
The linkage between TMT knowledge diversity and firm-level innovation: the role of organisational search scope and managerial discretion

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Abstract: In this study, we develop a new perspective on the linkage between the knowledge base of the top management team (TMT) and innovation performance. Using longitudinal data on the patent activities of 120 firms in US manufacturing industries, we find that the knowledge diversity based on a TMT's prior experiences affects organisational innovation. Specifically, firms can achieve greater innovativeness if their top teams have a higher degree of knowledge diversity, i.e., a more generalised knowledge base. In addition, the degree of organisational search scope positively moderates this linkage between TMT knowledge diversity and firm innovation. In addition, we also found that the degree of managerial discretion at the industry level enhances the linkage between TMT knowledge diversity and firm innovation.

Keywords: top management team; TMT; knowledge diversity; search behaviour; managerial discretion; innovativeness.

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1 Introduction

Organisational scholars have long argued that firm-specific knowledge is a key asset in sustaining a competitive advantage (Bahra, 2001; Boisot, 1998; Doz et al., 2001; Von Krogh et al., 2000). Because firm-specific knowledge cannot easily be replicated or substituted, it can serve as a valuable source of competitive advantage (Helfat, 1994) and competence (Teece, 2000). Because organisational knowledge is held and maintained at the individual level (Argyris and Schön, 1978; Nonaka and Takeuchi, 1995), previous researchers have argued that firms need to cultivate, protect, and leverage their firm-specific human assets to enhance competitiveness (Chakravarthy et al., 2003; Grant, 1996). Drawing from this literature, in this paper, we focus on the top management team (TMT) as a critical embodiment of these knowledge assets. Members of the TMT play a pivotal role in organisational decision-making; in fact, a substantial body of research indicates that TMTs have a significant impact on their organisation's processes and outcomes (Hambrick, 1994, 2005; Hambrick and Mason, 1984; Tushman et al., 1985). In particular, TMTs play an instrumental role in driving firm innovation (Bantel and Jackson, 1989; Jehn et al., 1999; Pegels et al., 2000; Wiersema and Bantel, 1992). Indeed, the senior executives of a TMT exercise authority and formulate and implement strategies that are relevant for organisational innovativeness (Barker and Mueller, 2002; Zahra and Pearce, 1989).

In recent years, researchers have been increasingly interested in linking the cognition of TMTs with firm-level innovation (Choi et al., 2011; Hodgkinson and Sparrow, 2002; Lant and Shapira, 2001; Miller et al., 1998; Rodan and Galunic, 2004; Tegarden et al., 2009). Among the different processes that have been found to be relevant in this linkage is the role of the knowledge diversity of the TMT (Kilduff et al., 2000; Knight et al., 1999; Rodan and Galunic, 2004), which refers to the heterogeneity of the background knowledge, know-how, and expertise gained through prior experience (Rodan and Galunic, 2004). TMT's knowledge diversity, which is based on the members' prior work experience, influences the decision-making and information processing of their firms (Baty et al., 1971; Hambrick and Mason, 1984; Kraatz and Moore, 2002; Sørensen, 1999). This is mainly because the TMT's knowledge diversity is associated with a broadened pool of cognitive resources, which, in turn, determines their attention patterns, strategic choices, and reorientation (Cho and Hambrick, 2006). We also believe that knowledge diversity influences the process and the level of sharing and creating knowledge within the top team (MacCurtain et al., 2010; Smith et al., 2005), problem-solving competencies (Jehn and Mannix, 2001; Gatignon and Xuereb, 1997), and, ultimately, the level of innovation performance at the firm level. Despite the importance of TMT knowledge diversity, however, researchers have not yet addressed the relationship between knowledge diversity at the top team level and the technological innovation of the firm.

In this study, we examine the effects of the TMT's knowledge diversity, which is defined as the degree of heterogeneity in industry experience, on firm-level innovation. Prior studies have usually examined diversity using the functional background (e.g., Cohen and Bailey, 1997; Monge and Eisenberg, 1987), the educational background (e.g., Carpenter and Fredrickson, 2001; Wiersema and Bantel, 1992), or demographic characteristics, such as age diversity or gender diversity (e.g., Ruiz-Jiménez et al., 2016; Yoon et al., 2015). However, previous researchers have found that recognising technological opportunities and developing technologies are driven primarily by industrial background, rather than by functional experience or academic major (Shane, 2000). Hence, in this study, we chose to focus on the prior industry experience of the top executives in gauging the degree of TMT-level knowledge diversity. Although previous studies, such as Bantel and Jackson (1989), have considered the various types of demographic heterogeneity of TMTs, our study, to date, would be the first to test the impact of knowledge diversity in industry experience on the firm's innovation performance.

In pursuing our theoretical query on the linkage between TMT knowledge diversity and firm-level innovation, we also consider two factors that are expected to moderate the relationship: the scope of organisational search and managerial discretion. First, organisational search scope is a crucial factor that affects the organisational processes of creation, the recombination of novel ideas (Nelson and Winter, 1982), and innovation outcome (Katila and Ahuja, 2002). The organisational search scope defines the boundary of innovation efforts at the TMT level, and it determines the degree to which the members of the TMT utilise their knowledge base. In addition, we also believe that managerial discretion, or the latitude of action of the TMT, is the second moderator of the TMT knowledge diversity-innovation linkage, as the impact of the TMT on an organisation is likely to be more prominent in a high-discretion situation (Crossland and Hambrick, 2007; Finkelstein and Boyd, 1998), as is the impact of TMT knowledge diversity. This study shows that the diversity of the TMT knowledge base will lead to greater innovation performance if the industry environment endows a high level of managerial discretion.

