Master Thesis

Impact of CEO career horizon on firm's R&D investment: Examining the CEO-TMT interface

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Abstract

In this study, the effect of CEO-TMT interface on firm's innovation is examined. The TMT characteristics incorporated in this study include TMT age, tenure, education and functional diversity. Based on a sample of 75 German high-tech firms from 2011 to 2019. I find that TMT characterized by higher education will reduce the tendencies of short career horizon CEO to reduce R&D investment. Similarly, high average tenure TMT also found to have equivalent effect on CEO with short career horizon. On the other hand, the investigation on interfacing effect of CEO career horizon and TMT age/functional diversity yield mixed and inconclusive results. Additionally, by considering the firm's innovation output - proxied by Patent. I found that TMT education's influences remain prevalent regardless of innovation type. TMT age is also found to have a significant influence on firm's innovation output. Finally, I found that the effect of CEO-TMT interface on firm's innovation vary across different industry sub-samples.

Keywords: *CEO-TMT interface, CEO career horizon, TMT characteristics, innovation, German firms, High-tech,*

Contents

1. INTRODUCTION

1.1 Problem statement

The stream of literatures about the key determinants of R&D engagement (pursuit of new patents, R&D spending…) in the past century received significant attention. The focus has been on firm's corporate strategy (Baysinger et al. 1989) or institutional shareholders (Graves 1988; Hansen and Hill 1991). Although elaborate researches have been conducted in these line of thinking, little attention is paid to the relationship between executive's demographic characteristics and innovative endeavours. The relationship between executive and firm's outcomes is first posit by Hambrick and Mason (1984), known as the upper echelon perspectives of the organization. In which firm's strategic choices and outcomes reflects executive's values, competences and cognitive capabilities. Early upper echelon studies focused on the CEO, whereas the review of Carpenter, Geletkanycz and Sanders (2004) have emphasize the magnitude of influences of the top management team (TMT) as well. balanced the interest of upper echelon studies on both the CEO and the TMT

There's a multitude of studies attempted to analyse the underlying influences of executive's characteristics on firm's innovation and firm's outcomes. These studies focus primarily on two powerful actors within the organization – the CEO and the TMT. Overall, the empirical findings often yield inconclusive and conflict results. Dechow and Sloan (1991) found short career horizon CEOs spend less on R&D expenditures on their final years in office. Conform with this view is the study of Barker and Mueller (2002), in which older CEOs will reduce firm's innovation proxied by reduction of R&D expenditure. Whereas scholars such as Conyon and Florou (2006) claimed that the pattern of R&D investments of CEO near retirement do not differ from CEOs that are not near retirement. Cheng (2004) nevertheless claimed that short career horizon CEOs do not curtail R&D investments. Talke, Salomo and Kock (2011) found TMT education and functional diversity to be strongly associated with firm's innovation orientation. Similarly, Simon, Pelled and Smith (1999) suggested TMT functional diversity positively affect the comprehensiveness of decision-making process and firm's performance. On the other hand, TMT diversity is seen as hindrance toward firm's strategic changes and responses to the environment (Hambrick, Cho and Chen 1996). Additional, Qian, Cao and Takeuchi (2013) found no association between TMT diversity and firm's innovation. They even suggested that diverse TMT are less capable of implementing innovation in institutional environment with high uncertainty Longer tenured TMT is found to be associated with strategic changes by Boeker (1997). Finkelstein and Hambrick (1990) posit that TMT tenure positively related to firm's performance. Lee et al (2007) found TMT with higher average tenure encourage firm to increase explorative innovation. Contrarily, Camelo-Ordaz, Hernandez Lara and Valle-Cabrera (2005) stated that TMT tenure is negatively related to firm's innovation instead.

The conflict and inconclusive findings regarding the studies of executive's characteristics on firm's innovation can be attributed to the fact that CEOs does not make decisions alone. As Cao, Simsek and Zang (2010) noted that CEO, although hold chiefly responsible for firm's decision, often consults their top management team (TMT) for advices to form the final decision. Hambrick and Mason (1984) suggested that organization outcomes is a reflection of its top manager's decisions, which are handled by not only the CEO alone, but also the TMT. Nevertheless, there is an interplay between the CEO and TMT regarding firm's decision-making process. Inevitably, a new stream of research is initiated that attempt to analyze the influence of executive on firm's outcomes by considered not only the CEOs, but also the TMTs that assisting them in day-to-day decision making. The application can be seen in study of Heyden et al. (2013); Cao Simsek and Zang (2010); Simsek (2007); Lin and Lin (2019); Heyden et al (2017); Ling et al (2008). Considering the different approach to the same question, it would be interesting to look at the influences of executive's characteristics on firm's outcome by examining a CEO-TMT interface.

The examination of CEO-TMT interface proved to be not only a prospect avenue for future empirical researches, but also provide valuable managerial implications. Examining the CEO's characteristics under the presence of their corresponding TMT would yield new insight for policy makers and firm's executives, particularly those belong to HRM functions and the supervisory board of firms, whose job is to assess and appoint appropriate executive members to fulfil the company's strategic interests. Late stage CEO often exhibit unwillingness to invest in R&D activities due to their increasing risk-averse attitude, the results of this study can provide the aforementioned actors within the firm with suggestions on how certain TMT compositions can alleviate this horizon problem. The results are particularly relevant to high-tech industry, where R&D play an important role in the survival and sustained competitive advantage.

1.2 Motivation and research question

Empirical literature concerns the influences of executive's characteristics on firm's outcomes by examining the interaction between CEOs and their corresponded TMTs is limited due to its recent rise into popularity. Additionally, this line of thinking could potentially reconcile previous conflicted empirical results by representing an old stream of study under a completely different perspective. These two arguments cement my motivation to conduct this research. Additionally, the influences of country's specific national system and industry specific managerial discretion proposed by Hambrick (2007) have encourage me to focus on the German high tech and medium-high tech manufacturing industry because they allow me to examine the effect of executive's characteristics on firm's innovation without having to over-complicated the scope of the study. Hence, the following question is formulated:

What are the influences of CEO-TMT interface on CEO's R&D investment decision in German high-tech firms?

1.3 Contribution

This study contributes to the literatures in the following way. It contributes to the literature regarding CEO-TMT interface and firm's innovation under a two-tier board system of Germany, in which the absence of non-executive directors on the TMT allow for more accurate examination of this CEO-TMT relationship. Moreover, the interfacing effects were analysed both individually and at the same time to fully capture the magnitude of each TMT characteristics. This thesis supports and challenge some previous empirical studies regarding the influence of TMT characteristics on firm's innovation, particularly TMT age, education, tenure and functional diversity. Additionally, the literature of CEO-TMT interface studies that interest in firm's innovation is particular scarce. Therefore, this thesis could potentially provide valuable empirical evidences for this specific research direction. Next, the outcomes of this thesis further solidified the influences of executive's characteristics on firm as illustrated by upper echelon theory and managerial capabilities as sustained competitive advantage illustrated by resource-based theory. Last but not least, it help firms evaluate and adjust the composition of their TMT, particularly those at the very top executive levels, to remedy the possibility of horizon effect stem from late stage career CEOs and to align their TMT characteristics with firm's strategies.

1.4 Structure

This paper is structured as follow: Chapter 1 provide the background, motivation/research question, summary of findings and contributions of this research. Chapter 2 present the following elements: First, some key theories that explain the influence of executives on firm's decisions is analysed. Second, the importance of R&D investment to firm is discussed. Third, the CEO-TMT interface and CEO career horizon phenomenon are explained as the basis to form the hypotheses. Chapter 3 discuss the relationship between CEO career horizon and various TMT characteristics to arrive at the hypotheses. Chapter 4 present the methodologies applied, data sampling process and variable definitions. Chapter 5 show empirical results, together with robustness tests and additional analysis. The paper concluded with chapter 6, which summarize key findings, discussion of the results and limitation/recommendations for future researches

2. LITERATURE REVIEW

2.1 Theories about executive's influence on firm decisions.

2.1.1 Upper echelon theory

One of the most influential theory of the past century regarding factors that influence and dictate organizational outcomes, both strategical and organizational is Upper Echelons proposed by Hambrick and Mason (1984). Previously, traditional theorists have argued on why organization behave/act the way they are, including the view of Pfeffer and Salancik (1978) which stated that external constraints and the extent of resource dependence control organization's behaviour, through political and inter-organizational measures, organizations can absorb these uncertainties and partially control organization's behaviour. On the other hand, Hannan and Freeman (1977)'s population-ecology perspective on organization-environment relation suggest that organization is vastly affected by external inertial components that lower organization's flexibility and adaptability. As oppose to the views of traditional theorist, Hambrick and Mason (1984)'s proposition embraced a completely different perspective, which focus on the most important figures within the organization – the top management rather than external or environmental factors. They proposed that the dominant actors that affect organizational outcomes are the top managers. Their characteristics, values and cognitive abilities are reflected on the strategy choices and performance of firms. This theory is based on the premise that information posed to executives are complex and cannot be dissect objectively. And the processed information is merely "interpretation" from the executives themselves (Hambrick 2007).

Upper echelons perspective differentiate itself from the rest of organizational theories by focus on observable managerial characteristics under different scenarios rather than psychological measures. On paper, this decision give room for doubt– managerial characteristics does not necessarily a better indicator for psychological ones and often contain more room for error. Attempted to look at this phenomenon using managerial characteristics will leave an incomplete picture on how psychological processes would influence executive's behaviour, which is describe by Lawrence (1997) as the "black box problem". However, when we look at the empirical possibility of upper echelons, it can be seen why the perspective receive so much attention from scholars. As Hambrick (2007) described two reason why study the psychological measures is not recommended. First, cognitive and psychological of managers/executives are hard to quantify or measure. In certain situation it is even impossible to do so. Secondly, top managers and executives rarely let researcher asking intrusive questions, or probing them. As a result, inadequate and often misleading data is obtained that hinder the progress of research. Finally, observable managerial characteristics will allow researcher to conduct more thoroughly empirical tests.

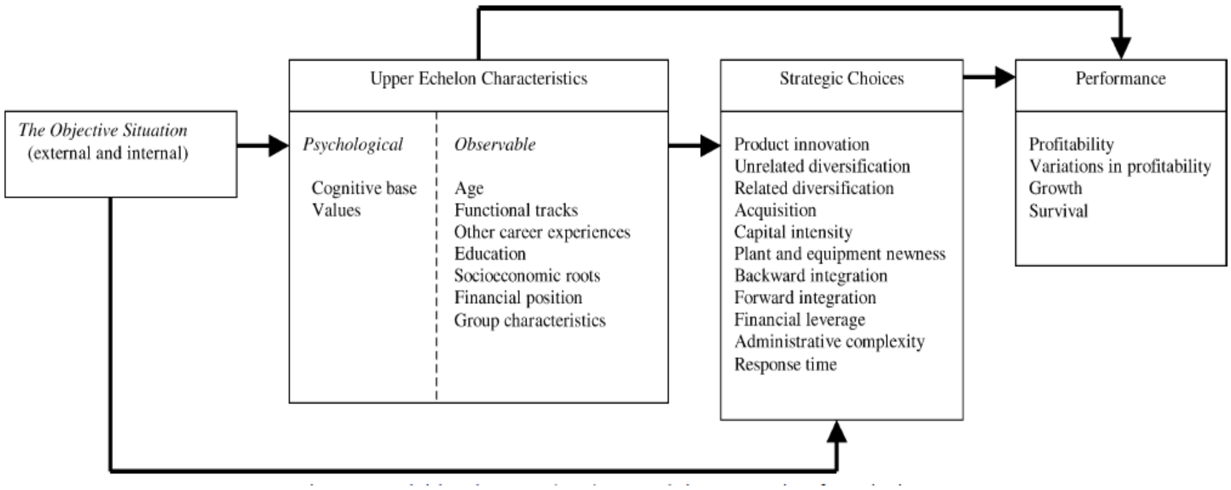

Figure 1: The Upper Echelons Perspective. Adopted from Hambrick and Mason (1984)

The figure above illustrated the original model of Upper Echelons Perspective of Organization, include characteristics of upper echelons perspective and the relationships between each individual elements of the perspective. The relationship is portrayed by one direction arrows, indicate the sequential nature and reliance of each subsequent elements on the elements preceding it. Upper echelon characteristics determine the strategic choices of managers. Effectiveness of chosen strategies and implementation will eventually be reflected in firm’s performance. However, this proposed figure does not consider contingency relationships/variables which may enable strategic choices that would not easily be predicted or discovered. Such as potential moderators like Managerial discretion (Hambrick 2007; Hambrick and Abrahamson ,1995). Executive job’s demand (Hambrick, Finkelstein and Mooney. 2005). These moderators/variables will be discussed in detail in subsequent sections.

The study of upper echelons perspective starts by Hambrick and Mason (1984)’s initial propositions of potent observable characteristics of managers, including Age, Education and Functional tracks. Since then, the nature and quantity of characteristics has been expanding into different directions and pave way for various stream of subordinate ideas. Despite studies that focus on individual characteristics of executive yield important evidence and implications for subsequent researches. They often represent individual facets of management’s influence on organization’s outcomes. Hence, the ideas that stimulated a major stream of research change the focus into firm’s top management team (TMT)’s characteristics rather than the individual top executive. Looking at executive’s influences from this new lens yield much more impactful and complete picture of the effect of these characteristics on organization outcomes. The increasing attention to TMT characteristics is portrayed in many researches, particularly Heyden et al (2017), in which they attempted to find the link between CEO’s career horizon and R&D engagement of firms under a CEO-TMT configuration (CEO and their interactions with corresponded TMT), this focus on CEO-TMT configuration allow them to scrutinize the effect of CEO career horizon on firm's R&D engagement in a more thoroughly fashion, hence the reason why this research paper adopted the same core premise. The idea of CEO-TMT configuration is already investigated by Iaquinto and Fredrickson (1997), in which they found that the level of agreement between top executives (CEO included) is an important driver for effective and collective strategic decision making, subsequently affecting firm's financial performance. Additionally, many researches have contributed to the stream of literature about TMT and its effect on firm's strategic decisions, especially R&D related. Such as TMT and firm explorative R&D (Lee et al. 2017), TMT conflict and exploratory innovation (Wang, Su and Guo, 2019), CEO-TMT interplay and exchange level (Lin and Lin, 2019), TMT composition on R&D strategy (Kor, 2006), TMT's academic experience and R&D promotion (Shen et al., 2020).

2.1.1.1 Managerial discretion

Managerial discretion is first introduced in 1987 was a way to reconcile two different perspective regarding effect of top management on organizational outcomes (Hambrick 2007). On one end, managers greatly influence what happen to their organization. The other end sees what happen to organizations as natural and inevitable, firms are driven by external forces such as competitive environment, regulation and social norms, executives have little to no impact to the outcomes resulted from these forces. Manager's freedom of choice can adversely enable or constraint their course of action. Managerial discretion is categorized into indirect measures (Environmental and Organizational) and direct measures – the degree to which executives can create multiple course of action (Abatecola and Cristofaro, 2018). High managerial discretion is characterized by small number of constraints and the presence of multiple alternatives for executives to tackle a challenge. Managerial discretion is vital to the predicting power of upper echelon theory, as the extent of executive's characteristics that reflect on organizational outcome is directly related to the amount of discretion available to them. Hambrick and Abrahamson (1995)'s revision of managerial discretion further fortified this view – they found that different industry displayed low and high level of discretion. On the other hand, their results also suggest that not all determinants of managerial discretion are weighted equal and some are more potent than other in different industries.

Managerial discretion received much attention from scholar due to its implications on CEO and TMT's influences on organizational outcomes. Finkelstein and Hambrick (1990) was among the first to conduct empirical research on this moderator. Their results support the initial hypothesis – results vary based on level of discretion and highest result is found in context that allow manager high discretion in manager's actions. Although providing an initial supporting result, their research only focus on one single factor – TMT tenure with data used include only big firms, making generalizability difficult. Moreover, following empirical research have indicate that managerial discretion needs to be analyse together with the context that TMT operate in and TMT power distribution (will be discuss later in the chapter).

Several notable research on managerial discretion include: Adams, Almeida and Ferreira (2005) on CEO's power to influence decisions; Quigley and Hambrick (2012) on successor CEO's discretion when former CEO stay on the board; Crossland and Hambrick (2007) on national system's constraints on executive's discretion. They either introducing TMT context or including TMT power or both, adding more predictive power to their research.

2.1.1.2 Executive's job demand

Executive's job demand is the second moderator introduced by Hambrick et al (2005). The basic premise of this moderator is the rejection of the stereotype that CEO and top management jobs require heavy commitment, involve immense stress and pressure. In reality, CEO and top management's job demand rely heavily on the executive's surroundings and environment. For example, CEOs with clear strategical goals, capable subordinates and advisors would bear little pressure compare to CEOs without such accommodation. Therefore, to be able to determine the extent of managerial characteristics influence on organizational outcomes, researchers need to control for these variables. Ganster (2005) attempted to look at Executive's job demand under the stress and affect lenses. He suggests that CEO's work is stress induced and therefore CEO's decision is inevitably being affected by the amount of stress that they exposed to. He also mentioned the "narrowing effect" where executive's interest is focus on fewer source of information as a result of consistent exposure to stress-induced activities. As a result, organizational outcomes would be limited by the executive's inability to look at possible alternatives to tackle the problem.

2.1.1.3. Power distribution

TMT power distribution is another notable moderator which was introduced by Finkelstein (1992), in which he stated that TMT characteristics' prediction power on strategical outcomes would be a lot more accurate and powerful when the weight of individual member's power is accounted for. He proposed 4 different types of power: (1) Structural power, (2) Ownership power, (3) Expert power, (4) Prestige power, each with its own indicators and proxies leave room for future researches. From the empirical evidences from his research, Finkelstein reinforced the upper echelons perspective and consider power distribution to be a factor that must be taken into account in any upper echelons related studies. On the other hand, he stressed the importance of considering both CEO and the TMT of the organization to assess how executives affect organizational outcomes due to their level of integration, information exchange and influence on each other. Literatures on TMT power distribution saw some conflicting arguments. Negative perspective includes Pitcher and Smith (2001)[i] who argued that CEO's concentration of power will negatively affect the heterogeneity of perspectives and ideas within the management team. This consolidation of power will consequently make firm's strategic direction to be less creative, resulted in poorly designed strategic constructs. Dewett (2004) also support Pitcher and Smith's view of TMT power distribution's influence on strategical outcomes of firms. He strongly supports Finkelstein (1992)'s idea that power is central to researches onto TMT. Management member show tendencies to favour a particular solution and refrain themselves from considering alternatives. In teams where power is distributed unevenly, strategic decisions are often a reflection of powerful TMT member's will without consider weaker member's proposition, leading to less alternative strategical choices. On the other side of the spectrum is the positive perspective with author like Roberto (2003). He argued that a single team with stable composition does not make strategic choices in organization. Instead, powerful actors from different division within firms collaborating to reach the most efficient strategic choices, which is highly unlikely in team environment where everybody possess equal voices. This argument stem from the fact that upper echelons theory often focus exclusively on top level management without considering the effect of lower-management's persuasions on the importance of specific strategic matter. This demonstrate the needs of power inequality among TMT as an antecedent for effective strategic decision making. Last but not least, one of the most important implication suggested is that researchers should focus their analysis on senior or core subgroup that involve in most strategic decisions. As these targets would have more profound influence on firm's strategic outcomes that other TMT members.

Apart from the aforementioned influential moderators, there have been many researches that concentrate on less known moderators. Patzelt, Aufseb and Nikol (2008) introduced organization's business model as a contingency variable that moderate the effect of TMT composition on organizational performance. Empirical results show stronger managerial effect for one type of business model over another, support their initial propositions. In addition, Hambrick, Humphrey and Gupta (2014) considered TMT structural interdependence as a potential moderator. They argue that the mixed results from studies of TMT composition on organizational outcomes could be explained by looking into how the TMT is fundamentally structured – namely the extent of independent or interdependent of members within the management team by looking at 3 key facets: horizontal, vertical and reward interdependence, empirical evidences from their research also support this view. The general consensus when it comes to less known moderators as illustrated above is that they are not necessarily applicable to other research design and settings. Therefore, researchers need to pay extra attention on the applicability of such moderators when conducting their research.

2.1.2 Agency theory

Beside Upper echelons theory, Agency theory is another pertinent theory that explain top managements and executives (the agents)'s tendencies toward management decisions. Scholar from various discipline have adopted agency theory, with the most prominent usage of agency theory regarding organization behaviour can be found in Eisendhart (1985)'s work. Eisendhart (1989) posit that, in an agency relationship, one party (the agents) is acting on behalf of another (the principals). Due to the consequential nature of agent's decisions and its effects on principal's interest and welfare, conflicts and problem will arise. This relationship also reflects the degree of information asymmetry and risk-bearing costs.

Eisendhart (1989) proposed the agency problem under an economic lens. Two main problem is documented: (1) the conflict of interests between the two parties and the difficulties of principal in monitoring agent's behaviour and their alignments with their interests, this divergence of interests is also referred as "managerial mischief" by Nyberg et al (2010). This self-interest behaviour of the agent often regarded as one of the essential agency problems (Bendickson et al 2016) and (2) Conflict arise when agents and principals have different attitude toward risks and how they perceived risks, they would resolve to different course of action due to this difference in preferences. This behaviour is first monitored by Jessen and Meckling (1976), as they found the two parties resort to different approaches to tackle the same problem. Shapiro (2005) further elaborate regarding the conflict of interest between the 2 parties, she stated that the assumption principals are in the driver's seat is often misleading and problematic. Principal seek out agent's expert knowledges because of their deficiencies in understanding what's best for business. Eventually the power is shifting from the principal to the agent due to the delegate of decision making and the possession of expert power of the agent. Bendickson et al (2016) further support this idea, when this principal agent initiated the cost and risks are clear to the principal. However, as the agent express self-interest behaviour, principal would perceived that they have accumulated additional risks stem from agent's behaviour (shifting in risk sharing between the agent and principal). The second agency problem arise when the agents hold ownership or equity in the firm they manage. In such situation, the agents display tendencies to reconcile their own goals with those of the principals (Fama and Jensen 1983). Eisendhart (1989) further theorize that when such condition exists, the agents will lean more toward the interests of principal. However, if an inequality is perceived by the agents, they will be more incline toward self-serving behaviour again under the inability of principal to proper monitor their behaviour (often refer to as information asymmetry problem)

The stream of agency theory research diverged into two main types: positivist and principal-agent (Eisendhart, 1989). The positivist research stream focus almost exclusively on the relationship between owners and managers. The point of interests lies in the situations where agent-principal are likely to have conflict of interests, positivist researchers then focus on find out optimal governance mechanisms that limit the agent's exploitation tendencies and their self-serving behaviours. Theoretically speaking, positivist stream of research took a solution-based perspective to agency problem by determine the most optimal governance mechanism to tackle the agency problem. Whereas Principal-agent research stream identified two agency problem: risk-taking and agent monitoring. It focuses on determine the optimal mechanism in monitoring and controlling agent's behaviour, and optimally design a contract that eliminate the risk-shifting phenomenon between the two parties. Principal-agent stream does not have an interest in a particular relationship (like owner vs managers in positivist stream), they focus on a wider range of relationship and interest in general theoretical implications. Despite the differences, the two streams of research are harmonizing in nature. In which positivist stream provide a set of different mechanisms and principal-agent would determine which mechanism would be the most effective for the circumstance.

Empirical evidence of the influence of agency problem on top management's decision making and firm's outcomes is ample. Qiao et al (2017) show that powerful CEOs, under appropriate agency mechanism and cost management will improve firm performance despite the weak corporate governance mechanism in Chinese firm's context. Qin and Kuang (2013) found that the degree of risk-incentive compensation for executive vastly influence their risk-appetite and their tendencies to align self-interests to those of the owners. This implication can be inferred from one of the paper's findings, in which equity incentive of executive have significant positive influence on firm's credit rating and the changes in credit rate.

Nyberg et al (2010) found a positive and significant association between CEO pay and shareholder return, which sharply contrast the conventional wisdom within the literature that positive association between the two is often limited or even non-existent. An explanation for this interesting result is the fact that the authors considered CEO not only as an agent, but also as a shareholder of the firm. Financial alignment between CEO pay and shareholders wealth predicting subsequent shareholder's return. Francis and Smith (1995) found that CEO and managements that hold ownership in the same firm they work on will lead to more innovation and innovative initiatives than diffusively held firms. These results elevate the importance of ownership of CEOs to their commitments to uphold shareholder's interests and showing how efficient shareholder's monitoring effort can alleviate agency costs. These evidences lend strong support for Fama and Jensen (1985) proposition – CEO as a shareholder holding ownership of the firm will be more likely to align their goal with the shareholders – to maximize shareholder's returns.

Agency conflicts often result in negative economics and organizational outcomes (Bendickson et al 2016). Dey (2008) found that the level of agency conflict is positively related to governing mechanism in place suggesting the overall effectiveness of governing mechanism in place vary from firms to firms and industries to industries. Following this direction, Valencia (2017) further solidified the importance of corporate governance and its influence on CEO's innovative tendencies. In which appropriate platform to monitor and encourage CEO is imperative to their inclination toward innovation. Furthermore, Nguyen (2018) provide evidence on how appropriate incentive measures can promote CEO's commitment to innovation and reduce high agency costs that often associate with it. Last but not least, Bonazzi and Islam (2006) posit that there is an optimal monitoring level and it should be based on target outcomes and extent of accountability of CEOs rather solely on CEO's performance. Such approach to monitoring CEO can enhance their productivity, result in superior performance

All in all, the economic perspective on agency theory help explain top management's behaviours and commitment toward improving firm's performance and innovation engagement in a variety of way.

