF_{t+1}$			$PAT\ EFF_{t+2}$			$TCW\ EFF_{t+1}$			$TCW\ EFF_{t+2}$		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Diff in Horizons	0.041***	0.056***	0.064***	0.050***	0.079***	0.084***	0.040***	0.069***	0.083***	0.048***	0.085***	0.094***
	(4.55)	(4.26)	(4.62)	(5.27)	(5.78)	(5.81)	(4.49)	(5.36)	(6.15)	(5.18)	(6.37)	(6.70)
CEO's Age		-0.169	-0.178		-0.334***	-0.355***		-0.332***	-0.365***		-0.423***	-0.449***
		(-1.56)	(-1.57)		(-2.96)	(-2.99)		(-3.13)	(-3.32)		(-3.86)	(-3.93)
CEO's Delta			0.002			-0.001			-0.003			-0.007
			(0.23)			(-0.06)			(-0.4)			(-0.79)
CEO's Vega			0.018*			0.017			0.012			0.012
			(1.78)			(1.57)			(1.24)			(1.15)
HHI	0.003	0.004	-0.018	-0.032	-0.030	-0.056*	0.023	0.025	0.002	-0.004	-0.001	-0.021
	(0.1)	(0.14)	(-0.59)	(-1.08)	(-1.01)	(-1.73)	(0.82)	(0.9)	(0.06)	(-0.15)	(-0.05)	(-0.66)
Stk. Ret	-0.002	-0.002	-0.000	0.022**	0.021**	0.021**	0.015	0.014	0.016	0.027***	0.026***	0.024**
	(-0.18)	(-0.21)	(-0.04)	(2.15)	(2.08)	(1.96)	(1.58)	(1.53)	(1.63)	(2.67)	(2.58)	(2.35)
Analyst Cov.	0.013	0.014	0.001	0.020	0.021	0.004	0.038*	0.040*	0.030	0.038	0.040*	0.023
	(0.57)	(0.61)	(0.06)	(0.80)	(0.87)	(0.16)	(1.66)	(1.75)	(1.27)	(1.6)	(1.7)	(0.92)
Instit. Owners	-0.164***	-0.166***	-0.153***	-0.154***	-0.158***	-0.138***	-0.143***	-0.148***	-0.145***	-0.121***	-0.126***	-0.117***
	(-4.52)	(-4.59)	(-3.91)	(-4.06)	(-4.17)	(-3.38)	(-4.02)	(-4.16)	(-3.81)	(-3.28)	(-3.42)	(-2.98)
Ln (Sales)	-1.152***	-1.122***	-1.117***	-1.055***	-0.990***	-0.925***	-1.079***	-1.020***	-0.980***	-0.929***	-0.847***	-0.721***
	(-6.38)	(-6.18)	(-5.66)	(-5.52)	(-5.15)	(-4.4)	(-6.08)	(-5.72)	(-5.11)	(-4.99)	(-4.52)	(-3.57)
Leverage	-0.013	-0.014	-0.007	-0.007	-0.008	-0.008	-0.021	-0.022	-0.014	-0.007	-0.008	-0.008
	(-0.81)	(-0.84)	(-0.41)	(-0.42)	(-0.48)	(-0.46)	(-1.33)	(-1.39)	(-0.86)	(-0.43)	(-0.5)	(-0.43)
Tobin Q	-0.047*	-0.048*	-0.064**	-0.091***	-0.093***	-0.103***	-0.044*	-0.046*	-0.063**	-0.081***	-0.083***	-0.086***
	(-1.89)	(-1.93)	(-2.46)	(-3.44)	(-3.5)	(-3.69)	(-1.79)	(-1.86)	(-2.46)	(-3.13)	(-3.22)	(-3.2)
ROA	-0.014	-0.014	-0.020	0.000	-0.000	-0.008	-0.026*	-0.026*	-0.029**	-0.015	-0.015	-0.024
	(-1.06)	(-1.05)	(-1.4)	(0.00)	(0.00)	(-0.52)	(-1.95)	(-1.93)	(-2.08)	(-1.03)	(-1.04)	(-1.6)
Tangibles	0.222***	0.226***	0.230***	0.201***	0.209***	0.204***	0.160***	0.168***	0.167***	0.136***	0.145***	0.134***
	(7.5)	(7.61)	(7.35)	(6.45)	(6.67)	(6.1)	(5.51)	(5.77)	(5.48)	(4.47)	(4.77)	(4.15)
Z- Score	0.059***	0.059***	0.072***	0.084***	0.085***	0.097***	0.085***	0.085***	0.101***	0.116***	0.118***	0.128***
	(3.17)	(3.19)	(3.67)	(4.25)	(4.3)	(4.64)	(4.62)	(4.67)	(5.34)	(6.02)	(6.09)	(6.36)
	-0.001	-0.002	0.001	-0.013	-0.014	-0.007	0.001	-0.000	0.001	-0.012	-0.013	-0.006

Interest Cov.	(-0.14)	(-0.17)	(0.06)	(-1.33)	(-1.39)	(-0.62)	(0.06)	(0.00)	(0.10)	(-1.22)	(-1.3)	(-0.55)
Cash	-0.004	-0.004	-0.004	0.021	0.021	0.025	0.026	0.026	0.027	0.047**	0.046**	0.054***
	(-0.23)	(-0.23)	(-0.22)	(1.11)	(1.1)	(1.22)	(1.47)	(1.48)	(1.45)	(2.5)	(2.49)	(2.73)
Invest	-0.039**	-0.041**	-0.039**	-0.003	-0.007	0.005	-0.007	-0.012	-0.008	0.024	0.019	0.034*
	(-2.13)	(-2.26)	(-2.01)	(-0.13)	(-0.35)	(0.24)	(-0.41)	(-0.68)	(-0.41)	(1.29)	(1.01)	(1.73)
SIC. FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Adj-R^2	0.680	0.680	0.674	0.677	0.678	0.667	0.692	0.692	0.692	0.694	0.695	0.692
N	5801	5801	5429	5348	5348	4990	5801	5801	5429	5348	5348	4990

