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The effect of technology management capability on new product development in China's service-oriented manufacturing firms: a social capital perspective

Weiwei Wu[a], Yexin Liu[a] and Tachia Chin[b]

[a]School of Management, Harbin Institute of Technology, Harbin, China; [b]School of Management, Hangzhou Dianzi University, Hangzhou, China

ABSTRACT

Technology management capability (TMC) and new product development (NPD) are important for China's service-oriented manufacturers to achieve competitive advantage. In this study, TMC is conceptualized as comprising of four sub-level capabilities: searching, selecting, implementation and learning capabilities. Drawing from the theory of social capital, we hypothesize that social capital plays a role in the relationship between TMC and NPD performance. Our findings indicate that NPD performance and social capital are influenced by all the four sub-capabilities of TMC but the effect of each capability of TMC varies. Selecting capability is more significantly and positively related with NPD performance, while learning capability exerts the most significant positive effect on social capital. Moreover, our empirical findings indicate the partial mediating role of social capital in the process of TMC influencing NPD performance. This study makes a particular contribution to the literature by providing a more complete understanding of how social capital plays a role in the relationship between TMC and NPD performance. In terms of managerial implications, our results indicate that improving TMC is essential in enhancing a service-oriented manufacturing firm's NPD performance. Managers should also pay particular attention to nurturing social capital as a pathway to realize the true value of TMC.

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Technology management capability; social capital; new product development

Introduction

Emerging new technologies, new products, new markets and new management concepts are increasingly used by firms to achieve competitive advantage (Kapoor and Adner 2012; Lourdes Sosa 2013; Zaefarian et al. 2017). China's manufacturing industry is undergoing radical transformations due to mega-competition taking place on a global scale. The industry is gradually integrated with services, leading to the growth and importance of service-oriented manufacturing (Gao et al. 2011; Brax and Visintin 2017). In order to meet customers' special requirements, there is a strong need for new product development (NPD), as product innovation leads to market differentiation that could consequently create a variety of novel

CONTACT Tachia Chin tachia1231@yahoo.com.sg

opportunities for manufacturers in the increasingly competitive markets (Jeong, Pae, and Zhou 2006; Matsui et al. 2007; Cao, Jiang, and Wang 2016). Nevertheless, the majority of Chinese manufacturing firms remain relatively weak in NPD performance (Guan et al. 2006; Ma et al. 2015; Chin and Liu 2016, 2015). This essentially is the biggest challenge for China's service-oriented manufacturing firms to pursue transformation and upgrading in the course of sustaining their competitiveness (DCRIC 2011).

Previous research has investigated the barriers to improve NPD performance of Chinese firms. Li (2013) argues that managerial issues are significant matters that need to be considered in the NPD performance of Chinese manufacturers. Kotabe, Jiang, and Murray (2011) suggest that managerial ability in integrating and transforming knowledge is paramount in enhancing product innovation performance. Based on a survey of senior executives from 150 large-and medium-sized Chinese manufacturers, DCRIC (2011) claims that 47% of the challenges these firms faced are related to their internal management. Chinese firms cannot rely on traditional production factors (such as low-cost labour) to compete, but instead must enhance the efficiency and effectiveness of managing technologies (DCRIC 2011). Many Chinese firms have had poor innovation and competitive performance because of the lack of management skills and their failure to cultivate technology management capability (TMC). Despite TMC being expected to influence NPD, there have been limited studies investigating the impact of TMC on NPD performance.

Adopting the knowledge-based view, the process of TMC in influencing NPD performance is closely aligned with knowledge acquisition, assimilation, transformation and exploitation (Cetindamar, Phaal, and Probert 2009). Guan et al. (2006) show that Chinese firms are used to spend a large portion of their innovation costs on the acquisition of technological equipment from world-renowned multinational enterprises (MNEs), but had largely overlooked the importance of building interpersonal trust and cooperation with these MNEs (Redding 2005; Rowley and Harry 2010; Rowley and Redding 2014). Such cooperation and trusting relationships are the foundations of social capital (Kim, Im, and Slater 2013; Kwon and Adler 2014; Suseno and Pinnington 2018), which could facilitate the acquisition and utilization of technological knowledge. Indeed, firms do not face difficulties in the transfer of hardware blueprints, product specifications and pricing lists, but they find it more challenging to transfer the intangible 'know-how'. Chinese firms should not merely cultivate TMC, but they need to further develop social capital to foster more social interactions, communications and reciprocity between firms when transferring technologies and know-how in order to maintain their creativity and innovation (Camps and Marques 2014). Thus, social capital may play a significant role in the relationship between TMC and NPD performance. However, current literature has not extensively examined this important role of social capital in building a firm's TMC and its NPD performance, in which this study seeks to explore.