The potential contributions to the extant literature offered by our study are as follows. First, this study broadens the literature on diversity theory in the upper echelon perspective by linking the industrial knowledge diversity of the TMT and firm innovation. This expands the breadth of the perspective on the origin of firm innovation. Second, building on the works of McLuhan (1967) and Sveiby (1997, 2001) on the knowledge-based view, we link the TMT's knowledge base to organisational search behaviour, which explains that an appropriate fit with organisational behaviour that represents the internal structure and decision makers' knowledge capacity allows for the leveraging of intangible value, such as innovativeness. Third, this study extends the literature on organisational innovation by introducing the role of managerial discretion. Defined as the latitude of actions with which top managers are endowed (Hambrick and Finkelstein, 1987), this study found that managerial discretion plays a significant role in the relationship between TMT knowledge diversity and the firm's innovation performance. To our knowledge, this is the first study to incorporate the notion of managerial discretion into the literature on firm innovation.

2 Theory development

2.1 TMT knowledge diversity

The cognitive base of the TMT reflects the educational and functional backgrounds and prior experience of the executives (Smith et al., 1994; Tushman and Nadler, 1978). In particular, previous research has shown that knowledge that is gained through prior experience plays a significant role in the development of a cognitive base and subsequent decision-making (Baty et al., 1971; Hambrick and Mason, 1984; Kraatz and Moore, 2002; Sørensen, 1999). For instance, the industrial background and prior work experience determine the cognitive scope in which the executives perceive technological opportunities (Shane, 2000) and combine existing expertise with new knowledge, thus improving their value-creation capabilities (Talke et al., 2011). Therefore, this accumulated knowledge, which is based on the TMT's prior work experience, is significant in shaping team members' decision-making styles.

The upper echelons view, which was put forth by Hambrick and Mason (1984) and others, draws on the concept of bounded rationality (Cyert and March, 1963). Specifically, managers are constantly bombarded with ambiguous and complex information cues, and thus, they will draw from their experiences, preferences, and other biases. Therefore, the upper echelons perspective is principally a theory of information processing with managers acting on the basis of their filtered construals of the situations they face (Hambrick, 1994, 2005; Cho and Hambrick, 2006; Hambrick and Mason, 1984; Tushman et al., 1985). In other words, TMT members are prone to making irrational decisions because of their limited information-processing capability, decision-making complexity, and incomplete information (Cyert and March, 1963; March and Simon, 1958). Their limited field of vision predisposes them to focus only on phenomenal issues, which further deepens their perceptual limitations. Such limited information is therefore interpreted and processed based on the cognitive base of each TMT member (Hambrick and Mason, 1984), and they subsequently make strategic decisions (Hambrick and Mason, 1984). Hence, the cognitive base is the very foundation for TMT members' decision-making styles and capabilities (Souitaris and Maestro, 2010).

Based on this literature, several scholars have classified the composition of the TMT as being specialised or generalised depending on its knowledge breadth or diversity (Buyl et al., 2011; Datta and Iskandar-Datta, 2014; Hambrick et al., 1996; Usher, 1999). A *generalised TMT*, or a TMT with a high level of knowledge diversity, has a broad knowledge scope from its members' prior experience in a heterogeneous set of industries. In contrast, a *specialised TMT*, or a TMT with a low level of knowledge diversity, holds expertise in just a few industries and has a narrow knowledge scope.

Generalised TMTs have an advantage in generating greater innovativeness than specialised TMTs because of their diverse knowledge base. First, with a broad range of knowledge, they are aware of new opportunities and developments in various fields that facilitate the development of new technology in new fields (Li et al., 2013; Walsh and Fahey, 1986). In particular, experiential knowledge of an industry helps managers to assess emerging technologies and to strategically position new technologies (Castanias and Helfat, 2001). Thus, they are superior in predicting, interpreting and responding to changes in the industry (Eisenhardt et al., 1997; Keck, 1997).

Second, recent studies have confirmed that, faced with high uncertainty, TMTs with a broad knowledge scope have an advantage in effectively solving problems (Talke et al., 2011). TMTs that are equipped with a diversified cognitive base tend to review problems from various perspectives and to seek solutions in a variety of ways (Lawrence, 1997). The knowledge based on industrial experience includes technological trends, the demand and supply of technologies, opportunities, threats, competitive conditions and regulations (Kilduff et al., 2000). A diverse knowledge base helps managers to build a sound understanding of the relationships between the elements in a complex environment, which helps them to navigate a project to a successful outcome (McGrath et al., 1996). Thus, a TMT with a diverse industrial knowledge base has a greater opportunity to accomplish complex technological innovation projects.

Third, a generalised TMT is superior in terms of creativity. Knowledge diversity raises the odds of finding feasible exploratory innovations that are far from the firm's existing trajectory (Heyden et al., 2015). Therefore, it reduces groupthink and derives creative alternatives to solve difficult problems (Carpenter et al., 2004; Doz and Kosonen, 2007; Jackson, 1992; Wiersema and Bantel, 1992; Zenger and Lawrence, 1989). Moreover, it is more likely that a TMT with more non-redundant knowledge will arrive at a novel synthesis during the decision-making process (Rodan and Galunic, 2002).

Conversely, a specialised TMT with a relatively narrow knowledge base shows different characteristics. A specialised TMT tends to strengthen the capacity of the existing trajectory rather than explore new trajectories. If the knowledge base of the TMT is narrow or homogeneous, it overlooks critical opportunities and signs in the external environment because it fails to recognise their importance (Lyles and Schwenk, 1992). A specialised TMT may find it more difficult to apply new stand-alone technologies that are distant from their core competencies to the existing technology base; integrating diverse knowledge in disparate fields would also be a challenge (Bantel and Jackson, 1989). Such difficulties hinder a specialised TMT from conducting innovation, especially in new fields or volatile industries.