Panel B: Market Value of Innovation						
	$TSM\ EFF_{t+1}$			$TSM\ EFF_{t+2}$		
	(1)	(2)	(3)	(1)	(2)	(3)
Diff in Horizons	0.017**	0.036***	0.038***	0.017**	0.048***	0.045***
	(2.53)	(3.68)	(3.79)	(2.28)	(4.43)	(3.98)
CEO's Age		-0.214***	-0.224***		-0.353***	-0.342***
		(-2.67)	(-2.72)		(-3.94)	(-3.71)
CEO's Delta			0.000			0.002
			(0.06)			(0.27)
CEO's Vega			0.024***			0.009
			(3.27)			(1.13)
HHI	0.008	0.009	0.001	0.002	0.004	0.005
	(0.37)	(0.44)	(0.03)	(0.08)	(0.17)	(0.21)
Stk. Ret	0.045***	0.045***	0.048***	0.051***	0.050***	0.052***
	(6.34)	(6.29)	(6.52)	(6.27)	(6.19)	(6.18)
Analyst Cov.	0.140***	0.141***	0.139***	0.147***	0.149***	0.144***
	(8.17)	(8.24)	(7.88)	(7.61)	(7.72)	(7.24)
Instit. Owners	-0.043	-0.046*	-0.031	-0.060**	-0.064**	-0.050
	(-1.58)	(-1.69)	(-1.1)	(-2)	(-2.15)	(-1.59)
Ln (Sales)	2.981***	3.018***	2.933***	2.575***	2.643***	2.647***
	(22.21)	(22.38)	(20.4)	(16.93)	(17.3)	(16.22)
Leverage	-0.012	-0.012	-0.008	-0.013	-0.014	-0.009
	(-0.96)	(-1.02)	(-0.65)	(-0.94)	(-1.02)	(-0.66)
Tobin Q	0.243***	0.242***	0.233***	0.209***	0.207***	0.199***
	(13.16)	(13.1)	(12.22)	(9.92)	(9.85)	(9.16)
ROA	-0.021**	-0.021**	-0.026**	-0.010	-0.010	-0.015
	(-2.1)	(-2.08)	(-2.44)	(-0.89)	(-0.9)	(-1.24)
Tangibles	0.063***	0.068***	0.064***	0.067***	0.075***	0.070***
	(2.88)	(3.11)	(2.8)	(2.69)	(3)	(2.69)
Z- Score	0.059***	0.059***	0.067***	0.054***	0.055***	0.064***
	(4.24)	(4.28)	(4.73)	(3.44)	(3.51)	(3.91)
Interest Cov.	-0.017**	-0.018**	-0.017**	-0.015*	-0.015*	-0.014*
	(-2.46)	(-2.51)	(-2.3)	(-1.83)	(-1.92)	(-1.68)
Cash	0.055***	0.055***	0.049***	0.046***	0.046***	0.047***
	(4.05)	(4.05)	(3.46)	(3.05)	(3.04)	(2.95)
Invest	0.007	0.003	0.003	-0.002	-0.007	-0.001
	(0.49)	(0.25)	(0.18)	(-0.15)	(-0.43)	(-0.07)
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.824	0.824	0.827	0.796	0.797	0.799
N	5801	5801	5429	5348	5348	4990

Table 3: Positive vs. Negative Difference in Horizons

This table reports the regression results for positive and negative differences in horizon samples. Panel A (Panel B) presents the regression results for positive age difference (negative age difference). We replace the negative age difference by the absolute value of age difference. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively. Variable definitions are provided in the Appendix.

Panel A: Positive Difference in Horizons

Variables	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
Diff in Horizons	0.058***	0.090***	0.067***	0.088***	0.052***	0.048***
	(3.49)	(5.26)	(4.07)	(5.20)	(3.93)	(3.26)
HHI	-0.000	-0.035	0.023	-0.012	-0.003	-0.004
	(0.00)	(-0.97)	(0.67)	(-0.34)	(-0.09)	(-0.13)
Stk. Ret	-0.005	0.029**	0.015	0.037***	0.048***	0.056***
	(-0.43)	(2.47)	(1.38)	(3.17)	(5.4)	(5.59)
Analyst Cov.	0.021	0.016	0.034	0.030	0.155***	0.152***
	(0.78)	(0.55)	(1.28)	(1.08)	(7.26)	(6.31)
Instit. Owners	-0.227***	-0.205***	-0.190***	-0.169***	-0.058*	-0.070*
	(-5.21)	(-4.61)	(-4.41)	(-3.87)	(-1.68)	(-1.83)
Ln(Sales)	-1.223***	-1.059***	-1.036***	-0.883***	2.956***	2.533***
	(-5.73)	(-4.75)	(-4.91)	(-4.02)	(17.58)	(13.28)
Leverage	0.001	0.005	-0.007	0.006	-0.004	-0.002
	(0.05)	(0.25)	(-0.35)	(0.30)	(-0.24)	(-0.1)
Tobin Q	-0.038	-0.107***	-0.041	-0.094***	0.261***	0.210***
	(-1.25)	(-3.37)	(-1.38)	(-2.99)	(10.94)	(7.69)
ROA	-0.004	0.017	-0.015	-0.001	-0.012	-0.005
	(-0.25)	(1.00)	(-0.92)	(-0.07)	(-0.95)	(-0.37)
Tangibles	0.187***	0.121***	0.114***	0.042	0.015	-0.012
	(5.21)	(3.22)	(3.2)	(1.13)	(0.51)	(-0.39)
Z- Score	0.031	0.073***	0.048**	0.092***	0.027	0.040*
	(1.36)	(3.02)	(2.11)	(3.87)	(1.5)	(1.91)
Interest Coverage	-0.012	-0.019	-0.008	-0.018	-0.025***	-0.025**
	(-1.06)	(-1.6)	(-0.72)	(-1.57)	(-2.77)	(-2.51)
Cash	0.005	0.019	0.048**	0.056**	0.048***	0.025
	(0.25)	(0.85)	(2.24)	(2.53)	(2.8)	(1.34)
Invest	-0.028	0.012	0.012	0.046**	0.007	-0.006
	(-1.24)	(0.53)	(0.54)	(2.02)	(0.4)	(-0.29)
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.695	0.702	0.702	0.710	0.811	0.782
N	4020	3704	4020	3704	4020	3704

Panel B: Negative Difference in Horizons						
Variables	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
Diff in Horizons	0.039	-0.028	-0.004	-0.056**	0.024	-0.024
	(1.48)	(-1.00)	(-0.15)	(-2.08)	(1.41)	(-1.28)
HHI	0.022	-0.016	0.035	0.012	0.037	0.021
	(0.41)	(-0.27)	(0.68)	(0.21)	(1.07)	(0.53)
Stk. Ret	0.004	0.008	0.004	-0.002	0.036***	0.034**
	(0.21)	(0.41)	(0.24)	(-0.12)	(3.06)	(2.58)
Analyst Cov.	0.019	0.040	0.076*	0.074	0.122***	0.148***
	(0.44)	(0.83)	(1.77)	(1.6)	(4.21)	(4.52)
Instit. Owners	-0.109	-0.098	-0.136**	-0.074	-0.064	-0.077
	(-1.53)	(-1.27)	(-1.98)	(-1)	(-1.38)	(-1.47)
Ln(Sales)	-0.665*	-0.644	-0.847**	-0.576	3.117***	2.566***
	(-1.81)	(-1.59)	(-2.38)	(-1.49)	(13.01)	(9.39)
Leverage	-0.042	-0.043	-0.070**	-0.058*	-0.040*	-0.055**
	(-1.30)	(-1.25)	(-2.25)	(-1.75)	(-1.9)	(-2.38)
Tobin Q	-0.047	-0.050	-0.030	-0.048	0.228***	0.206***
	(-1.06)	(-1.05)	(-0.71)	(-1.05)	(7.9)	(6.35)
ROA	-0.049*	-0.047	-0.068***	-0.060**	-0.027	0.006
	(-1.79)	(-1.61)	(-2.58)	(-2.16)	(-1.54)	(0.3)
Tangibles	0.368***	0.387***	0.309***	0.339***	0.175***	0.205***
	(6.45)	(6.22)	(5.59)	(5.71)	(4.72)	(4.9)
Z- Score	0.100***	0.089**	0.132***	0.146***	0.085***	0.051**
	(3.06)	(2.42)	(4.15)	(4.16)	(3.96)	(2.08)
Interest Coverage	0.027	0.005	0.024	0.003	-0.002	0.013
	(1.52)	(0.26)	(1.4)	(0.19)	(-0.19)	(1)
Cash	0.039	0.086**	0.032	0.079**	0.100***	0.110***
	(1.1)	(2.25)	(0.94)	(2.16)	(4.38)	(4.3)
Invest	-0.060*	-0.005	-0.031	0.011	0.013	0.037
	(-1.8)	(-0.15)	(-0.94)	(0.31)	(0.60)	(1.48)
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.699	0.678	0.718	0.706	0.873	0.854
N	1684	1559	1684	1559	1684	1559

Table 4: Endogeneity

Panel A presents the results for propensity score matching. Average treatment effect (ATE) is reported with z-statistics in parentheses. In the first step, a logit model is used to calculate the propensity score using all the control variables in our baseline specification. In the second step, the difference in innovation efficiency between high and low internal governance firms is reported. High (low) internal governance is defined as firms with above (below) median difference in horizon. Panel B presents the results of instrumental-variable regression. We treat difference in horizon measured by the age difference between the CEO and his or her immediate non-CEO executives as an endogenous variable. We use industry-adjusted age difference as an instrumental variable. Ind. adjusted age difference is defined as the difference between the average non-CEO executives' age in each firm and the average age of peers of non-CEO executives in the same industry.

