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Contingent contingency: Knowledge heterogeneity and new product development performance revisited

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Abstract This paper re-conceptualizes the meaning of knowledge heterogeneity—an important but under-developed collective-level concept that influences innovation. The new conceptualization extends the construct of knowledge heterogeneity beyond the traditional assessments of variability in professional background. This research further explores the quadratic relationship between knowledge heterogeneity and new product development performance. Drawing on and synthesizing knowledge clarity and uncertainty avoidance literature to consider work context, the possibility of a positive quadratic, rather than a linear or a negative quadratic, relationship between knowledge heterogeneity and innovation is suggested. This relationship is explored using data collected from 128 new product development teams from companies in knowledge-intensive and innovation-oriented industries located in Taiwan. Results are discussed in terms of the hypothesized positive quadratic relationship. The outcome of the study is discussed in terms of the influence of the knowledge structure and cultural factors, which suggest potential *contingent contingencies* across different contexts.

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Knowledge is a key success factor for both intra- and inter-organizational innovation (Brown & Eisenhardt, 1995). By performing tasks that include knowledge creation, acquisition, sharing, integration, and application, knowledge-intensive units (e.g., work units, teams, groups, etc.) are important for organizations because they contribute to collective innovation activities, including new product development (NPD) (Madhavan & Grover, 1998). Developing a good understanding regarding the nature and use of collective knowledge thus has been recognized as a critical step to achieve innovative success, especially in units comprised of professional workers (Troy, Hirunyawipada, & Paswan, 2008).

While the issues of knowledge content and flow have received considerable research attention (Andersen & Munksgaard, 2009; Goffin & Koners, 2011; Hirunyawipada, Beyerlein, & Blankson, 2010; Pitt & McVaugh, 2008; Slater, 2008), there has been less empirical attention directed toward knowledge structures within organizations (Rodan, 2002; Rodan & Galunic, 2004). Organizations operate in a knowledge economy that emphasizes the combination and utilization of heterogeneous knowledge (Goffin, Koners, Baxter, & van der Hoven, 2010; Rodan, 2002). Since it has been increasingly accepted that organizations can be treated as diverse knowledge bases, differences in the knowledge (e.g., skills, experiences, cognitive or interpretative schema) possessed by individuals within an organizing unit are inevitable (Oosterhof, Van der Vegt, Van de Vliert, & Sanders, 2009; Schmickl & Kieser, 2008). Accommodation and application of heterogeneous knowledge within an organization, accounting for both the benefits and potential costs of such heterogeneity, is vital for everyday group and organizational functioning (Goffin et al., 2010; Karakowsky & McBey, 2001). Hence, innovation, as the novel application of knowledge, depends on understanding both the accumulated content and the structure of knowledge (Argote, McEvily, & Reagans, 2003).

The present study differs from previous research in that a direct measure of knowledge heterogeneity is used, rather than proxy measures such as demographic differences. Further, we will explore the influence of knowledge heterogeneity on innovation in NPD teams. We suggest that the effect of the knowledge structure within NPD teams may be influenced by the cultural context within which the team functions.

Literature review

Knowledge heterogeneity is an important construct in NPD teams. Scholarship on knowledge heterogeneity will be reviewed in order to determine the dimensions underlying this construct. In addition, research on the relationship between knowledge heterogeneity and innovation will be examined. Hypotheses regarding knowledge heterogeneity and its relationship to innovation within an Eastern culture will be presented.

Knowledge heterogeneity

The knowledge-based view of the firm makes explicit the firm's reliance on intellectual resources to successfully create value through innovation in order to compete in markets (Moustaghfir, 2008; Nonaka, 1994; Shankar, Acharia, & Baveja, 2009). For organizations to create value, management of heterogeneous knowledge bases in order to facilitate knowledge sharing within the organization is critical (Rodan, 2002). However, the management of dispersed and embedded heterogeneous knowledge is difficult (Andersen & Munksgaard, 2009; Hirunyawipada et al., 2010; Tsoukas, 1996). Due to differences in context, division of expertise, local inertia with respect to knowledge acquisition, and the developmental path-dependence of knowledge, it is unrealistic to expect full knowledge homogeneity within organizations (Nooteboom, 2000; Schmickl & Kieser, 2008). In addition, individuals, as the basic unit for knowing, often vary in processing and interacting with different aspects of knowledge (Amin & Roberts, 2008; Hirunyawipada et al., 2010). Thus, knowledge heterogeneity is a fact of life within organizations.

Knowledge heterogeneity among individuals can be distinguished from individual differences in professional background in that differences in professional background represent surface-level diversity, whereas knowledge heterogeneity represents deep-level diversity (Harrison, Price, & Bell, 1998). In addition to demographic characteristics that imply the potential for knowledge heterogeneity, knowledge heterogeneity should reflect how members differ in their current thoughts, expertise, and cognitive structures with respect to ongoing tasks (Brown & Eisenhardt, 1995; Dougherty, 1990; Karakowsky, McBey, & Chuang, 2004). That is, knowledge heterogeneity should reflect the different knowledge portfolios made available to the team by its members (Rodan, 2002; Rodan & Galunic, 2004). As an idiosyncratic configuration of intangible assets, knowledge heterogeneity has great potential to affect both the perceptions and behavior of professionals and, thus, the success of team innovation (Mudambi & Swift, 2009; Rodan & Galunic, 2004).