Including the importance of resolving agency conflicts, goal misalignment, monitoring level and incentive measures

2.1.3 Resource-based theory

Another theory that explain management's influence on organization is resource-based theory with the view of management's knowledges and capabilities as valuable resources for firm. Resource-based theory of the firm, also called resource-based view (RBV) is proposed by many scholars such as Wernerfelt (1984) and Barney (1991), is a framework that explain firm's competitiveness based on the resources in their possession. One important assumption of this view is the heterogeneity of resources and capabilities across different firms within the same industry (Peteraf 1993). Which enable this managerial framework to explain the difference between firm's specific factors such as resources and capabilities that contribute to firm's performance and competitive advantages (Barney 1991). Overall, firm resources are sorted into tangible and intangible. Tangible resources of firms include physical capitals such as buildings, machinery, cash, inventory…Intangible assets, include patents, R&D research, Good Will, Knowledge/Capabilities etc... holding equally importance to firm's success. Adapting a resource-based perspective toward management meaning a shift in firm's priorities from product and product development into competing for resources and resource development, which often result in drastic strategy changes (Andersen 2010). Logically, organizations often evaluate their existing resources in term of strength and weaknesses, then adopt the most appropriate strategy available (Hsu and Wang 2012). Furthermore, Castanias and Helfat (2001)'s paper treated managerial skills and abilities as important firm resources enable organization to generate rent (excessive return over opportunity costs). They also expand on the classification of managerial resources to the 4 fundamental characteristics of Barney (1991)'s

The striking difference of RBV is the focus on the firm's resources rather than output products to explain firm's outcomes, which yield different insights. Among RBV studies, the study of Peteraf (1993) and Barney (1991) are milestones that exemplified resources as a sustainable competitive advantage. Peteraf (1993) conform with Barney's heterogeneity assumption, implying that firm's performance do not necessarily depends upon the nature of industry, stating the importance of upholding this assumption in resource-based researches. On the other hand, he proposed that firms possessed marginal resources is likely to break even, while firms with superior resources will be more likely to earn more substantial profit.

There is a growing literature on management knowledge and competitive advantage that is built upon RBV by focusing on dynamic capabilities (Barney et al 2001). Dynamic capabilities are organizational routines, in which managers alter their resources, integrate them together and recombining them to generate value-creating strategies (Eisenhardt and Martin 2000). Fiol (2001) concluded that dynamic capability is an important aspect of competitive advantage due to its influences on firm's ability to change. However, in dynamic, rapidly changing market, such competitive advantage cannot be sustained. Eisenhardt and Martin (2000) suggested that some firms are faster, more alert and more proactive toward changes. They often are the first player in the market to adopt trends and executing changes in strategies, thus giving them a source of sustained competitive advantage.

Barney (1991) suggested firm resources included all assets, capabilities, organizational processes, firm attribute, information, knowledge controlled by firm that enable them to conceive or implement strategies that improve its efficiency/effectiveness. Different type of resources doesn't have equivalent contribution to firm's competitive advantage. Accordingly, he specified that firm's resources that enable competitive advantages has the following 4 attributes: (1) must be valuable ;(2) must be rare ;(3) must be inimitable (4) must be non-substitutable. Maintaining sustainable competitive advantages often depends on how well firm utilize resources with the 4 aforementioned attributes to align with their current strategic decisions.

The following paragraphs describe researches that utilizing RBV to explain manager's influence on firm performance and decisions.

Alonso and Bressan (2016) aligned their findings with Barney's 4 RBV attributes, cited innovative practices as valuable and accumulation of knowledge/strategy executions of managers as rare resources, advocating the importance of management's knowledges and their decisions as both competitive force and important resource. Clulow, Gerstman and Barry (2003) found that management capabilities enable firms to not only survive, but also consistently outperforming rival firms through superior strategic decisions and utilization of available resources, especially in environment characterized by high complexity and low barrier of entry. Moreover, existing resources may impact managers differently. In which their form different strategies in accordance with firm's readily available resources. The existence of market imperfection and manager's reaction toward it can elevate firm performances. In this sense, Managerial perception play an important role in firm's decisions and act as an important competitive resource (Lockett, Thompson and Morgenstern 2009). Managerial capability, learning and adoption of best practice are positively associated with increasing firm performance, whereas internal fit will have detrimental effects on firm's flexibility improvement (da Silveria and Sousa 2010)

Hadjimanolis (2000) found that management's accumulation and development of capabilities is the most influential factor for firm's innovativeness. Managerial skills and capabilities explain innovation tendencies of firms. Hsu and Wang (2012)'s study draw on a similar line, focus on Firm's intellectual capital and human capital. Their finding suggested that both aforementioned type of capital positively associated with firm performance and the relationship is meditated by dynamic capabilities. Accumulated dynamic capabilities enable managers to make better decisions will enhance firm's performance in the long run, highlighting the importance of organization learning and continuously enhancement of human capital to boost organization's competitive advantage. Craighead, Hult and Ketchen Jr (2009) using survey and archival data, suggested that different strategies required different intellectual capitals and knowledge development capabilities, and is essential to firm's superior performance. Last but not east, managerial capabilities and available resources affect manager's perception in weighting investment decision. Which does not only affect the firm performance, but also the growth and volatility of the industry (King and Slotegraaf 2011)

The empirical results suggesting that firms view resources as a pivotal element in designing and implementing their strategies. Given the limited availability of particular resources, firms will need to prioritize certain strategies for added value maximization. Managerial capabilities and skills allow firms to pursuit the most profitable strategies given their available resources. It's also believed to be the type of resource that yield firm's sustainable competitive advantage that ensure their survival in the long run

2.1.4 Knowledge-based theory

The transition from a material-based economy into information flow-based economy could explain the emergence of the focus on knowledge in determining organization's goals and strategy (Child and McGrath 2001). Knowledge-based theory, also called knowledge-based view (KBV) consider knowledge as the most important strategical resource available to firm (Grant 1996). It demonstrates the importance of intangible resources in creating and developing firm's sustained competitive advantage. Apart from physical resource monopoly, intangible resources often produce superior competitive advantage compare to tangible resource, which can be attribute to the fact that intangible resources are often socially complex and hard to imitate (Hitt et al 2001). The theory sees organization as heterogeneous entities that possess different knowledges and capabilities, exist to create, integrate knowledge to transfer them into competitive advantage (Kogut and Zander, 1992).

Because KBV focus on knowledge as an important inimitable resource of firm, it is often regard as an extension of RBV due to its general consensus that view knowledge as crucial firm's resource (Rouse and Daellenbach 2002); (Grant 1996). Moreover, the transition from RBV to KBV is seen as natural to adequately explain the evolution patterns of firm's capabilities and how it affects their competitive advantage. Despite this relationship, the two view differ greatly in many aspects (Helfat and Peteraf, 2003). Although sharing the similar view on resource as the driver for competitive source, KBV view the firm as an institute for knowledge creation, coordination and integration to articulate strategies that yield competitive advantage. Whereas RBV view firm as an institute that, through utilizing different resources, turning input into output that allow them to gain competitive advantages (Grant 1996). Rouse and Dallenbach (2002) stated that the uniqueness that stem from intangible resources – specifically knowledges, competencies and capabilities are the basis for sustained competitive advantages, whereas available resource regardless of types are all important to firm's sustained competitive advantage under RBV as long as they possess the four suggested characteristics (Barney 1991)

Dynamic capabilities are regarded as the most important antecedent that facilitate the extension of RBV into KBV (Malerba and Orsenigo 2000). Dynamic capabilities allow managers to reconfigure, integrate and recombining existing knowledge and tangible resources into useful competitive strategies that benefit firms in a fast-changing competitive environment (Eisenhardt and Martin 2000). In such environment, learning and adapting faster than competitors is key to firm's survival and competitive advantage, which are enabled by dynamic capabilities.

KBV are often seen through the lenses of managers and explain their influence on firm's decisions and performance. According to Grant (1996) the quality of managerial decision making is largely depending on the relevant knowledge that is concentrated on the decision maker and on the ability to transfer and aggregate knowledge onto the decision maker. Hitt et al (2001)'s study found that management's knowledge and experience (proxied by human capital) affects the strategy implementation and firm's outcome both direct and indirectly. The knowledge-based perspective of Nickerson and Zenger (2004) suggested that managers choose a problem they want to intercept while considering existing technology or knowledge available that could potential help solving the problem. In this sense, manager's perception and pre-existing beliefs affect their selection of relevant knowledge to achieve maximum probability of choosing a valuable solution.

2.2 The importance of innovation and R&D investments

The definition of innovation has been a prevalent issue amongst scholars. As individual interpretation produced different definitions. For example, Tushman and Nadler (1986, p75) defined innovation as "Innovation is the creation of any product, service or process which is new to a business unit". Additionally, Benner and Tushman (2002, p679) defined innovation as: "Exploitative innovations involve improvements in existing components and architectures and build on the existing technological trajectory, whereas exploratory innovation involves a shift to a different technological trajectory" In order to pursuit innovative endeavors, firms often investing their resources into Research and Development (R&D) initiatives. However, innovation in an organization goes far beyond the internal creation of new knowledges/ideas, or final product delivered to customer. Kimberly and Evanisko (1981) stated that researchers often focus on a single type of innovation. Which result in more robust and reliable outcomes, although raising generalizability problem. The differences in classification of innovation depict the complex nature of the term itself. For example, innovation can be categorized based on the extent of new knowledges applied, namely exploitative and explorative innovation (Benner and Tushman 2003). R&D activities related to exploitative innovation often associate with proven, familiar, reliable knowledge or techniques that aimed to further enhance an existing product. whereas R&D activities related to explorative innovation often required firm to venture into the unknown with many uncertainties, often involve extensive experiments and investments before it yields useful outcomes (March 1991; Benner and Tushman 2003). On the other hand, Tushman and Nadler (1986) suggest 2 basic type of innovation: Product related R&D – involve in making changes to the existing product and Process related R&D – involve in changing the way products are made or services are provided. Kimberly and Evanisko (1981) divided innovation based on its nature of application within firm – administrative innovation and technological innovation. The aforementioned classification suggested the needs to focus on a certain aspect of innovation to conduct a feasible research (Carmelo-Ordaz, Hernandez -Lara and Valle-Cabrera 2004). One essential remark is the importance of organizational variables, especially organization size in predicting the type of innovation that firm's R&D investment aimed for (Kimberly and Evanisko 1981)

Tushman and Nadler (1986) suggested that different type of product innovation's relative importance change according to the organization's life cycle. For example, firms at introductory stage will be more likely to adopt explorative R&D to attract capital fund's interest, while firm at mature stage would be more inclined to follow exploitative R&D based on their existing knowledge with small incremental change. The balancing between the 2 types of innovation is the main motivation for organization ambidexterity argument. He and Wong (2004) argued that, although exploration and exploitation represent two opposite view toward organization learning and perspective. There is a need for firm to balance between the two, hence the importance of ambidextrous organizations (organizations that employ both exploitation and exploration of innovation). They found that corporate strategy needs to pay equal attention to their explorative and exploitative innovation activities, as the relative imbalance between the two will lead to negative sale growth rate. Similarly, Gupta, Smith and Shalley (2006) found both exploration and exploitation R&D projects are equally important to the firm's ambidexterity.

R&D activities are not strictly performed internally. They can be outsourced to strategic alliance members, educational institutions or through collaboration with outside firms. Belderbos et al (2010) found that firms who engage extensively on collaboration tend to focus more on their explorative R&D activities. It's often believed that collaboration will result in beneficial performance outcomes for firm. However, another important implication from this paper - negative relationship between collaborative technological activities and firm's market value suggested otherwise. The value enhancing potentials of explorative activities do not offset the complexity arise from these collaborative activities. This result supported the notion that explorative innovation activities will not always be beneficial for firms, and leaning too much toward one type of innovation activities will result in detrimental effects on firm's performance. Similarly, Bauer and Leker (2013) found an inverted U shaped between R&D expenditure allocated to exploratory R&D and new product performance. Uotila et al (2009) also found an inverted U-shaped relationship between explorative R&D and firm performance, which is positively moderated by R&D intensity. These finding are consistent with the benefits of organizational ambidexterity arguments proposed by many scholars (March 1991; Gupta et al 2006; He and Wong 2004)

Greve (2007) found that firms invest in exploitative R&D projects because they are less risky than explorative R&D. They also help reduce uncertainties associated with R&D processes. Belderbos et al (2010) posit that exploitative activities help firms improve the efficiency and effectiveness of its existing core capabilities that often result in short-term performance enhancement. However, such enhancement often results in core competence rigidness that consequentially discourage exploration-related activities, hurting firm's ambidexterity capability. Similar pattern is recognized by Gupta et al (2006) with the so called "success trap" when firms experience early success by exercising exploitative activities. Therefore, developing a routine that allow room for explorative activities is of utmost importance.

So, why paying attention to R&D such a critically important concern for firms? First of all, R&D investment are not only pursued to create competitive advantage and increase firm value, it also reflects the firm's strategic choices and commitment to developing internal capabilities for future growth and research discoveries (Vithessonthi and Racela 2016). Additionally, pursuing the appropriate type of R&D projects under specific scenarios is particularly important to firm's competitiveness or even survival. To further elaborate on this point, Gereve (2007) suggested that the magnitude of importance of each type of R&D activity vary from industries to industries. March (1991) noted that returns from explorative R&D are systematically less certain, resolve in much more distant in time than exploitative R&D. In high tech industry – characterized by short product life-cycle, explorative R&D will yield more potential for future growth than exploitative R&D due to the fact that the ones who are first to adopt cutting-edge technology will gain immense competitive advantage. Existing explorative R&D investment almost never yield immediate performance boost. They're conducted to ensure the sustained competitive advantage of firms. Especially in high tech industry, where explorative R&D posed as a critical source of competitive advantage for long-term survival (Gupta et al 2006). Similarly, Garcia, Calantone and Levine (2003) found that technological-oriented firms tend to pursuit new emerging technologies to increase their competitive advantage rather than relying on existing proven knowledge. Moreover, Rosenberg (1990) suggested that there are some key activities that are imperative to the success of business firm required certain explorative R&D capability. On the other hand, exploitative R&D often thrives in stable environments that characterized by long product life-cycle, where technological advancement is characterized by incremental changes of existing technological design (Benner and Tushman 2003)

2.3 CEO career horizon

CEO career horizon is defined as the amount of time for a CEO to reach retirement age (Kang 2016). The nearer the CEO to retirement, the shorter their career horizon (Matta and Beamish 2008). Upper echelon theory proposed by Hambrick and Mason (1984) discussed in previous section is a widely used theoretical framework to explain tendencies of CEOs as they reach later stage of their career (Davidson, Xie and Ning 2007); (Romancho et al 2019); (Musteen, Barker and Baeten, 2010); (Krause and Semadeni 2014). CEOs are often thought as the person in charge of firm's information processing, strategic formulation through their resource allocation decisions. (Heyden et al 2017). The theory is based on bounded rationality, in which (1) CEO acts based on their interpretation of the problem and (2) their interpretations depends on their demographic characteristics such as age, education, experience etc… This idea provide support for Hambrick and Fukutomi (1991) study, in which they proposed that

CEOs exhibit discernable phases of their tenure by following a certain paradigm, give rise to distinct pattern of behaviors, attention and performances.

The studies into CEO's career horizon phenomena utilize two main constructs: CEO Age and CEO Tenure. Tenure reflect the amount of time the CEO assumed the position. Longer-tenured CEOs tend to develop psychological commitments and embedded social relationship with the firms. They're also associated with prior firm success, which help them retain the position. Both of these observations lend a logical explanation to CEO Tenure being a pronounced determinant of CEO's commitment to maintain the status quo (Hambrick, Geletkanycz and Fredrickson 1993). CEO with long tenure restrict information processing and increase reliant on past performance instead of new possibilities, reduce their inclination to adopt changes of CEOs (Finkelstein and Hambrick 1990). As tenure increase, CEOs will display a lack of adaptability, evidently in the tendencies to recruit and promote subordinates that share the same view as them to avoid potential conflicts (Miller 1991; Musteen et al 2010).

As age increase, tendencies to focus on personal interest of CEOs will become more apparent. As CEOs reach retirement age, career concerns seem less and less irrelevant in guiding their motives and behaviors (Davidson, Xie and Ning 2007). As CEOs age, flexibility decrease and rigidity/resistant to changes will increase (Wiersema and Bantel, 1992). This rigidity is reflected on Finkelstein and Hambrick (1990)'s paper, they found that older CEOs tend to adopt safer strategies that yield consistent result that follow industry's average closely than risky projects that promise more handsome rewards. Additionally, Hambrick and Mason (1984) established a proposition that age can make CEO become more risk-averse, reluctant to changes and avoid risky activities like innovation and R&D projects. Many scholars share similar consensus. For example, Dechow and Sloan (1991) posit that the degree of risk aversion is positively associated with age. Barker and Mueller (2002) found age as an important determinant to firm's R&D spending. (Gray and Cannella 1997) suggested executive's age influences their decision-making time horizon, in which younger CEOs are more willing to take long-term approach due to potential future rewards, while older CEOs enjoy stability of firm returns, favor a shorter decision horizon

Consequentially the CEOs may focus their interest on personal wealth-being rather than serving shareholder's interest when they reach retirement age. This is essentially the agency problem described by Eisendhart (1989), making the shareholders bear extra agency costs associated with this divergence of interest. Ward, Sonnenfeld and Kimberly (1995) noted that the extent of agency conflict getting more noticeable as CEO reach later stage of their career could be explain by the reduced career mobility. As they get older, the chances to acquire a similar position is considerably unlikely compare to the young CEOs. Combining the risk-averse nature as they get older and the risk of losing their job due to the and uncertainty nature risky projects, older CEOs would not incline to pursuit such projects (McClelland, Barker and Oh 2012).

The following two paragraphs below describes studies that empirically utilize career horizon to analyze CEO's behaviors and their influence on firm's decisions. Start with studies that focus on R&D, followed by other firm's decisions.

Several researchers have found the influence of CEO career horizon on R&D investment and innovation practices. Dechow and Sloan (1991) found that CEO who are at the end of their tenure often exhibit tendencies to spend less on R&D activities. Barker and Mueller (2002) found that CEO characteristics, specifically CEO Age is negatively associated with R&D spending of firm and is a much stronger predictor for R&D spending than CEO Tenure. This implication is important, as they treated Age and Tenure not as synonymous, but as two different construct that require separate investigation. Yunlu and Murphy (2012) found that during recession, firms decrease their R&D spending. And CEO with short career horizon tend to reduce R&D spending such more significantly compare to their horizon counterpart. The study highly recession as an important backdrop that explain CEO's behavior under one particular circumstance. Musteen et al (2010) found that CEO tenure strengthen the relationship between CEO's attitude toward changes and firm's approach to innovation, in which attitude toward changes is more potent under the presence of high tenured CEO.

Horizon problem also explain CEO's inclinations toward various firm's strategic decisions as well. Davidson et al (2007) found that CEO with relatively shorter career horizon will be highly motivated to manage earnings prior to a turnover decision. McClelland et al (2012) argued that CEOs with shorter career horizon will adopt risk-averse strategies, that will subsequently affect future firm performance adversely. This negative relationship is amplified by CEO ownership due to the level of power accompanied with such high level of ownership. Matta and Beamish (2008) found that CEOs with longer career horizons are associated with higher probability of international acquisitions. Which often seen as risky endeavors due to heighten firm's future income uncertainties, increase costs for coordination and monitoring. Serfling (2014) found that CEOs age influence their risk-taking behavior, and ultimately firm performance. More specifically, older CEOs tend to reduce firm risks and risky investment policies significantly. Averse risk-taking tendency of shorter career horizon CEOs is also found in Romano et al (2017) study, in which shorter career horizon CEOs take longer time to make risky decision – reflected in the negative relationship between career horizon and time taken to start the initial public offering. Kang (2016) found CEO with short career horizon negatively influence firm's commitment toward long-term investment, specifically CSR initiatives.

Although the previous mentioned empirical evidences help understand the influence of CEOs on R&D investments. Most of them omitted the influences of the TMT on CEO's decisions, as the R&D investment decisions does not entirely depend upon CEO's demographic characteristics and risk preferences. They depend on the TMT characteristics such as tenure, diversity, education and their collective preferences as well. Thus, the CEO cannot singlehandedly dictate R&D investment decisions of firms. Several papers have highlighted the importance of this CEO-TMT relationship (Barker and Mueller 2002; Heyden et al 2017; Lin and Lin 2019). Which motivate this paper to focus on the CEO-TMT interface that will be discuss in the following section

2.4 CEO-TMT interface.

The studies on CEO-TMT interface stem from Hambrick and Mason (1984)'s upper echelon perspective on executives, in which TMT is defined as the dominant coalition in an organization. Although conceptually sound, this definition cannot be easily applied in empirical research. As most empirical definition of TMT is articulated for the purpose of easier sampling (Carpenter et al 2004). In this CEO-TMT relationship, CEO is seen as the dominant actor that held chiefly responsible for firm's strategic formulation, implementation and outcome. However, as Cao, Simsek and Zang (2010) noted, strategy implementation is often accompanied by CEO's interaction and consultation with the TMT before final decision is reached, therefore this decision is almost never stem from the CEO alone. As seen from the previous argument, TMT participate and contribute their competences together with the CEO to shape strategic decision. Therefore, analyzing either the CEO or TMT characteristics alone would yield inconclusive conclusion regarding the complex nature of the decision-making process (Heyden et al 2017).

Before discussing the CEO-TMT interface, it is imperative to clearly identify which directors belong to the TMT in this study because it could serious affect the implications of empirical results. Carpenter et al (2004) noted this issue in their paper, they found TMT studies often utilize TMT definitions that differ from one another. Which stem from desire for sampling convenience, consistency with theoretical constructs to be as representative as possible. Many studies asked key informant such as firm's HR department or the CEOs for their clarification regarding who constitute the TMT. Studies such as Lin and Lin (2019), Ling et al (2008), Simons et al (1999) adopted this approach, they identified TMT by mean of interviewing or sending questionnaire to the CEO. This process is very time-consuming and raised the issue of non-response bias. This divergence of TMT constitution lends explanations to some of the inconsistent findings of TMT studies. Moreover, Smith et al (2005) and Simsek et al (2005) considered involvement in firm's decision making to be an important criterion in selecting TMT members. Regarding the TMT in this thesis, Germany is one of the first country to adopt a two-tier board system, in which the separation of executive and non-executive directors making their difference in executive power and day-to-day decision-making involvement apparent and executives belong to the management boards are undoubtedly taking part in firm's day to day decision making. This thesis follows TMT definition of Lee et al (2007) and Kor (2003), considering TMT member as executives that take part in firm's day to day decision making, that belong to the management board of the firm (for example: CFO, CTO, COO etc…) and do not held any supervisory role, or belong to both the executive board and supervisory board. Lee et al (2007) and Kor (2003) included the CEO in their TMT definition. However, as this study focus on the interfacing effect of CEO and TMT, the CEO is not included in the

TMT. As discussed above, CEO-TMT interface study utilize interviewing CEOs of sample firms to yield more accurate data of TMT information. However, it is not possible for the scope and available resources for this thesis. Additionally, follow Simsek et al (2005), this thesis excludes any firms with TMT consist of only one member. As it is incompatible with the theoretical construct developed that the CEO is interacting with a "team" instead of individual.

More recently, the prominent role theory of Biddle (2013) called for a systematically categorization of many CEO-TMT positions by carefully conceptualize them based on the CEO-TMT interactions (Georgakakis et al 2019). The gist of role theory suggest that roles portray set of norms, rights, expectations and functions that individuals assigned to the role is expected to fulfill. Through extensive review of relevant researches, Georgakakis et al (2019) proposed 3 predominant role theory specifications, namely: functionalism; social-interactionism and structuralism. This particular study focuses on the functionalism perspective of role theory, which view roles as static constructs, and is a priori based on formal function titles with a heavy emphasis on the CEO-TMT functional interdependence and complementarity. It highlights the importance of TMT functional arrangement and how this CEO-TMT functional complementary affect firm's performance.