Panel A: Propensity Score Matching

	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
ATE	0.063*	0.084***	0.059*	0.099***	0.062**	0.070***
	(1.91)	(2.89)	(1.91)	(3.42)	(2.39)	(2.61)

Panel B: 2SLS – Instrumental Variable Regression

	1st Stage	2nd Stage				
		$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
CPI (Sub/CEO)	0.832						
	(107.34)						
Diff in Horizon (Instrumented)		0.036**	0.053***	0.037**	0.051***	0.028**	0.027**
		(2.40)	(3.26)	(2.230)	(3.071)	(2.219)	(1.970)
HHI	0.053	0.003	-0.026	0.020	-0.004	0.007	0.002
	(3.14)	(0.12)	(-1.09)	(0.860)	(-0.145)	(0.381)	(0.079)
Stk. Ret	-0.001	-0.002	0.030*	0.021	0.038**	0.070***	0.079***
	(-0.08)	(-0.18)	(1.91)	(1.362)	(2.312)	(5.570)	(5.335)
Analyst Coverage	0.030	0.011	0.015	0.030*	0.030*	0.117***	0.121***
	(2.85)	(0.73)	(0.97)	(1.886)	(1.792)	(7.769)	(7.542)
Instit. Own	-0.004	-0.071***	-0.067***	-0.067***	-0.056***	-0.021	-0.030*
	(-0.35)	(-4.14)	(-3.82)	(-3.569)	(-2.917)	(-1.511)	(-1.876)
Ln(Sales)	-0.035	-0.143***	-0.129***	-0.143***	-0.121***	0.416***	0.355***
	(-2.49)	(-6.53)	(-5.64)	(-6.262)	(-5.134)	(21.421)	(16.885)
Leverage	0.005	-0.013	-0.007	-0.023	-0.008	-0.014	-0.016
	(0.49)	(-0.72)	(-0.39)	(-1.236)	(-0.398)	(-1.002)	(-0.995)
Tobin Q	-0.021	-0.034*	-0.063***	-0.033	-0.059***	0.196***	0.164***
	(-1.87)	(-1.75)	(-3.05)	(-1.552)	(-2.644)	(11.280)	(8.843)
ROA	0.012	-0.014	0.001	-0.028*	-0.015	-0.025*	-0.012
	(1.32)	(-0.97)	(0.04)	(-1.765)	(-0.875)	(-1.947)	(-0.862)
Tangibles	-0.011	0.237***	0.211***	0.182***	0.151***	0.078***	0.080**
	(-0.53)	(6.53)	(5.84)	(4.844)	(4.020)	(2.619)	(2.499)
Z- Score	-0.005	0.053**	0.074***	0.082***	0.108***	0.061***	0.054***
	(-0.39)	(2.56)	(3.34)	(3.359)	(4.380)	(3.531)	(3.022)

Interest Coverage	0.001	-0.002	-0.022	0.001	-0.021	-0.033**	-0.028**
	(0.09)	(-0.15)	(-1.48)	(0.045)	(-1.410)	(-2.561)	(-1.985)
Cash	0.021	-0.004	0.019	0.025	0.044**	0.057***	0.048***
	(1.97)	(-0.27)	(1.17)	(1.374)	(2.417)	(3.989)	(2.921)
Investment	0.032	-0.045*	-0.003	-0.009	0.029	0.009	-0.003
	(2.22)	(-1.860)	(-0.11)	(-0.339)	(1.065)	(0.465)	(-0.144)
SIC. FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
F-stat (P-value)	0.000						
R^2		0.031	0.032	0.042	0.045	0.364	0.300
N	5801	5801	5348	5801	5348	5801	5348

Table 5: Alternative Measures of Horizon

This table presents regression results for measures of non-executives' horizon. Scaled Diff in Horizon is the age difference between the CEO and his or her immediate non-CEO executives scaled by CEO's age. Sub. Age is the average of non-CEO executives' (subordinate managers) age, and Sub. remaining horizon is the difference between the expected retirement age of 65 and the average subordinate managers' age. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively. Variable definitions are provided in the Appendix.

	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
Panel A: Scaled Diff in Horizon						
Scaled Diff in Horizon	0.036***	0.042***	0.035***	0.041***	0.013**	0.013*
	(4.10)	(4.55)	(4.00)	(4.58)	(2.06)	(1.79)
Control	Y	Y	Y	Y	Y	Y
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.680	0.677	0.691	0.6938	0.824	0.796
N	5801	5348	5801	5348	5801	5348
Panel B: Sub. Age						
Sub. Age	-0.294***	-0.437***	-0.404***	-0.489***	-0.222***	-0.298***
	(-3.43)	(-4.93)	(-4.82)	(-5.66)	(-3.49)	(-4.23)
Control	Y	Y	Y	Y	Y	Y
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.680	0.677	0.693	0.694	0.824	0.797
N	5801	5348	5801	5348	5801	5348
Panel C: Sub. Remaining Horizon						
Sub. remaining horizon	0.090***	0.135***	0.124***	0.151***	0.068***	0.092***
	(3.43)	(4.93)	(4.82)	(5.66)	(3.49)	(4.23)
Control	Y	Y	Y	Y	Y	Y
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.680	0.677	0.692	0.694	0.824	0.797
N	5801	5348	5801	5348	5801	5348
Panel D: Sub. Ind. Adj. Horizon						
Sub. Ind. Adj. horizon	0.035***	0.049***	0.043***	0.053***	0.024***	0.031***
	(4.11)	(5.48)	(5.18)	(6.12)	(3.86)	(4.47)
Control	Y	Y	Y	Y	Y	Y
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.680	0.677	0.692	0.695	0.824	0.797
N	5801	5348	5801	5348	5801	5348

Table 6: Alternative Measures of Innovation Efficiency

This table presents regression results for an alternative measure of innovation efficiency - Research Quotient (RQ). RQ is defined as the percentage increase in revenue from a 1% increase in R&D. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively. Variable definitions are provided in the Appendix.