Previous research on knowledge heterogeneity suffers from three limitations. First, knowledge heterogeneity is assessed using proxy measures based on individual differences in demographic background (usually differences in education or functional background) (Lawrence, 1997). Surface-level diversity, such as diversity in professional background, and deep-level diversity, such as differences in knowledge or cognition portfolios, can both influence significant organizing mechanisms for collective decisions and actions (Williams, Parker, & Turner, 2007). However, these two different levels of diversity may not have the same effect on outcomes (Elfenbein & O'Reilly, 2007). It is reasonable to expect that a more direct assessment of knowledge heterogeneity may reveal stronger effects on outcome variables than can be found using proxy measures.

A second concern is the timing of the assessment of knowledge heterogeneity. The concept of knowledge heterogeneity should include a recognition of the human capital's ongoing acquisition of knowledge and competences. Educational and functional diversities have often been studied and are suggested to be *representative of* heterogeneous knowledge portfolios. A project team with individuals from different functions and educational backgrounds is naturally thought to represent different knowledge portfolios. However, this definition of collective knowledge stock is

incomplete, because the breadth and content of the knowledge stock possessed by the team can constantly change.

Knowledge heterogeneity may be enhanced if, after team formation, people of similar educational backgrounds are involved in different knowledge applications or processes and as a result develop new additions to the original knowledge stocks (Amin & Roberts, 2008). In addition, significant learning may accompany work designed to satisfy different types of customers and to meet differing customer needs (Sánchez-González, González-Álvarez, & Nieto, 2009), also resulting in enhanced knowledge heterogeneity. Knowledge activities and mechanisms occurring after team formation render knowledge composition measures based on education and functional experiences incomplete with respect to representing true knowledge diversity.

Third, using educational or functional diversity to depict knowledge heterogeneity represents a rather blunt measure. In addition to variability in knowledge domains, differences may also exist with respect to knowledge processing and knowledge tacitness (Rodan & Galunic, 2004). Team members may have diverse working styles or methods of knowledge communication (e.g., Williams et al., 2007). Variance among individuals in expressive style, use of metaphor, narrative style, reliance on symbolic communication, and other knowledge processing mechanisms may result in heterogeneous schemas and interpretation of knowledge (Patriotta, 2003; Roberto, 2004). Additionally, disparity in knowledge tacitness is important, because the differences in tacitness may influence the proportion of individuals who possess overlapping knowledge bases. In sum, knowledge heterogeneity is defined here as a *state of collective knowledge* that is composed of different domains, forms, contextual meanings and methods of representation and exists within an organizing unit. This expanded definition of knowledge heterogeneity leads to the first hypothesis.

Hypothesis 1 Knowledge heterogeneity is distinct from the demographic diversity of members' professional background (e.g., education and functional records).

Knowledge heterogeneity in NPD teams

Developing new products or services demands high-quality knowledge management, involving individuals with different knowledge portfolios (Goffin & Koners, 2011; Rodan, 2002). Innovation is a result of collective knowledge dynamics (Frenz & Ietto-Gillies, 2009; Leonard-Barton, 1995). Innovation generates new knowledge while, in turn, it is also influenced by the knowledge so created (Nonaka, 1994). Madhavan and Grover (1998) denoted that NPD is a process of re-combining and re-creating internal and external knowledge to be embodied in a product-service bundle. In this sense, the way firms manage their heterogeneous knowledge bases has the potential to strongly influence the effectiveness of NPD (Madhavan & Grover, 1998; Moustaghfir, 2008; Slater, 2008).

Knowledge heterogeneity in NPD teams has been shown to enhance team innovation, although it may also have some drawbacks with respect to implementation (Ancona & Caldwell, 1992). Borrowing from a somewhat different decision context, knowledge heterogeneity (as represented by diversity in functional backgrounds) has been found to have a positive effect on decision outcomes within top management

teams (e.g., Simons, Pelled, & Smith, 1999). Similarly, Rodan and Galunic (2004) reported that access to heterogeneous knowledge positively influenced managerial innovation performance as well as overall performance. These findings were limited to performance as assessed at the individual level; however, the results are suggestive with respect to knowledge heterogeneity and team performance.

Later studies further explored the possible non-linear relationship between heterogeneity and performance. Accumulated results in research have led researchers to a nearly consensus of contingent relationship. On the one hand, diversity in information bases and sources enhances creativity and enables multiple and non-redundant idea generation (Smith, Collins, & Clark, 2005). On the other hand, such diverse resources may result in inaccurate communication, ineffective decision-making processes, distorted perceptions, and intra-group conflict (Pelled, Eisenhardt, & Xin, 1999; Reagans & Zuckerman, 2001; Van der Vegt, Bunderson, & Oosterhof, 2006). Thus, expansion of knowledge has the potential to enhance team innovation. However, beyond a certain point, knowledge heterogeneity may have a damaging effect on innovation due to a lack of mutual understanding across working areas, overloads in processing complexity, ambiguity in the variety of knowledge, or costs in interpersonal knowledge coordination (Pitt & McVaugh, 2008; Schmickl & Kieser, 2008).