The functionalism perspective of the CEO-TMT interface often focuses on the organization characteristics that shape the CEO-TMT interaction in an attempt to gain insight on how these interactions lead to specific organizational outcomes. There are several scholars that interested in this particular facet of the CEO-TMT interface. For example, Heyden et al (2013) found that the extent of advice seeking of CEO from the TMT is more profound in environment characterized by uncertainties and high dynamic. The decision of CEO to turn into intra or extra organizational source for advices is based on TMT heterogeneity and often reflect subsequent changes in strategic choices. Cao et al (2010) suggested that CEO play an integral part in enabling firms to achieve organization ambidexterity by contributing valuable resources such as network and social capitals. More importantly, this relationship is significantly reinforced by CEO-TMT interactions, including improved communication and functional complementarity toward achieving the goal. Lin and Lin (2019) found the quality of CEO-TMT relationship will enhance firm's responsiveness to competitive actions, response to market forces, and ultimately resulting in superior performance. Heyden et al (2017)'s study found empirical evidence that suggest TMT Age and Tenure play pivotal role in reducing the inclination of CEO with shorter horizon to curtail R&D investment. Last but not least, Ling et al (2008) suggested transformational CEOs directly affect their most closely coalition – the TMT in four characteristics: behavioral integration, decentralization of responsibility, risk-taking propensity and long-term compensation, in which all but behavioral integration are significantly related to corporate entrepreneurship

As seen from the argumentation above, CEO-TMT interface can be a useful tool to analyze the relationship between firm's R&D activities and CEO with short career horizon. Although often held chiefly responsible for firm's outcome, CEO's decisions are often accompanied TMT's consultation, in which their influences can sometime be apparent and significantly alter CEO's initial decision. For example, CEO with shorter career horizon may be less inclined toward reducing R&D activities when interfacing with TMT characterized by high risk tolerant and openness to innovation (Heyden et al, 2017). The following section will further explore the effect of this CEO-TMT interface by examining the interface of CEO Career Horizon and each individual TMT characteristics

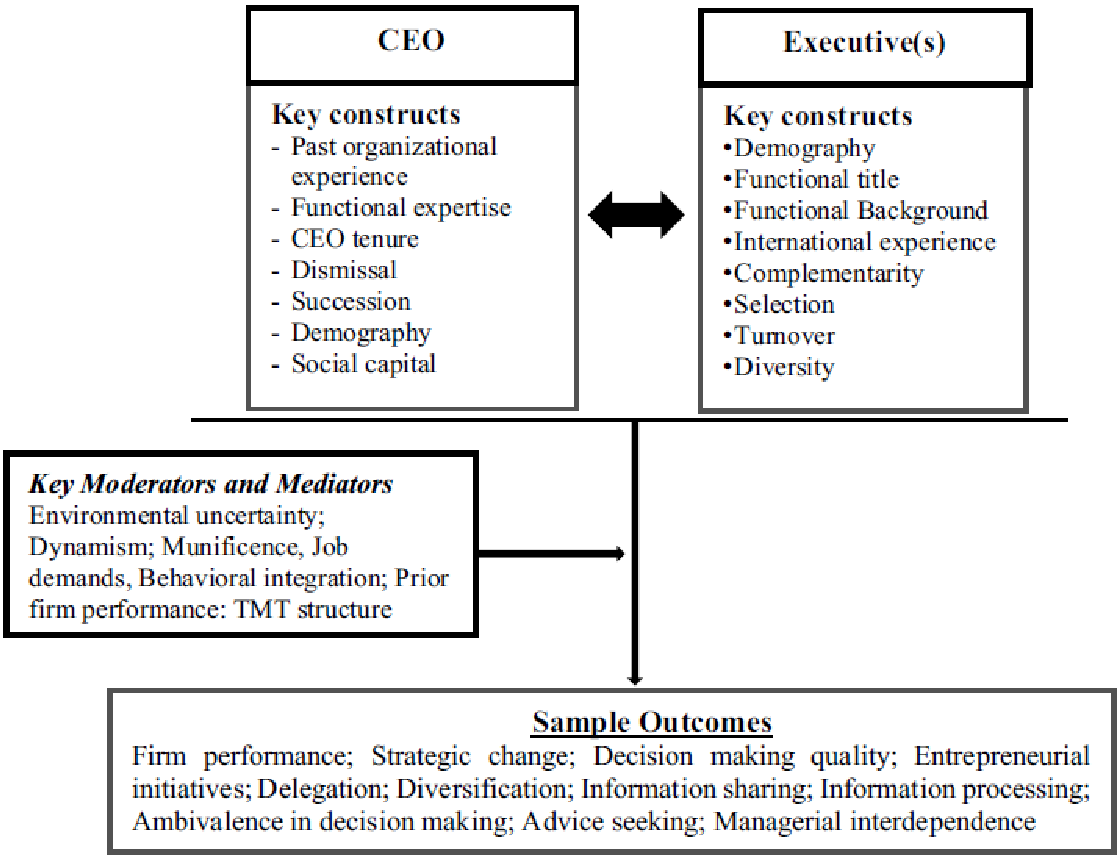

Figure 2: Functionalism perspective of the CEO-TMT interface. Adopted from Georgakakis et al. (2019)

3. HYPOTHESES DEVELOPMENT

3.1 Empirical evidence of TMT's characteristics on innovation and firm performance

Table 1: Empirical evidences of TMT's demographics characteristics influences on firm's innovation and performance

Author(s) (year)	TMT definition	Data sources	Data sample	Methodology	Key outcomes and implications
Hambrick et al (2006)	All the executives above vice-president level	Industry publication	32 major airline companies	Generalized least-squared regression	TMT characterized by diversity in functional background, education exhibit greater propensity for fast response to competitor's initiative with greater magnitude as well. The diversity yield both positive and negative influences, it ultimately results in positive profit and improved performance.
Bantel and Jackson (1989)	The dominant coalitions that act as a decision-making unit	Questionnaire survey	460 state chartered national banks	2 step least squared regression	TMT characteristics are more predictive of organization innovation than CEO characteristics innovation is negatively correlated with average age and tenure; positively correlated with education. Team heterogeneity is positively and significant indication of firm's innovation
Knight et al (1999)	Top managers that involved in organization's decision making	CEO interview	83 high tech firms	Structural equation modelling (SEM)	TMT diversity (age, education, tenure and function) is negatively associated with strategic consensus between TMT members.
Boeker (1997)	The team of managers that report directly to the CEO	Archival data	67 semiconductor producers	Pooled time series/Cross-sectional data structure	Moderating role of firm performance in determining strategic changes is important. TMT characterized by long tenure and high tenure diversity is associated with strategic changes, this effect is more potent under poor performance.
Talke, Salomo and Kock (2011)	N/A	Questionnaire survey & document research	122 firms from 10 manufacturing industries	Partial Least Squared (PLS) structural modelling	TMT (education, functional) diversity has a strong positive effect on firm's innovation orientation, which in turn encourage enaction of innovative strategies. TMT characteristics are important antecedents for innovation strategies and outcomes

Simons, Pelled and Smith (1999)	Top managers that involve in organization's decision making	Questionnaire survey/ CEO interview	57 electric component manufacturing firms	Hierarchical regression	TMT diversity (age, tenure, function) have positive association with comprehensiveness of decision making and firm's performance.
West and Anderson (1996)	General managers	Questionnaire survey	27 hospitals	Stepwise regression	Team size influence the radicalness of team innovation. Proportion of innovators within the team will affect team innovation. The result suggest TMT composition affect its innovativeness.
Qian, Cao and Takeuchi (2013)	CTOs of the firm	Questionnaire survey	122 high tech firms	Ordinary Least Squared regression	Institutional environment moderating the impact of TMT functional diversity on TMT conflict. TMT function diversity do not have an association TMT conflict and firm's innovation
Buyl, Boone, Hendriks and Matthyssens (2011)	TMT members identified by the CEO	Questionnaire survey, structured interview	54 IT firms	Ordinary Least Squared regression	CEO characteristics greatly affect TMT processes. And the interaction between TMT and CEO help realized the benefit of TMT functional diversity. TMT functional diversity can lead to improving firm's innovativeness under guidance of CEO with fitting demographic characteristics
Alexiev et al (2010)	N/A	Survey	705 SMEs from various industry	Hierarchical regression	Both Internal and external advice seeking are essential TMT determinants to firm's exploratory innovation. In which it provides not only new insight, but also legitimacy for the innovations. Advice seeking has stronger relationship with innovation under TMT heterogeneity
Liu et al (2012)	Corporate officers, including CEO, COO and vice presidents	IPO prospectuses, US patent and Trademark Office, National Bureau of Economic Research (NBER)	185 biotech firms	Negative binomial regression	TMT's novel knowledge and experience contribute to invention performance. TMT characterized by shorter intra-firm tenure also contribute to invention performance. However, too many founders on TMT will decrease invention performance. TMT also act an important medium for incorporating external knowledge to enhance organizational expertise.
Lee et al (2017)	Firm's CEO, CFO, COO, CTO and heads	LexisNexis, Compustat, Thompson Reuters	89 high tech firm	Ordinary Least Squared regression	TMT with education background in science and engineering have a positive effect on firm's explorative R&D. Long tenured TMT with innovative-related

	of business units				experiences positively moderate the relationship between TMT characteristics and firm's explorative R&D activities
Kor (2006)	Top managers including CEO, COO, head of business units and vice presidents	IPO prospectuses, Compustat	77 surgical instrument firms (which completed an IPO)	Generalized Least Squared regression	TMT composition (tenure, shared team-specific experiences, functional diversity) and corporate governance have direct and additive effect on R&D investment intensity. Firms that competitiveness rely heavily on R&D investment can alter their TMT composition and governance mechanism to suit the circumstances.

3.2 CEO and TMT education level

Education level is one of the most crucial determinant of manager's cognitive ability and their ability to generate creative solutions to intricate problems. Level of education reflect individual's cognitive capabilities and proficiencies in discriminate potential opportunities from threats. It was considered one of the more prominent proxies in determining manager's cognitive capabilities and predictor of strategic and innovative preferences (Carpenter, Geletkanycz and Sanders, 2004), or how they approach management decisions (Hambrick and Mason 1984). Consistent findings suggest that level of education is positively related to receptivity to innovation (Hambrick and Mason 1984; Kimbery and Evanisko 1981; Daellenbach, McCarthy and Schoenecker, 1999). Education level directly affect the cognitive formation, which shape preferences, positive tendencies toward R&D activities, propensity to take risk (Lee et al, 2017) and problem-solving capabilities (Kimbery and Evanisko, 1981). Moreover, it provides exposures to different perspectives, viewpoints and knowledges that promote out of the box thinking and diverse problem-solving strategies (Tierney and Farmer, 2002). Highly educated individuals will be more likely to tolerate uncertainties and ambiguity, engaging on boundary-expanding endeavours that are risky in nature and possess superior information processing capabilities (Wiersema and Bantel, 1992; Castle and Holl 1997). The relationship between education and cognitive abilities/attitude toward innovation suggest that highly innovative firms is associated with a more highly educated top management team (Bantel and Jackson, 1989). Highly educated managers would be more likely to adopt innovations given appropriate facilitation measures (Castle and Holl, 1997), they would also respond more positively toward changes (Bantel and Jackson 1989). Educated managers would also possess greater awareness toward the needs for strategic or innovative changes within the organization (Wiersema and Bantel, 1992). Additionally, Lindberg (2009) found that more educated managers tend to be forward thinking, more future oriented and focus on future perspectives. They often weigh the benefits of short-term payoffs against a potential larger, more handsome payoff in the long run much more stringent than their lower-educated counterparts.

Education level of managers also affect the comprehensiveness of their decision-making processes and their rationalizing regarding potentials of R&D endeavours (Carpenter et al, 2004). This idea conforms with Bantel and Jackson (1989)'s argument that highly educated managers are more qualify to identify propensity of different R&D options. Moreover, education does not only affect manager's assessment of R&D potentials, but also the productivity of such activity (Norburn and Birley, 1988). Education level also help managers with time, resource management and monitoring the results (Smith, Collins and Clark, 2005). Given the above arguments regarding highly educated TMT's attitude toward innovations, highly educated TMTs will be more likely to resist or mitigate the tendencies of late stage career CEO to reduce R&D spending and R&D engagement in general. Thus, the following hypothesis is articulated:

Hypothesis 1: Highly educated TMTs will reduce the tendencies of CEOs with shorter career horizon to curtail R&D investment

3.3 CEO and TMT age

Manager's age posits a lot of information, such as their accumulated work experiences/knowledge (Bantel and Jackson 1989), general management philosophies, expertise, competence, general norms and beliefs shaped throughout their career (Hambrick and Mason 1984). TMT age is one of the key determinants for the shaping of firm's strategies and strategic changes (Boeker 1997) as they interpret given data differently (Weber 2009). The effect of TMT average age on organizations is suggested by Hambrick and Mason (1984) in which they set forth two general propositions: (1) young managers drive firms to pursuit risky strategies, namely: diversification, innovation and financial leverage; and (2) firms with younger managers experience greater growth. Child (1974) supported the former proposition, stated that mental strength of older managers would hinder their will to absorb new knowledge. Similarly, learning and reasoning skills are also believed to be diminishing with age (Bantel and Jackson 1989). Additionally, Hitt and Tyler (1991)'s research indicate that age influence the extent of risk-taking tendencies of managers during strategic decision making. Conform with this idea, Wiersema and Bantel (1992) found that TMT's characteristics change with age, for example flexibility decreasing with age while rigidity and resistant to changes increase with age. The diminishing in learning capabilities is reflected on the basis of decision making, as older managers tend to rely on historical data to make decisions (Marcel 2009). The reason why information absorbing and learning capabilities was so imperative lying in the fact that they positively affect knowledge creation potential, which is an important antecedent to innovation activities (Smith et al, 2005). Older manager's rigidity, resistance to change and diminished learning capabilities posed huge hindrances should an organization wish to undertake innovative activities.

Therefore, it is argued that late stage CEO would benefit immensely from the presence of younger TMTs. As Younger TMTs are more likely to pursuit new ideas and exhibit more tolerant toward risks (Hambrick and Mason 1984), more open to new ideas and placed a greater emphasis on pursuit of innovative differentiation strategies rather than historical best practices (Goll, Johnson and Rasheed 2007). They possess more learning and information processing capabilities, which help immensely in detecting and weighting different R&D opportunities. Younger TMTs also tend to have a more contemporary and reflective view on the current environment than older TMTs, who often draw conclusion based on historical patterns and previously successful practices (Zimmerman 2008). In this sense, younger TMT would provide the CEO with more profound understanding of the surrounding environments and allowing for early capitalization of opportunities. Providing further support for this angle, Fernandez, Rodriguez and Simonetti (2014) found that younger TMT are less receptive to change and more willing to take risk, which is an important trait that enable firm to make changes and embarking in innovative activities. Last but not least, cognition and interpretation capabilities of younger TMTs would help detecting new trends or emerging technologies and offer insights to old CEO on R&D investment decisions (Thomas, Clark and Gioia, 1993). Accordingly, the presence of younger TMTs would potentially reduce the inclination of old CEO to curtail R&D investment or engagement in R&D activities. Thus, the following hypothesis is formed:

Hypothesis 2: TMTs with lower average age will alleviate the tendencies to curtail R&D investment of CEOs with shorter career horizon.

3.4 CEO and TMT tenure

Of all the potent TMT demographic characteristics suggested by Hambrick and Mason (1984), TMT tenure received the most comprehensive and significant theoretical and empirical implication since upper echelon theory's rise of attention among scholars (Goll, Johnson and Rasheed 2008); (Finkelstein and Hambrick 1990); (Mule et al 2019). TMT team tenure reflect the accumulated cooperating working experiences of managers and the collective of team member's tacit knowledge Mule et al (2019); Camelo-Ordaz, Hernandez Lara and Valle-Cabrera (2005).

Researcher are aware of the influence of TMT tenure as a key determinant of organizational outcome, Katz (1982) highlight the importance of team composition factors, such as team tenure as the decisive factor upon organizational outcomes. He suggests possible increase of manager's commitment toward established norms/practices as tenure increase. Additionally, team often develop norms/standards in communication and homogeneity in perspective that allow for efficiency in group interaction after working together for a certain amount of time (Katz 1982). Classic theory that highlighted the relevance of tenure suggested that team with longer tenure tend to be better and more efficient, leading to better organizational outcomes (Finkelstein and Hambrick, 1990). However, there are many conflicting arguments that suggested otherwise.

Although long-tenured team develop homogeneity in their perspective and group interaction (Wiersema and Bantel (1992). Intra-group communication efficiency and shared norms also reduce the degree of interaction with outside information sources, thus decrease the adoption of potential innovative or unique strategies (Katz 1982). As TMT tenure accumulated, members will steadily develop shared norms, beliefs and best management practice resulted from past succeeded activities. Long tenured TMT suffer greatly from a narrower scope of view due to their commitment to the status quo (Bantel and Jackson 1989); (Katz 1982). Their valuable experiences can be an impediment to important corporate changes (Liu et al, 2012). Collective norms and belief posted great hindrance toward new voices in the team that suggest innovative measures. (Finkelstein and Hambrick 1990). Similarly, Abatecola and Cristofaro (2018) noted that higher tenure added more resistance to changes and less inclination toward innovation

There are several scholars lending supports to the view that long tenured would hinder innovative strategies. Wierseman and Bantel (1992) found that, as average tenure increase, the average age of TMT will also increase, leading to a diminish in manager's willingness to take risk and receptivity to changes – an inherent part of innovation (Bantel and Jackson 1989). As they rely more on strategies that has proven its effectiveness in the past rather than new strategies that can potentially benefit the organization. This argument conforms Bantel and Jackson (1989)'s proposition - age is the primary determinant of TMT cognitive ability which enable detection and interpretation of innovation opportunities and TMT tenure is the key factor that affect their attitude toward innovation.

Finkelstein and Hambrick (1990); Broeker (1997) suggested that TMT tenure have a significant influence on firm's performance and degree of change in strategy employed. Long-tenured TMT team would follow more persistent strategies that adhere to industry's standard, consequentially, their performance is monitored to be closely resemble industry's average. Norburn and Birley (1988) found that shorter tenure is associated with superior firm performance. Michel and Hambrick (1992) posit TMT average tenure as a key indicator of team's cohesion. Longer tenure members are the one who accepted, embraced the collective established norms and share values. And due to this commitment toward preserving group's cohesion, thought-provoking and unconventional interpretations are often omitted from discussions, inevitably leading to a stronger commitment to the status quo. (Boeker 1997); (Michel and Hambrick 1992). Kor (2003) advocated that longer tenured TMT will develop closer ties and possess goodwill with different actors such as suppliers, stakeholders and key clients. These ties, together with their well-developed industry experiences fortified their belief that more stable, reliable strategies should be more desirable, and exhibit bias perspective on adopting safer strategy instead of pursuing novel ideas. Longer tenured managers often lack the capabilities and knowledge when firm enter a period characterized by radical changes both internally and externally (Liu et al, 2012). Last but not least, Schwenk (1993) stated that longer tenured TMT tend to possess a self-serving behaviour. The most crucial consequence of this behaviour pattern is poorer future performances stem from negative response of the TMT

On the other hand, shorter tenured TMT possess more capable learning/cognitive ability to absorb new information, that is essential for innovation (Hambrick and Mason 1984). Due to their inherent characteristics, they tend to possess more novel knowledge and perspectives that is crucial to invention performance (Liu et al, 2012). They are more willing to take risks that often diverge greatly from industry's standard as opposed to long-tenured TMT whose perception is restricted from the developed collective norms/shared value (Finkelstein and Hambrick 1990). The presence of lower tenured TMT will amplify CEO's inclination toward innovative changes. Hence the following hypothesis is articulated:

Hypothesis 3: TMTs characterized with lower average tenure will mitigate shorter career horizon CEO's inclination to curtail R&D investment.

3.5 CEO and TMT functional diversity

Functional diversity reflects the degree to which TMT members differ in term of their functional background (Boone et al, 2018). Scholars often see diversity as a key driver for innovation as it portrays manager's skill, knowledge and capabilities (Qian, Cao and Takeuchi, 2013). TMT functional diversity receive increasing attention, which can be attributed to the general development of TMT in many firms, both quantitatively and qualitatively. In which TMT members are analysed not only individually but also as a collective based on their seniority and functional area in the organization (Menz 2012). TMT function can be categorized into output vs throughput orientation. In which output orientation stem from domains such as research & development (R&D), sales and marketing that is more externally focus in nature (Gauthier, Cohen and Meyer 2019). Their main aim is improving firm growth and the search for new innovations and opportunities. Whereas throughput orientation often stems from expertise in departments such as engineering and accounting, which focus on more internal-oriented goals such as efficient and refined process of turning input into output (Heyden et al 2015)

Finkelstein and Hambrick (1990) stated that bounded rationality influence manager's decision-making outcomes based on their education, prior knowledge, experiences and general worldview. As a result, managers with different functional background/experience often portray different perspective, attitude and knowledge when it comes to managerial decision making (Hambrick and Mason 1984). Different work experiences in different function area will further affect manager's attitude, cognitive capabilities and perspective toward innovation. Functional background strongly influences TMT's perception of which issues are important, thus govern how they design solution to tackle these problems. Diversity of expertise also beneficial to complex problem solving (Bantel and Jackson 1989). Similarly, (Koyunku et al 2010) suggested that functional experience is an important factor in determining organization performance, because different TMTs member possess different biases directly linked to their area of expertise. They also possess information differently and identify problems under different angle, inevitably affect the organization's outcomes differently depend on their functional backgrounds. Last but not least, functional experience plays an important role in manager's sensitivity in detecting and evaluating changes in organizational effectiveness, which help the managers allocating necessary resources or increase workloads where appropriate (Waller, Huber and Glick 1995)

Theories on the influence of TMT functional diversity on firms yield conflicting arguments. On one hand, diverse functional background is associated with strategic changes of firm. More specifically, increasing functional diverse TMT will result in more radical changes under environmental uncertainties (Fernandez et al 2014). Functional diverse TMT possess a wide range of perspectives, skills and knowledge from individual members that allow them to collectively search for alternative solutions. Which often regarded as a valuable resource that is not available to more homogeneous TMT (Certo et al 2006). Functional diversity greatly contributes to the comprehensiveness and optimal level of decision making (Simons, Pelled and Smith 1999). Similarly, Hambrick, Cho and Chen (1996) find TMT functional heterogeneity bring broader gathering of information and more creativity in decision making. Bantel and Jackson (1989) added that functional diversity also positively associated with innovativeness of organization. On the other hand, each member of the TMT has their own orientation that developed from their individual's primary functioning area. Such diverse perspective can potentially cause conflict and fragmentation in decision making (Certo et al 2006). Additionally, Buyl et al (2011) found that although CEO specialized on output-oriented functions such as R&D, marketing, operating is more effective at utilize the potentials of a functional diverse TMT. Benefits of TMT functional diversity, however can only be attained by providing a "learning period" for executives to get acquaintance to the team. In case such period is not feasible, a functional diverse TMT wouldn't bring benefits to the CEO.

One possible explanation for this conflict is the conceptualization of the term "Functional Diversity". As Bunderson and Sutcliffe (2002) noted that functional diversity has been conceptualized and put into empirical scrutiny in different way, each conceptualization yields different empirical results and implications when employed. They suggested 3 conceptualizations of functional diversity: (1) dominant function diversity (the area that individual TMT member spent the most time in their career); (2) functional background diversity (diversity in the complete function background of TMT members and (3) functional assignment diversity (diversity in TMT member's functional assignment).

Taken the conceptualization of the functional diversity into account, it's suggested that more diverse TMTs would amplify the CEO's inclination to pursuit more novel, innovative. Hence the following hypothesis is suggested:

Hypothesis 4: TMTs with more diverse functional experience will reduce shorter career horizon CEO's inclination toward curtailing R&D investment.

4. RESEARCH DESIGN

4.1 Research methods

The following sections will discuss the methods applied in related studies to analyse the effect of executive's characteristics on firm's innovation and firm's outcomes. The discussion will include a brief analysis of the method involved, included its strengths, weaknesses, assumptions and application in related studies.

4.1.1 Ordinary Least Squared (OLS)

Ordinary least squared, also called linear or multiple regression depend on number of independent variables employed, is one of the most popular statistical method that estimate the relationship between a dependent variable and one or more independent variables. The observed error terms indicate an imperfect relationship between the independent variables and dependent variable, that explain the OLS principle - minimization of sum of squares between the observed and predicted values of the explanatory variable, in other word, minimize the sum of squares of residuals. Therefore, OLS determine the regression coefficient that make the regression model lies as close to the observed values as possible.

Similar to other regression techniques, OLS draw a sample from a population, perform statistical analysis on that particular sample to draw some conclusions on the population. The applicability of OLS is based upon the following main assumptions: (1) normality of the residual, (2) linearity of the coefficient and error terms (3) constant variance of the error terms (homoscedasticity) (4) independence of the error terms (no multicollinearity). Firstly, normality of the residual meaning that the residuals (difference between predicted and observed values) of the regression should follow a normal distribution. Normality can be checked via the normal P-P plot or a histogram of the residuals. If the error terms are not deviate too much from the diagonal line of the P-P plot, or the histogram follow a normal distribution, the normality assumption is met. Secondly, linearity of the coefficient and error terms refer to the degree of changes in dependent variables are associated with the independent variables. Scatterplot can be use to assess the degree of linearity, in which the data should be distributed closely around the diagonal line in the graph. Thirdly, homoscedasticity refers to the degree of equal distribution of the residuals, which can be check by plotting the predicted variables against the corresponding residuals. If the scatterplot showing no clear patterns, the data is said to be homoscedastic. Otherwise, this assumption is violated. Lastly, multicollinearity refer to the phenomenon that predictor variables are highly correlated with each other. Multicollinearity lead to inaccurate associate the variances with the designated independent variables, ultimately resulted to distorted outcomes that cause misleading inferences. Multicollinearity can be check in two way, via correlation coefficients and Variance Inflation Factor values. By examining the correlation matrix, highly correlated variables can be identified, that signal potential multicollinearity problem. VIF values can be used to assess the degree of multicollinearity, with the value of 10 or above reflect a dangerously high degree of multicollinearity. As Curto and Pinto (2010) suggested, the tolerance threshold of VIF value should not be exceeding 10.

OLS regression is a widely used method for studies of the influences of executive's characteristics on firm's innovation (Barker and Mueller, 2002; Bostan and Mian 2019; Chen 2013; Cheng 2004; Fu 2019; Kraiczy, Hack and Kellermanns 2015; Lunstrum 2002; Wang, Su and Guo 2019). The biggest advantage of this method is its simplicity in conducting the analysis, and the outcomes are often easy to interpret. On the other hand, under the Gauss-Markov theorem, if all the assumptions are met, OLS regression would produce the least unbiased estimation of the population parameter, allowing for the least variance in sampling distribution of population beta that result in better estimations. Despite the strengths mentioned, OLS regression suffer from endogeneity problems stem from unobservable heterogeneity, often refer to as omitted variable bias. In which a firm-specific variable affects both the independent and dependent variables (Fu 2019). Moreover, the cross-sectional nature of data used in the researches also give rise to potential bias (Cazier 2011) and violation of the OLS assumptions (Barker and Mueller 2002). OLS regression using cross-sectional data is not suitable to establish causality (Wang, Su and Guo 2019), with can cause reverse causality problem. Last but not least, OLS regression employed many assumptions about predictor and its residuals that tend to cause the model to be overfit to the sample if a large number of predictors is presented.

Apart from meeting the assumption, it's imperative to address the endogeneity mentioned above. There are many solutions available to mitigate the endogeneity problem. For example, Barker and Mueller (2002) found cross-sectional choice of data often results in heavily skewered data in favour of more R&D-intensive industries such as biotech and pharmaceutical. By subtracting industry's average R&D from firm level R&D, a normal distribution is achieved that make OLS a suitable technique. Stem from the omitted variable bias, Fu (2019) attempted to mitigate endogeneity problem by lagged the independent variable and introducing some executive and firm's specific variables that can affect both the dependent and independent variable. Similarly, Chen (2013) suggested including potential moderators and control variables. Additionally, Bostan and Mian (2019) introduced firm's fixed effect in the baseline specification to address endogeneity concerns. Last but not least, Kraiczy, Hack and Kellemanns (2015) introducing instrumental variables to address the reverse causality problem that often arise from the inability to establish causality of cross-sectional studies.

4.1.2 Fixed/Random effects

Fixed/random effects are statistical model that can be utilize in regression methods, in which model's parameters are either fix, non-random quantities (fixed effect model) or random (random effect model). These models can be use along with many types of multilevel data, especially panel data (Bruderl and Ludwig 2015). Panel data, also known as longitudinal data, are multi-dimensional data that contain measurements of various phenomena of the same set of individuals or entities across several time periods. Panel data is considered balance when all the elements observed across all the time frame are present. Contrarily, unbalance panel data presented some missing in person-year observation for certain entities. The missing data posed no threat to the model when it is missing at random. However, when it is not random (i.e it's related to the idiosyncratic error term), the sample selection will be bias and statistical estimation power of the model will be reduced (Griliches Hall and Hausman 1978). They also discussed the potential problem of self-selection bias – the problem arises when individual "select" themselves into a group instead of it being purely randomly selected. It results in a biased sample that make complicate the determination of causality.