Scholars of innovation have also noted the importance of the characteristics of the members of TMTs (Bantel and Jackson, 1989; Jehn et al., 1999; Pegels et al., 2000; Wiersema and Bantel, 1992). A top executive team assumes responsibility and exerts authority to control the budgets required for the planning and executing of innovation (Zahra and Pearce, 1989); its demographic characteristics, such as average age, tenure, educational background, and career experience, are significantly associated with the level of R&D expenditures and the directions of innovation initiatives (Barker and Mueller, 2002). In addition, the upper echelon theory highlights the importance of the collective traits of a TMT. In fact, the collective characteristics of the entire top team have greater predictive power for organisational performance than the characteristics of the individual executives (Bantel and Jackson, 1989; Hambrick and Mason, 1984). This study draws from the stream of literature on the scope and diversity of the TMT knowledge base in our examination of organisational innovation.

2.2 TMT knowledge diversity and organisational innovation

The knowledge diversity of a TMT is closely related to firm innovation because it determines the strategic orientation of firm innovation (Talke et al., 2011). Specifically, assessing technological potential and expecting technological trends (Gatignon and

Xuereb, 1997), understanding market needs (Narver and Slater, 1990), knowledge sharing with team members (MacCurtain et al., 2010), and creating new knowledge (Smith et al., 2005) depend on a TMT's knowledge base. This ultimately affects the performance of firm innovation (Rodan and Galunic, 2004; Talke et al., 2011).

The previous literature classified TMTs' knowledge by each team's function, such as finance, marketing, and HR (Cannella et al., 2008) or by academic major (Carpenter, 2002). However, for tasks that are relevant to innovation, recognising technological opportunities and developing technologies are more important. Previous researchers have found that this recognition and development are driven primarily by industrial background rather than by functional experience or academic major (Shane, 2000). In particular, in the innovation research based on patent activities, industrial knowledge is critical because it is closely related to technological domains. As several scholars argued that the classification of patents is strongly synchronised with industry classification (Kortum and Putnam, 1997; Schmookler, 1966; Hirabayashi, 2003), it is easy to compare industrial knowledge with technological outcomes, such as patents. Hence, this study measures the degree of TMT knowledge diversity by the prior industry experience of its members to examine its effect on the innovation performance of the firm.

Overall, a generalised TMT is more beneficial for generating greater firm innovativeness than a specialised TMT. In other words, the innovation performance of the firm will increase as TMT knowledge diversity increases. Therefore, we suggest the following hypothesis.

Hypothesis 1 TMT knowledge diversity will be positively associated with the innovation performance of the firm.

2.3 Organisational search scope

Although we believe that a TMT's knowledge diversity has a significant impact on firm innovation performance, we also acknowledge the importance of the role played by the organisational context in such a linkage. In particular, organisational search behaviour, more specifically, the scope of search would be the crucial moderator that strengthens or weakens the impact of the TMT-level knowledge base on organisational innovation. Organisational search scope is the routine that executes the efforts of the TMT at the initial stage of the innovation process, which affects the organisational processes of creation and the recombination of novel ideas (Nelson and Winter, 1982), as well as innovation outcomes (Katila and Ahuja, 2002).

Organisational search scope is classified into two categories: a narrow search scope (i.e., local search) and a broad search scope (i.e., distant search) (Greve and Taylor, 2000). With a narrow search scope, a local search based on knowledge closely related to the firm's internal knowledge is utilised (Helfat, 1994; Martin and Mitchell, 1998; Stuart and Podolny, 1996). These firms seek exploitative, rather than explorative, ways to create profit based on the existing knowledge base rather than by acquiring new knowledge (Smith and Tushman, 2005). Narrow searchers are also likely to pursue cohesiveness instead of openness (March, 1996), with the ultimate goal of reducing uncertainty and preventing problems pre-emptively, which is inherently variance-decreasing (Flynn et al., 2001; Rivkin and Siggelkow, 2003). They also strive to exploit technologies along their established trajectory (Benner and Tushman, 2003; Rosenkopf and Nerkar, 2001; Vermeulen and Barkema, 2001). In contrast, a firm with a broad search scope would tend

to perform wide and distant searches that often necessitate a knowledge base that is far removed from the firm's existing knowledge and routines (Helfat, 1994). Explorative in their outlook, these firms strive to acquire new knowledge (Smith and Tushman, 2005).

According to the upper echelons perspective, the scope of organisational search, in theory, is a manifestation of TMT-level traits, such as the diversity of knowledge base and others (Hambrick and Mason, 1984). In reality, however, the knowledge diversity of TMTs and organisational search scope are often decoupled for the following reasons. First, a TMT constantly undergoes changes in its membership through the retirement, recruitment, and promotion of the members. Subsequently, the frequent changes in TMT composition result in fluctuations in TMT knowledge diversity. In contrast, search routines at the organisational level are characterised by stickiness and rigidity. Standard operating procedures and protocols become routinised and more irreversible over time (Sydow et al., 2009); inertia grows, giving rise to organisational path dependence (David, 1994). Even reasonable timeframes or cost parameters would not be sufficient to modify the search routines with such irreversibility (Vergne and Durand, 2011). Thus, once a pattern of search is established, it would be rather difficult to change it unless there is a significant threat or performance downturn (David, 1994). Due to this difference in volatility, misalignment between a TMT knowledge base and organisational search scope is inevitable.

In addition, a TMT knowledge base and organisational search behaviour often become incongruent with each other due to shifts in the firm's strategic posture. According to the knowledge-based view, organisations establish both internal and external structures to accomplish their strategic objectives. Internal structures would include the innovation process or organisational search routine, while external structures would include technological acquisitions, alliances or strategic relationships (McLuhan, 1967; Sveiby, 1997). When market conditions change, TMTs may become pressured by the board and other stakeholder groups to change the internal structure in response. If the TMT originally maintained a broad knowledge base and was accustomed to exploration, a shift toward an internal structure that aims for narrow search gives rise to a misalignment between the two. Similarly, misalignment can also arise when a TMT with a broad knowledge base acquires a firm with technological specialisation in specific areas. The pre-existing internal structure of the firm, which is optimised for narrow search, would not fit with the exploratory nature of the TMT with a broad knowledge base.