Heterogeneity and performance revisited: Contingent contingency

However, the influences of knowledge heterogeneity on innovation performance may not be that simple. Most existing literature discussed such relationship regardless of contexts across or within organizations. Past results in studies of diversity and innovation are mostly stemmed from western business world, thus leading to context specificity when discussing implications from the study results (Wolfe, 1994). In organization studies, there are two options for moving beyond such specificity limit. The first is to conduct cross-contextual research (e.g., Shane, 1995). The second is to compare studies that are context-specific, but represent different contexts. We chose the latter approach (further discussion in the "Methods"), theorizing and testing data from a Chinese culture with unique intrinsic and extrinsic higher-order coordinative forces influencing group dynamics. By adding the present study, scholars can compare it with extant studies together for more generalized (at least wider coverage of) consideration when investigating organizational diversity's impacts (e.g., Farh, Earley, & Lin, 1997; Farh, Zhong, & Organ, 2004).

A different context may alter the relationship between knowledge heterogeneity and NPD team performance. Contextual differences may result in differences in contingent effects between diversity and innovative outcomes (e.g., Richard, McMillan, Chadrick, & Dwyer, 2003; Troy et al., 2008). The fact that the relationship between knowledge heterogeneity and team performance is often examined in Western contexts suggests a limited understanding of the influence of such heterogeneity in non-Western cultures (Soltani, Syed, Liao, & Shahi-Sough, 2011). Incorporating context-specific factors into the discussion of innovation may generate new insights with respect to innovation based on known cultural variation (Nakata & Sivakumar, 1996). The wide range and complexity of NPD knowledge activities means that many internal and external, objective and subjective factors may influence NPD team success (Frenz &

Ietto-Gillies, 2009; Sivadas & Dwyer, 2000). Culture is a significant factor that may affect how individuals respond to and work with heterogeneous knowledge stores within a group or team, resulting in different attitudes, cognitions, and mechanisms relating to knowledge processing (Hedlund & Nonaka, 1993; Tyran & Gibson, 2008). Thus, heterogeneous knowledge may have differentiated influences on innovation depending on the cultural context (Zaidman & Brock, 2009). Extending heterogeneity research to other cultural contexts may add valuable scientific knowledge to current understandings (Tsui & Farh, 1997; Tsui, Farh, & Xin, 2000).

Knowledge processing may unfold differently within NPD teams based on different knowledge structures and cultural-specific characteristics (Bhagat et al., 2002; Hedlund & Nonaka, 1993; Zaidman & Brock, 2009). The functions of teamwork (i.e., communication, working style, members' relationship, etc.) are influenced by cultural characteristics and current knowledge bases. For cultural-specific attributes, uncertainty avoidance that characterizes Chinese employee motivation is critical in organizations pursuing change and innovation (Jackson & Bak, 1998). For knowledge state, we discuss the impact of knowledge state clarity. Holsapple and Joshi argued that knowledge and its management can only been effectively proceeded under a clarity framework that enables employees to clearly perceive current state of knowledge (i.e., people know clearly that they know, or that they do not know) (Holsapple & Joshi, 2000, 2006).

Drawing on such theoretical ground, our main argument is: culture may serve as a grand contextual force affecting the way how people face and respond to homogeneous/heterogeneous knowledge situations; and knowledge may be more beneficial for innovation in extreme clear knowledge structure situations (i.e., the very homogeneous or very heterogeneous collective knowledge state). Moreover, while culture may serve as influencing factor for the motivation, knowledge state clarity may play a role as the influencing factor for the capability for members to well respond to the knowledge-processing situation they face. On the one hand, for teams working within a collectivist culture, such as a Chinese culture here, integration of relatively homogeneous knowledge bases is quite straightforward. This integration is facilitated by directing team members to utilize the applicable and easily shared (homogeneous) knowledge possessed by different members. In such circumstances, utilization of commonality is the focus; however, innovation as the desired result can be generated through the combination of the different perspectives that professionals can bring to bear on the process, or members may share understanding toward a similar imagination of innovation (Brown & Eisenhardt, 1995). The shared knowledge base reduces the possibility of incomplete implementation of NPD arising from limited overlap in knowledge portfolios resulting in gaps in the team's shared knowledge base (Ancona & Caldwell, 1992; Shankar et al., 2009). By the same token, the eagerness for avoiding uncertainty can also typify a work environment with a high degree of heterogeneous knowledge. The desire to prevent uncertainty may drive people to understand, or just accept, that others knowing what they do not know (Chen & Tjosvold, 2007; Hobman & Bordia, 2006; Hobman, Bordia, & Gallois, 2004; Peters & Karren, 2009). A belief system that emphasizes the value of collective identification and serves to bridge over potential conflicts resulted from the differences between professional backgrounds (Mudambi & Swift, 2009). Team

members will struggle to accommodate one another, absorbing and accepting others' heterogeneous knowledge and make best possible usage (Gibson, 2001). Dissimilar or incompatible knowledge is valued, but not intervened, with the shared focus on helping team members avoid the trap of unproductive disputes or disagreements arising from knowledge heterogeneity (Wang, Chen, Tjosvold, & Shi, 2010).