In Fixed effects (FE) model, time-invariant unobserved individual characteristics that correlated with the independent variables are controlled for. Hence reducing the omitted variable bias problem discussed in the OLS regression section. The reason why removing this unobserved heterogeneity is imperative is due to the fact that between-subject comparison only works when the unit of interest does not differ in anything but the treatment given (Bruderl and Ludwig 2015). Violation of this assumption will lead to biases in the analysis. FE model remove this unobserved heterogeneity through differencing - demeaning the variable by subtracting the within-subject mean from the observed variable make the demeaned time-invariant variables have the value of 0, hence removed from any further analysis. The procedure gets rid of all the between-subjects variability and left only within-subject variability for further analysis procedures. Bruderl and Ludwig (2015) further illustrate the superiority of Fixed effect model by comparing 3 regression method: Cross-sectional OLS, Pooled OLS and FE. They found both Cross-sectional OLS and POLS results to be heavily bias upward because they take both between-subject (which is contaminated with unobserved heterogeneity) and within-subject variation into consideration. Fixed effect model is not without disadvantages. Firstly, the model excluded any time-invariant variables, making it unable to estimate any time-constant variables. Secondly, repeat observations of the same individual often yield substantial correlation, and any methods that don't take it into consideration would produce biased standard error estimates. Despite the drawbacks mentioned, fixed effect model is often considered to be one of the most attractive and promising method for analysing panel data (Allison 1994, Bruderl and Ludwig 2015)

In contrast, Random effects (RE) model controlled for time-invariant unobserved heterogeneity that is not correlated with the independent variables. RE model is often thought as a special case of FE model. It's assumed that the individual unobserved heterogeneity not correlated with the independent variables. If there is no omitted variable bias, random effect models are often more preferable to fixed effect model because it estimate the effect of time-invariant variables rather than just controlled for them. Additionally, the standard error produced by the analysis tend to be smaller as well. However, if such time-invariant variable that is relevant to the research is omitted, the result of RE model will yield inconsistent results. As Allison (2009) noted, the reason why FE model have such higher standard errors compare to RE model is due to the fact that FE model only taken the within-subject variation into account, which controlling for omitting variable bias, but the trade-off is larger standard error.

Consequentially, RE model will provide more efficient estimation at the risk of exposing to potential omitted variable bias.

There are two contrasting assumptions between FE and RE model. FE model assume that individual-specific effects are correlated with the independent variables, whereas RE model assume that individual-specific effects are uncorrelated with the independent variables. Whether the Fixed or Random effect model is more consistent and more efficient in its prediction can be tested by conducting Durbin-Wu-Hausman test, in which the consistency of one method is compare to another less efficient method that is already known to be consistent. In this test, RE model is more preferred when the null hypothesis is true due to their efficiency, if the alternative hypothesis is true, FE model is shown to be at least equally efficient to RE model, which make it more desirable. Both models proved to be superior to traditional linear model for analysing panel data due to its less stringent assumption requirement and less bias produced from the estimations by account for unobservable heterogeneity.

The application of FE/RE models to analyse executive's influence on firm's decisions can be found on studies of Cho and Kim (2017); Goll Johnson and Rasheed (2007); Kang (2016); Sariol and Abebe (2017); Xu and Yan (2014). Cho and Kim (2017) run both FE and RE models as they believed fixed model suffer from omitted bias at firm level. The RE models controlled for the time-invariant industry effect. However, the estimations were found to be the same as FE model. This result support the initial Dubin-Wu-Hausman test that suggest FE model is more preferable over RE model. Goll Johnson and Rasheed (2007) use a FE model to identify whether there's a significant influence of TMT characteristics on firm performance while controlling for the regulated/deregulated airline industry. Kang (2016) discussed how the self-selection bias problem mentioned above could potentially affect his study. He found CEO retirement to be a non-random variable and cause endogeneity problem for the model. The company may dismiss their CEOs at certain age for different reasons. He attempted to remedy the problem by introducing both time variant and time invariant variables that related to CEO retirement into both FE and RE model. Sariol and Abebe (2017) utilize RE instead of FE model due to the fact that their explanatory variable – CEO power is composed of many time-invariant variables. The Hausman test also support their argument as the p value of the test was non-significant, suggesting RE model is more efficient that FE model. Similarly, Xu and Yan (2014), in their study to determine CEO retirement's influence on R&D investments found a RE model more desirable because the main independent variable of interest is whether CEO is retired or not (labelled as Exit in the paper) is a dummy variable that is time-invariant in nature.

4.1.3 Generalized Estimating Equation (GEE)

Generalized Estimating Equation (GEE) is an extension of the Generalized Linear model (GLM), which was introduced by Liang and Zeger (1986). It is a multivariate research technique that give consistent estimation of the regression parameter without the needs for stringent assumptions about time dependence. GEE derive maximum likelihood estimates and required the researchers to specify a distribution family – specified the type of distribution connect with the dependent variables that depend on the type of dependent variable's data, a link function – specified the transformation needed for the construction of parameter estimation matrix, and an appropriate working correlation structure (Ballinger 2004). Prescribing an appropriate distribution and applying necessary transformation of dependent variable is critically important, so that the variance can be appropriately calculated and interpreted. For example, a combination of Gaussian distribution family and an Identity link function (involve no transformation) is appropriate for response variables that are normally distributed. While binomial distribution with Logit link function would be recommended for response variables that are dichotomous in nature (take 0/1 value only)

There are many advantages of using GEE model. Although generalized linear model is often sufficient to obtain descriptions about the variables if the data is cross-sectional in nature, for repeated measures of the same target, autocorrelation between the repeated response will arise and need to be address. This is where GEE is superior to GLM, in which it accounts for firm heterogeneity and autocorrelation of the repeated measures on the same target (van de Wal et al., 2020). Additionally, GEE allow researchers to tackle data that contain non-normally distributed response variables and time-dependent covariates. Due to this issue, researchers often resort to pre-emptively transform their data before conducting the analysis because the response variables don't follow a normal distribution, GEE allow researchers to work with non-normally distributed dependent variables that can potentially bias the outcomes without having to transform the data in advance. Moreover, GEE offered much easier and straightforward to application to the analysis of longitudinal data when comparing to GLMM (General Linear Mixed Model) (Pekar and Brabec 2017). GLMM required the latent effects to be explicitly specified, modelled and estimated, which can also lead to problems with correlation and heteroscedasticity in the results. GEE provide asymptotically correct estimates and inferences without raising the aforementioned issues. GEE's estimations of the parameter are easier to interpret when population-level inferences are desired instead of individual-level inferences.

However, GEE is not without limitation. As noted by Ballinger (2004), estimations under GEE can be heavily biased when the number of clusters, in which the observations are nested within is smaller than 20. When a researcher is interested in random effects within the model, GLMM will provide a more accurate estimations of the parameter compare to GEE (Pekar and Brabec 2017). On the other hand, one very important assumption of GEE is that any missing data is considered missing at random (MAR), and violation of this assumption can have consequences on the estimations. Lastly, there is no universal accepted test for goodness of fit for GEE that is equivalent to the changes in amount of variance explained (ΔR^2). Zeng (2000) developed a goodness of fit measures for GEE model, by calculating the marginal R^2, which is prominent amongst studies of executive's influence on firm's outcomes. Another popular method to assess the model when utilizing GEE is investigate the Wald chi squared parameter.

The application of GEE on studies of executive's influence on firm's outcomes can be seen in studies of Chatterjee and Hambrick (2007); Quigley and Hambrick (2012); Heyden et al., (2017); van de Wal et al., (2020). Particularly, the study of Van de Wal et al., (2020) show GEE's versatility in tackling different non-normal distributions of the response variables. They specified a negative binomial distribution with a log link function to calculate the variances in the number of patents, because the number of patents is a non-negative integer that can take the value of 0 for firms in certain years. For R&D intensity, they specified Gaussian family with identity link function because the variable is a ratio measure. Similarly, Chatterjee and Hambrick (2007) utilized negative binomial distribution with log link function because their main variable of interest – number of acquisitions, is a discrete variable. GEE also allow for interpretation and inferences of interaction term, as seen in Heyden et al (2017) and van der Wal et al., (2020). GEE's power in dealing with unbalanced panel data can be seen in Quigley and Hambrick (2012)'s study, in which it safeguards the results from potential biased estimations of the parameters

4.1.4 Hierarchical Model

Hierarchical model, also known as multilevel model is a statistical model that can be apply to linear regression methods. The basic premise of hierarchical model is that the data utilize in the research is organized at different levels. The dependent variable is analysed at the lowest level, while the independent variables are grouped into different "level" based on theoretical arguments, shared attributes that are predicted by the researchers, or grouping using multivariate statistical techniques such as SEM (Structural Equation Modelling). SEM analyse the structural relationship between related variables and their latent constructs and is often utilize to group variables into different level as mentioned above. Hierarchical models consider the "clustering" or "grouping" effect of the sample, in which multiple regression often ignore which could potentially result in misleading conclusions. In Hierarchical modelling, the baseline model will be consisting of control variables, and the independent variables are inserted into the model in a sequential manner. This approach enable researcher to assess the predictive capabilities of the chosen independent variable beyond the said control variables. Each model is analysed based on the changes of R^2 (proportion of variance explained by the model) to determine whether adding a new variable result in improvement of the model or not. The significant level of the changes in R^2 is also often included, for example in the study of Tanikawa and Jung (2016). A The sequence of insertion of variables is often determine based on theorical arguments, educated guesses or researcher's intuitions. Hierarchical regression inherited all of the linear regression's assumptions, such as assumptions of normality, linearity, homoscedasticity and multi-collinearity.

There are many studies that provide empirical evidences on the relationship between executive's characteristics and firm's outcomes using hierarchical modelling such as Balkin, Markman and Meijals (2000); Lin and Lin (2019); Tanikawa and Jung (2016); Yunlu and Murphy (2012). Balkin et al (2000) found One shared similarity between the studies is the incorporation of cross-sectional data rather than longitudinal data, studying the relationship between the variables of interest at one specific year rather than a period. For example, Yunlu and Murphy (2012) found evidence on the moderating role of CEO's characteristics on the relationship between recession and R&D spending of firms by comparing the results before and after the recession. Balkin et al (2000) found a relationship between innovation and CEO pay. However, the result is subjected to reverse causality due to the cross-sectional nature of research design

4.2 Method specification

To test the influence of executive's characteristics on firm innovation. I will utilize an OLS regression as the baseline to identify the relationship between executives' characteristics and firm innovation (proxied by R&D intensity). Following the specification of previous studies (Barker and Mueller, 2002; Bostan and Mian 2019; Chen 2013; Cheng 2004; Fu 2019; Kraiczy, Hack and Kellermanns 2015; Lunstrum 2002; Wang, Su and Guo 2019). Wooldridge test for auto correlation and modified Wald test for group-wise heteroskedasticity are conducted to see if panel data experienced auto-correlation and heteroskedasticity. The test results for these two tests indicated that panel data is suffer from serial correlation and heteroskedasticity, therefore I will utilize robust standard error instead of standard error to improve the accuracy of regression outcomes. The OLS model is as follow:

$$
\begin{aligned}
R\&D\_INTENSITY_{it} \\
&= \beta_0 + \beta_1 CEO\_CH_{it} + \beta_2 TMT\_AGE_{it} + \beta_3 TMT\_EDUCATION_{it} \\
&+ \beta_4 TMT\_TENURE_{it} + \beta_5 TMT\_FD_{it} + \beta_6 (CEO\_CH_{it}\ x\ TMT\_AGE_{it}) \\
&+ \beta_7 (CEO\_CH_{it}\ x\ TMT\_EDUCATION_{it}) + \beta_8 (CEO\_CH_{it}\ x\ TMT\_TENURE_{it}) \\
&+ \beta_9 (CEO\_CH_{it}\ x\ TMT\_FD_{it}) + \beta_{10} CEO\_TENURE_{it} + \beta_{11} CEO\_FD_{it} \\
&+ \beta_{12} FIRM\_AGE_{it} + \beta_{13} FIRM\_SIZE_{it} + \beta_{14} FIRM\_PERFORMANCE_{it} \\
&+ \beta_{15} FIRM\_LEVERAGE_{it} + YEAR_t + INDUSTRY_i + \varepsilon_{it}
\end{aligned}
$$

As for robustness test, I will run the analysis using Random effect model and Generalized Estimating Equation, then compare the results to the baseline model to see if the results are consistent. For additional analyses. I will run a comparison of the result between the aggregated high tech and medium-high tech firms. Additionally, I will incorporate Patent data as an alternative dependent variable and run the model again. The results will be discussed.

4.3 Variables

4.3.1 Dependent variables

The studies of executive's demographics characteristics influence on firm's innovation effort utilize many different proxies for innovation. Innovation is often measured differently, as Lin et al (2011) noted that, to fully capture the magnitude of innovation activities, one should consider innovation on both innovation input and output. This classification has been done by many scholars such as (Balkin, Markman and Mejia 2000); (Chen 2013); Lin et al (2011). The two type of innovation proxy represent different facets of firm's innovation practices and often yield different implication when employed. As Balkin et al (2000) noted, a study on both type of innovation activities is imperative to fully capture the effect of managerial characteristics on organizational innovation

Regarding innovation input, R&D expenditure divided by sales is one of the most dominant, well-established constructs to measure firm's innovation. Lee et al (2017) argued that R&D intensity capture the budget that firms allow to maintain and facilitate innovative activities, hence illustrate the commitment to innovation of firms. There are some variations of this construct such as R&D expenditure divided by firm's assets or number of employees (Kor 2006); (van der Wal et al., 2020). They're usually applied when observations are firms at early stage of their product development, making sales figure not completed or not yet available. This measure served as the main dependent variable for many studies such as Heyden et al (2017); Chen (2013); Lin et al (2011); Yunlu and Murphy (2012); Balkin et al (2000). Although this measure is straightforward, and more importantly, easy to obtain from data sources. They do not necessarily represent the innovation outcome and how it illustrates the innovativeness of the firms analysed (Lin et al 2011)

The second type of innovation – innovation output, often treated firm's patent data as the main target of interest. The most widely used proxy for innovation output is the new (raw) number of patents applied for a specific year (Balkin et al., 2000); Chen (2013); Xu and Yan (2014); Lener and Wulf (2007). This measure translates the innovation effort of firm's R&D activities into innovative outcomes, as seen in the number and magnitude of patent data. There have been other proxies for innovation output stem from number of patents, such as Patent citation (Lee et al., 2007); Citation-weighted patent count (Liu et al., 2012), which is superior to un-weighted patent counts because it captures the technological impact of a particular patent. Or breakthrough patents (Cho and Kim 2017), the patents that belong to the 95th percentile of total forward citations. Additionally, new product as a proxy for innovation output is also considered by researchers such as (Lin et al., 2011) and (Sariol and Abebe 2017). They argued that new product performance would overcome traditional innovation output measures such as patent counts by explicitly measure the commercial values stem from the introduction of these products.

For a more throughout analysis of executive's characteristics influences on firm's innovation. I will utilize both innovation output and innovation input measures discussed above. For innovation output, the measure chosen is the raw number of patents count that firm achieve in each year. I applied a natural logarithm due to the skewed distribution and presence of extreme values that can affect the analysis, this is also done by researchers such as Lener and Wulf (2007) and Bostan and Mian (2019). To account for firms that don't file new patent for a specific year, I'm adding 1 to the raw number of patents so that the logarithm of them is possible. Moreover, the reasoning for choosing this variable is that patent count is a well-known construct that is supported by a large number of studies. And more importantly, the data on patent's citation and its influences are not readily available. For innovation input, I choose R&D intensity proxied by R&D expenditure divided by sales. This measure is widely employed, allow for comparison with similar studies. Last but not least, literatures have shown inconsistent decisions on whether to lag the dependent variables or not. Some papers such as Yunlu and Murphy (2012); Kor (2006) didn't utilize lagged variable, while studies such as Heyden et al., (2017); Lee et al (2007); Chen (2013) applied a one year lagged dependent variable to let executive's characteristics influences to manifest accordingly to the theorized arguments.

4.3.2 Independent variables

I use CEO career horizon and four TMT attributes (Age, Education, Tenure and Functional diversity) as proxies for executive's demographic characteristics to investigate the effect of aforementioned traits on firm's innovation. The variables are defined as follow:

Several scholars have theorized that **CEO career horizon** is negatively related to firm's innovation because older CEO tend to be more risk-averse and often focusing on preserving their legacy (Matta and Beamish 2008); (Heyden et al 2017); (Krause and Semadeni 2014). The empirical evidences also show strong support for theorized direction. **CEO career horizon** is the amount of time the CEO has left before retirement. It is calculated by subtracting CEO's chronological age from the retirement age (cut-off point). Several studies employed different cut-off point, for example Matta and Beamish (2008) used 65 years and Heyden et al (2017) used 60 years. To accommodate the sample firms (which are all Germans), I will use a cut-off point of 67 years, the retirement age of Germany.

Before discussing TMT characteristics, it is imperative to understand what compose of the TMT in this paper. Carpenter et al. (2004) suggested, the TMT consist of the "dominant coalition" within the firms. As previously discussed, German firms adopt two-tier board system. In which strict separation between management and supervisor is ensured. This allow me to identify TMT member more easily. I consider all the executives that have the following characteristics a TMT member: belong to the management board of firms, taking part in firm's day to day decision making, report directly to the CEO. And do not participate in both supervisory and executive function at the same time.

TMT Age is related to not only cognitive abilities, but also the capabilities to absorb new knowledge, as suggested by Wiersema and Bantel (1992). Hitt and Tyler (1991) found that willingness to try new possibilities and risk-taking tendencies of executive during decision making change with age. Therefore, it's theorized that TMT Age is negatively related to innovation due to a diminishing in the aforementioned qualities. **TMT Age** is universally defined as the average age of all the TMT members at the observation year (Lee et al 2007); (Heyden et al 2017); (Yunlu and Murphy 2012); (Tanikawa and Jung 2016).

TMT education is the attained capabilities result from academic experiences. Higher education enables executives to solve complex problem, superior capabilities, creating alternatives and generally more tolerant toward risk and uncertainties. Carpenter et al., (2004) stated that TMT education is a prominent predictor of manager's cognitive abilities and strategic preferences. Adopted from Heyden et al (2017). I coded the highest attained education level of the TMT members as follow: 1 = high school, 2 = college or associate degree, 3 = undergrad degree, 4 = graduate school, 5 = master degree, 6 = attended doctoral program, 7 = doctorate degree. Then I took the median among the TMT member as the value of **TMT education**.

TMT Tenure often reflect the degree of homogeneity of decision making and way of thinking within the TMT. Wiersema and Bantel (1992) suggested that higher tenured team tend to share team-specific norms and values that developed through extended interaction, making their decision making more and more conform with each other. Decision making as a collective can be benefit if the team is highly innovative. However, high tenure will facilitate additional difficulties for enacting innovative idea should the TMT team is risk averse in nature**.** Katz (1982) supported this notion – they find higher tenured TMT tend to have narrower view due to the commitment to status quo. **TMT Tenure** construct is straightforward, it is calculated as the average year since appointment of all individuals of the TMT Finkelstein and Hambrick (1990); Lee et al, (2007); Tanikawa and Jung (2016); van de Wal et al., (2020)

TMT Functional Diversity illustrate the functional heterogeneity of TMT members. High degree of diversity brings in expertise and idea from different disciplines, which can nurture new ideas from constructive discussions. Fuctional diversified TMT allowing for more optimal decision making (Simons et al., 1999). On the other hand, heterogeneity can also cause conflicts due to clash of interest and different point of view, lead to many TMT deficiencies (Certo et al 2006). To account for **TMT Functional Diversity**, I will adopt Blau's (1977) index of heterogeneity, this method is adopted by studies such as Bantel and Jackson (1989); Musteen et al., (2006); Zimmerman (2008). The formula is as follow:

$$H = 1 - \sum_{i=1}^{n} p_i^2$$

Where p_i is the proportion of TMT members that belong to the i function and n is the total number of functions within the TMT. The value of H is between 0 and 1, bigger value means higher degree of functional diversity.

4.3.3 Control variables

In this section, I will discuss the control variables of the research. First, the control variables are divided into CEO level (consist of CEO Tenure, CEO education and CEO Experience) and Firm Level (Age, Size, Performance, Leverage, Industry dummies and Year Dummies). These variables are chosen by reviewing related researches such as (Barker and Mueller 2002; Chen 2013; Yunlu and Murphy 2012; Kang 2016; Liu et al., 2012; Heyden et al., 2017; Musteen et al., 2006 etc..). These studies acknowledge some shared variables that are not of main interest, but can potentially influence firm's innovation. The incorporation of these control variables will safeguard the model from bias arise from unobserved heterogeneity, improving the model's statistical power.

CEO level control variables are interpreted and constructed the same way as the TMT's characteristics discussed above. **CEO tenure** is defined as the number of years since CEO appointment to their position (Barker and Mueller 2002). Long tenured CEOs are risk-averse in nature, stem from increased personal stake and stronger commitment to the company. Longer tenured CEOs tends to prioritize stability and efficiency instead of pursuing of novel ideas through R&D investment (Barker and Mueller 2002). Similar to the way TMT tenure affect firm's innovation, I predict that longer tenured CEOs will negatively affect firm's innovation

CEO Age is defined as the chronological age of the CEO. (check CEO age, if distribution is skewed, apply a natural logarithm transformation). As Hambrick and Mason (1984) suggested, older executives tend to be more conservative about their decision making. Chowdhury and Fink (2017) found that age does not make CEO reduce their R&D investment, they also do it sub-optimally. Similarly, Barker and Mueller (2002) also found a negative correlation between CEO Age and firm's R&D spending. Therefore, I expected CEO Age to be negatively related to firm's innovation.

CEO Education is defined as a categorical variable that take the following value: 0 = no college, 1 = undergraduate degree, 2 = master degree, 3 = phD degree or above. These are adopted from (Daellenbach et al., 1999) and (Barker and Mueller 2002).

CEO Functional Diversity play a much important role. Barker and Mueller (2002) noted, classic theorist suggest that functional experience of CEO would cause bias accordingly to their primary functioning area. This notion received additional scrutiny from scholars, but the findings don't seem to align with the expectation. A possible explanation lying in the cross-section multi-functional nature of CEO's job in recent years. Additionally, Musteen et al., (2006) suggested that functional diversity is an important determinant to CEO's attitude toward changes, in which exposure to different functional experiences enhance their adaptability and tolerance toward changes. Therefore, I expect CEO Functional Diversity to have a positive influence on firm's innovation. To account for the degree of functional diversity, I utilize Blau's (1977) heretogeneity index. The application of this index can be found in the study of Musteen et al., (2006). The formula is as follow:

$$H = 1 - \sum_{i=1}^{n} p_i^2$$

Where i denote the different functions that the CEOs had been in throughout their career and p is the proportion number of years the CEOs have been in that position relative to their total experience. Value of H is between 0 and 1, higher the value means more diverse CEO.

Next, I will discuss firm level control variables. The first variable, **Firm Age**, is defined as the number of years since the company's establishment (Liu et al 2012; Chen 2013; Tanikawa and Jung 2016). According to Liu et al., (2012), firm age moderates the relationship between TMT experience and invention performance. Chen (2013)'s result suggest that younger firms are generally more R&D intensified than older firms. Similarly, Abdel-Khalid (2014) also suggest that youngers firm spend more on R&D investment in proportion to their sales. Therefore, I expect Firm Age to be negatively related to firm's innovation

Firm size is the next variable that I'd like to control for. Firm size is defined as the number of employees of the company (Barker and Mueller 2002; Finkelstein and Hambrick 1990; Kraiczy et al., 2015; Liu et al 2012; van der Wal et al., 2020). Similar to the aforementioned studies, I applied a natural logarithm transformation to account for the skewness distribution. Firm size is considered one of the most influential factors that related to studies on R&D investment. Larger firms, although possess greater available resources and financial slacks for R&D investment, are often less likely to invest in such project because it may change the status quo (Barker and Mueller 2002). Large firms hold market power would not have the incentive to do so. There are many empirical evidences to support this view (Yunlu and Murphy 2012; Barker and Mueller 2002; Chen 2013; Kraiczy et al., 2015) in which a negative relationship between Firm size and R&D investment is found. Additionaly, Liu et al., (2012) found that firm size moderates the relationship between TMT experience and invention performance. Therefore, I expect a negative relationship between firm size and firm innovation.

To control for **Firm Performance**, I choose to incorporate Return on Asset (ROA) as a proxy for firm's performance (Yunlu and Murphy 2012; Chen 2013; Cho and Kim 2017; Balkin et al., 2000; van der Wal et al, 2020). Firm performance is in line with R&D intensity, in which financially successful firms will have more slacks to dedicate to R&D projects. However, empirical evidences suggested otherwise (Cho and Kim 2017; Yunlu and Murphy 2012; Balkin et al., 2000), in which a negative relationship between the variables is found instead. A possible explanation for this phenomenon is that successful firms will be likely to follow the proven formula instead of exploiting new possibilities. Therefore, I'm expecting a negative relationship between Firm Performance and firm innovation in support for these arguments.

Firm Leverage is the next notable variable for this study. Leverage is defined as the firm's long-term debt divided by Total assets (Barker and Mueller 2002; Chen 2013). Chowdhury and Fink (2016) used Total debts divided by Total assets instead, but the inclusion of short-term debt will inevitably distort the true magnitude of leverage on firm that should be expressed through long-term debt. Leverage represent liquidity problem of firms; therefore, managers will be less inclined to spend on long term R&D projects (Barker and Mueller 2002). Chen (2013) found a negative relationship between firm leverage and R&D intensity. The same relationship is expected in this paper.

Last but not least, I will also control for Industry dummy and Year dummy to capture the time-invariant effects of those variables. These control variables are widely utilized in studies on firm's innovation to control for any R&D trends over time and over different industry (Chen 2013; Cho and Kim 2017; Bostan and Mian 2019 etc.)