In sum, it is easy for organisational search behaviour to be misaligned with the configuration of the TMT knowledge base. A misalignment between the TMT's knowledge capacity and internal structure has the potential to limit the creation of intangible values, such as innovativeness (Sveiby, 2001). To maximise the effect of TMT knowledge diversity on innovation, the configuration of the TMT knowledge base should be aligned with the scope of organisational search.

Therefore, we expect that a broad search will fortify the effect of TMT knowledge diversity on innovation performance; however, a narrow search will weaken the effect. Although a TMT's knowledge diversity is likely to foster entrepreneurship and innovation at the firm level, these positive outcomes would not be actualised if the scope of organisational search is narrow and routinised by inertia (Benner and Tushman, 2002; Sull, 1999). This misalignment of direction and the scope of organisational search would compromise the process of innovation, even if the intended strategy of the TMT is to pioneer a new market, thereby inducing inefficiency. However, broad search

organisations that prefer to constantly increase new knowledge by exploring new areas and recombinatory search will fit well with a TMT's generalised needs. A knowledge pool obtained through broad search will enrich the alternatives to solving complex problems in the area pursued by the TMT (March, 1991).

Meanwhile, the same logic applies when a TMT's knowledge diversity is low. A specialised TMT has a disadvantage in achieving innovation performance, but if the organisational search scope increases, the negative effects will worsen. It is difficult for a specialised TMT to pursue the development of technologies that are distant from the core or to increase the variance. Such difficulties therefore hinder a specialised TMT from conducting a broad search. In addition, an organisation that conducts broad search requires more knowledge and skill sets, while incurring higher costs (Grant, 1996; Katila and Ahuja, 2002). Considering the specialised TMT's tendency to remain with the status quo rather than to explore new territory, broad search would create more obstacles to developing a new technology. Therefore, conducting a broad search in a firm that possesses specialised TMT aggravates the innovation performance of the firm, while broad search in a firm with generalised TMT improves the performance.

In sum, the diversity of the TMT knowledge base would lead to greater innovation performance, as the organisational search scope would become wider. Therefore, we suggest the following hypothesis.

Hypothesis 2 The organisational search scope will positively moderate the effect of TMT knowledge diversity on innovation performance, such that the impact of TMT knowledge diversity on innovation performance becomes greater as organisational search scope increases.

2.4 Managerial discretion

Noting that executives are not uniform in their influence over their organisations, organisational scholars have increasingly studied the notion of managerial discretion (Hambrick and Finkelstein, 1987). The upper echelons perspective emphasises the influences of the TMT on organisational performance. However, executives do not always have complete latitude of action or managerial discretion (Hambrick and Finkelstein, 1987; Lieberman and O'Connor, 1972). Defined as the latitude of action available to managers, managerial discretion accounts for different levels of constraint for the members of the TMT (Hambrick and Finkelstein, 1987). Previous studies have found that managerial discretion influences the impact of TMT members on decisions and outcomes (Hambrick, 2007; Hambrick and Finkelstein, 1987). In a high-discretion situation, a TMT has wide latitude for action; thus, their impact on organisational outcomes is greater (Crossland and Hambrick, 2007; Finkelstein and Boyd, 1998; Finkelstein and Hambrick, 1990). However, in a low-discretion situation, a TMT has limited latitude of action; therefore, attributes such as their knowledge base would not necessarily be reflected in the organisational outcomes. In other words, if the environment has a low level of managerial discretion, the degree of TMT knowledge diversity would not have much impact on the level of firm innovativeness. Drawing from this literature, we believe that managerial discretion influences the relationship between TMT knowledge diversity and innovation performance.

Managerial discretion is expected to enhance the hypothesised effect through the following conduits. First, it affects the potential marginal productivity of TMTs (Finkelstein and Boyd, 1998). TMTs that are endowed with high discretion would have a greater impact on the firm's innovation activities; consequently, the impact of the configuration of the TMT's knowledge base would be more immediate. In other words, if top managers are endowed with a high level of discretion, the negative effects of specialised TMT would be detrimental to firm-level innovation. In a high-discretion environment, for example, technologies are likely to experience more rapid change, thereby requiring TMTs to make changes to remain congruent with the industry environment (McClelland et al., 2010). As such, firms that fail to respond to the needed change and that remain committed to the status quo will be at a greater risk of becoming incongruent with the industry environment. Therefore, the weakness of specialised TMT will worsen in high-discretion environments. Conversely, the positive effects of knowledge diversity could foster efficient and productive organisational activities if the top managers are endowed with a high level of discretion and allowed to exploit a full set of strategic options.

Although Hambrick and Finkelstein (1987) identified multiple sources of managerial discretion at the environmental, organisational, and individual levels, researchers have so far focused primarily on the industry-level factors (Finkelstein and Hambrick, 1990; Hambrick and Abrahamson, 1995). Indeed, Hambrick et al. (1993) emphasised that the external environment is the fundamental determinant of managerial discretion. Drawing from this literature, this study focuses on the factors that stem from the industry environment to decipher the effects of discretion on the linkage between the TMT knowledge base and innovation. Specifically, we expect that managerial discretion as an external context can moderate the relationship between the TMT knowledge diversity and a firm's innovation performance.

TMT knowledge base diversity leads to greater organisational performance if and only if the industry environment endows a high level of managerial discretion to a TMT that is equipped with a broad and rich knowledge base. However, with a low level of managerial discretion, this linkage between the TMT knowledge base and firm-level innovation would be severely weakened. Therefore, we hypothesise the following:

Hypothesis 3 Managerial discretion will positively moderate the effect of TMT knowledge diversity on innovation performance such that the impact of TMT knowledge diversity on innovation performance becomes greater as the level of discretion increases.