In contrast to the extremely homogeneous or heterogeneous situations, however, the focus on collective achievement may be more difficult to accomplish within groups that encompass moderate levels of knowledge heterogeneity. For Chinese workers who generally avoid uncertainty, an unclear knowledge distribution makes them hesitant (motivation) and difficult (action) in responding to collective knowledge-processing. When the group is characterized as neither heterogeneous nor homogeneous with respect to knowledge possessed by its members, the context may offer ambiguous cues for knowledge management. Clear cognitive and symbolic understandings among members are necessary to help remedy the tension between efficiency and consensus (Roberto, 2004). Given that diversity is of both subjective belief and objective phenomenon (Allen, Dawson, Wheatley, & White, 2008; Harrison, Price, Gavin, & Florey, 2002; Shrivastava & Gregory, 2009), team members may need clear signals identifying the state of collective knowledge (either homogeneous or heterogeneous is okay, just to be clear enough), in order to strive for shared sense and appropriate action for knowledge processing. Even the motivation of uncertainty avoidance remains, people are less able to achieve it if they need to be bothered by unclear knowledge situation (i.e., a moderate level of heterogeneity). Thus, when knowledge heterogeneity is at a modest level, the cognitive signal people can perceive from the collective state of knowledge is relatively ambiguous, making it difficult for members to figure out, utilize, or respond well to one another's knowledge. This may in turn results in less effective knowledge activities for innovation. In sum, the importance of joint consideration of both culture and knowledge structure is evident for knowledge heterogeneity's influences on innovation. While there is a strong rationale to hypothesize a nonlinear relationship between knowledge heterogeneity and NPD team performance, the nature of that relationship may be influenced by the cultural context and knowledge state. Given the setting for our research and the discussion above, we offer the following hypothesis:

Hypothesis 2 There is a positive quadratic relationship between collective knowledge heterogeneity and NPD performance under the Chinese culture.

Methods

Sample and data collection

We drew our sample from the chemical, semi-conductor, electro-optical, communication and networks, and electronics industries in the Database of the Common Wealth Top 1,000 Companies, a database including information on the largest 1,000 companies in Taiwan. This source provides data that can be used in studies on knowledge management and innovation within organizations (Saxenian, 1994).

Taiwan is appropriate as a research context because of its representativeness as an innovation-oriented economy (Dodgson, Mathews, Kastelle, & Hu, 2008; Mathews, 2002) and its increasing emphasis on diverse human capital development (Chi, Huang, & Lin, 2009).

While we emphasize the cultural influences on team work dynamics and discuss our hypotheses against findings from studies of other cultures, we did not actually collect data from multiple cultures. Peng, Peterson, and Shyi (1991) extended the definition of Adler (1983) and categorized cross-national research in management field as unicultural, comparative, intercultural, and general. As defined in this article, unicultural studies are those that "focus on the management of organizations in a nation other than the United States" (Peng et al., 1991: 91). While the United States has been the perceived "major venue" for compariative (cross-cultural) research or investigations of interactions between representatives of different cultures (intercultural research), it is also possible for studies to propose arguments and generate implications by examining data derived from one culture that is then discussed in conjunction with previous studies. The present study incorporates a culture-specific rationale to discuss the team work dynamics between knowledge heterogeneity and innovation. We do not only "contrast" our findings against those found in other cultures; rather, we go further and develop a theoretical basis for the hypothesis that there is an overall "contingent contingency" phenomenon. In practice, our findings suggest that if a multinational corporation looks at the relationship between heterogeneity and innovation at, for example, its German subsidiary, the relationship would very possibly be different from that at its Korean subsidiary. Our findings have implications for both the practice of knowledge management in organizations and future research that combines the Peng et al. (1991) unicultural and general research strategies at different stages in order to gain more precise results and interpretations for issues studied within multiple cultures.

There were 347 companies in the relevant industries included in the database. We sent out requests to the most representative NPD team identified in these 347 firms; 148 teams agreed to participate in this study. Great care was taken with data collection for reducing the potential effect of same source bias (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Given the wide coverage of industries for generalizability and limited project time (window), we chose to select one representative (leader) and one random (member) actor in every responding project, in order to prevent common method variance. After the company agreed to respond to our survey, they referred us to the project team leader and offered a list of team members' names. We chose the member randomly with the median number in each of the list from every project. In order to enhance the ability to draw causal inferences, data for predictor and criterion variables were collected at different time points. Given the merit in our sampling design, it also suffered from the drawback of no full coverage of all members of each specific sampled project. Nonetheless, the remedy is that we found the randomly selected members have tenured over three months in current project and averaged 29.12 months of tenure in the current company, indicating capability to offer relatively objective ratings for our questionnaires.