Table 2: Variables definition and measurement

Name	Measurement	Supporting Literature
R&D_INTENSITY	= R&D expenditure divided by Sales	Heyden et al (2017) Lee et al (2007) Finkelstein and Hambrick (1990) Chen (2013) Lin et al (2011Yunlu and Murphy (2012)
PATENT	= Natural Logarithm of number of patents submitted per year	Balkin, Markman and MejiaIs (2000); Lerner and Wulf (2007); Liu et al (2012); Xu and Yan (2014); Bostan and Mian (2019)
CEO_CH	= 67 minus CEO chronological age	Heyden et al (2017); Yunlu and Murphy (2012); Matta and Beamish (2008)
TMT_AGE	= Average age of TMT members	Lee et al (2007) Heyden et al (2017) Yunlu and Murphy (2012), Tanikawa and Jung (2016)
TMT_EDUCATION	= median value of TMT education	Heyden et al (2017)
TMT_TENURE	= Average tenure of TMT members	Heyden et al (2017) Finkelstein and Hambrick (1990) Lee et al (2007)
TMT_FD	= TMT functional diversity, calculated using Blau's heterogeneity index	Bantel & Jackson, (1989); Musteen et al., (2006); Zimmerman (2008)
CEO_TENURE	= Tenure of CEO in years	Sariol and Abebe (2017); Musteen et al., (2006) Yunlu and Murphy (2012); Barker and Mueller (2002) Chen (2013) Chen, Chen and Yang (2016) Cho and Kim (2017); van der Wal et al., (2020)
CEO_FD	= CEO functional diversity, calculated using Blau's heterogeneity index	(Bantel & Jackson, 1989; Musteen et al., 2006; Ping 2007; Zimmerman 2008)
FIRM_AGE	= Number of years since firm is founded	Liu et al (2012); Barker and Mueller (2002); Chen (2013)
FIRM_SIZE	= Natural logarithm of number of employees	Barker and Mueller (2002); Finkelstein and Hambrick (1990); Kraiczy, Hack and Kellermanns (2015); Liu et al (2012) Yunly and Murphy (2012); van der Wal et al., (2020)
FIRM_ PERFORMANCE	= Return on Assets (EBIT/Total Assets)	Yunlu and Murphy (2012); Chen (2013); Cho and Kim (2017) Balkin, Markman and MejiaIs (2000); Kang (2016); van der Wal et al., (2020)
FIRM_LEVERAGE	= Long-term debts/Total assets	Barker and Mueller (2002) Fu (2009) Chen, Chen and Yang (2016); Kang (2016); Conyon and Florou (2006); Finkelstein and Hambrick (1990)
YEAR	= Year dummies	Matta and Beamish (2008); Kang (2016); Fu (2019); Chen (2013); Bostan and Mian (2019)
INDUSTRY	= Industry dummies	Xu and Yan (2014); Fu (2019); Bostan and Mian (2019)

4.4 Data:

The data gathered for this study come from many sources. For financial data and firm's related financial ratios, I used ORBIS database created by Bureau van Dijk which contain extensive financial information of firms worldwide. For executive's information, I use Nexis Uni to search for journals, newspaper, press release that contain announcements made by companies. Furthermore, I used LinkedIn, in combination with director's information on ORBIS and firm's annual reports to find information about executives (age, tenure, education, functional experiences…). Executive information from ORBIS will be cross checking with the annual reports to enhance reliability.

I focus mainly on high and medium-high tech manufacturing firms because R&D investment is critically important to their survival, and that the managerial implications may prove to be considerably useful for not only the firms in the sample, but also firms in similar high-tech context. I used several search filters to estimate the final sample firm included in this paper. By using the ORBIS database, I applied the following search criteria: (1) Firms must be originated or based their operation primary in Germany (2) Firms must belong to the chosen industry classification, which are high and medium high tech industry, the further elaboration on the classification will be discussed later, (3) Firms must have information about their R&D investment, or actively engage in R&D activities for the last available year, (4) Firm must have patent data available, and (5) Firms must have complete R&D, patent data and executive information throughout the analysed period or missing data of not more than 2 years. It is often difficult to obtain a balance panel data; therefore, I choose to also include firms with less than 2 years missing data. The final dataset is reduced from 71133 firms to 75 firms with 9 years period, making a grand total of 662 firm-years observation from 2011-2019. I extracted the data obtained from ORBIS into excel, then manually collect executive's information. Any variable transformations are done in Stata to arrive at the final dataset. Appendix 8.1 illustrate the availability of specific firm-year observation.

The German firms chosen are classified by the two-digit SIC code from the ORBIS database. The industry classification applied is adopted from the Statistical Classification of Economic Activities in the European Community, abbreviated into NACE, which is the standard classification system used in the EU. NACE Rev.2 classified the chosen firms into 5 sub-group: (1) Manufacture of basic pharmaceutical products and pharmaceutical preparations, (2) Manufacture of computer, electronic and optical products, (3) Manufacture of chemicals and chemical products, (4) Manufacture of electrical equipment and (5) Manufacture of machinery and equipment. There are two additional industry that belong to high-tech/medium high-tech aggregations, which are manufacture of motor vehicles, trailers and semi-trailers and manufacture of other transport equipment. However, there are no firms that satisfied the search criteria used. Table 4 summarized the number of firms per industry classification. Manufacture of machinery and equipment is the largest group, account for approximately 36% of firm, followed closely by Manufacture of computer, electronic and optical products with 32%. The full list of sample firms can be found in Appendix 8.2 with detail information of their classifications

Table 3: Summary of data selection procedures

Sample Firms	Number of firms
German firms 2011-2019 (Initial dataset)	71133
Less: Firms not belong to the relevant industry classification	-65458
Less: Firm with missing R&D information	-5399
Less: Firm with missing patent information	-192
Less: Firm with incomplete R&D expenditure/patent information or executive information for more than 2 years	-9
Final sample firms	**75**

Table 4: Summary of firms by industry classification

Type	Number of firms
Manufacture of basic pharmaceutical products and pharmaceutical preparations;	6
Manufacture of computer, electronic and optical products	24
Manufacture of chemicals and chemical products	11
Manufacture of electrical equipment	7
Manufacture of machinery and equipment	27
Total	**75**

5. EMPIRICAL RESULTS

5.1 Descriptive statistics

Table 5 provided a summary statistic for all dependent, independent and control variables incorporated in the study. Outliers are winsorized at the 1st percentile and 99th percentile. Patent is transformed using log transformation to account for skewed distributions. The first section of table 5 report the summary statistics of the dependent variables R&D intensity and patent data. The statistic results of R&D_INTENSITY show the mean of 5.05%, median of 3.9% and standard deviation of 3.78%. The min and max value of R&D intensity are 0.15% and 18.83% respectively. The statistics suggested a strong right-skewed distribution, which can check via histogram plot. This right-skewed distribution is consistent with many studies on firm's innovation activities such as Lerner and Wulf (2007); Xu and Yan (2014); Lee et al., (2007); Heyden et al (2017); Lee, Kim and Bae (2020); Chen (2013) and Lin et al (2011). All of the aforementioned studies experienced extreme right skewed distributions, which can be explained by the fact that there are a handful number of firms that are substantially more R&D intensified than the rest of the analysed firms. This phenomenon can be seen particularly in the study of Lenrner and Wulf (2007) (4.75% mean, std dev of 4.66% and maximum of 48.53%), Lin et al (2011) (mean of 1.3%, std dev of 5.3% and maximum of 91.9%) or Abdel Khalid (2014) (mean of 0.7%, std dev of 3.6% and highest quartile of 1.1%). The lesser degree of skewness reported in table 5 can be attribute to the fact that the sample firms consist of both high-tech and medium high-tech firms rather than only firms in strictly high-tech aggregate. PATENT show a mean of 965.09, standard deviation of 2827.46 with 0 and 25020 minimum/maximum patent count respectively. Similar to R&D_INTENSITY, PATENT also show a strongly right-skewed distribution of the observations. This phenomenon is consistent with those in Xu and Yan (2014); Bostan and Mian (2019); Lee Kim and Bae (2020), in which the standard deviation is consistently higher than mean. In overall, the dependent variables statistic shows a consistent concentration of innovation endeavours by a number of firms that are excessively more R&D intensify than the rest of the firms.

The second section of table 5 report the statistics of main independent variables associated. The average career horizon of CEO (CEO_CH) is 12.38 years, which is similar to those analysed by Heyden et al., (2007) of 5.54 years; The differences main lie in the cut-off point chosen (67 versus 60 years). Matta and Beamish (2008) found an average career horizon of 11.68 years with 70-year cut-off point. In sample firm TMT_EDUCATION is 5.14 which suggested that on average, most of TMT members attained at least a master degree or equivalent. The low standard deviation (0.86) and high minimum value (4) suggesting that the education level of sample firms is not too disperse, consistent with the notion that highly innovative firms required their management team to have the capabilities and expertise expressed through their education records. The average tenure of the TMT is expressed through TMT_TENURE, in which on average TMT members assume their position of approximately 6 years. Lee et al (2007) and Liu et al (2012) found similar mean tenure of TMT (5.91 years and 6.06 years respectively) while

Heyden et al (2017)'s study suggested much higher results (9.66 years). This can be attribute to the fact that both Lee et al (2007) and Liu et al (2012) utilize firm sample from high-tech industry, whereas Heyden et al (2017) choose randomly 100 manufacturing firms. In high-tech industries, lower average tenure of TMT reflects the fast-changing nature of the industry and the need to embrace changes through dismissal and appointment of new member. The average TMT_AGE is 52.88 with standard deviation of 3.39 is comparable with those find in Heyden et al (2017). High average age and low standard deviation suggested that TMT of firms in the study consist of senior managements and it doesn't differ too greatly from firm to firm across observation years. Seniority of TMT member represent extensive experience that make up the core management team assisting CEO in decision making. Last but not least, TMT_FD represent the functional diversity level of TMT firms, the mean value of 0.627 is comparable to results from Liu et al (2012) which utilize the same measurements model.

The last section described the control variables utilized in the study. CEO_TENURE strongly resemble TMT's average tenure at 6.55 years. Similarly, CEO_FD – represent the degree of functional diversity of CEO follow similar patterns of TMT_FD with approximately similar mean value (0.627 and 0.7) and std dev (0.12). The average FIRM_AGE is 90.18 years, with the oldest firm in record at 352 years suggesting that the analysed firm have been founded and go through many historical changes. FIRM_SIZE show an average of 8.62 with std dev of 1.72. This result is strongly resembled Kang (2016) study, which show mean firm size at 8.453 and std dev of 1.486 respectively. This similarity can be explained by the usage of big firms in both studies. Additionally, study of Cho and Kim (2017); Lee et al (2007) also show similar pattern regarding firm size. FIRM_PERFORMANCE proxied by Return on Asset is averaged at 6.6%, is somewhat comparable to study of Kang (2016) (6.003%) and Cho and Kim (2017) (4%). Kang (2016)'s study consists of big firms that lend explanation to the similarity in ROA mean founded in this study. Apart from that, there are many studies show significant deviation from this paper, particularly the study of van der Wal et al (2020) that show a mean value of -10% instead.

Table 5: Summary statistics

This table report descriptive statistics of variables for the 662 firm-years observation from 2011 to 2019

Panel A: Descriptive statistics of dependent, independent and control variables						
Variable	**N**	**Mean**	**Std. dev**	**Median**	**Min**	**Max**
Dependent variables						
R&D_INTENSITY (%)	662	5.05	3.78	3.9	0.15	18.83
PATENT (Count)	662	965.09	2827.46	84	0	25020
PATENT (Ln (1+ PATENT))	662	4.668	2.235	4.488	0	10.127
Independent variables						
CEO_CH	662	12.38	5.33	12	0	25
TMT_AGE	662	52.88	3.39	53	41.5	61.5
TMT_EDUCATION	662	5.14	0.86	5	4	7
TMT_TENURE	662	5.76	2.91	5.33	1	19
TMT_FD	662	0.627	0.12	0.65	0.255	0.9
Control variables						
CEO_TENURE	662	6.55	5.53	5	1	31
CEO_FD	662	0.7	0.12	0.73	0.255	0.896
FIRM_AGE	662	90.18	71.79	70	4	352
FIRM_SIZE (Ln)	662	8.62	1.72	8.61	5.66	12.92
FIRM_PERFORMANCE (ROA in %)	662	6.6	6.92	6.67	-26.26	37.53
FIRM_LEVERAGE (%)	662	13.8	10.4	12.6	0	41.6

Summarize of descriptive statistic of all variables

Table 6 reports the correlation coefficients that form the Pearson correlation matrix. The correlation matrix served as a preliminarily analysis of the variables to identify patterns and potential issues that can affect the regression results such as multicollinearity. The first two column posit the more interesting correlation results between the two dependent variables and the remaining variables. Correlation show a negative significant relationship between R&D intensity/PATENT and CEO_CH lend support for our priori predictions that short horizon CEO may display inclination to reduce innovation activities. Overall, the correlation between variables stay within the acceptable threshold with the only two exception of PATENT and FIRM_SIZE (0.85) and CEO_TENURE and TMT_TENURE (0.52). The correlation of PATENT and FIRM_SIZE is significantly higher than the remaining results. The presence of many significant correlation between the dependent and independent variables raised the issue of multi-collinearity between variables. Therefore, an analysis of variance inflation factor (VIF) is also conducted for all the dependent, independent and control variables incorporated in the study. The full result is included in the appendix, the VIF values stay between 1.092 and 2.069 which is considerably lower than the alert threshold suggested by Curto and Pinto (2010). VIF values indicate that multicollinearity is not an inherent problem for the specified model.

Table 6: Pearson Correlation Matrix

	R%D INTENSITY	PATENT	CEO_CH	TMT_AGE	TMT_EDUCATION	TMT_TENURE	TMT_FD	CEO_TENURE	CEO_FD	FIRM_AGE	FIRM_SIZE	FIRM_PERFORMANCE	FIRM_LEVERAGE
R&D_INTENSITY	1												
PATENT	0.22**	1											
CEO_CH	-0.14**	-0.15**	1										
TMT_AGE	0.02	0.02	-0.52**	1									
TMT_EDUCATION	0.48**	0.02	-0.14**	-0.04	1								
TMT_TENURE	0.05	-0.23**	-0.23**	0.31**	-0.13**	1							
TMT_FD	0.29**	0.29**	-0.07	-0.13**	0.17**	-0.14**	1						
CEO_TENURE	0.17**	-0.24**	-0.29**	-0.05	0.06	0.52**	0.01	1					
CEO_FD	0.01	0.18**	-0.05	0.16**	0.07*	-0.14**	-0.02	-0.41**	1				
FIRM_AGE	-0.05	0.36**	-0.19**	0.03	-0.05	-0.12**	0.08*	-0.12**	0.15**	1			
FIRM_SIZE	-0.00	0.85**	-0.18**	0.07*	0.01	-0.31**	0.23**	-0.29**	0.24**	0.47**	1		
FIRM_PERFORMANCE	-0.11*	0.02	0.11*	0.09*	-0.23**	0.24**	-0.01	0.00	0.01	-0.09*	-0.08*	1	
FIRM_LEVERAGE	-0.03	-0.12**	-0.13**	0.04	0.11**	0.03	0.04	0.08*	-0.09*	-0.15**	-0.00	-0.17**	1

* Denote correlation significant at 5% level (2-tailed)

** Denote correlation significant at 1% level (2-tailed)

5.2. OLS results and robustness tests

Table 7 till 10 reports the OLS regression results illustrate the influence of interfacing effect between CEO and their corresponding TMT on firm's innovation (proxied by R&D intensity). Each table test one hypothesis separately with different model specifications utilized. Model 1 incorporate all the dummy, CEO control and industry control variables. Model 2 to 5 testing different specification regarding 2 CEO control variables – CEO tenure and CEO functional diversity. Finally, all the variables are incorporated into the full model (model 6). Although many firm level and CEO level control variables are incorporated to improve the predictive capabilities of the baseline model. The results need to be validated through a robustness test in order to enhance its reliability. For this reason, I will employ two additional estimation methods – Random Effect (RE) model and Generalize Estimating Equation (GEE), then compare the outcomes with those received from the baseline model. I conducted Durbin-Wu-Hausman test to choose between fixed and random effect model. Results of the test from Appendix 3 did not refute the null hypothesis, indicate that random effect model is more efficient. For both robustness estimation method, first model includes all the controls and independent variables. Model 2 to 5 incorporate the individual interaction effect that represent the interfacing between CEO career horizon and each TMT characteristic. Model 6 includes all the independent variables and control variables, together with all four interaction effects. For each hypothesis, I will first discuss the main OLS results, then compare them to the results obtained from RE and GEE estimation. All the interaction plots are derived from full model of each tables. The full results of the two robustness tests can be found in Appendix 4 and 5, together with their corresponding interaction plots.

5.2.1. Hypothesis 1: Interface of CEO career horizon and TMT education

Table 7 reports the OLS regression result of the interfacing effect between CEO career horizon and TMT education on firm's innovation (proxied by R&D intensity). The first hypothesis posits that TMT with higher education will mitigate CEO with shorter career horizon's tendency to curtail firm's R&D investment. The independent variable TMT_EDUCATION – represent the highest average attained education achievement of TMT is positive and significantly related to R&D intensity in all incorporated model (model 2 to 5, with significant level at the 10% level for model 4 and 6, and at the 5% significant level for model 2,3 and 5). The coefficients are similar across model 3 to 6 (β ranging from 0.407 to 0.431). This coefficient is significantly higher in model 2 ($\beta = 0.729$), when the interaction term is excluded. Turning into the interaction effect, it can be seen from model 3 to 6 (in which the interaction effect is present). The results are universally positive and significant across all different model specification, the coefficients of each model also stay relatively the same with the exception of model 5, when CEO functional diversity is excluded. The result from model 6 ($\beta = 0.025$, t value = 3.87) should be interpreted in conjunction with the corresponding interaction term illustrated in Figure 3. Inspecting the interaction figure show that the two lines are intersected, representing a very strong indication of an interaction effect. Moreover, as CEO career horizon shorten, the level of R&D intensity is incrementally increase for TMT characterized by higher average education level than those with lower education level.

Which suggest that highly educated TMT team, when interacting with shorter career horizon CEO, will alleviate the degree of curtailing of R&D investment.

With regard to control variables, most of them are insignificant, with the exception of CEO tenure and firm performance. Regarding CEO tenure, the coefficients are positive and significant for all model at different significance level (10% for model 1 and 6, 5% for model 2 and 1% for model 5). Similarly, firm performance witnessed a consistently negative and significant trend across all analysed models. The coefficients and significance level are almost identical for model 2 till 6. Model 1 diverged slightly from the rest with slightly higher coefficients and significant level of 10% instead of the rest (at 5%). This negative and significant trend of firm performance is seen not only in the baseline models, but also in the robustness test, albeit the significant levels and coefficients diverge slight across different models= specifications. This result is in line with the initial expectation mentioned in variable description section – firms experience financial growth will likely to maintain its strategy and preferences around the current formula of success instead of exploiting new possibilities.

Robustness tests using RE and GEE estimation methods (reported in table 13 and 14 respectively) on the variable TMT education show strongly consistent result, the coefficients are universally positive and mostly significant, with the exception of model 3 and 6 of both RE and GEE estimation. All the coefficients are significant at 1% level for RE estimations and at 5% level for GEE estimations. This positive effect of TMT education level is also documented in the studies of Bantel and Jackson (1989), Carmelo-Ordaz et al (2005), Heyden et al (2017). TMT with higher educations possessed superior cognitive capabilities and higher awareness toward innovative possibilities. They are more tolerant toward ambiguity and often see new, uncertain directions as opportunity rather than hazards that should be avoided. Therefore, they are more likely to capitalize on such opportunities, hence the positive influence on R&D investment. Turning into the main interest – interaction term between CEO career horizon and TMT education. The coefficients of the interaction are all positive and significant at the 1% level except model 6 of RE model. Investigate the corresponding interaction plots (Figure 3, 8 and 12 for baseline model, RE and GEE estimation respectively), which represent full model result (model 6 from each regression model). It can be seen that the mitigation of CEO horizon effect on R&D investments by TMT with high average is apparent and consistent across different model specification. These robustness tests further enhance the validity of the baseline outcomes. Therefore, hypothesis 1 that highly educated TMTs will reduce the tendencies of CEOs with shorter career horizon to curtail R&D investment is supported.

Table 7: Interfacing effect of CEO-TMT education on firm innovation – OLS regression

	R&D intensity					
Model	**1**	**2**	**3**	**4**	**5**	**6**
CEO_CH		0.026*	-0.13**	-0.128**	-0.94*	-0.096*
		(2.68)	(-3.00)	(-3.83)	(-2.58)	(-2.71)
TMT_EDUCATION		0.729**	0.426**	0.407*	0.431**	0.419*
		(3.07)	(2.77)	(2.56)	(2.81)	(2.73)
CEO_CH x TMT_EDUCATION			0.025**	0.026**	0.242**	0.025**
			(3.15)	(3.71)	(3.59)	(3.87)
CEO_TENURE	0.026*	0.046**			0.05***	0.044*
	(2.7)	(3.11)			(6.01)	(2.73)
CEO_FD	-1.134	-0.729		-1.347		-0.817
	(-0.9)	(-0.6)		(-1.22)		(-0.7)
FIRM_AGE	-0.013	-0.037	-0.043	-0.027	-0.041	-0.032
	(-0.25)	(-0.82)	(-0.85)	(-0.61)	(-0.89)	(-0.73)
FIRM_SIZE	0.64	0.398	0.393	0.428	0.386	0.408
	(0.96)	(0.78)	(0.60)	(0.70)	(0.70)	(0.75)
FIRM_PERFORMANCE	-0.086*	-0.056**	-0.058**	-0.059**	-0.058**	-0.059**
	(-2.55)	(-3.27)	(-3.31)	(-3.38)	(-3.54)	(-3.51)
FIRM_LEVERAGE	-0.993	-0.519	-0.879	-0.743	-0.707	-0.644
	(-0.83)	(-0.4)	(-0.67)	(-0.62)	(-0.5)	(-0.48)
_constant	2.006	1.491	3.833*	3.046	2.958**	2.579
	(1.54)	(1.78)	(2.33)	(1.42)	(3.45)	(1.93)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.164	0.335	0.339	0.345	0.353	0.355
N	662	662	662	662	662	662

*, ** and *** denote significance level at the 10%, 5% and 1% respectively. t-values are reported in parentheses. Refer to table 2 for definitions and measurements of variables

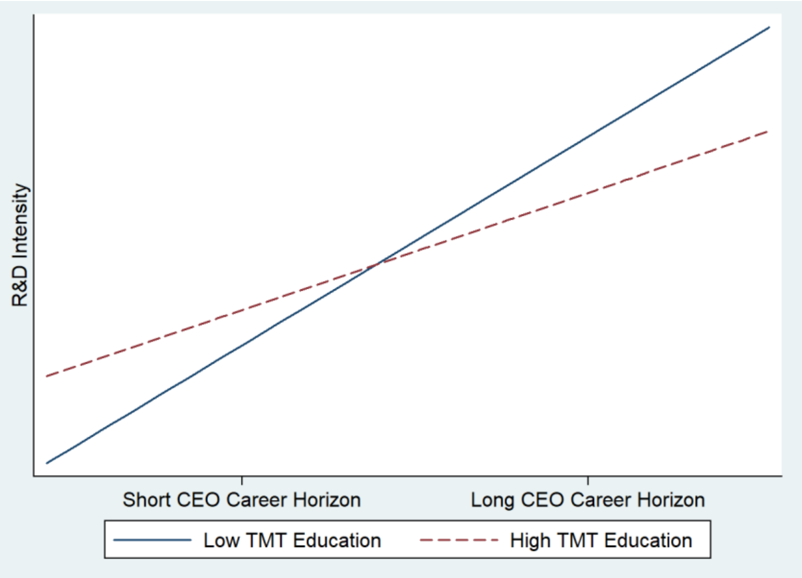

Figure 3: Interaction Effect of CEO career horizon and TMT education on R&D Intensity

5.2.2. Hypothesis 2: Interface of CEO career horizon and TMT age

Table 8 reports the OLS regression result of the interfacing effect between CEO career horizon and TMT age on firm's innovation (proxied by R&D intensity). The average age of the TMT (TMT_AGE) is consistently negatively related to firm's innovation, though it's mostly insignificant across all 5 models (except model 2 – significant at the 5% level, with $\beta = -0.096$, t value = -3.41). The corresponding interaction term CEO_CH x TMT_AGE, which represent the interfacing effect of TMT average age and CEO career horizon on R&D intensity received mixed outcomes. The coefficients are found to be negative and significant at 10% level in model 5 and 6. Whereas it's negative and insignificant in model 3 and 4 instead. Inspecting Figure 4 – representing this interfacing effect, yield contradicting outcome to the hypothesized direction. The plot allure to the conclusion that TMT with higher average age will actually mitigate the horizon problem of late stage CEOs instead of amplifying it. Regarding control variables. Both CEO tenure and firm performance retain its coefficient sign across all analysed model. However, the significant level for firm performance is reduced from mostly at 5% level to 10% in all models.

Tables 13 and 14 also report robustness tests of the influences of TMT age and its interaction with CEO career horizon on firm's R&D investment based on RE and GEE model. Contrast to the results found in baseline models. TMT Age is found to be consistently positive and significant for GEE estimation. For the RE estimations, model 2 and 3 are positive significant at the 5% level, model 10 is significant at the 10% level while the rest (model 1, 4 and 5) are positive but insignificant. The positive results contrast those found in relevant TMT research such as Liu et al (2012), Heyden et al (2017), Tanikawa and Jung (2016) and conform with Lee et al (2007). A possible explanation is that the firm chosen in this study belong to high-tech aggregate, which is comparable to the biotech and pharmaceutical firms used by Lee et al (2007). Older TMT members who work the high-tech field drive by constant learning to stay up to date are less likely to subjected to the increasing risk averse phenomenon experienced by senior managers from other lower-tech industries. Next, the interaction coefficients CEO_CH x TMT AGE, which represent the interface effects of CEO career horizon and TMT age, are found to be universally negative across all analysed models. However, the significant level differs significantly based on estimation methods. The coefficient is non-significant in model 3 and 4 in the baseline results and significant at 10% level for model 5 and 6. For RE estimations, the coefficients are highly significant in both model 2 and 6, in which the interaction term is incorporated. GEE estimations found supporting evidence in favour of RE outcomes, in which both interaction coefficients in model 2 and 6 are found to be negative, but non-significant instead. Inspecting the relevant interaction plots (Figure 4, 7 and 11) further solidified this divergence in conclusion. The plot in figure 4 – represent the baseline result, found that TMT with higher average age will mitigate CEO's horizon problem, whereas according to figure 7 and 11, TMT with lower average age will mitigate the curtailment of R&D when interfacing with late stage career CEOs. Due to the mixed findings under different estimation techniques, the evidences found is considered inconclusive, thus hypothesis 2 cannot be supported.