3 Method

3.1 Data and sample

In this study, we collected data on TMT attributes, firm-level innovation in terms of patenting activities, and firm-level accounting measures of U.S. manufacturing firms with SIC codes 2011 through 3999. Asset status and patent data were extracted from the COMPUSTAT business segment file and the National Bureau of Economic Research

(NBER) patent citation data file, respectively. The data and information on TMTs were obtained from Dun and Bradstreet's Reference Book of Corporate Managements and the 10K (Annual Report) of each firm. The information on managerial discretion was acquired from Hambrick and Abrahamson's (1995) industry discretion ratings for four-digit SIC code industries.

We defined our focal year as 2006 because this was when the greatest number of patents was applied within a ten-year time period after 2000, according to Triadic Patent Families of OECD. To build a lag structure, we measured innovation performance over the next four years (2006 through 2009). We then measured search scope in each of the four years before the focal year of 2006 (2002 through 2005). Focal patents were defined as the patent applications in the focal year of 2006. The TMT data were collected on the TMT members at the vice presidential level and above in each company for each of the focal year. However, because the executives with short firm tenure typically have little impact on corporate search activities, we excluded from the TMT data TMT members who joined the firm in the focal year.

With 2006 as the focal year, we also collected firm-level accounting data between 2002 and 2009, four years before and after the focal year of 2006. We then randomly selected 503 manufacturing firms that existed during this period. Then, we filtered the samples by next steps. First, we matched COMPUSTAT financial and NBER patent data for the period using CUSIP numbers. We limited the firms that had both financial and patent data available for our time window. Second, we also limited the sample to firms listed in Dun and Bradstreet's Reference Book of Corporate Management, which is the source of TMT information. These two processes left us with 142 samples. Furthermore, we excluded firms without information on industrial discretion, which resulted in 120 sample firms. The final sample consisted of 40 firms in the chemical and allied products industry, 23 firms in the computer and office equipment industry, 18 firms in the laboratory apparatus and analytical, optical, measuring, and control equipment industry, 29 firms in the surgical, medical and dental instruments and supplies industry, and ten firms in other manufacturing industries. The organisation size in terms of employees in our sample ranged from 22 to 140,000; the average size was 16,570 employees. Therefore, our analysis was based on 1,058 TMT members and on 6,059 focal patents. In our sample, the number of forward citations earned was 8,095, and the number of backward citations was 99,036.

3.2 *Measurement*

3.2.1 *Innovation performance*

Our dependent variable for innovation performance is the output index, which indicates outputs produced by firms through R&D efforts. We measure the innovation performance of the focal firm by counting the total number of times its patents are cited by other patents during the four-year period from the focal year (Miller et al., 2007). This measurement is an indication of the qualitative outcomes of R&D activities. Because the number of forward citations is closely related to the technological importance of patents (Trajtenberg, 1990), many researchers have adopted this qualitative outcome as a key performance measure of innovation (Kim et al., 2013; Trajtenberg, 1990).

3.2.2 *TMT knowledge diversity*

Because Gunz and Jalland (1996) maintained that TMT members' work experience is the foundation of their knowledge, in this study we focused on their industrial background in order to operationalise the collective knowledge base at the TMT-level. We first classified each executive's dominant industrial background by the three-digit SIC code of the company for which they had worked for the longest period of time. To determine TMT knowledge diversity, we used the Herfindahl-Hirschman index (Bantel and Jackson, 1989; Blau, 1977; Michel and Hambrick, 1992), which is most commonly used to measure industry diversity (Simon, 1988).

$$1 - \sum_i^N P_i^2$$

where P_i is the proportion of the dominant industry in the three-digit SIC code i for a firm with N different three-digit SIC industries. The index ranges between 0 and 1. That is, as the result approaches 1, the diversity increases; as the result approaches zero, diversity decreases.

3.2.3 *Search scope*

Previous studies have used patent classification to measure the scope of innovation activities (Katila and Ahuja, 2002; Kim et al., 2013), which shows the heterogeneity among patents (Li et al., 2008). In this study, we review the total number of backward citations of the focal patents during the four-year period prior to the focal year. Then, we use the entropy measure developed by Palepu (1985) to determine the scope of patent classes among its backward citations. According to Jacquemin and Berry (1979), the entropy measure performs best as a measure of concentration:

$$\sum_j^N P_j \times \ln\left(\frac{1}{P_j}\right)$$

where P_j is the portion of the three-digit technological category j . As the search scope broadens, the technological roots of the underlying study broaden (Trajtenberg et al., 1997). In other words, more diverse citations of focal patents suggest that a firm pursues a broader search scope (Argyres and Silverman, 2004). As the search scope approaches zero, the backward-cited patent classes become more concentrated; as the search scope approaches one, the classes become more diverse.

3.2.4 *Managerial discretion*

Finkelstein and Hambrick (1990) identified six sets of determinants of managerial discretion: product differentiability, demand instability, low capital intensity, competitive market structure, market growth, and freedom from government regulation. Based on this model, a substantial number of previous studies have used Hambrick and Abrahamson's (1995) industry discretion ratings for seventeen four-digit SIC code industries to analyse industrial discretion (Adams et al., 2005; Baum and Wally, 2003; Finkelstein and Boyd, 1998). Consistent with this stream of research, we also use industry ratings to classify the

industries of our sample firms into high discretion categories. To maximise the positive matches with our data, this study averages their measures by three-digit SIC industry and constructs an indicator variable (Adams et al., 2005), thereby noting managerial discretion as a dummy variable. High discretion industries – that is, industries at the top 20% of the distribution of the three-digit SIC code rating of managerial discretion, such as computer equipment and engineering/scientific instruments – are marked as 1.