	RQ_{t+1}	RQ_{t+2}	RQ_{t+1}	RQ_{t+2}	RQ_{t+1}	RQ_{t+2}	RQ_{t+1}	RQ_{t+2}	RQ_{t+1}	RQ_{t+2}
Diff in Horizons	0.042***	0.036***								
	(4.24)	(3.45)								
CEO's Age	-0.276***	-0.262***								
	(-3.46)	(-3.11)								
Scaled Diff in Horizon			0.016**	0.011*						
			(2.54)	(1.66)						
Sub. Age					-0.281***	-0.252***				
					(-4.40)	(-3.73)				
Remaining Horizon							0.084***	0.075***		
							(4.40)	(3.73)		
Sub. Ind. Adj. horizon									0.023***	0.022***
									(3.93)	(3.48)
HHI	0.036*	0.048**	0.036*	0.048**	0.036*	0.048**	0.036*	0.048**	0.037*	0.050**
	(1.75)	(2.23)	(1.74)	(2.22)	(1.75)	(2.24)	(1.75)	(2.24)	(1.83)	(2.31)
Stk. Ret	0.005	0.012	0.005	0.012*	0.005	0.012	0.005	0.012	0.005	0.012
	(0.67)	(1.61)	(0.75)	(1.68)	(0.66)	(1.61)	(0.66)	(1.61)	(0.68)	(1.63)
Analyst Coverage	-0.039**	-0.044***	-0.038**	-0.044***	-0.039**	-0.044***	-0.039**	-0.044***	-0.038**	-0.044***
	(-2.44)	(-2.63)	(-2.42)	(-2.61)	(-2.44)	(-2.64)	(-2.44)	(-2.64)	(-2.4)	(-2.61)
Instit. Own	0.034	0.044	0.038	0.048*	0.033	0.044	0.033	0.044	0.035	0.045*
	(1.31)	(1.61)	(1.46)	(1.75)	(1.28)	(1.6)	(1.28)	(1.6)	(1.34)	(1.65)
Ln(Sales)	0.664***	0.746***	0.616***	0.700***	0.666***	0.749***	0.666***	0.749***	0.652***	0.739***
	(5.10)	(5.42)	(4.75)	(5.11)	(5.11)	(5.44)	(5.11)	(5.44)	(5.01)	(5.37)
Leverage	-0.037***	-0.035***	-0.036***	-0.035***	-0.037***	-0.035***	-0.037***	-0.035***	-0.037***	-0.035***
	(-3.22)	(-2.92)	(-3.15)	(-2.85)	(-3.23)	(-2.92)	(-3.23)	(-2.92)	(-3.21)	(-2.91)
Tobin Q	-0.021	-0.005	-0.020	-0.004	-0.022	-0.005	-0.022	-0.005	-0.021	-0.005
	(-1.23)	(-0.29)	(-1.15)	(-0.22)	(-1.24)	(-0.29)	(-1.24)	(-0.29)	(-1.21)	(-0.26)
ROA	0.051***	0.044***	0.050***	0.044***	0.051***	0.044***	0.051***	0.044***	0.051***	0.045***
	(5.12)	(4.22)	(5.04)	(4.15)	(5.16)	(4.23)	(5.16)	(4.23)	(5.16)	(4.24)
Tangibles	-0.209***	-0.199***	-0.215***	-0.204***	-0.208***	-0.198***	-0.208***	-0.198***	-0.211***	-0.200***
	(-10.07)	(-9.05)	(-10.39)	(-9.34)	(-10.05)	(-9.04)	(-10.05)	(-9.04)	(-10.17)	(-9.14)
Z- Score	0.027**	0.019	0.027**	0.019	0.027**	0.019	0.027**	0.019	0.027**	0.018
	(2.11)	(1.4)	(2.07)	(1.36)	(2.11)	(1.39)	(2.11)	(1.39)	(2.06)	(1.35)

Interest Coverage	0.002	0.006	0.002	0.006	0.002	0.006	0.002	0.006	0.002	0.006
	(0.27)	(0.79)	(0.32)	(0.84)	(0.27)	(0.79)	(0.27)	(0.79)	(0.29)	(0.81)
Cash	0.002	-0.000	0.001	-0.001	0.002	-0.000	0.002	-0.000	0.002	-0.000
	(0.15)	(-0.01)	(0.08)	(-0.08)	(0.16)	(0)	(0.16)	(0)	(0.12)	(-0.03)
Investment	-0.003	0.011	0.001	0.014	-0.003	0.011	-0.003	0.011	-0.003	0.011
	(-0.24)	(0.76)	(0.06)	(1.03)	(-0.27)	(0.76)	(-0.27)	(0.76)	(-0.20)	(0.81)
SIC. FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Adj-R^2	0.788	0.763	0.787	0.762	0.788	0.763	0.788	0.763	0.787	0.763
N	7553	7553	7553	7553	7553	7553	7553	7553	7553	7553

Table 7: Internal Governance and CEO's Horizon

This table reports the regression results of the impact of CEO's horizon on the relationship between innovation efficiency and the difference in horizon inside the top management team. Old CEO is an indicator variable that takes the value of 1 if the CEO's age is above the sample median age of CEOs, and 0 otherwise. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively. Variable definitions are provided in the Appendix.

Variables	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
Diff in Horizons x Old CEO	0.028	0.078***	0.039**	0.065***	0.035**	0.046***
	(1.50)	(4.05)	(2.14)	(3.49)	(2.55)	(3.01)
Diff in Horizons	0.025	0.010	0.024	0.020	-0.005	-0.004
	(1.55)	(0.62)	(1.51)	(1.21)	(-0.42)	(-0.29)
Old CEO	-0.012	-0.048***	-0.033**	-0.053***	-0.012	-0.034***
	(-0.74)	(-2.92)	(-2.11)	(-3.28)	(-1.02)	(-2.62)
HHI	0.003	-0.033	0.023	-0.005	0.008	0.001
	(0.10)	(-1.1)	(0.81)	(-0.16)	(0.37)	(0.06)
Stk. Ret	-0.002	0.022**	0.015	0.026***	0.045***	0.051***
	(-0.19)	(2.11)	(1.56)	(2.63)	(6.34)	(6.24)
Analyst Cov.	0.012	0.017	0.037	0.037	0.139***	0.146***
	(0.53)	(0.71)	(1.62)	(1.54)	(8.1)	(7.56)
Instit. Owners	-0.164***	-0.156***	-0.144***	-0.123***	-0.043	-0.062**
	(-4.53)	(-4.14)	(-4.05)	(-3.34)	(-1.59)	(-2.06)
Ln(Sales)	-1.129***	-0.969***	-1.025***	-0.841***	3.006***	2.633***
	(-6.2)	(-5.03)	(-5.73)	(-4.49)	(22.22)	(17.19)
Leverage	-0.013	-0.009	-0.022	-0.008	-0.012	-0.014
	(-0.82)	(-0.5)	(-1.35)	(-0.5)	(-0.98)	(-1)
Tobin Q	-0.046*	-0.089***	-0.043*	-0.079***	0.244***	0.210***
	(-1.87)	(-3.37)	(-1.75)	(-3.07)	(13.2)	(9.99)
ROA	-0.015	-0.001	-0.027**	-0.015	-0.021**	-0.011
	(-1.07)	(-0.04)	(-1.99)	(-1.08)	(-2.11)	(-0.93)
Tangibles	0.221***	0.202***	0.162***	0.138***	0.062***	0.068***
	(7.47)	(6.45)	(5.55)	(4.53)	(2.82)	(2.73)
Z- Score	0.058***	0.081***	0.083***	0.114***	0.057***	0.053***
	(3.11)	(4.1)	(4.55)	(5.91)	(4.13)	(3.34)
Interest Coverage	-0.001	-0.014	0.000	-0.012	-0.017**	-0.015*
	(-0.14)	(-1.36)	(0.05)	(-1.27)	(-2.44)	(-1.87)
Cash	-0.003	0.024	0.028	0.049***	0.057***	0.048***
	(-0.15)	(1.27)	(1.59)	(2.63)	(4.18)	(3.16)
Invest	-0.038**	-0.002	-0.008	0.024	0.008	-0.002
	(-2.09)	(-0.1)	(-0.43)	(1.27)	(0.56)	(-0.15)
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.680	0.678	0.692	0.695	0.824	0.797
N	5801	5348	5801	5348	5801	5348

Table 8: Internal Governance and CEO Power

This table reports the regression results of the impact of CEO's power measured by CEO's total pay. CEO power is an indicator variable that takes the value of 1 if the CEO's total pay is above the sample median value of other CEOs in the same operating industry during the same year, and 0 otherwise. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively. Variable definitions are provided in the Appendix.