Information about knowledge heterogeneity, the predictor variable, was collected first (in November 2006) from the senior project leader in consultation with one team member. The team leader-member dyad was considered a sufficient source of information with regard to the level and distribution of knowledge (Szulanski, 2000). NPD

team performance, the dependent variable, was assessed by the head of the R&D or Marketing Department (or in some cases, a top manager, depending on which unit was most responsible for innovation in the particular company). Criterion data were collected after project completion, typically 1.5 years later.

To ensure that data collection procedures were followed as specified, we conducted on-site interviews to confirm that different individuals provided predictor and criterion data. In addition, individuals who supplied information on NPD team performance were encouraged to provide their assessments with the aid of objective records whenever possible in order to enhance data quality. For example, development speed is generally objectively documented through organizational records.

Given the length of time that passed between collection of the predictor and criterion data, we were unable to collect criterion data from 15 of the 148 teams due to early termination of the team project. In addition, five teams were removed from the study due to incomplete responses on the predictor variables, resulting in a sample of 128 teams (36.9 % participation rate). To test for non-response bias, *t*-tests were conducted to assess any differences in contextual variables, such as team size, between those teams that responded early and those that responded later (Joshi & Sharma, 2004). No significant differences were found between early and later responses.

Measures

Independent variable Knowledge heterogeneity (Cronbach's α = .88) was rated by the team leader along with a team member. Knowledge heterogeneity was assessed with a three-item scale based on the definition provided in this study and in previous literature (Rodan & Galunic, 2004). However, we extended the measure offered by Rodan and Galunic (2004) to encompass three dimensions of knowledge heterogeneity. Heterogeneity with respect to knowledge domain, knowledge processing, and knowledge tacitness were each assessed with one item. Further, knowledge heterogeneity was assessed as a characteristic of the NPD team, rather than at the individual level.

The three items comprising this measure are: "Please indicate the extent to which colleague in your team have similar knowledge content" (reverse coded), "Please indicate the degree to which colleagues in your team use similar ways to express and interpret knowledge" (reverse coded), and "Please indicate the extent to which the team members' knowledge varies with respect to whether it is mostly tacit or mostly explicit." The items that assess knowledge heterogeneity are "reference shift" items (Chan, 1998). That is, they refer not to the individual's store of knowledge, but instead to the store of knowledge possessed by the team. There are only two respondents to these items, thus the responses are only "aggregated" over two individuals, with high agreement between the assessments. This type of aggregation is somewhat different than aggregating responses over several group members.

Participants responded to all items on a 7-point scale, where "1" was disagreement and "7" was agreement. Reliability and validity increasing efforts were made. First, to ensure that respondents were utilizing similar definitions of the key concepts, we provided explanations of the terms such as *knowledge processing*, *tacit*, and *explicit* in the questionnaire. Second, we added real-life examples and instructions for

responses preceding each of the three items in order to enhance comprehension of the constructs assessed. Third, to strengthen the measure of knowledge heterogeneity as a construct that is complex and multi-dimensional, we used multiple items to make a good collective concept. First, since knowledge is complex with three related dimensions (Tsoukas, 2005), it should be comprehensively measured with multiple items. Second, single-item measures have long been criticized as deficient in both reliability and validity for organization and management studies (Churchill, 1979).

Dependent variable NPD team performance was measured using scales adapted from Atuahene-Gima's (2003) scale. The scale consists of five multi-item scales (16 total items) of NPD team outcomes: development speed (Cronbach's α = .89), product quality (α = .83), solution found (α = .64), problem-solving speed (α = .89), and solution quality (α = .87). Example items for these scales include: "The project duration met the planned time schedule," "The product conformed to performance specifications required by customers," "We identified several alternative solutions for each problem the project team encountered," "Solutions found for problems we faced were not timely" (reverse coded). Participants responded to these items on a 7-point scale, where "1" represented high disagreement and "7" represented high agreement.

Control variables We controlled for the R&D investment ratio (i.e., R&D investment for each project divided by estimated total investment) and team size (i.e., number of members), as well as heterogeneity in both educational and functional background, as these four variables can potentially influence the outcome variables (Damanpour, 1991). Information on R&D investment ratio and team size was obtained from company records. Following Blau (1977), the two control variables assessing diversity in professional background were calculated as follows:

$$\text{Professional background diversity} = \left(1 - \sum p_i^2\right),$$

where

p The proportion of a particular category of education or function
i the number of different categories represented

Results

Three statistical analyses were conducted to explore Hypothesis 1. First, descriptive statistics (see Table 1) indicated initial evidence of a distinction between knowledge heterogeneity and diversity in professional background. Low and non-significant correlations were found between knowledge heterogeneity and educational diversity (r = .087) and functional diversity (r = .069), which suggested that these variables measure different constructs. Second, we tested for intra-construct congruency with inter-item correlation (IIC) analysis (Hattie, 1985). Table 2 lists the intra- and inter-construct correlations of the items that measure knowledge heterogeneity and educational and functional diversity. An average IIC of .15 to .50 indicates acceptable within-construct consistency (Clark & Watson, 1995) and Table 2 shows that the IIC

within constructs all exceed the lower limit of this range. Similarly, IIC across constructs represent low and non-significant relationships between the knowledge heterogeneity items and the two measures of professional background diversity.