3.2.5 Control variables

Because a variety of factors can influence firm performance, we include several control variables, such as firm size, R&D expenditure, TMT size, and TMT tenure. Except for R&D expenditure, all the control variables are calculated using the data from the focal year. Firm size is measured by calculating the log of total sales of the focal year (Hall and Weiss, 1967; Montgomery, 1979). Previous studies have reported that firm size could positively affect innovation (Cohen and Klepper, 1996). R&D expenditure is measured by calculating the log of accumulated R&D expenses for the four-year period prior to the focal year. R&D expenditure could potentially improve innovation performance because it allows a firm to initiate new R&D projects and expand the support of existing projects (Kim et al., 2013). For TMT size, we used the number of TMT members, which is also positively associated with innovation outcome (Alexiev et al., 2010). TMT tenure has a significant influence on innovation (Barkema and Shvyrkov, 2007), which is averaged by the number of years that each TMT member has worked for the focal firm.

3.3 Analysis

Firm-level innovation is used as our unit of analysis. This study tests the hypotheses using negative binomial regression (NBR). Our dependent variable (i.e., the number of forward citations of patents held by a firm) is a discrete variable. The variable does not satisfy the assumption of homoscedasticity that is required by classical linear regression models but follow a Poisson distribution. Therefore, a Poisson regression is better suited for this case (Hausman et al., 1984). However, our data could not satisfy the assumption of a Poisson distribution, mainly that the variance should be the same as the mean. NBR, or the extended Poisson regression model, can provide better predictions if there is over-dispersion in the data (Hausman et al., 1984). Therefore, NBR has been used in most existing studies, where the number of patents granted to a firm is used as a dependent variable (Song et al., 2003).

4 Results

Table 1 provides descriptive statistics and correlations between each variable. The sample data comprise observations across 120 firms for the years 2002 through 2009. No strong correlation is found for any combination of variables. The average value of the variance inflation factor (VIF) is lower than 2, and the highest VIF is 2.88, which is an indication of the absence of serious multicollinearity.

Table 1 Descriptive statistics and correlations

<i>Variables</i>	<i>VIF</i>	<i>Mean</i>	<i>s.d.</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>
1 Innovation performance	-	69.0	153.14							
2 TMT knowledge diversity	1.05	0.4	0.29	.18*						
3 Search scope	1.45	1.4	0.96	.62*	-.12					
4 Managerial discretion	1.12	0.2	0.40	.12	.08	.12*				
5 Sales	2.88	13.4	2.74	.39*	-.19*	.50*	.02			
6 R&D expenditure	2.57	12.3	2.11	.45*	-.14*	.49*	-.07	.76*		
7 TMT size	1.29	8.8	4.20	.12	-.12*	.20	-.17*	.43*	.36*	
8 TMT tenure	1.15	12.5	4.27	.11	-.14*	.23*	-.12*	.30*	.26*	.10

Note: * $p < .05$

Table 2 shows the results of the negative binomial model. Model 1 includes all the control variables. Model 2 adds TMT knowledge diversity to show the main effect of our model. Models 3–6 provide the interactions one at a time. Model 3 adds search scope, while model 4 adds both TMT knowledge diversity and search scope. Model 5 adds a managerial discretion dummy, while model 6 adds both TMT knowledge diversity and a managerial discretion dummy.

The results in model 2 show that, as TMT knowledge diversity increases, its effect on innovation performance increases ($\beta = .87$, $p < 0.05$). The pseudo R-square for model 2 (0.0603) is much higher than that for model 1 (0.0568). Thus, model 2 has higher explanatory power than model 1. In short, the empirical results for this model strongly support Hypothesis 1, which predicts that TMT knowledge diversity is positively associated with the firm's innovation performance.

Model 4 adds an interaction term between TMT knowledge diversity and managerial discretion by search scope. The results show that model 4 has a higher pseudo R-square (0.1218) than that of model 2 (0.0603) or model 3 (0.1165). The interaction effect between TMT knowledge diversity and the search scope of model 4 is statistically significant ($\beta = .76$, $p < 0.05$), and it has the same sign (positive) as the TMT knowledge diversity of model 2. In other words, innovation outcome increases as TMT knowledge diversity increases, and this propensity becomes stronger as organisational search scope broadens, which indicates support for Hypothesis 2. Figure 1 graphically depicts the interaction predicted by Hypothesis 2.

The results for model 6 also show that the moderating effects of managerial discretion on the relationship between TMT knowledge diversity and firm-level innovativeness are highly significant and positive ($\beta = 2.06$, $p < 0.05$). Model 6 has a higher pseudo R-square (0.0658) than that of model 2 (0.0603) or model 5 (0.0592), which suggests that, as TMT knowledge diversity increases, firm-level innovativeness increases; in addition, this propensity becomes even greater in high-discretion industries. This finding indicates that the effects of the diversity of TMT knowledge based on organisational innovation will be stronger when firms are in a high-discretion industry. Figure 2 shows graphs of the effect for this hypothesis.

Table 2 Result of the negative binomial model predicting innovation output

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Firm size	.15*	.15*	.11*	.10*	.13	.15*	0.11*
R&D expenditure	.24**	.20**	.14*	.12*	.24**	.18*	0.10
TMT size	.07**	.07***	.00	.02	.08***	.07**	0.01
TMT tenure	.01	.02	-.03	-.02	.02	.03	-.02
TMT knowledge diversity		.87**		-.53		.21	-.70
Search scope			.92***	.54***			.54***
TMT knowledge diversity × search scope				.76**			.74**
Managerial discretion					.48*		-.57
TMT knowledge diversity × managerial discretion						2.06**	.89
N of firms	120	120	120	120	120	120	120
Log likelihood	-563.37607	-561.31797	-527.74519	-524.57075	-561.93347	-558.00185	-523.66586
Pseudo R-square	0.0568	0.0603	0.1165	0.1218	0.0592	0.0658	0.1233

Notes: * $p < .10$; ** $p < .05$; *** $p < .01$.