	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
Diff in Horizons x CEO Power	-0.029**	-0.031**	-0.031**	-0.028**	-0.017*	-0.013
	(-2.31)	(-2.36)	(-2.48)	(-2.2)	(-1.79)	(-1.25)
Diff in Horizons	0.062***	0.072***	0.062***	0.068***	0.029***	0.026**
	(4.84)	(5.38)	(4.9)	(5.18)	(3)	(2.46)
CEO Power	0.025	0.015	0.041**	0.032**	0.049***	0.030**
	(1.57)	(0.91)	(2.57)	(1.97)	(4.12)	(2.25)
HHI	0.003	-0.033	0.023	-0.004	0.008	0.002
	(0.1)	(-1.09)	(0.82)	(-0.14)	(0.39)	(0.1)
Stk. Ret	-0.002	0.022**	0.015	0.027***	0.045***	0.051***
	(-0.18)	(2.18)	(1.56)	(2.67)	(6.24)	(6.24)
Analyst Cov.	0.013	0.020	0.037	0.038	0.139***	0.147***
	(0.57)	(0.81)	(1.64)	(1.59)	(8.12)	(7.6)
Instit. Owners	-0.169***	-0.154***	-0.154***	-0.128***	-0.060**	-0.070**
	(-4.58)	(-4.02)	(-4.26)	(-3.44)	(-2.19)	(-2.29)
Ln(Sales)	-1.201***	-1.061***	-1.191***	-1.014***	2.803***	2.469***
	(-6.28)	(-5.24)	(-6.34)	(-5.15)	(19.74)	(15.35)
Leverage	-0.014	-0.008	-0.022	-0.008	-0.013	-0.014
	(-0.86)	(-0.46)	(-1.41)	(-0.49)	(-1.07)	(-1)
Tobin Q	-0.048*	-0.091***	-0.046*	-0.083***	0.239***	0.207***
	(-1.93)	(-3.45)	(-1.89)	(-3.2)	(12.94)	(9.81)
ROA	-0.014	0.000	-0.024*	-0.013	-0.019*	-0.009
	(-1.00)	(0.00)	(-1.81)	(-0.94)	(-1.82)	(-0.75)
Tangibles	0.223***	0.201***	0.164***	0.138***	0.069***	0.070***
	(7.54)	(6.42)	(5.63)	(4.53)	(3.14)	(2.81)
Z- Score	0.059***	0.084***	0.084***	0.116***	0.059***	0.054***
	(3.17)	(4.25)	(4.62)	(6.03)	(4.26)	(3.45)
Interest Coverage	-0.001	-0.013	0.001	-0.012	-0.017**	-0.014*
	(-0.11)	(-1.32)	(0.12)	(-1.19)	(-2.37)	(-1.78)
Cash	-0.004	0.021	0.026	0.046**	0.054***	0.045***
	(-0.23)	(1.11)	(1.45)	(2.45)	(3.97)	(2.97)
Invest	-0.039**	-0.002	-0.008	0.024	0.005	-0.003
	(-2.15)	(-0.11)	(-0.46)	(1.27)	(0.37)	(-0.19)
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.680	0.678	0.692	0.694	0.824	0.796
N	5801	5348	5801	5348	5801	5348

Table 9: Internal Governance and non-CEO inside Directors

This table reports the regression results of the impact of non-CEO inside directors on the relationship between the difference in horizons and innovation efficiency. # inside directors is the number of non-CEO inside directors. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively. Variable definitions are provided in the Appendix.

	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
Diff in Horizons x # Inside directors	0.028***	0.022**	0.025**	0.018*	0.012	0.008
	(2.82)	(2.08)	(2.54)	(1.82)	(1.62)	(0.99)
Diff in Horizons	0.026**	0.039***	0.028***	0.040***	0.013	0.016*
	(2.43)	(3.44)	(2.59)	(3.54)	(1.64)	(1.73)
# Inside directors	0.009	0.019	0.014	0.021*	0.027***	0.030***
	(0.78)	(1.59)	(1.24)	(1.84)	(3.16)	(3.12)
HHI	-0.002	-0.034	0.020	-0.005	0.006	0.002
	(-0.08)	(-1.13)	(0.7)	(-0.17)	(0.29)	(0.1)
Stk. Ret	-0.002	0.021**	0.015	0.026**	0.046***	0.051***
	(-0.24)	(2.01)	(1.56)	(2.57)	(6.38)	(6.25)
Analyst Cov.	0.014	0.019	0.036	0.036	0.137***	0.144***
	(0.6)	(0.77)	(1.59)	(1.5)	(7.96)	(7.39)
Instit. Owners	-0.150***	-0.138***	-0.131***	-0.107***	-0.032	-0.050
	(-4.13)	(-3.64)	(-3.67)	(-2.88)	(-1.18)	(-1.64)
Ln(Sales)	-1.158***	-1.059***	-1.077***	-0.925***	2.992***	2.590***
	(-6.42)	(-5.54)	(-6.07)	(-4.97)	(22.25)	(17)
Leverage	-0.012	-0.006	-0.020	-0.006	-0.011	-0.012
	(-0.76)	(-0.36)	(-1.27)	(-0.38)	(-0.92)	(-0.89)
Tobin Q	-0.048*	-0.091***	-0.044*	-0.081***	0.243***	0.209***
	(-1.92)	(-3.44)	(-1.81)	(-3.12)	(13.14)	(9.92)
ROA	-0.016	-0.001	-0.027**	-0.016	-0.023**	-0.012
	(-1.15)	(-0.1)	(-2.03)	(-1.14)	(-2.25)	(-1.03)
Tangibles	0.225***	0.204***	0.161***	0.136***	0.060***	0.063**
	(7.64)	(6.54)	(5.55)	(4.48)	(2.73)	(2.53)
Z- Score	0.059***	0.085***	0.084***	0.116***	0.057***	0.053***
	(3.18)	(4.26)	(4.59)	(5.98)	(4.12)	(3.34)
Interest Coverage	-0.001	-0.013	0.001	-0.012	-0.017**	-0.015*
	(-0.11)	(-1.34)	(0.08)	(-1.23)	(-2.43)	(-1.84)
Cash	-0.004	0.021	0.027	0.047**	0.056***	0.048***
	(-0.25)	(1.08)	(1.49)	(2.51)	(4.11)	(3.11)
Invest	-0.043**	-0.006	-0.010	0.022	0.006	-0.003
	(-2.33)	(-0.3)	(-0.53)	(1.18)	(0.45)	(-0.16)
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.682	0.679	0.692	0.695	0.823	0.796
N	5772	5321	5772	5321	5772	5321

Table 10: Internal Governance and the CEO's Ability

This table reports the regression results of the impact of CEO's abilities, measured by the General Ability index from Custodio, Ferreira, and Matos (2013), on the relationship between innovation efficiency and the difference in horizons inside the top management team. GAI is an indicator variable that classifies the CEO as a Generalist and takes the value of 1 if the CEO's GAI score is above the sample GAI median, and 0 otherwise. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively. Variable definitions are provided in the Appendix.