Table 8: Interfacing effect of CEO-TMT age on firm innovation – OLS regression

	R&D intensity					
Model	**1**	**2**	**3**	**4**	**5**	**6**
CEO_CH		0.03	0.313	0.384	0.395*	0.432*
		(2.68)	(1.92)	(1.92)	(2.65)	(2.63)
TMT_AGE		-0.096**	-0.025	-0.01	-0.008	-0.001
		(-3.41)	(-0.43)	(-0.14)	(-0.12)	(0.01)
CEO_CH x TMT_AGE			-0.006	-0.007	-0.007*	-0.007*
			(-1.79)	(-1.81)	(-2.32)	(-2.29)
CEO_TENURE	0.026*	0.042*			0.054**	0.045**
	(2.7)	(2.61)			(2.83)	(2.92)
CEO_FD	-1.134	-1.196		-1.926		-1.409
	(-0.9)	(-0.91)		(-1.10)		(-0.99)
FIRM_AGE	-0.013	0.012	-0.006	0.015	-0.006	-0.009
	(-0.25)	(0.24)	(-0.09)	(0.27)	(-0.10)	(0.18)
FIRM_SIZE	0.64	0.621	0.692	0.756	0.703	0.748
	(0.96)	(0.90)	(0.86)	(0.99)	(1.03)	(1.10)
FIRM_PERFORMANCE	-0.086*	-0.082*	-0.082*	-0.085*	-0.083*	-0.085*
	(-2.55)	(-2.33)	(-2.34)	(-2.41)	(-2.43)	(-2.47)
FIRM_LEVERAGE	-0.993	-0.198	-0.383	-0.169	-0.235	-0.105
	(-0.83)	(-0.13)	(-0.26)	(-0.14)	(-0.15)	(-0.08)
_constant	2.006	4.399*	1.507	-0.568	-0.351	-1.543
	(1.54)	(2.58)	(0.49)	(-0.12)	(-0.12)	(-0.40)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.164	0.192	0.179	0.192	0.196	0.212
N	662	662	662	662	662	662

*, ** and *** denote significance level at the 10%, 5% and 1% respectively. t-values are reported in parentheses. Refer to table 2 for definitions and measurements of variables

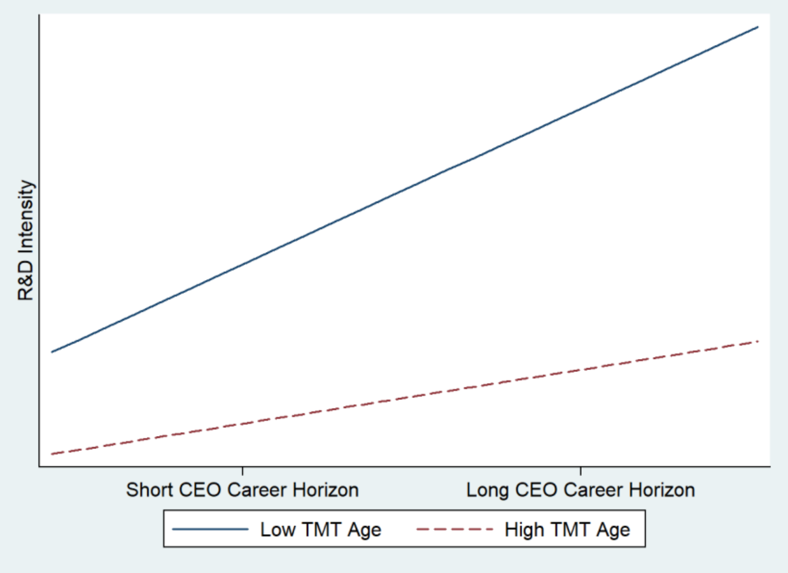

Figure 4: Interaction Effect of CEO Career Horizon and TMT Age on R&D Intensity

5.2.3. Hypothesis 3: Interface of CEO career horizon and TMT tenure

Table 9 represent the OLS regression results of the interfacing effect between CEO career horizon and TMT tenure on firm's innovation (proxied by R&D intensity). TMT_TENURE – represent the average tenure of TMT members, is found to have positive coefficient, but no significant effects on firm's innovation in all 5 models. The interaction term CEO_CH x TMT_TENURE represent the interfacing between the CEO and TMT tenure is incorporated into model 3 to 6. The interaction terms coefficients are negative and significant at the 10% level with very marginal difference (Coefficient of -0.019, -0.018, -0.016, -0.015 and t values of -2.26, -2.31, -2.18, -2.33 respectively). By inspecting the matching interaction plot (Figure 5), it can be seen that the two lines that represent different level of TMT tenure intersected, which strongly suggest an interacting effect between CEO career horizon and TMT average tenure. As CEO career horizon decrease, TMT with higher average tenure is associated with higher level of R&D intensity than TMT with lower average tenure. This observation advocated a rather counterintuitive finding that TMT characterized by lower average tenure actually amplify the horizon problem of CEO with short career horizon to curtail R&D investment instead of alleviating it.

Table 13 and 14 report the robustness tests using RE and GEE estimation technique. TMT tenure coefficients are mostly insignificant with mixed directions across different models. Results from model 1,2,3 and 5 from both tables are negative, whereas it is positive in model 4 and 6 when the corresponding interaction term – CEO_CH x TMT_TENURE is present. Lee et al (2007) also experienced similar mixed results as well regarding TMT tenure. Whereas Camelo-Ordaz et al (2005), Liu et al (2012) found consistent negative influence of TMT Tenure on firm's innovation. Turning into the interaction term, both the results from RE and GEE estimations found negative and significant coefficients, conforming with those found in the baseline models. Despite the mixed results regarding TMT tenure coefficients, all the relevant variables show similar sign across different model specifications (for example, CEO career horizon is persistently positive, while TMT tenure and the interaction term are both negative in model 4 and 6 for both RE and GEE estimations). By inspecting the corresponding interaction plots (Figure 5, 9 and 13), it can be seen that the counterintuitive finding from baseline results is also found in the robustness tests. All the three relevant plots illustrated a significant interaction effect, in which a TMT with high average tenure, when interfacing with late stage CEOs, will exhibit higher commitment to innovation compare to TMT with lower average tenure. From this result, it can be inferred that hypothesis 3 is partially supported, a statistically significant result of the interaction effect is found, however it opposed the hypothesized direction.

Table 9: Interfacing effect of CEO-TMT tenure on firm innovation – OLS regression

	R&D intensity					
Model	**1**	**2**	**3**	**4**	**5**	**6**
CEO_CH		0.111*	0.102	0.099	0.113*	0.111*
		(2.6)	(2.02)	(2.05)	(2.63)	(2.60)
TMT_TENURE		0.156	0.069	0.053	0.022	0.156
		(0.14)	(0.55)	(0.43)	(0.20)	(0.14)
CEO_CH x TMT_TENURE			-0.019*	-0.018*	-0.016*	-0.015*
			(-2.26)	(-2.31)	(-2.18)	(-2.33)
CEO_TENURE	0.026*	0.044*			0.048**	0.044*
	(2.7)	(2.67)			(3.32)	(2.67)
CEO_FD	-1.134	-0.671		-1.122		-0.671
	(-0.9)	(-1.14)		(-1.43)		(-1.14)
FIRM_AGE	-0.013	-0.019	-0.029	-0.016	-0.027	-0.019
	(-0.25)	(-0.36)	(-0.47)	(-0.28)	(-0.47)	(-0.36)
FIRM_SIZE	0.64	0.702	0.697	0.722	0.686	0.702
	(0.96)	(1.39)	(1.21)	(1.31)	(1.34)	(1.39)
FIRM_PERFORMANCE	-0.086*	-0.082**	-0.081*	-0.082**	-0.081**	-0.082*
	(-2.55)	(-2.89)	(-2.74)	(-2.77)	(-2.81)	(-2.76)
FIRM_LEVERAGE	-0.993	-0.524	-0.646	-0.563	-0.567	-0.524
	(-0.83)	(-0.73)	(-0.96)	(-0.90)	(-0.76)	(-0.73)
_constant	2.006	1.023	1.816	1.241	1.328	1.025
	(1.54)	(0.52)	(0.86)	(0.54)	(0.69)	(0.52)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.164	0.236	0.223	0.226	0.235	0.256
N	662	662	662	662	662	662

*, ** and *** denote significance level at the 10%, 5% and 1% respectively. t-values are reported in parentheses. Refer to table 2 for definitions and measurements of variables

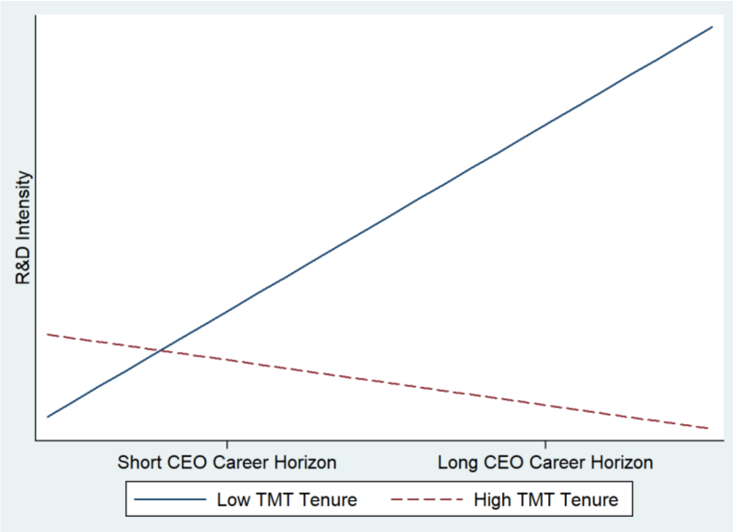

Figure 5: Interaction Effect of CEO Career Horizon and TMT Tenure on R&D Intensity

5.2.4. Hypothesis 4: Interface of CEO career horizon and TMT functional diversity

TMT functional diversity represent the difference of the firm's top manager regarding their functional background. TMT_FD is found to have unanimously positive and significant influence on R&D intensity at the 1% level for model 2,3,5 and 6 (β = 0.099, 0.086, 0.086, 0.082, t values = 4.72, 4.57, 4.56 and 4.16 respectively). The effects of TMT functional diversity on firm's R&D investment can be seen as significant and the magnitude of influence is comparable across all 5 models. The next point of interest is the interaction term CEO_CH x TMT_FD, the coefficient in all 4 models are positive, but marginally different from zero with significant level only at 10% for model 4 and 6 and insignificant for model 3 and 5. Inspecting the corresponding interaction plot (Figure 6) offer a graphical representation of the interfacing effect between CEO career horizon and TMT functional diversity. The two lines that illustrating low and high level of TMT functional diversity are almost parallel, exemplifying a typical no interaction scenario between two variables. Despite robust evidences that suggest TMT functional diversity's positive influences on firm's innovation (proxied by R&D intensity), the evidences regarding the interaction effect refute Hypothesis 4 that TMT with more diverse functional experience will reduce shorter career horizon CEO's inclination toward curtailing R&D investment.

Robustness tests reported in table 13 and 14 included TMT functional diversity as one of the main independent variables. TMT functional diversity posed positive and significant effect that is omnipresent across all analysed models. This result is in line with Bantel and Jackson (1989), Boone et al (2011) and Liu et al (2012), this result substantiates the upper echelon view that functional diverse TMT offer different expertise and perspective toward the problem and offer novel solutions to the problem that homogenous TMT could not achieve. Turning into the interaction term CEO_CH x TMT_FD – representing the interfacing effect, the coefficients and magnitude of influences is reported in model 5 and 6 of table 13 and 14. It can be seen that all four models experienced insignificant coefficient across the board. The coefficient of the interaction is negative in model 6 instead of positive as seen in the remaining 3 models. Therefore, the robustness test does not support hypothesis 4 that TMTs with more diverse functional experience will reduce shorter career horizon CEO's inclination toward curtailing R&D investment. Investigating the relevant interaction plots (Figure 6, 10 and 14), patterns similar to the one in baseline model can be found. The two lines represent different degree of TMT functional diversity are almost parallel.

Table 10: Interfacing effect of CEO-TMT functional diversity on firm innovation – OLS regression

	R&D intensity					
Model	**1**	**2**	**3**	**4**	**5**	**6**
CEO_CH		0.022	-0.065	-0.078	-0.037	-0.067
		(1.65)	(-1.29)	(-1.79)	(-0.73)	(-1.64)
TMT_FD		0.099***	0.086***	0.082**	0.086***	0.082***
		(4.72)	(4.57)	(4.18)	(4.56)	(4.16)
CEO_CH x TMT_FD			0.001	0.002*	0.001	0.001*
			(1.50)	(2.57)	(1.22)	(2.42)
CEO_TENURE	0.026*	0.014			0.025	0.009
	(2.7)	(1.51)			(0.99)	(0.83)
CEO_FD	-1.134	-1.831		-2.159		-2.037
	(-0.90)	(-1.20)		(-1.41)		(-1.44)
FIRM_AGE	-0.013	0.022	0.004	0.029	0.004	0.028
	(-0.25)	(0.71)	(0.08)	(0.93)	(0.09)	(0.89)
FIRM_SIZE	0.64	0.252	0.240	0.297	0.239	0.293
	(0.96)	(0.71)	(0.54)	(0.80)	(0.61)	(0.82)
FIRM_PERFORMANCE	-0.086*	-0.061	-0.060	-0.062	-0.060	-0.062
	(-2.55)	(-1.87)	(-1.78)	(-1.86)	(-1.82)	(-1.88)
FIRM_LEVERAGE	-0.993	-0.310	-0.576	-0.349	-0.497	-0.332
	(-0.83)	(-0.21)	(-0.38)	(-0.26)	(-0.33)	(-0.25)
_constant	2.006	-4.214*	-2.449	-3.675	-2.843*	-3.751*
	(1.54)	(-2.52)	(-2.08)	(-2.10)	(-2.37)	(-2.25)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.164	0.396	0.374	0.365	0.388	0.399
N	662	662	662	662	662	662

*, ** and *** denote significance level at the 10%, 5% and 1% respectively. t-values are reported in parentheses. Refer to table 2 for definitions and measurements of variables

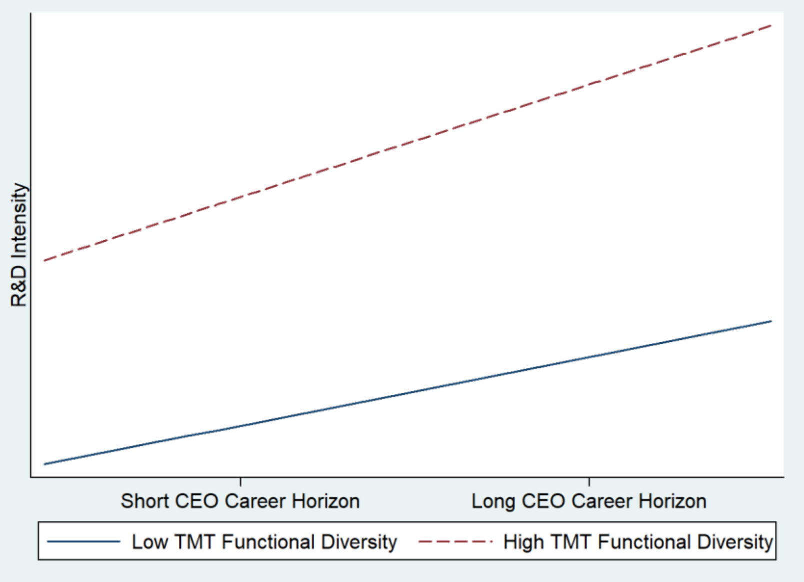

Figure 6: Interaction Effect of CEO Career Horizon and TMT Functional Diversity on R&D Intensity

5.3. Additional analysis

As previously discussed, innovation input and output represent different facet of firm's innovation. Therefore, it is imperative to consider both type of innovation activities to fully capture the impact of the interfacing effect of CEO Career horizon and TMT characteristics on firm's innovation. Therefore, in this section I will carry out the analysis using Patent data as the main dependent variable and compare the result with the baseline model. Additionally, I conduct a split sample analysis between high-tech and medium high-tech industry aggregate based on their NACE Rev. 2 classification to determine whether the interfacing effect diverge from full sample results.

5.3.1 Alternative dependent variable

Table 11 represent the regression result using alternative dependent variable Patent data. The coefficients of CEO career horizon also show mixed results. However, the sign and significant level are largely inconsistent with those from the baseline models. TMT age remain completely insignificant across the board. TME education show mixed direction instead of universally positive in the baseline results. TMT tenure and functional diversity largely follow the influence directions from the baseline results. However, TMT functional diversity is no longer overwhelmingly statistically significant (significant at 10% and 5% level for model 5 and 6 respectively)

Regarding the interaction term. The first interfacing effect CEO_CH x TMT_AGE is negative and insignificant in both model 5 and 6. CEO_CH x TMT_EDUCATION coefficients are both positive and significant. However, the interaction plot (Figure 16) suggested that this result contradict the hypothesized direction of this relationship. Despite the consistent sign and coefficient, the result from this table contradict the one found in baseline models. CEO_CH x TMT_TENURE coefficients are both negative and insignificant, which challenge the results from baseline model. Figure 17 supported this outcome, the two lines represent high and low level of TMT tenure are parallel, suggesting the absence of an interaction effect. CEO_CH x TMT_FD yield some interesting divergence from the baseline results. The coefficient in model 6 is negative and significant at 5% level (t value = -2.93). By inspecting the corresponding plot (Figure 18), a very apparent interaction effect is found. According to this model, more functional diverse TMT when interfacing with shorter career horizon CEO will result in higher amount of patent filed compare to more functional homogenous TMT.

Table 11: Impact of executive's characteristics and CEO-TMT interface on firm's innovation - Alternative dependent variable

	Patent					
Model	**1**	**2**	**3**	**4**	**5**	**6**
CEO_CH	-0.022*	0.001	-0.079**	-0.018	0.019	-0.026
	(-2.29)	(0.01)	(-4.34)	(-1.25)	(1.06)	(-0.36)
TMT_AGE	-0.003	0.003	0.001	-0.003	-0.003	0.003
	(-0.46)	(0.1)	(0.13)	(-0.5)	(-0.48)	(0.12)
TMT_EDUCATION	-0.036	-0.037	-0.183**	-0.036	-0.037	-0.239***
	(-1.11)	(-1.04)	(-4.08)	(-1.15)	(-1.13)	(-4.82)
TMT_TENURE	-0.015	-0.015	-0.014	-0.005	-0.016	-0.016
	(-1.66)	(-1.59)	(-1.57)	(-0.16)	(-2.03)	(-0.74)
TMT_FD	0.146	0.157	0.264	0.139	0.961*	1.728**
	(0.29)	(0.29)	(0.49)	(0.28)	(2.44)	(3.9)
CEO_CH x TMT_AGE		-0.000				-0.000
		(-0.21)				(-0.04)
CEO_CH x TMT_EDUCATION			0.012**			0.016**
			(4.07)			(3.98)
CEO_CH x TMT_TENURE				-0.001		-0.000
				(-0.31)		(0.01)
CEO_CH x TMT_FD					-0.068	-0.118**
					(-1.87)	(-2.93)
CEO_TENURE	-0.016	-0.016	-0.017	-0.017	-0.014	-0.014
	(-1.63)	(-1.72)	(-1.82)	(-1.44)	(-1.47)	(-1.51)
CEO_FD	0.261	0.248	0.213	0.28	0.356	0.358
	(0.64)	(0.61)	(0.6)	(0.65)	(0.8)	(0.83)
FIRM_AGE	-0.221***	-0.221***	-0.219***	-0.221***	-0.224***	-0.223***
	(-12.45)	(-12.96)	(-13.03)	(-12.94)	(-11.88)	(-13.09)
FIRM_SIZE	0.664*	0.671*	0.668*	0.664*	0.646*	0.638*
	(2.37)	(2.62)	(2.29)	(2.4)	(2.38)	(2.35)
FIRM_PERFORMANCE	0.005	0.005	0.004	0.006	0.006*	0.004*
	(1.76)	(2.08)	(1.45)	(1.78)	(2.25)	(2.15)
FIRM_LEVERAGE	-1.278***	-1.272***	-1.353**	-1.26**	-1.268***	-1.363**
	(-4.39)	(-4.04)	(-4.37)	(-4.05)	(-4.82)	(-4.12)
_constant	19.05***	18.7***	19.35***	19.02***	18.89***	19.13***
	(7.28)	(6.45)	(6.89)	(7.49)	(7.58)	(6.23)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.092	0.091	0.091	0.092	0.093	0.093
N	662	662	662	662	662	662

*, ** and *** denote significance level at the 10%, 5% and 1% respectively. t-values are reported in parentheses. Refer to table 2 for definitions and measurements of variables

5.3.2 Split sample analysis – High vs Medium high tech

Table 12 report the split sample results of high tech versus medium high-tech aggregate. Consistently with previous results, TMT functional diversity is positive and significantly related to R&D intensity. TMT education is highly significant in base model with no interaction effect. However, when the interaction term is introduced, it loses its significant level considerably, especially between model 1 and 2. Turning into the main interest – the interaction term. It can be seen that, for high tech sample, there is a significant interfacing effect between CEO career horizon and TMT education. For medium high-tech sample, the interfacing effect between CEO career horizon and TMT functional diversity is more prevalent. By investigating the corresponding interaction plot from figure 19, it can be inferred that high education TMT actually amplify the curtailing tendency of short career horizon CEO instead of mitigating it for the high-tech industry. Figure 20 was more difficult to interpret, as the interaction is a lot less apparent. However, the plot allure to a counterintuitive finding that less functional diverse TMT actually reduce the curtailing tendency of short career horizon CEO. Regarding control variables, almost all of the coefficients are statistically insignificant. The most notable result lies in firm performance, in which all the coefficients across all 4 models are negatively related to R&D intensity. The significance level is retained for the high-tech sub-sample, whereas comparable influences wasn't found on the results of medium-high tech sub-sample. It can be inferred that high-tech firms are more inclined to maintain their current strategy should they proved to work under said circumstances.

Table 12: Impact of executive's characteristics and CEO-TMT interface on firm's innovation – Split sample (Dependent variable: R&D Intensity)

	High tech		Medium high tech	
Model	**1**	**2**	**3**	**4**
CEO_CH	0.038	0.172	-0.000	0.188
	(1.27)	(0.59)	(-0.06)	(1.00)
TMT_AGE	0.088*	0.155	-0.429*	0.012
	(1.83)	(1.27)	(-1.96)	(0.28)
TMT_EDUCATION	0.653***	0.049	0.171***	0.262*
	(4.84)	(1.05)	(3.04)	(1.89)
TMT_TENURE	-0.106**	-0.035	-0.006	0.006
	(-1.9)	(-1.65)	(-0.27)	(0.1)
TMT_FD	0.967***	0.127**	0.637***	0.438***
	(6.11)	(3.18)	(7.33)	(3.6)
CEO_CH x TMT_AGE		-0.004		-0.004
		(-0.96)		(-1.39)
CEO_CH x TMT_EDUCATION		0.043**		-0.007
		(2.04)		(-0.7)
CEO_CH x TMT_TENURE		-0.005		-0.002
		(-1.5)		(-0.43)
CEO_CH x TMT_FD		-0.159		-0.166**
		(-1.21)		(2.00)
CEO_TENURE	-0.002	-0.019	0.006	-0.001
	(-0.06)	(-1.16)	(0.42)	(-0.09)
CEO_FD	-3.302*	-0.373	0.759	0.382
	(-2.08)	(-1.96)	(1.48)	(0.68)
FIRM_AGE	-0.028	0.007	0.169	0.017
	(-0.64)	(0.13)	(0.93)	(0.86)
FIRM_SIZE	0.467	0.423	-0.181	-0.057
	(0.91)	(0.87)	(-0.98)	(-0.30)
FIRM_PERFORMANCE	-0.092***	-0.09**	-0.009	-0.011
	(-5.01)	(-3.86)	(-1.17)	(-1.38)
FIRM_LEVERAGE	-1.03	-0.918	-0.259	-0.186
	(-0.72)	(-0.42)	(-0.35)	(-0.25)
_constant	-5.62*	-10.16	3.69	-2.74
	(-2.53)	(-1.96)	(0.15)	(-0.82)
Year Dummy	Yes	Yes	Yes	Yes
Adjusted R^2	0.026	0.093	0.035	0.056
N	329	329	333	333

*, ** and *** denote significance level at the 10%, 5% and 1% respectively. t-values are reported in parentheses. Refer to table 2 for definitions and measurements of variables

6. CONCLUSION

6.1. Findings and discussions

This thesis investigates the effect of CEO-TMT interface on the firm's innovation proxied by R&D intensity. The result of OLS regression found a significant interfacing effect portraying in Figure 3, which provide evidence to support hypothesis 1. This outcome substantiates the upper echelon perspective on TMT education. In which highly educated TMT possess superior cognitive capabilities/problem solving skills, more open toward changes and willing to take risks in pursuit of novel ideas. Their forward thinking and future oriented tendencies offer late stage career CEOs with alternative solutions and more comprehensive understanding of the ongoing situation, encourage them not to curtail R&D investment and firm's innovation activities in pursuit of personal welfare and preservation of their prestige. Figure 4, which portray the interfacing between CEO career horizon and TMT Age, illustrated a very apparent interaction effect. However, the coefficient in the OLS model is non-significant, refute hypothesis 2 that TMT characterized by lower average age will mitigate. The interfacing effect of TMT tenure is recorded in Figure 5 suggest a counterintuitive outcome that challenge hypothesis 3. This result is also documented in the study of Heyden et al (2017), in which they also found high tenured TMT tend to mitigate the horizon problem of CEO instead of low tenured TMT. Despite the universal positive relation with R&D intensity, TMT functional diversity is found to have no effect on mitigating the horizon problem of late stage CEO, both the coefficient in the baseline models and interaction plot in figure 6 substantiate this outcome.