Figure 1 Interaction between TMT knowledge diversity and organisational search scope

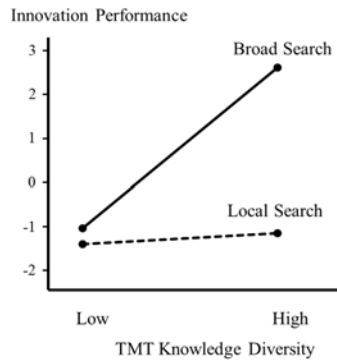
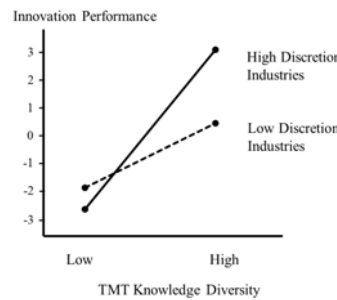


Figure 2 Interaction between TMT knowledge diversity and managerial discretion at industry level



Model 7 includes all the main effects and interactions. However, the coefficient for the interaction effect of TMT knowledge diversity and managerial discretion, significant in the individual model, is no longer significant. While this full model provided a partially insignificant result, overall, we found empirical evidence to support all the hypotheses in the results of the additional sensitivity tests.

4.1 Sensitivity analysis

To improve the robustness of our test results and to conclude whether the hypotheses are supported even in the full model, we conducted additional analyses with different test settings. We tested our model by changing the measurement of the dependent variable in several ways because there are different ways to measure innovation performance. First, we conducted the analysis using a ‘patent count’ measure for innovation performance. The number of patent applications is generally accepted as one of the most frequently used indicators for innovation performance (Acs and Audretsch, 1989; Cantwell and Hodson, 1991; Hagedoorn and Cloodt, 2003). This approach generates a quantitative measure of the patents, while the number of forward citations in our original analysis gauges the degree of innovativeness of the patents. We measured innovation performance by this alternative method, i.e., calculating the nominal number of patent applications in the focal year.

Table 3 Result of the negative binomial model predicting innovation output (sensitivity analyses with two different setting)

	Patent counts					Citation-weighted patent counts				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Firm size	.21**	.10	.03	.07	.01	.19**	.14*	.08	.12	.08
R&D expenditure	.24**	.27**	.30***	.30***	.31***	.23**	.20**	.18***	.21**	.18***
TMT size	.05	.07**	.02	.11***	.03	.06*	.07***	.01	.09***	.01
TMT tenure	-.024	.03	-.01	.04	.00	-.01	.02	-.02	.03	-.01
TMT knowledge diversity		2.52***	1.34**	1.67***	.95*		1.68***	.37	.86*	.02
Search scope			.65***		.68***			.58***		.60***
TMT knowledge diversity × search scope			.84**		.63*			.80**		.68**
Managerial discretion				.31	-.12				-.25	-.47
TMT knowledge diversity × managerial discretion				1.74*	1.56**				2.04**	1.58**
N of firms	120	120	120	120	120	120	120	120	120	120
Log likelihood	-557.7050	-543.2835	-506.7760	-534.4257	-500.8473	-650.0936	-641.8201	-602.7967	-635.5046	-599.0590
Pseudo R-square	0.0414	0.0662	0.1289	0.0814	0.1391	0.0454	0.0576	0.1149	0.0668	0.1204

Notes: * $p < .10$; ** $p < .05$; *** $p < .01$.

Second, the number of citation-weighted patents is another approach to measure innovation performance. Trajtenberg (1990) demonstrates that the number of citation-weighted patents is more closely correlated with their output measures of innovation. For this reason, many studies have adopted a citation-weighted patent count to calculate innovation output (Ahuja, 2000; Henderson and Cockburn, 1994). To analyse this approach sensitively, we measure our dependent variable as the number of patent applications in the focal year weighted by the number of citations that were subsequently received.

Table 3 presents the test results of our two different settings. Model 1 to model 5 show the results when the dependent variable is measured as the number of patents, while model 6 to model 10 show the results when innovation performance is measured as the number of citation-weighted patents.

For both analyses, our results not only suggested additional support for all the hypotheses in the individual models but also provided significant results in the full models. The concern about inconsistent results in the previous main analysis was mitigated by these two additional analyses. Because multiple tests show significant results for each hypothesis, we argue that all the hypotheses in this study are supported.

5 Discussion and conclusions

This study offers a new perspective on the linkage between TMTs' knowledge base and organisational innovation by broadening the concept of knowledge diversity and by examining the factors that reflect the internal context, such as the organisational search scope and external context, such as industrial discretion. We argued that the effects of TMT knowledge diversity on firm-level innovation performance depend on both how knowledge diversity is conceptualised and the context in which it is embedded.

An important contribution of this study is our consideration of the industrial knowledge diversity of TMTs. This concept has received much less attention than functional diversity (e.g., Cohen and Bailey, 1997; Monge and Eisenberg, 1987) and educational background diversity (e.g., Carpenter and Fredrickson, 2001; Wiersema and Bantel, 1992) in upper echelon theory. However, our results show that the knowledge diversity that is based on a TMT's prior industrial experiences has a critical impact on firm-level innovation. A generalised TMT with various industry experiences can generate greater innovativeness due to its capability to recognise new opportunities with a broad range of knowledge, to effectively solve complex problems in an uncertain environment and to generate creative alternatives (Li et al., 2013; Kilduff et al., 2000; Kor, 2003). These results highlight that examining a TMT's industrial knowledge is important for facilitating firm-level innovation performance.