Finally, a confirmatory factor analysis (CFA) was conducted for further validation (Arbuckle, 1997) (see Table 3). The tests reveal fit and statistically support the proposed one-factor structure for knowledge heterogeneity ($X^2(2) = 2.48$, $p > .1$; GFI = .99; AGFI = .96; RMSR = .03) (Bollen, 1989). When adding the educational and functional diversity indices (symbolized as Professional Diversity in the table) into the factor model, the findings show an oblique two-factor model ($X^2(4) = 8.33$, $p > .05$; GFI = .98; AGFI = .95; RMSR = .024). This indicates that knowledge heterogeneity is distinct from professional diversity. In contrast, the measurement model that places all items and indices within one latent variable did not demonstrate good fit nor converge. These three analyses offer support for Hypothesis 1.

Hierarchical and quadratic regression analyses were adopted for Hypothesis 2. Hierarchical regression was conducted using each of the five NPD performance measures as outcomes (see Table 4). For each dependent variable, the first model tested the effects of the control variables, including educational and functional diversity. The second model added the effect of knowledge heterogeneity to the control variables. The distinction between demographic diversity and knowledge heterogeneity has been supported from our result of IIC and CFA. Theoretically, the advance from educational and functional diversity to knowledge heterogeneity is that we may construct a more up-to-date understanding of the current state of diversity in collective knowledge. Put differently, knowledge heterogeneity measures more current state of collective knowledge structure in terms of knowledge (1) domain, (2) processing methods, and (3) tacitness configuration of collective knowledge. Thus, statistically, knowledge heterogeneity should function "beyond" the educational and

Table 1 Descriptive statistics

	Mean	s.d.	1	2	3	4	5	6	7	8	9	10
1. Team size	8.85	7.09	1.00									
2. R&D investment	16.45	15.76	−.05	1.00								
3. Educational div.	2.70	1.27	.43**	−.10	1.00							
4. Functional div.	2.37	1.44	.46**	.18*	.26**	1.00						
5. KH	3.61	.75	.06	.08	.087	.069	1.00					
6. NPD speed	4.38	.99	−.15	−.07	*.03*	*−.02*	*.10*	1.00				
7. Product quality	5.17	.17	.05	.00	*.12*	*.12*	*.17*	.51**	1.00			
8. Solution found	4.94	.72	−.08	−.05	*−.08*	*−.06*	*.06*	.38*	.52	1.00		
9. Problem-solving speed	3.64	.95	−.04	−.17	*.07*	*−.10*	*.06*	.18**	.08	.05	1.00	
10. Solution quality	4.57	.85	−.07	.05	*.06*	*.07*	*.12*	.48**	.55	.60**	−.04	1.00

** $p < .01$; * $p < .05$ level

Table 2 Intra- and extra-construct inter-item correlation

	1	2	3	4
1. KH-1	1.00			
2. KH-2	.68	1.00		
3. KH-3	.66	.75	1.00	
4. Educational div.	.11	.01	.04	1.00
5. Functional div.	.05	.06	.05	.26

$N = 128$; Gray cells: low correlation between items for different constructs

KH Knowledge heterogeneity

functional diversities. Based on this reason, we controlled for the educational and functional diversities in the regression models and tested the main effect of knowledge heterogeneity. The regression analysis results have also demonstrated such effect of knowledge heterogeneity beyond educational and functional diversity. Finally, in the third step of the regression analyses, the quadratic term for knowledge heterogeneity was added to the control variables and the linear effect of knowledge heterogeneity.

The results of hierarchical regression show some interesting results. Knowledge heterogeneity by itself, prior to the inclusion of the quadratic term, adds significant prediction only for the dependent variable of development speed (see Table 4). The linear effect is positive, suggesting that development speed increases as knowledge heterogeneity increases. The knowledge heterogeneity measure does not add predictability over and above the effects of professional background diversity for the remaining four dependent variables. However, it should be noted that the professional background diversity measures do not significantly predict any of the outcome variables. Then, the linear, positive relationship between knowledge heterogeneity and innovation receives only very limited support, which legitimizes our proposition that we should interpret linear relationship very cautiously in light of the more significant quadratic effects.

Table 3 Confirmatory factor analysis results

Summary for the 3 measurement models				
Model	X^2	GFI	AGFI	RMSR
1. KH as one factor	2.48 ($p > .1$)	.99	.96	.05
2. KH vs. professional diversity as two distinct factors	8.33 ($p > .05$)	.98	.95	.02
3. KH and professional diversity as one factor	Model did not converge			