Two estimating methods is incorporated as the mean to assess the reliability of the baseline model. Overall, the interaction results found in the 3 estimating methods are comparable. With interaction term of TMT education and Tenure follow closely to the results found in the baseline model. The most notable divergence is the interaction term of TMT Age found in Random Effect models. The coefficient was negative and significant. Inspecting the corresponding interaction plot yield result that support hypothesis 2 that lower TMT age will reduce the tendencies of short career horizon CEO to curtail R&D investment. However, the results from baseline models and GEE suggested an insignificant interfacing effect. Hence the reliability of RE model's outcomes are not guaranteed.

Additional analysis was conducted using alternative dependent variable and a split sample analysis. Using patent as the dependent variable, the OLS regression found results that are significantly different from those obtain from the baseline models. TMT characterized by lower education and higher functional diversity is found to have significant influence on mitigate Patent curtailing tendencies of short career horizon CEO. The differences do not necessarily challenge the main results. Instead, it illustrates how TMT's influence would differ based on the type of innovation employed. Split sample analysis also found incompatible result. For the high- tech sample, TMT education play an integral part in mitigate the horizon problem of CEO, whereas TMT functional diversity is the more prevalent element for the medium-high tech sample

To finalized this study, the research question: *What are the influences of CEO-TMT interface on CEO's R&D investment decision in German high-tech firms?* Can be answered as follow: TMT characterized by high level of education and high average tenure will help reducing the tendency of short career horizon CEO to reduce R&D investment of German high-tech manufacturing firms. The interfacing effect of the two aforementioned TMT characteristics prevail under different method of estimation lend strong supports to its reliability. Whereas the interfacing effect of TMT age and functional diversity met with mixed or insignificant results. Moreover, this study substantiates upper echelon theories regarding executive's influences on firm's innovation and contributes empirical results to CEO-TMT interface studies. Specifically, on firm's innovation, in which empirical evidences are particularly scarce.

6.2. Limitations and recommendations

Although the outcomes of this study provide some interesting insights, it is important to identify its shortcomings. The first limitation lies in the geographical context of this study. The studied firms are all German firms, which belong to a very specific legal and national system. Therefore, the generalization of outcomes from this study to different demographic setting very unlikely. Secondly, the conceptualization of certain variables can influence the result, especially TMT functional diversity. As Bunderson and Sutcliffe (2002) mentioned 3 different conceptualizations to TMT functional diversity, which explain the conflicting empirical results. Thirdly, only four TMT characteristics are incorporated into the study, which leave out some potentially important characteristics such as TMT power distribution that was discussed in the literature review. Fourthly, the operationalization of who belong to the TMT in this thesis imply that the results appeal mostly to studies that pursuit the interfacing effect at the very top level (executive level). Therefore, it is advisable to utilize empirical results from this study very carefully. Finally, part of the final data is manually collected through firm's annual reports and press releases. Therefore, the data is not completely free from incorrect input.

Beside the limitations, some recommendations are suggested to further the researches in this direction. First, as Hambrick (2007) noted, study of executive's characteristics will yield different results in different institutional and national system. Therefore, it is useful to conduct the research in different setting to see how it influences the outcomes. Second, the study of CEO-TMT interface can be expanded by utilizing different CEO characteristics such as CEO compensation or CEO confidence. Each of those CEO characteristics are unique and will yield profound results that can advance the studies of CEO-TMT interface. Third, future researchers can utilize different proxies for firm's innovation such as the rate of new product development, number of new products introduced instead of R&D intensity. Fourth, the two-tier board system, which is mandatory in Germany make it easier to analyse the CEO-TMT interface. The CEO-TMT interaction is much less apparent in unitary board system, in which both the executive and non-executive directors are working together. This challenge called for empirical study in such setting. Fifth, subsequent studies can consider incorporate lower level executives into the TMT to see if the influences of CEO-TMT interface on firm's innovation remain consistent. Finally, CEO-TMT interface studies often resort to CEO interview as the mean to determine who constitute the TMT. This cause inconsistent result across studies due to unclear TMT constitution because CEOs often have different perspective on which executive belong to the TMT. Developing a robust and well-accepted TMT definition can reconcile previous mixed findings, enabling future studies to be more comparable.

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Appendixes

Appendix 1: Collinearity diagnostics

Variable	VIF	1/VIF
CEO_CH	1.95	0.51
TMT_AGE	1.80	0.56
TMT_EDUCATION	1.16	0.86
TMT_TENURE	1.82	0.55
TMT_FD	1.09	0.92
CEO_TENURE	2.07	0.48
CEO_FD	1.31	0.77
FIRM_AGE	1.20	0.83
FIRM_SIZE	1.17	0.86
FIRM_PERFORMANCE	1.19	0.84
FIRM_LEVERAGE	1.10	0.91

Appendix 2: Panel Data assumption diagnostic

Wooldridge test for autocorrelation of panel data

H_0: No first order autocorrelation	
F (1, 60) =	9.195
Prob > F =	0.0036

Modified Wald test for groupwise heteroskedasticity in fixed effect regression model

H_0: sigma(i)^2 = sigma^2 for all i	
F (1, 62) =	10420.95
Prob > F =	0.000

Appendix 3: Durbin-Wu-Hausman test

	Coefficient			
	(b) FE	**(B) RE**	**(b-B) Difference**	**Sqrt(diag(V_b-V_B))**
CEO_CH	0.083	0.072	0.011	0.024
TMT_AGE	0.093	0.094	-0.001	0.008
TMT_EDUCATION	0.118	0.143	-0.244	0.014
TMT_TENURE	0.029	0.026	0.003	0.011
TMT_FD	0.076	0.075	0.001	0.002
CEO_CH x TMT_AGE	-0.002	-0.002	0.000	0.000
CEO_CH x TMT_EDUCATION	0.026	0.026	0.000	0.000
CEO_CH x TMT_TENURE	-0.009	-0.009	-0.000	0.000
CEO_CH x TMT_FD	0.000	0.000	0.000	0.000
CEO_TENURE	0.019	0.022	-0.003	0.002
CEO_FD	-0.014	-0.015	-0.001	0.001
FIRM_AGE	-0.014	0.001	-0.015	0.022
FIRM_SIZE	0.274	0.221	0.053	0.145
FIRM_PERFORMANCE	-0.052	-0.051	-0.001	0.001
FIRM_LEVERAGE	-0.51	-0.725	0.215	0.153

b = consistent under H_0 and H_a; obtained from xtreg
B = inconsistent under H_a, efficient under H_0; obtained from xtreg

Test: H_0: Difference in coefficient not systematic

chi2(14) = (b-B)'[(V_b-V_B)^(-1)] (b-B) = 13.35
Prob>chi2 = 0.8957

Appendix 4: Random Effect results

Table 13: Impact of CEO-TMT interface on firm's innovation – Random effects

	R&D Intensity					
Model	**1**	**2**	**3**	**4**	**5**	**6**
CEO_CH	0.018	0.394***	-0.14***	0.088***	-0.051	0.083
	(1.35)	(3.77)	(-2.77)	(4.39)	(-1.06)	(1.22)
TMT_AGE	0.049	0.139**	0.06**	0.043	0.051	0.089*
	(1.31)	(2.37)	(1.47)	(1.16)	(1.39)	(1.67)
TMT_EDUCATION	0.476***	0.462***	0.767	0.474***	0.482***	0.149
	(2.61)	(2.66)	(1.16)	(2.75)	(2.65)	(1.63)
TMT_TENURE	-0.075*	-0.074*	-0.075*	0.091	-0.079*	0.037
	(-1.74)	(-1.74)	(-1.79)	(1.05)	(-1.83)	(0.49)
TMT_FD	0.076**	0.078***	0.079***	0.075***	0.063***	0.079***
	(4.04)	(3.81)	(3.98)	(4.06)	(3.61)	(2.53)
CEO_CH x TMT_AGE		-0.007***				-0.013**
		(-3.45)				(-2.34)
CEO_CH x TMT_EDUCATION			0.030***			0.021*
			(3.07)			(1.69)
CEO_CH x TMT_TENURE				-0.013***		-0.009***
				(-3.42)		(-2.61)
CEO_CH x TMT_FD					0.112	-0.001
					(1.69)	(-0.01)
CEO_TENURE	0.03***	0.032***	0.028***	0.02	0.027**	0.022*
	(2.98)	(3.25)	(2.64)	(1.63)	(2.55)	(1.83)
CEO_FD	-1.194	-1.401	-1.253	-1.01	-1.28	-1.189
	(-0.97)	(-1.08)	(-1.16)	(-0.88)	(-1.11)	(-1.16)
FIRM_AGE	-0.004	-0.005	-0.045	0.005	-0.005	-0.005
	(-0.39)	(-0.44)	(-0.37)	(-0.41)	(-0.36)	(-0.40)
FIRM_SIZE	0.065	0.142	0.079	0.058	0.088	0.100
	(0.39)	(1.02)	(0.53)	(0.44)	(0.53)	(0.83)
FIRM_PERFORMANCE	-0.046*	-0.048**	-0.05**	-0.046**	-0.047*	-0.05**
	(-1.89)	(-2.09)	(-2.03)	(-2.11)	(-1.92)	(-2.23)
FIRM_LEVERAGE	-0.666	-0.586	-0.872	-0.349	-0.695	-0.59
	(-0.56)	(-0.54)	(-0.68)	(-0.31)	(-0.62)	(-0.51)
_constant	-3.654**	-9.1***	-2.482	-4.19**	-3.072*	-5.162*
	(-1.99)	(-2.71)	(-1.57)	(-2.01)	(-1.72)	(-1.84)
Adjusted R^2	0.165	0.181	0.179	0.175	0.181	0.205
N	662	662	662	662	662	662

*, ** and *** denote significance level at the 10%, 5% and 1% respectively. z-scores are reported in parentheses under coefficient estimates. Refer to table 2 for definitions and measurements of variables

Figure 7: Interaction Effect of CEO Career Horizon and TMT Age on R&D Intensity (Random Effect)

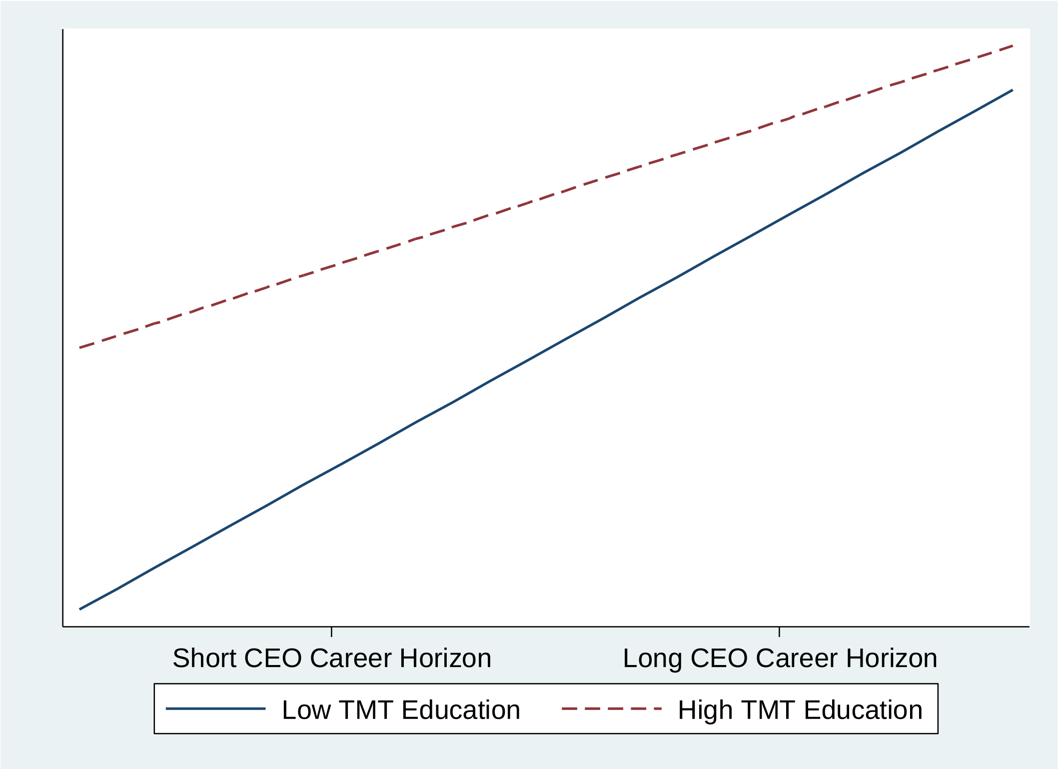

Figure 8: Interaction Effect of CEO Career Horizon and TMT Education on R&D Intensity (Random Effect)

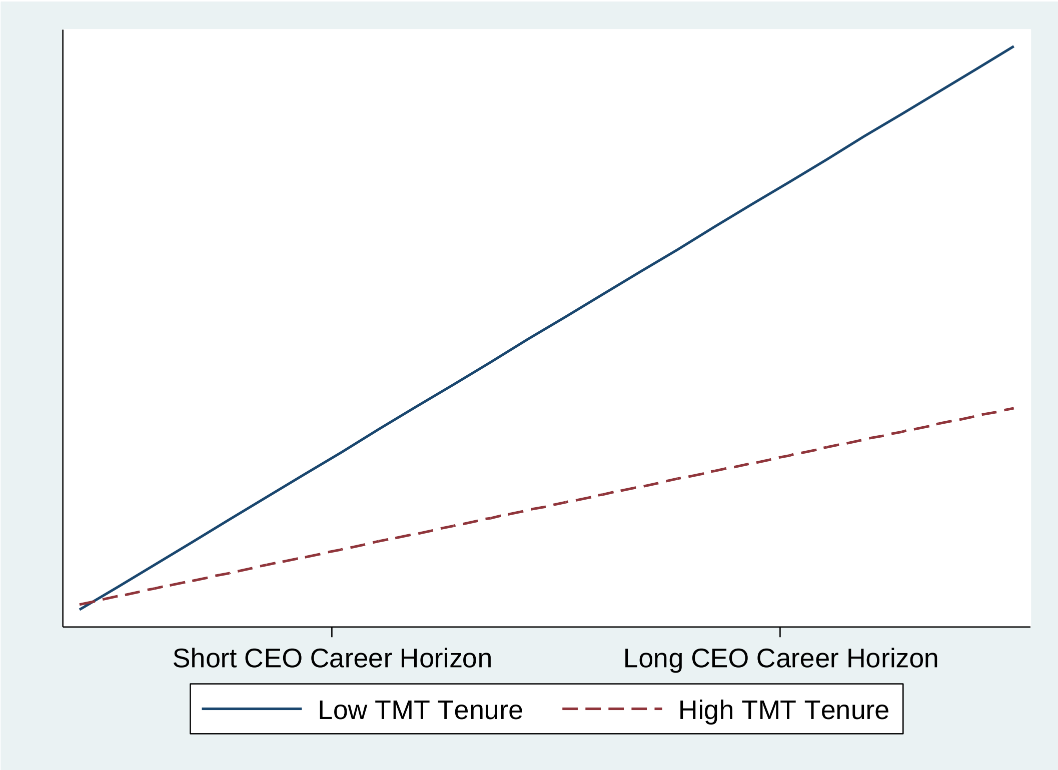

Figure 9: Interaction Effect of CEO Career Horizon and TMT Tenure on R&D Intensity (Random Effect

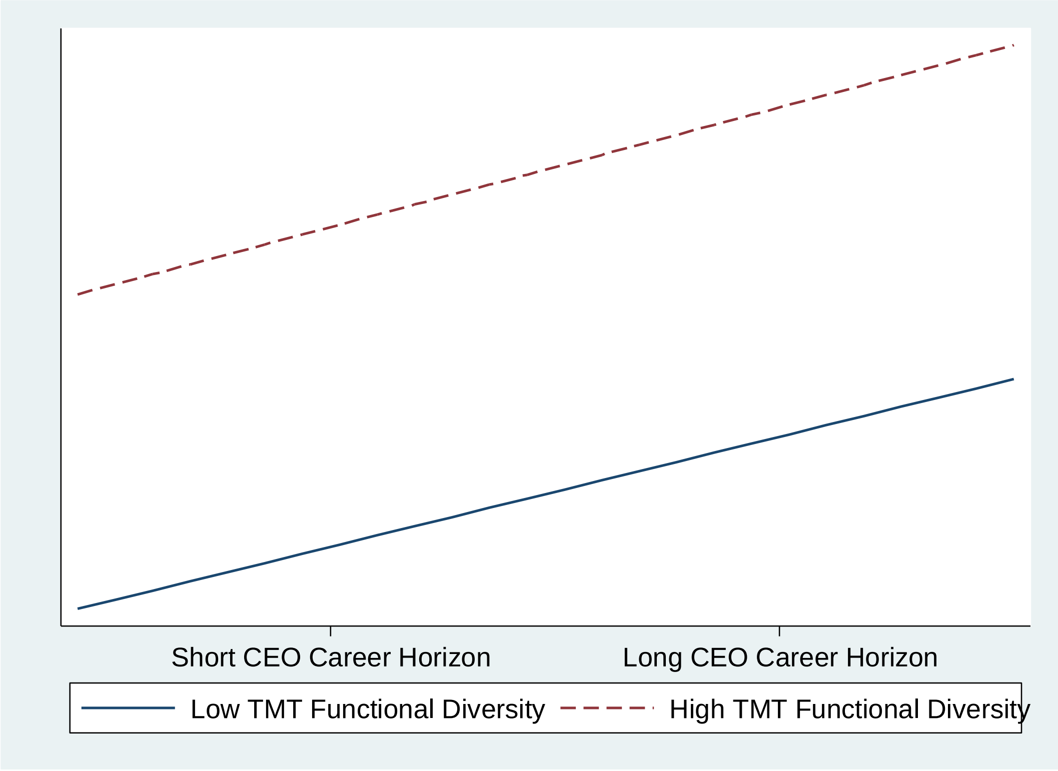

Figure 10: Interaction Effect of CEO Career Horizon and TMT Functional Diversity on R&D Intensity (Random Effect)

Appendix 5: Generalized Estimating Equation results

Table 14: Impact of executive's characteristics and CEO-TMT interface on firm's innovation – GEE

	R&D Intensity					
Model	**1**	**2**	**3**	**4**	**5**	**6**
CEO_CH	0.019	0.394***	-0.142***	0.087***	-0.064	0.071
	(0.01)	(1.14)	(0.05)	(0.02)	(0.05)	(0.16)
TMT_AGE	0.054**	0.144***	0.064***	0.051**	0.054**	0.094**
	(0.02)	(0.04)	(0.02)	(0.02)	(0.02)	(0.04)
TMT_EDUCATION	0.47**	0.456**	0.058	0.473**	0.472**	0.144
	(0.06)	(0.06)	(0.13)	(0.06)	(0.06)	(0.14)
TMT_TENURE	-0.084	-0.083	-0.082	0.081	-0.081	0.025
	(0.03)	(0.03)	(0.03)	(0.05)	(0.03)	(0.06)
TMT_FD	0.075***	0.077***	0.078***	0.074***	0.059***	0.075***
	(0.79)	(0.79)	(0.79)	(0.78)	(1.25)	(1.31)
CEO_CH x TMT_AGE		-0.01				-0.003
		(0.00)				(-0.00)
CEO_CH x TMT_EDUCATION			0.033***			0.026***
			(0.01)			(0.01)
CEO_CH x TMT_TENURE				-0.032***		-0.012**
				(0.00)		(0.01)
CEO_CH x TMT_FD					0.137	0.019
					(0.08)	(0.08)
CEO_TENURE	0.031**	0.032**	0.028*	0.02	0.026*	0.022
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
CEO_FD	-1.114*	-1.323**	-1.257**	-0.817	-1.301**	-1.141*
	(-0.61)	(0.61)	(0.6)	(0.61)	(0.62)	(0.63)
FIRM_AGE	0.001	0.001	0.001	0.002	0.002	0.001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
FIRM_SIZE	0.177	0.25	0.182	0.187	0.196	0.219
	(0.16)	(0.16)	(0.16)	(0.16)	(0.16)	(0.16)
FIRM_PERFORMANCE	-0.047***	-0.05***	-0.052***	-0.047***	-0.047***	-0.052***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
FIRM_LEVERAGE	-0.813	-0.728	-0.998	-0.521	-0.826	-0.739
	(0.78)	(0.77)	(0.77)	(0.77)	(0.77)	(0.77)
_constant	-7.283***	-5.162*	-5.757***	-8.236***	-6.3***	-8.638***
	(2.19)	(1.84)	(2.21)	(2.2)	(2.26)	(3.12)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Wald chi-square	471.16***	484.44***	495.79***	493.38***	495.79***	512.61***
N	662	662	662	662	662	662

*, ** and *** denote significance level at the 10%, 5% and 1% respectively. robust standard errors are reported in parentheses. Refer to table 2 for definitions and measurements of variables

Figure 11: Interaction Effect of CEO Career Horizon and TMT Age on R&D Intensity (GEE)

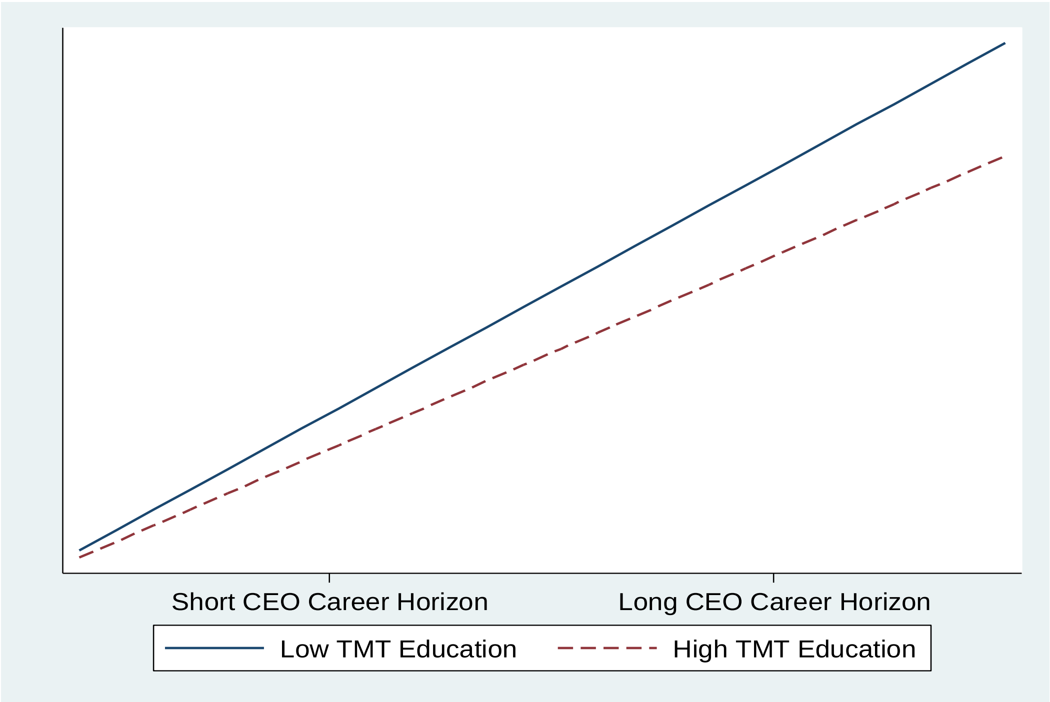

Figure 12: Interaction Effect of CEO Career Horizon and TMT Education on R&D Intensity (GEE)

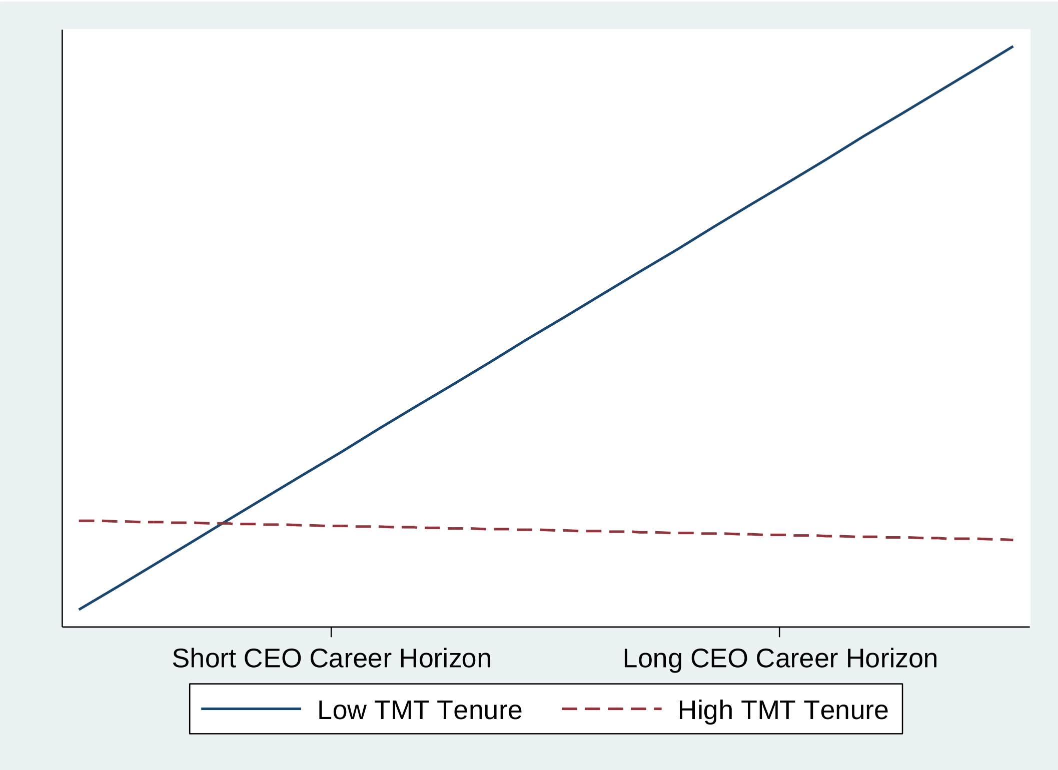

Figure 13: Interaction Effect of CEO Career Horizon and TMT Tenure on R&D Intensity (GEE)