	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
Diff in Horizons x GAI	0.031*	0.057***	0.041***	0.064***	0.016	0.023*
	(1.95)	(3.55)	(2.72)	(4.18)	(1.44)	(1.90)
Diff in Horizons	0.012	0.001	0.009	-0.001	0.006	0.004
	(0.79)	(0.06)	(0.6)	(-0.10)	(0.56)	(0.33)
GAI	-0.055***	-0.088***	-0.085***	-0.110***	-0.032***	-0.049***
	(-3.3)	(-5.14)	(-5.23)	(-6.7)	(-2.67)	(-3.76)
HHI	-0.036	-0.067*	-0.019	-0.038	-0.020	-0.029
	(-1)	(-1.77)	(-0.54)	(-1.04)	(-0.76)	(-1.02)
Stk. Ret	0.016	0.024**	0.033***	0.030***	0.056***	0.054***
	(1.42)	(2.08)	(3.01)	(2.65)	(6.92)	(6.12)
Analyst Cov.	-0.022	-0.009	0.011	0.018	0.102***	0.119***
	(-0.77)	(-0.32)	(0.38)	(0.66)	(5.04)	(5.4)
Instit. Owners	-0.148***	-0.159***	-0.085*	-0.102**	-0.033	-0.043
	(-3.25)	(-3.38)	(-1.93)	(-2.29)	(-1.01)	(-1.22)
Ln(Sales)	-0.689***	-0.727***	-0.619***	-0.660***	3.195***	2.848***
	(-3.1)	(-3.18)	(-2.86)	(-3.02)	(20.27)	(16.62)
Leverage	-0.028	-0.013	-0.030	-0.016	-0.009	-0.003
	(-1.40)	(-0.63)	(-1.53)	(-0.82)	(-0.64)	(-0.17)
Tobin Q	-0.058*	-0.087***	-0.065**	-0.081***	0.245***	0.206***
	(-1.9)	(-2.78)	(-2.19)	(-2.69)	(11.33)	(8.73)
ROA	-0.036**	-0.014	-0.046***	-0.020	-0.021*	-0.016
	(-2.12)	(-0.77)	(-2.77)	(-1.18)	(-1.69)	(-1.22)
Tangibles	0.164***	0.147***	0.086**	0.065*	0.008	0.023
	(4.49)	(3.95)	(2.43)	(1.84)	(0.31)	(0.81)
Z- Score	0.059***	0.076***	0.095***	0.100***	0.055***	0.058***
	(2.61)	(3.27)	(4.34)	(4.51)	(3.42)	(3.34)
Interest Coverage	0.006	-0.004	0.004	-0.003	-0.017**	-0.014
	(0.53)	(-0.33)	(0.39)	(-0.27)	(-2.18)	(-1.64)
Cash	0.005	0.018	0.025	0.038*	0.060***	0.039**
	(0.22)	(0.84)	(1.20)	(1.79)	(3.95)	(2.33)
Invest	0.005	0.029	0.030	0.048**	0.018	0.008
	(0.21)	(1.26)	(1.40)	(2.19)	(1.14)	(0.47)
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.692	0.679	0.709	0.707	0.845	0.819
N	4136	4055	4136	4055	4136	4055

Table 11: Internal Governance and CEO's Overconfidence

This table reports the regression results of the impact of CEO's overconfidence on the relationship between innovation efficiency and the difference in horizons inside the top management team. Overconfidence is an indicator variable that classifies the CEO as overconfident and takes the value of 1 if the CEO's overconfidence score is above the sample median, and 0 otherwise. All regressions control for industry and year fixed effects. T-statistics are based on robust standard errors. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively. Variable definitions are provided in the Appendix.

	$PAT\ EFF_{t+1}$	$PAT\ EFF_{t+2}$	$TCW\ EFF_{t+1}$	$TCW\ EFF_{t+2}$	$TSM\ EFF_{t+1}$	$TSM\ EFF_{t+2}$
Diff in Horizons	-0.006	-0.005	0.005	-0.003	0.006	-0.001
x Overconfidence	(-0.52)	(-0.47)	(0.48)	(-0.31)	(0.77)	(-0.16)
Diff in Horizons	0.045***	0.053***	0.037***	0.050***	0.013	0.018*
	(3.99)	(4.52)	(3.35)	(4.36)	(1.57)	(1.92)
Overconfidence	-0.003	-0.000	-0.014	-0.010	0.025***	0.018*
	(-0.21)	(-0.01)	(-1.21)	(-0.83)	(2.83)	(1.85)
HHI	0.003	-0.032	0.023	-0.005	0.009	0.002
	(0.1)	(-1.08)	(0.81)	(-0.16)	(0.41)	(0.1)
Stk. Ret	-0.001	0.022**	0.016*	0.028***	0.042***	0.049***
	(-0.11)	(2.17)	(1.71)	(2.79)	(5.83)	(5.98)
Analyst Cov.	0.013	0.020	0.038*	0.038	0.139***	0.147***
	(0.58)	(0.8)	(1.68)	(1.62)	(8.12)	(7.58)
Instit. Owners	-0.162***	-0.152***	-0.140***	-0.116***	-0.052*	-0.067**
	(-4.44)	(-4.01)	(-3.9)	(-3.13)	(-1.94)	(-2.21)
Ln(Sales)	-1.150***	-1.055***	-1.077***	-0.925***	2.975***	2.568***
	(-6.37)	(-5.51)	(-6.07)	(-4.97)	(22.19)	(16.89)
Leverage	-0.013	-0.007	-0.021	-0.008	-0.011	-0.013
	(-0.82)	(-0.43)	(-1.34)	(-0.45)	(-0.89)	(-0.92)
Tobin Q	-0.047*	-0.091***	-0.042*	-0.079***	0.239***	0.207***
	(-1.87)	(-3.43)	(-1.72)	(-3.08)	(12.95)	(9.81)
ROA	-0.014	0.000	-0.025*	-0.013	-0.024**	-0.012
	(-1)	(0.03)	(-1.86)	(-0.93)	(-2.4)	(-1.04)
Tangibles	0.221***	0.201***	0.158***	0.134***	0.068***	0.070***
	(7.46)	(6.42)	(5.43)	(4.39)	(3.1)	(2.82)
Z- Score	0.059***	0.084***	0.084***	0.115***	0.061***	0.056***
	(3.15)	(4.23)	(4.57)	(5.96)	(4.4)	(3.53)
Interest Coverage	-0.002	-0.013	-0.000	-0.013	-0.016**	-0.014*
	(-0.16)	(-1.34)	(-0.02)	(-1.28)	(-2.27)	(-1.72)
Cash	-0.004	0.021	0.026	0.047**	0.055***	0.047***
	(-0.23)	(1.12)	(1.45)	(2.51)	(4.07)	(3.05)
Invest	-0.038**	-0.002	-0.006	0.026	0.003	-0.004
	(-2.1)	(-0.12)	(-0.32)	(1.36)	(0.26)	(-0.29)
SIC. FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Adj-R^2	0.68	0.677	0.692	0.694	0.824	0.796
N	5801	5348	5801	5348	5801	5348

Appendix

Table A.1: This table presents summary statistics for our main measure of difference in horizons over the 1992-2010 period.