Table 4 Hierarchical regression results

DVs	Development speed			Product quality			Solution found			Problem-solving speed			Solution quality		
IVs	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
(constant) team size	−.05	−.06	.01	−.24	−.24	−.20	−.04	−.05	−.01	−.06	−.06	−.02	−.18	−.18	−.12
R&D ratio	−.01	−.03	−.03	−.09	−.10	−.10	−.06	−.06	−.06	−.15	−.16	−.16	.03	.02	.02
Edu div.	.11	.10	.02	.10	.10	.05	−.07	−.07	−.12	.11	.10	.05	.12	.11	.04
Func div.	.12	.12	.09	.09	.08	.06	−.01	−.02	−.04	−.08	−.08	−.10	.11	.11	.08
KH		.18*	−2.27***		.14	−1.40*		.07	−1.50**		.08	−1.37*		.12	−2.00***
KH^2			2.47***			1.52**			1.59**			1.46**			2.14***
R^2	.03	.06	.16	.05	.06	.10	.01	.02	.06	.04	.05	.09	.03	.05	.12
ΔR^2	.03	.03	.1	.05	.01	.04	.01	.01	.04	.04	.01	.04	.03	.01	.08
F	.73	1.30	3.24***	1.28	1.31	1.85*	.39	.82	.29***	1.24	1.12	1.62***	.83	.97	2.33***
ΔF	.73	3.51*	12.23***	1.28	1.45	4.31**	.39	.61	5.20**	1.24	.64	3.96**	.83	1.53	8.77***

M1: Predictors: (Constant), Team size, R&D invest. Ratio, Func div., Edu div

M2: Predictors: (Constant), Team size, R&D invest. Ratio, Func div., Edu div., KH

M3: Predictors: (Constant), Team size, R&D invest. Ratio, Func div., Edu div., KH, KH^2

*** $p < .01$; ** $p < .05$; * $p < .1$ level; M1 ~ 3 represent a set of models tested for each of the 5 NPD performance indicators

In the presence of the quadratic term for knowledge heterogeneity, the linear term is negative and significant for all five dependent variables. The quadratic term is positive and significant for all five models. Thus, it appears that the highest levels of performance are found when knowledge heterogeneity is either low or high, but that intermediate levels of knowledge heterogeneity result in lower levels of NPD team performance. These findings support Hypothesis 2.

Discussion

Contributions

The results of this study support the distinction between the most commonly used measures of knowledge heterogeneity—educational background and functional background diversity—and the new measure of knowledge heterogeneity. While educational and functional backgrounds represent proxy measures of knowledge heterogeneity, the measure introduced in this study is a direct assessment. The results of this study suggest that the direct assessment of knowledge heterogeneity may offer information that is different from and perhaps more current than the proxy measures. That is, the direct assessment reflects the state of knowledge heterogeneity as it exists within the team, whereas the proxy measures reflect the state of knowledge diversity prior to experience within the team. More traditional measures of knowledge diversity, such as educational and functional diversity, showed no relationship at all to innovation in this study, suggesting that they are rather superficial measures.

The one significant linear relationship exhibited in the data—i.e., between knowledge heterogeneity and development speed—mirrors the findings in previous research (e.g., Ancona & Caldwell, 1992). The present study provides evidence in a different culture and utilizing a direct measure of knowledge heterogeneity. While one might not expect a positive relationship between knowledge heterogeneity and the speed at which new products are developed, efficient and fast knowledge integration may be a key explanation for such result. NPD demands timely solutions and a NPD team that has a diversity of knowledge readily available may be able to meet these demands more effectively. A NPD team that incorporates a variety of knowledge will spend less time "backtracking" in order to revise results based on information not available to the team at the time that particular results were obtained. However, the linear effect reverses when the quadratic effect is included, rendering interpretation of the linear effect ambiguous.

Findings from the quadratic analysis suggest that the highest level of team performance will be achieved when knowledge heterogeneity is either low or high. All five measures of team performance—development speed, product quality, solution found, problem-solving speed, and solution quality—exhibited the same quadratic relationship to knowledge heterogeneity. Thus, the curvilinear relationship holds regardless of which dimension of team performance is assessed. Thus, the emphasis on collectivism and harmony within the team may cause individuals in NPD teams that are homogeneous with respect to knowledge to focus on effective application of shared knowledge, whereas individuals in NPD teams that are heterogeneous will focus on effective integration of

knowledge and then on application—they would chose to simplify and avoid uncertainty when responding to the knowledge structure (heterogeneity) and processing situation. Members of teams that are intermediate with respect to knowledge heterogeneity may respond to the ambiguity with respect to knowledge heterogeneity with uncertainty as to whether application of common knowledge or integration of diverse knowledge is more important.

These results stand in contrast to suggestions based on Western culture (e.g., Pelled et al., 1999). In a more individualist culture (such as many Western cultures), team members may focus on their own contribution to the common goal, rather than on harmony achieved with uncertainty avoiding behaviors or styles, resulting in a different relationship between knowledge heterogeneity and team performance. While the difference in the nature of the relationship between our results and some of the previous studies may be due to the difference in the measure of knowledge heterogeneity utilized, it is more likely the result of the difference in the national culture of the participants in the study. The sample in the study was drawn from a Chinese society that emphasizes harmony between co-workers, where people may work to accommodate either clearly homogeneous or clearly heterogeneous knowledge in collective. By contrast, people may not work well in situations where the cues regarding the current state of knowledge heterogeneity are unclear. The findings of the present study generally echo previous research suggesting that cultural factors may affect the process of NPD (Nakata & Sivakumar, 1996).