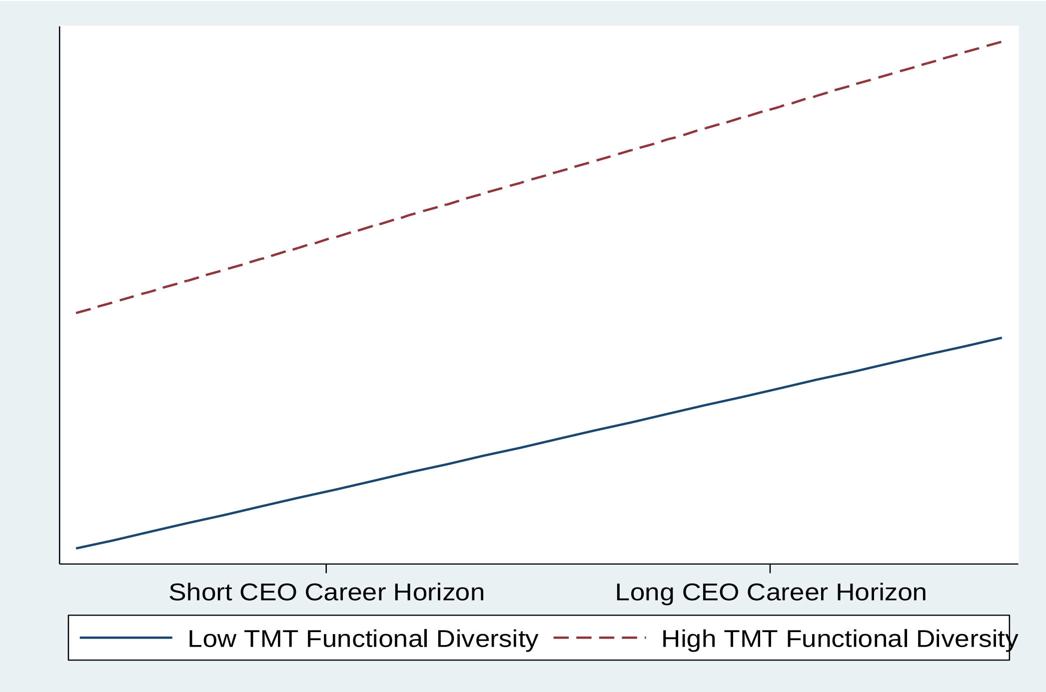

Figure 14: Interaction Effect of CEO Career Horizon and TMT Functional Diversity on R&D Intensity (GEE)

Appendix 6: Interaction Plot – Alternative dependent variable

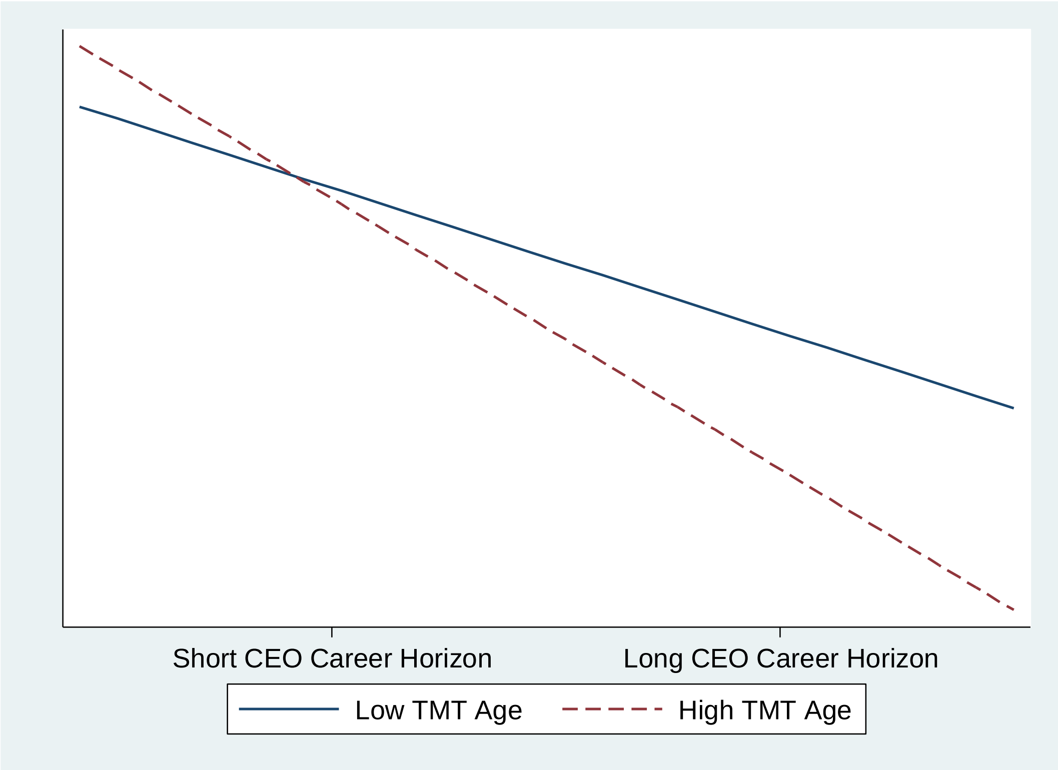

Figure 15: Interaction Effect of CEO Career Horizon and TMT Age on Patent

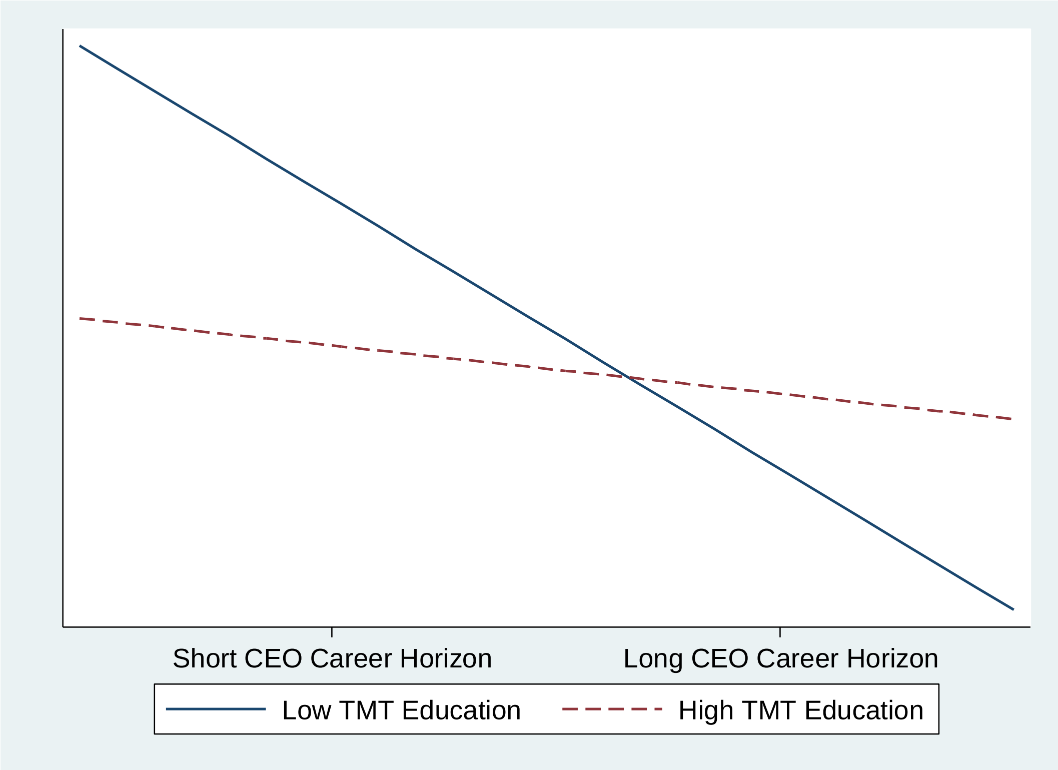

Figure 16: Interaction Effect of CEO Career Horizon and TMT Education on Patent

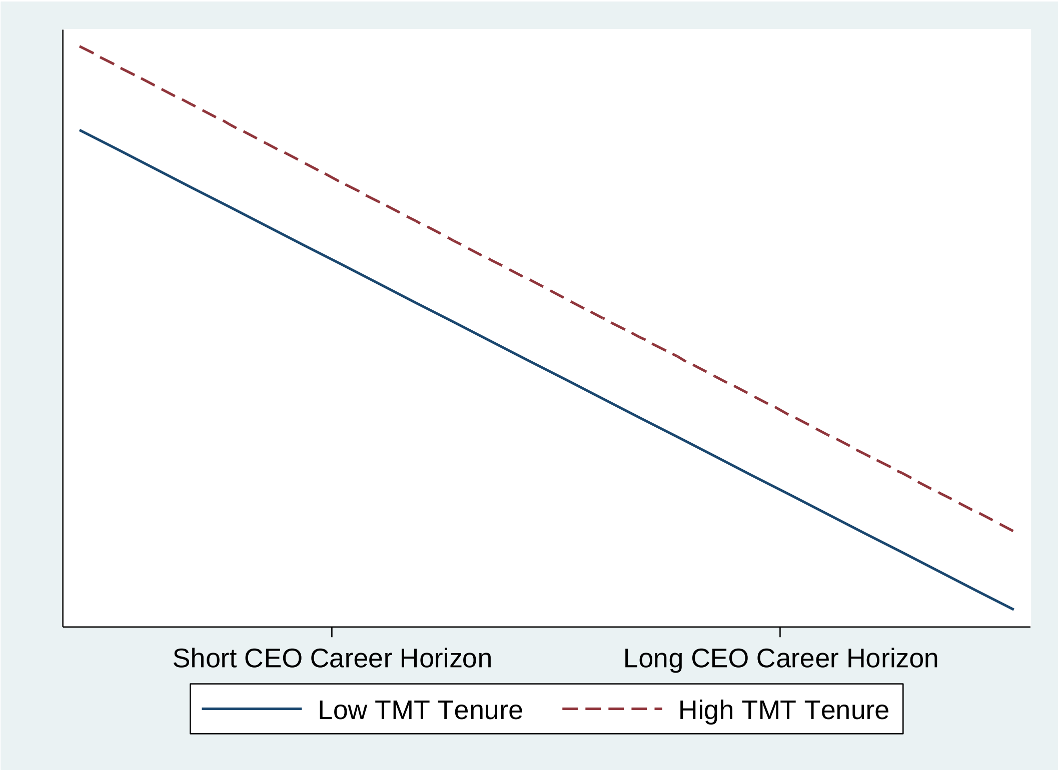

Figure 17: Interaction Effect of CEO Career Horizon and TMT Tenure on Patent

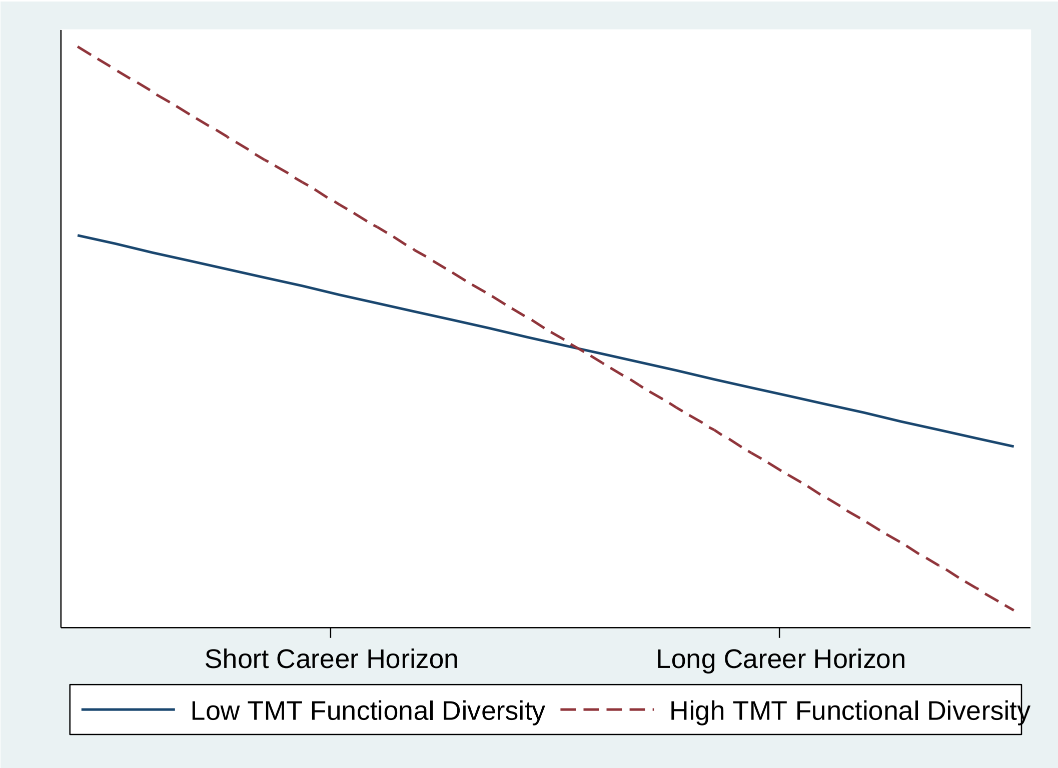

Figure 18: Interaction Effect of CEO Career Horizon and TMT Functional Diversity on Patent

Appendix 7: Interaction plot – Split sample

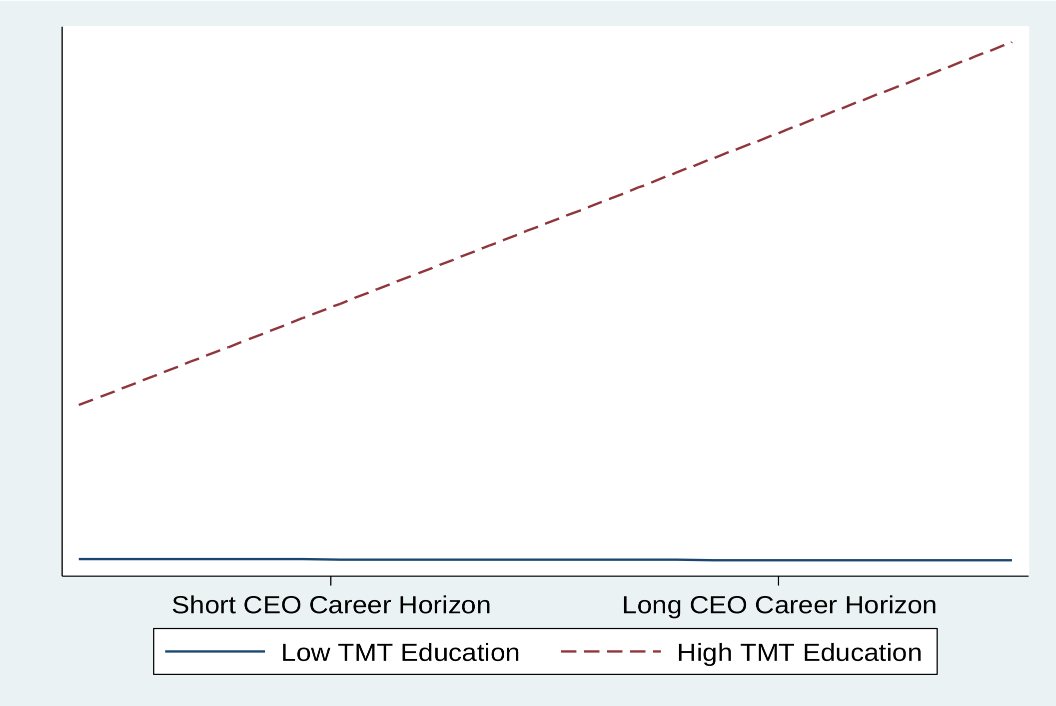

Figure 19: Interaction Effect of CEO Career Horizon and TMT Education on R&D Intensity (High tech sample)

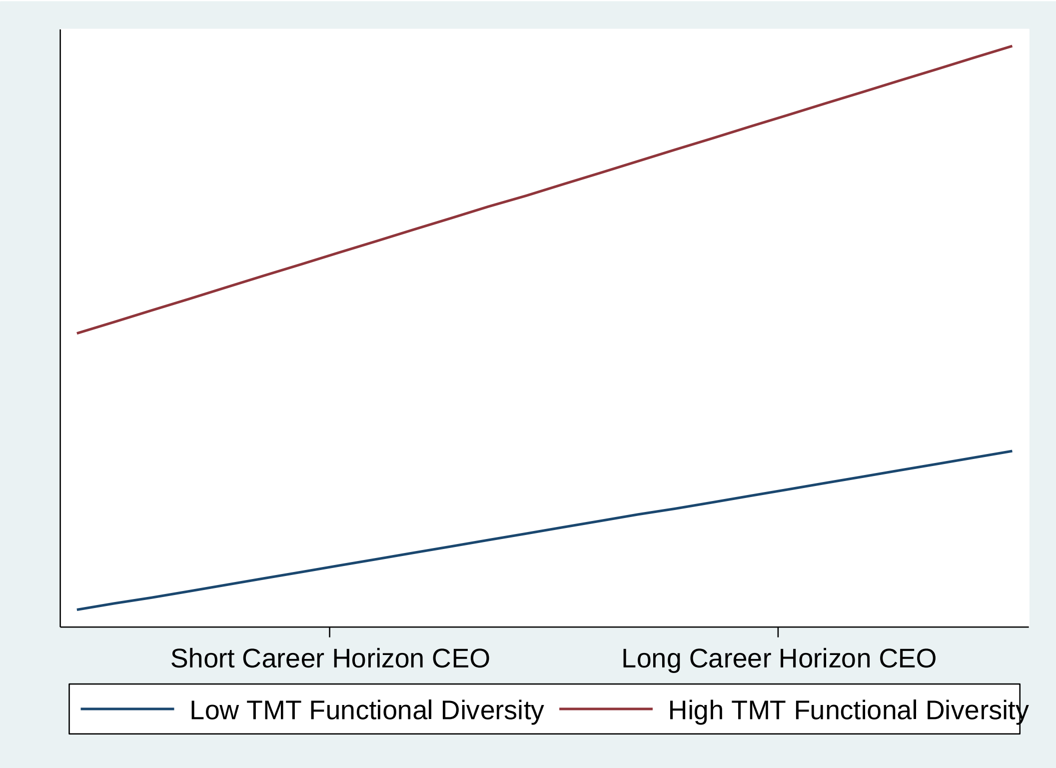

Figure 20: Interaction Effect of CEO Career Horizon and TMT Functional Diversity on R&D Intensity (Medium-high tech sample)

Appendix 8.1: List of sample firms

	Name/Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	2G ENERGY AG	X								
2	ADVA OPTICAL NETWORKING SE									
3	ALTANA AG									
4	AMS AG	X	X							
5	ATTOCUBE SYSTEMS AG									
6	AUTONEUM GERMANY GMBH									
7	BASF SE									
8	BASLER AG									
9	BAUER AKTIENGESELLSCHAFT									
10	BAYER AG									
11	B.BRAUN AVITUM AG									
12	BEIERSDORF AG									
13	BIOTEST AG									
14	CARL ZEISS MEDITEC AG									
15	COVESTRO AG									
16	DATA MODUL AG									
17	DATRON AG									
18	DEUTZ AG									
19	DR. HOENLE AG	X								
20	DRAEGERWERK AG & CO. KGAA									
21	DOCTER OPTICS SE									
22	DUERR AG		X							
23	DVS TECHNOLOGY AG									
24	ECKELMANN AG									
25	ELMOS SEMICONDUCTOR AG									
26	EVONIK INDUSTRIES AG									
27	FIELMANN AG									
28	FRESENIUS MEDICAL CARE AG & CO. KGAA									
29	FRIWO AG									
30	GESCO AG	X								
31	GOERLITZ AG									
32	GREIFFENBERGER AG									
33	HELLA GMBH & CO. KGAA									
34	HENKEL AG & CO.									
35	INDUS HOLDING AG									
36	INFINEON TECHNOLOGIES AG									
37	INIT INNOVATION IN TRAFFIC SYSTEMS SE									
38	ISRA VISION AG									
39	JENOPTIK AG									
40	K+S AKTIENGESELLSCHAFT									
41	KHD HUMBOLDT WEDAG INTERNATIONAL AG									
42	KOENIG UND BAUER AG	X								
43	KRONES AG									
44	KSB SE & CO. KGAA									
45	KUKA AG									
46	LANXESS AG									

47	MAN SE									
48	MANZ AG									
49	MAX AUTOMATION SE									
50	MERCK KGAA	X								
51	MOBOTIX AG									
52	MORPHOSYS AG									
53	NABALTEC AG									
54	OSRAM LICHT AG									
55	PARAGON GMBH & CO. KGAA									
56	PAUL HARTMANN AG		X							
57	PFEIFFER VACUUM TECHNOLOGY AG									
58	PVA TEPLA AG		X							
59	RATIONAL AG									
60	ROBERT BOSCH GMBH									
61	SARTORIUS AG									
62	SFC ENERGY AG									
63	SGL CARBON SE									
64	SIEMENS AG									
65	SINGULUS TECHNOLOGIES AG									
66	STADA-ARZNEIMITTEL AG									
67	STO SE & CO. KGAA									
68	STRATEC SE	X								
69	SYMRISE AG									
70	TECHNOTRANS SE									
71	UZIN UTZ AG		X							
72	WACKER CHEMIE AG									
73	WACKER NEUSON SE									
74	WASHTEC AG									
75	ZF FRIEDRICHSHAFEN AG	X								
	Total	67	70	75	75	75	75	75	75	75

Note: X represent missing firm-year observation of specific firm.

Appendix 8.2: NACE Rev. 2 classification per sample firm

	Name	NACE Rev.2 Classification	NACE Rev.2 Core code (4 digits)	TMT Size
1	2G ENERGY AG	27	2711	3
2	ADVA OPTICAL NETWORKING SE	26	2630	3
3	ALTANA AG	21	2120	8
4	AMS AG	26	2611	3
5	ATTOCUBE SYSTEMS AG	26	2651	2
6	AUTONEUM GERMANY GMBH	20	2059	5
7	BASF SE	20	2059	5
8	BASLER AG	26	2670	3
9	BAUER AKTIENGESELLSCHAFT	28	2892	3
10	BAYER AG	21	2120	4
11	B.BRAUN AVITUM AG	26	2651	6
12	BEIERSDORF AG	20	2042	6
13	BIOTEST AG	21	2120	2
14	CARL ZEISS MEDITEC AG	26	2670	2
15	COVESTRO AG	20	2014	3
16	DATA MODUL AG	26	2620	6
17	DATRON AG	28	2829	4
18	DEUTZ AG	28	2811	2
19	DR. HOENLE AG	27	2711	2
20	DRAEGERWERK AG & CO. KGAA	26	2651	4
21	DOCTER OPTICS SE	26	2670	5
22	DUERR AG	28	2899	3
23	DVS TECHNOLOGY AG	28	2849	2
24	ECKELMANN AG	26	2651	3
25	ELMOS SEMICONDUCTOR AG	26	2611	3
26	EVONIK INDUSTRIES AG	20	2059	3
27	FIELMANN AG	26	2670	3
28	FRESENIUS MEDICAL CARE AG & CO. KGAA	26	2660	7
29	FRIWO AG	27	2720	3
30	GESCO AG	28	2829	2
31	GOERLITZ AG	26	2620	6
32	GREIFFENBERGER AG	28	2829	2
33	HELLA GMBH & CO. KGAA	27	2740	3
34	HENKEL AG & CO.	20	2041	5
35	INDUS HOLDING AG	28	2892	3
36	INFINEON TECHNOLOGIES AG	26	2611	3
37	INIT INNOVATION IN TRAFFIC SYSTEMS SE	26	2651	5
38	ISRA VISION AG	28	2829	5
39	JENOPTIK AG	26	2670	8
40	K+S AKTIENGESELLSCHAFT	20	2015	2
41	KHD HUMBOLDT WEDAG INTERNATIONAL AG	28	2892	4
42	KOENIG UND BAUER AG	28	2899	5
43	KRONES AG	28	2899	4
44	KSB SE & CO. KGAA	28	2813	3
45	KUKA AG	28	2899	2

46	LANXESS AG	20	2016	4
47	MAN SE	28	2829	3
48	MANZ AG	26	2611	2
49	MAX AUTOMATION SE	28	2829	3
50	MERCK KGAA	21	2120	3
51	MOBOTIX AG	27	2790	2
52	MORPHOSYS AG	28	2899	2
53	NABALTEC AG	20	2016	2
54	OSRAM LICHT AG	27	2740	2
55	PARAGON GMBH & CO. KGAA	26	2611	2
56	PAUL HARTMANN AG	21	2120	3
57	PFEIFFER VACUUM TECHNOLOGY AG	28	2813	2
58	PVA TEPLA AG	28	2899	3
59	RATIONAL AG	27	2751	2
60	ROBERT BOSCH GMBH	28	2824	4
61	SARTORIUS AG	26	2651	3
62	SFC ENERGY AG	26	2611	2
63	SGL CARBON SE	27	2790	2
64	SIEMENS AG	28	2811	4
65	SINGULUS TECHNOLOGIES AG	28	2899	2
66	STADA-ARZNEIMITTEL AG	21	2120	2
67	STO SE & CO. KGAA	20	2030	3
68	STRATEC SE	26	2660	2
69	SYMRISE AG	20	2059	4
70	TECHNOTRANS SE	28	2899	3
71	UZIN UTZ AG	20	2052	3
72	WACKER CHEMIE AG	26	2611	3
73	WACKER NEUSON SE	28	2892	2
74	WASHTEC AG	28	2899	2
75	ZF FRIEDRICHSHAFEN AG	28	2815	6

Consolidation code description based on RAMON (Reference And Management Of Nomenclatures)[ii] from Eurostat. 2nd column represent the main classification of firm, 3rd column represent classification code of firm's main activity. For further description of firm's core activity, consult the link on footnote.

Classification codes of sample firm:

21: Manufacture of basic pharmaceutical products and pharmaceutical preparations
26: Manufacture of computer, electronic and optical products
20: Manufacture of chemicals and chemical products
27: Manufacture of electrical equipment
28: Manufacture of machinery and equipment

ii https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2&StrLanguageCode=EN&IntPcKey=18496334&StrLayoutCode=