Panel A: Difference in horizons by year					
Year	STD	Q1	Mean	Median	Q3
1992	8.03	-3.00	2.50	2.55	7.50
1993	7.83	-2.00	3.00	3.00	7.83
1994	7.93	-1.75	3.50	3.67	8.33
1995	7.71	-1.50	3.69	4.00	8.50
1996	7.80	-1.00	3.91	4.00	8.79
1997	7.85	-1.00	3.99	4.00	9.00
1998	7.59	-0.75	4.18	4.50	9.00
1999	7.30	-0.50	4.18	4.00	9.00
2000	7.22	-0.67	4.27	4.33	8.82
2001	7.22	-0.50	4.23	4.50	8.67
2002	6.97	-0.25	4.33	4.50	8.67
2003	6.82	-0.33	4.39	4.25	8.75
2004	6.82	-0.75	4.13	3.80	8.50
2005	6.77	-0.67	4.08	3.80	8.33
2006	6.62	-0.75	3.83	3.50	8.00
2007	6.47	-1.20	3.29	2.75	7.55
2008	6.58	-0.80	3.53	3.00	7.67
2009	6.53	-0.50	3.72	3.46	7.75
2010	6.60	-0.40	3.89	3.50	7.80
Panel B: Difference in horizons by size quintiles					
Size Quintiles	STD	Q1	Mean	Median	Q3
1 (Small)	7.67	-1.00	4.09	4.00	9.00
2	7.70	-1.00	4.08	4.00	9.00
3	7.36	-0.83	4.05	4.00	8.75
4	6.86	-0.75	3.86	3.50	8.33
5 (Large)	6.22	-0.67	3.31	3.00	7.00

Table A2: Variable definitions

Variable	Description	Source
PAT	Number of patents	KPSS (2017)
TCW	Number of citation-weighted patents.	KPSS (2017)
TSM	The stock market reaction to granted patents.	KPSS (2017)
R&D	Research and development expenses XRD.	Compustat
PAT EFF_{t+1}	Log of number of Patents in t+1 deflated by research and development expenses in year t.	KPSS (2017) and Compustat
PAT EFF_{t+2}	Log of number of Patents in t+ 2 deflated by research and development expenses in year t.	KPSS (2017) and Compustat
TCW EFF_{t+1}	Log of the citation-weighted patent in t+1 deflated by research and development expenses in year t.	KPSS (2017) and Compustat
TCW EFF_{t+2}	Log of the citation-weighted patent in t+2 deflated by research and development expenses in year t.	KPSS (2017) and Compustat
TSM EFF_{t+1}	Log of the market value of patents in t+1 deflated by research and development expenses in year t.	KPSS (2017) and Compustat
TSM EFF_{t+2}	Log of the market value of patents in t+2 deflated by research and development expenses in year t.	KPSS (2017) and Compustat
Research Quotient (QR)	Percentage increase in revenue from a 1% increase in R&D. RQ is the output elasticity of R&D. RQ offers a universal, uniform, and reliable measure of a firm's R&D productivity (Knott, 2008).	Research Quotient – RQ – WRDS
CEO's age	CEO's age for a firm in a given year.	ExecuComp
CEO's Delta	The expected dollar change in CEO's wealth for a 1% change in stock sensitivity price.	ExecuComp
CEO's Vega	The expected dollar change in CEO's wealth for a 0.01 change in stock return volatility.	ExecuComp
CEO's GAI	The CEO's general ability index from Custodio, Ferreira, and Matos (2013).	ExecuComp
Sub. Age	The average age of top 4 non-CEO executives.	ExecuComp
Difference in Horizons	The age difference between CEO's age and the average age of top 4 non-CEO executives.	ExecuComp
Remaining Horizon	The expected remaining subordinate managers' horizon based on 65 as the age of retirement.	ExecuComp
Ind. Adjusted diff in Horizons	The difference between non-CEO executives' industry average age and firm non-CEO executives' average age.	ExecuComp
Pay Ratio	Ratio of CEO's total compensation relative to the average non-CEO executives' total compensation.	ExecuComp
Institutional Ownership	Shares held by institutional investors as a fraction of shares outstanding.	TR13F Holdings
Analyst Coverage	Arithmetic mean of the 12-monthly numbers of earnings forecasts for firm i extracted from the IBES summary file over a fiscal year.	IBES
HHI	Herfindahl index calculated as the sum of squared market shares of firms' sales (Compustat SALE) at the two-digit SIC industry level.	Compustat
Stkret	Stock return calculated as follows (((prcc_f/ADJEX_F) +(DVPSX_F/ADJEX_F))/(lagprcc_f/lagADJEX_F))-1	Compustat
Ln (Sales)	Log value of total sales calculated as log(100000*sale)	Compustat

Leverage	Total leverage deflated by total assets (dltt + dlc)/at	Compustat
Tobin Q	Firm's Tobin Q calculated as (lt-txditc+(prcc_f*csho))/at	Compustat
ROA	Earnings before interest and taxes divided by the book value of total assets.	Compustat
Tangibles	Property, plant, and equipment deflated by the book value of total assets ppent/ at	Compustat
Z Score	Kaplan-Zingales(1997) Index defined as 1.2*((act-lct)/at) +1.4*(re/at) +3.3*(pi/at) +0.6*((prcc_f*csho)/lt) +0.999*(sale/at)	Compustat
Interest Coverage	Interest expenses divided by operating income.	Compustat
Cash	Cash holdings deflated by the book value of total assets.	Compustat
Invest	Capital expenditure deflated by the book value of total assets.	Compustat

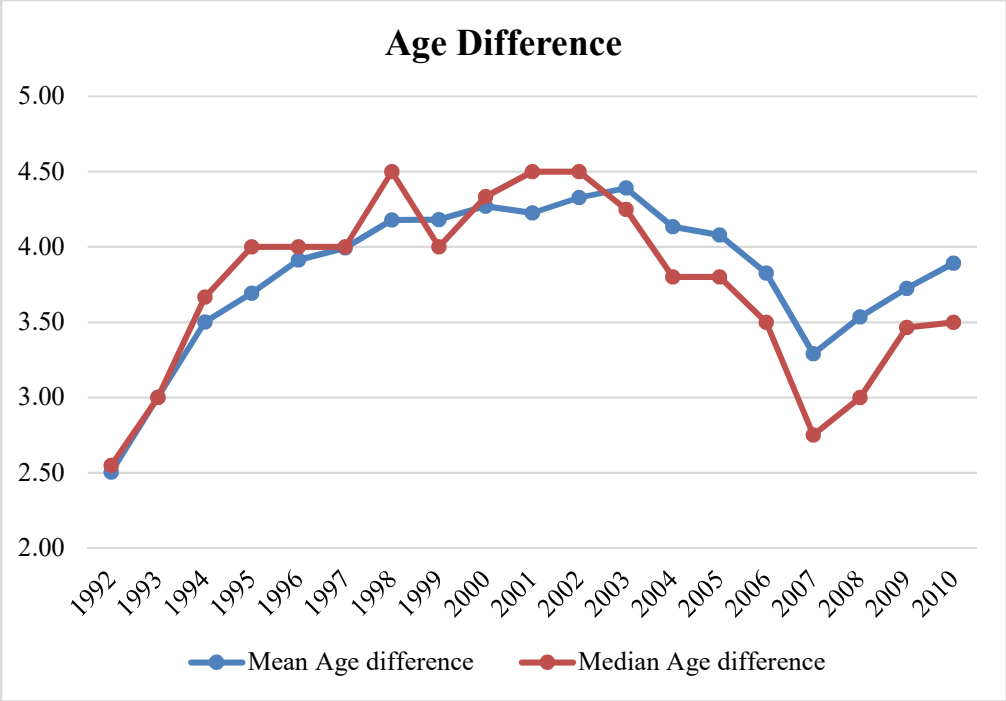

Figure 1: Mean and Median Age difference between the CEO and his or her subordinates over 1992-2010 period.