In this study, organisational search behaviour is also an important consideration. A TMT's needs and organisational behaviour can be constantly decoupled due to the difference in their volatilities, while the upper echelon perspective regards the organisation as a reflection of its top managers (Hambrick and Mason, 1984). The result of our statistic model also shows that there is no correlation between TMT knowledge diversity and organisational search scope. If the TMT pursues the development of new technology by internal organisation based on the source technology obtained from

different industries through technological acquisition; for example, an organisation that has pursued a narrow search so far will not be able to perform smoothly. It is difficult to change its behaviour suddenly due to path dependence (David, 1994). To maximise the effect of TMT knowledge diversity on innovation, firms need to minimise the restraint due to the mismatch. Thus, we examined the interaction effect of organisational search scope to identify the appropriate match between TMT knowledge diversity and search scope. Our results show that the positive effect of TMT knowledge diversity on firm innovation is further strengthened when the organisational search scope is broader. An appropriate fit between broad search and TMT with a diverse knowledge base fosters the condition to enhance innovation. Sveiby (2001) argued that a firm can create intangible value through strategic formulation by closely linking managers' knowledge capability and internal structure to transfer knowledge or relay a vision. Building on this perspective more specifically, we suggested that the appropriate fit between a TMT's knowledge base and organisational behaviour as an internal structure fosters strategic formulation to leverage intangible values such as innovativeness.

Another important and unique contribution of this study is to introduce and explain the issue of managerial discretion. Although managerial discretion has been a key factor in the explanation of the influences of the TMT on organisational outcomes, it has been neglected in the innovation literature. This study demonstrates that the degree of managerial discretion at the industry level has a critical role in moderating the relationship between TMT knowledge diversity and firm innovation performance, thus contributing to the extant literature. Our results show that the effect of the TMT knowledge diversity on innovation performance becomes stronger in a high-discretion context. In a low-discretion context, however, the effect of TMT knowledge diversity has less of an impact on innovation performance.

The managerial implications of this study are as follows. The findings highlight the importance of an appropriate configuration of top executives' knowledge base and alignment with search strategies for managing organisational innovation. Specifically, our study offers guidelines for selecting and retaining new TMT members. Whether promoting existing employees to management positions or recruiting TMT members from outside, firms generally tend to focus on individual-level attributes, such as academic background, professional credentials, and the relevance of their prior work. The cognitive fit of the new member with the rest of the TMT is not given much weight. However, the findings of our study highlight the importance of the configuration of the TMT knowledge base and alignment with the context of the firm's search scope. Therefore, a holistic view of the candidate's compatibility with the rest of the top team with respect to the strategic objectives of the firm should be adopted, including its intended search method and innovation strategies.

This study has several limitations. First, in this study, we examined the effect of TMT knowledge diversity on firm innovation. We measured the knowledge diversity based on dominant industrial experience by identifying the industry in which they spent the longest period of time. The study did not consider the other remaining industries for each member. The longest working career is the dominant factor in forming a knowledge base (Cannella et al., 2008), and this study focuses on the collective characteristics of the entire top team rather than that of individual executives. Therefore, the knowledge scope at the top team level based on the managers' dominant industry is deemed to be more suitable for this study, considering that the remaining experiences are also needed to fully

investigate the effect of industrial knowledge. Aside from team-level knowledge scope based on a manager's dominant industry; for example, an intra-personal knowledge scope offers another way to gauge the team's degree of knowledge scope. This measure is calculated by computing an intra-personal industrial scope score for each team member and then taking the average of this score across all team members (see Burke and Steensma, 1998). While the dominant industry based knowledge scope concerns a team's scope of experience across industries, the intra-personal industrial scope concerns the scope of industrial experiences of the individuals on the team. Considering these two methods together will offer a more comprehensive approach to understanding the effect of a TMT's industrial knowledge.

Moreover, this study relied on Hambrick and Abrahamson (1995)'s industry discretion ratings for four-digit SIC code industries to distinguish high-discretion industries. However, because the index is based on data from around 1995, it may not capture the more current industry environment. In fact, some industrial fields have appeared or disappeared since this time. To narrow the gap between the past and present, this study chose high-discretion industries by using the three-digit SIC code, which covers a wider range of industries than the four-digit SIC code. However, a more accurate analysis would require an update of the ratings so that they reflect the current industrial environment.

Finally, our dependent variable of innovation performance was measured by counting the forward citation; that is, the total number of times that its patents are cited by other patents. Although many researchers have adopted this qualitative outcome as a key performance measure of innovation (Kim et al., 2013; Trajtenberg, 1990), there are alternative methods to measure innovation performance, such as quantitative outcomes, measured as the number of successful patent applications by a firm in a given year (e.g., Ahuja and Katila, 2001), or radical innovation, measured as the fraction of the firm's turnover related to new products or technologies (e.g., Laursen and Salter, 2006) or product innovation measured by innovative sales productivity (e.g., Tsai, 2009). We believe that attempts to link the industrial knowledge diversity of a TMT with other types of innovation performance will further broaden upper echelon theory.

In conclusion, this study is the first to date to develop a model of the relationship between the industrial knowledge diversity of a TMT and firm-level innovation performance. Using data from multiple industries in the manufacturing sector, this study found that the industrial knowledge diversity of top managers is positively associated with innovation performance. The effect of TMT knowledge diversity on firm innovation is stronger as the organisational search scope broadens, and it is likely to be more prominent in a high-discretion situation. Given the importance of knowledge configuration and internal-external contexts as strategic considerations for enhancing core competencies, this study offers important implications for both researchers and practitioners who are interested in innovation. Indeed, the best resources that a firm can leverage to reap the benefits of a costly search may be the cognitive capabilities of its top managers. It is hoped that this study serves as a springboard for future studies on this important topic.

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