The research on knowledge heterogeneity to date has focused on Western cultures, whereas the present study was conducted in an Eastern culture. Our predictions regarding the effect of knowledge heterogeneity, based on the collectivist nature of Chinese culture and the resulting desire for harmony within the team, were supported. Clearly, more research, using direct measures of knowledge heterogeneity, is needed to explore the nature of the relationship. There may be other dimensions of culture, in addition to collectivism, that influence knowledge management. In addition to culture, there may be other boundary conditions, such as diversity in areas other than knowledge that can be identified. Yang and Rui (2009), for example, found varying forms of relationships between different aspects of knowledge management (acquisition, dissemination, and creation) and new product creativity in a Chinese setting. These results coupled with those of our study suggest that the process of knowledge development and knowledge integration across team members may vary based on contextual factors, leading to varying effects on innovation.

Directions for future research

Further studies are encouraged in several areas. First, although this study provides evidence for alternative contingent relationship between heterogeneity and innovation from a cultural context, it is noteworthy that intra-cultural differences may exist (Gong, Chow, & Ahlstrom, 2011). Empirically, in the context in which we conducted our research, ethnic diversity is not as obvious as it might be in countries that encompass visible and easily identifiable ethnic diversity, such as the United States. Rather, in terms of the types of ethnic

differences that influence organizational activities and outcomes, such as language or values, the context of this study represents a rather demographically homogeneous one. The result is that the effect of ethnic diversity has been naturally controlled, rendering our context suitable for examining the major arguments of our study. However, intra-cultural differences in various aspects and levels-of-analysis may also be sources of the contingent contingency in other empirical setting. Future studies are encouraged to examine both cross-cultural and intra-cultural differences with respect to knowledge management and incorporate variables such as ethnic diversity if it is a significant source of variation of the studied culture.

Second, capturing of knowledge heterogeneity in context, including the different knowledge dimensions as influenced by different cultural, institutional, organizational, social, psychological, or temporal settings should be incorporated in theory and empirical research. Third, exploration of interactive effects of various contextual variables would be revealing. Perhaps different types of diversity, in addition to knowledge heterogeneity, would influence the effectiveness of knowledge management activities. Further, it is possible that different types of cultures (e.g., sub-culture, organizational, or societal cultures) might interactively impact on each other.

Finally, cross-level or multilevel theorizing regarding knowledge heterogeneity and related phenomena are important issues. The present study deals with group level relationships between heterogeneity and innovation, the collective actions and decisions for innovation may root in and nest on the behavior of individuals, predicated on the real or perceived status of heterogeneity. In some contexts, knowledge workers may be less inclined to contribute to the collective and instead focus more on the individual contribution. Thus, there may be some cross-level effects with respect to knowledge heterogeneity and innovation.

Limitations

The findings from this study have been compared to previous findings in other cultural settings and tentative conclusions have been drawn with respect to the influence of culture on knowledge management. Clearly, it would be preferable to develop a cross-cultural study that made such comparisons directly. However, given the predominance of Western settings with respect to knowledge management, the present study makes a contribution in terms of broadening the cultural settings investigated. Thus, although we included cultural influence to strengthen the theory and to explain for the result of differences in team dynamics of diversity and innovation in the Easter economy against other Western ones, the effect of culture is not directly measured in the current study. Although a limit for the current paper, the methodological approach we adopted may generate new possibility for future research as discussed in the Methodology section.

The new measure of knowledge heterogeneity that was introduced has not been fully investigated with respect to its psychometric properties. However, this measure represents an improvement over indirect measures of knowledge heterogeneity, as reflected by an assessment of the diversity of the individuals within the team. The

present measure was designed to assess knowledge heterogeneity directly at the team level.

Conclusion

Our results enrich past studies by offering a re-conceptualization of knowledge heterogeneity and an alternative explanation for the relationship between knowledge heterogeneity and innovation. Further, this study refines the assessment of knowledge heterogeneity to fit the more complex reality of a knowledge economy. We have noted that there is much less empirical attention directed toward knowledge heterogeneity in the current organizational literature, and we wish to extend this research stream by suggesting the possibility of other kinds (forms) of contingent relationships—i.e., the contingency may be contingent. Such effort may shed light on the future of knowledge management in an age when businesses may operate in multiple national cultural contexts. For example, a multinational corporation should not expect that diversity of knowledge influences innovation in the same way across all of its units operating in different cultures.

Practical implications are especially critical for research addressing innovation and knowledge activities. First, a formal policy for diversity makes organizations more attractive to potential employees (Williams & Bauer, 1994). This paper reminds practitioners to communicate clearly the strategic importance of knowledge heterogeneity. Even in contexts of low surface-level diversity in terms of demography (e.g., ethnicity) or professional background (e.g., education, functional experiences), knowledge heterogeneity as deeper-level diversity may still be high. Attention must, therefore, be directed to effectively managing such knowledge diversity, leveraging positive aspects of heterogeneity while preventing potential liabilities.

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