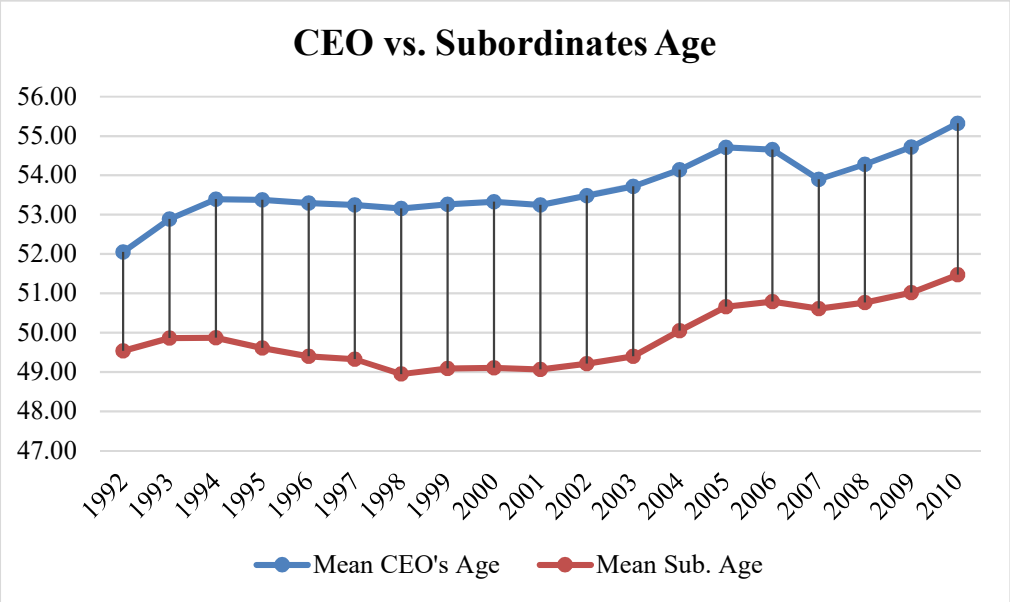

Figure 2: CEO vs subordinates' age over 1992-2010 period

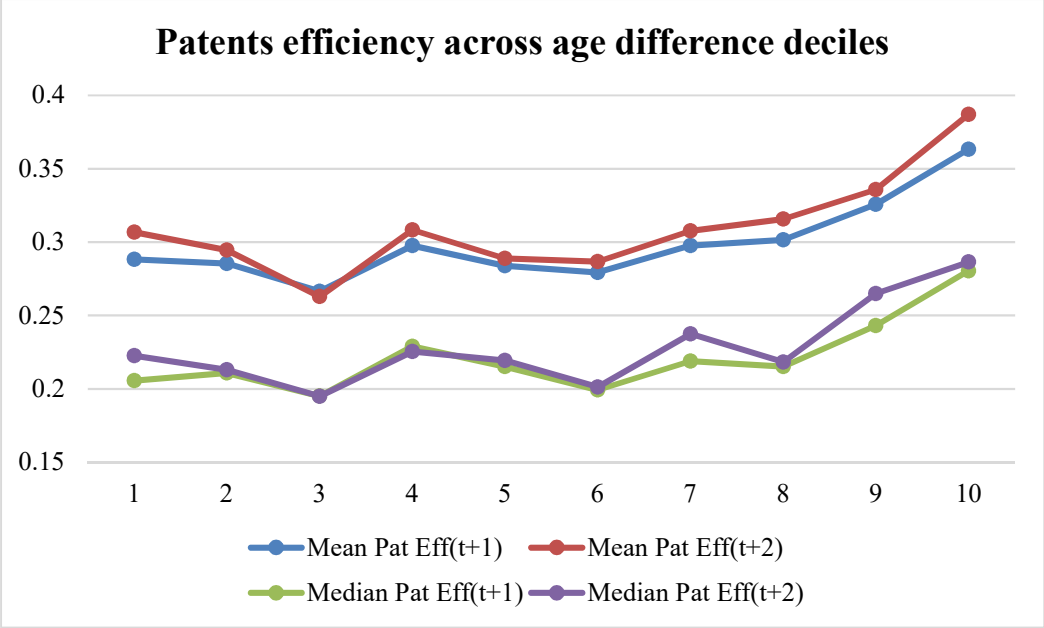

Figure 3: Mean and Median Patent Efficiency across age difference deciles over 1992-2010 period.

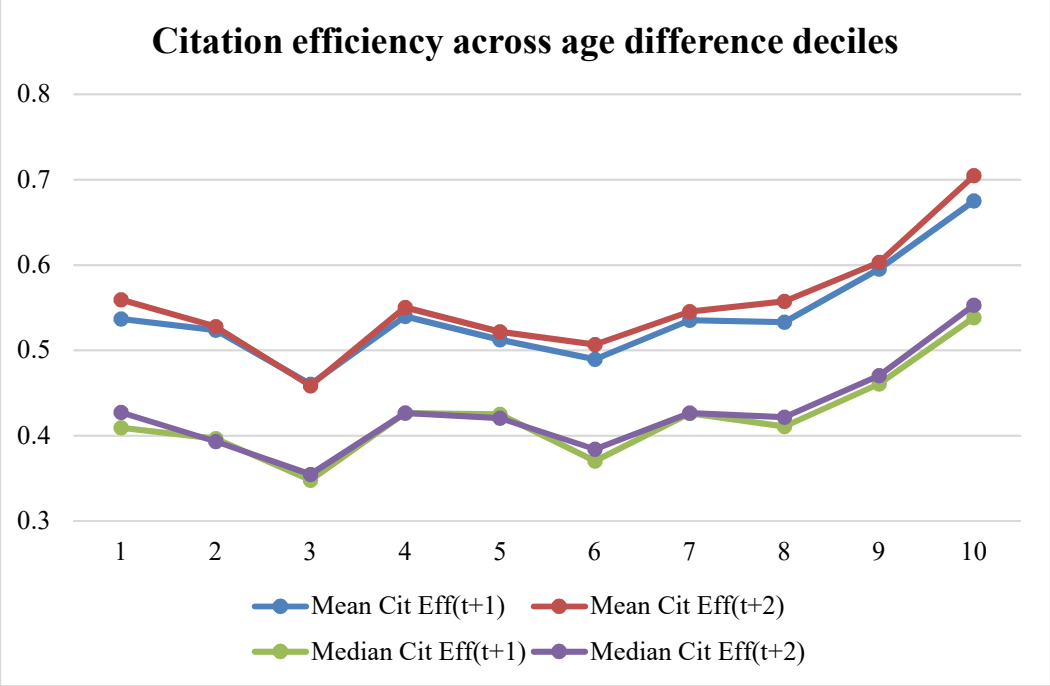

Figure 4: Mean and Median Citation weighted patent Efficiency across age difference deciles over 1992-2010 period.