This study is a response to the call of Rowley and Redding (2014) to focus on the processes within firms that can create competitive advantage. In this study, we provide valuable insights into the literature in several ways. First, we empirically test the relationship between TMC and NPD performance, given that most previous studies had merely implied the effects of TMC on NPD. Second, we examine the potential influences of TMC on social capital. This has interestingly not been extensively explored in previous studies (Gaimon, Hora, and Ramachandran 2017). Third, we indicate the mediating role of social capital in the process of TMC affecting NPD performance, which expands our understanding of the link between TMC and product innovation. Our findings are of interest to decision makers in China's

service-oriented manufacturing firms by highlighting the importance of TMC and social capital for NPD performance, which is consequently important in exploring relevant innovation creation issues in China's service-oriented manufacturing firms.

Literature review

TMC

Technology can be seen as the embodiment and deployment of technical and scientific knowledge that leads to the creation of goods and services. Technology management can be traced back to the early 1970s under such labels as research and development (R&D) management, innovation management, engineering management or strategic management (Drejer 1997). Firms have to implement an overall strategy for effectively managing technology. Technology management, therefore, is critical to firms' competitiveness because it is related to the strategic dimension and significant value of technology (Phaal, Paterson, and Probert 1998). Cetindamar, Phaal, and Probert (2009) have explored the topic of technology management through the lens of dynamic capabilities and presented a technology management framework with an emphasis on the development and exploitation of technological capabilities. They argue that TMC is a kind of dynamic capability that defines the way in which a firm generates and deploys its existing resources, and where it obtains new resources. In short, TMC can be viewed as the combination of routines and processes which are developed, deployed and protected for managing technology in the most efficient way to achieve long-term profit (Díaz-Díaz, Aguiar-Díaz, and De Saá-Pérez 2008). It is worth noting that TMC appears to be more vital to service-oriented manufacturers than to traditional manufacturers as TMC adds the value of producers' service offerings to the total prices of tangible goods (Gebauer et al. 2012; Zhen 2012). TMC can strengthen the value creation process since it is a process of effective integration and utilization of existing technological resources with business requirements. For example, when selling high-tech products, it would serve as an added value if firms provide professional consulting and training services that usually require a high level of TMC.

Various scholars have explored the structure and elements of TMC. For instance, Gregory, Probert, and Cowell (1996) identify five generic processes of TMC, namely identification, selection, acquisition, exploitation and protection. Levin and Barnard (2008) outline a technology management framework consisting of four categories: producing scientific and technological knowledge, transforming knowledge into working artifacts, linking artifacts with user requirements and providing organizational support. All these management processes seem linear, but Cotec (1998) identifies a nonlinear process of TMC that includes five key activities – scan, focus, resource, implement, and learn, and innovation can happen in any of the five key activities. Cotec's (1998) study may be the first that incorporates learning as an important component of TMC. Since then, the importance of learning has been widely recognized (Drejer 1997). For example, Cetindamar, Phaal, and Probert (2009, 2016) propose that TMC activities include learning from the development and exploitation of technologies, and they argue that learning forms a critical part of TMC as it embeds technologies into organizational processes and human resources.

In view of our study on service-oriented manufacturers, we regard TMC as a firm's dynamic capability of planning, developing and exploiting technological capabilities to improve firms'

competitiveness. More specifically, in our model, TMC involves searching inside and outside the firm, selecting valuable information to make strategic plans, and implementing these plans, with all of these activities being connected by learning. Thus, we propose that there are four sub-level capabilities of TMC, namely searching capability, selecting capability, implementation capability and learning capability.

Searching capability

Searching is an important aspect of TMC for ensuring a better fit between the firm's internal needs and external conditions. Firms search their internal and external environments to gather and process signals about their strengths, weaknesses, while identifying opportunities and threats. The key elements of searching capability include R&D environmental monitoring, business unit environmental monitoring, corporate environmental monitoring and technological capability monitoring (Cotec 1998; Levin and Barnard 2008).

Selecting capability

Selecting capability highlights the importance of understanding the specificities of technologies and its impact on the firm's functions. As such, this capability is about the firm committing resources to activities related to the strategic management of technology portfolios (Cetindamar, Phaal, and Probert 2016). Searching capability results in the acquisition of complex information, and knowing how to interpret signals that are most likely to impact the firm's competitiveness. The key elements of selecting capability include R&D strategy, R&D portfolio evaluation, R&D funding, post-project audit, technology roadmapping, product line planning, product portfolio evaluation, feasibility study, technology need assessment and new business unit development (Gregory, Probert, and Cowell 1996; Levin and Barnard 2008).

Implementation capability

Implementation capability involves resourcing and executing the decisions made in the selection process. Various kinds of activities are implemented to foster product innovation (Gregory, Probert, and Cowell 1996; Cetindamar, Phaal, and Probert 2009). The key elements of implementation capability include intellectual property management, project execution, technology transfer, technology adaptation, post-project support, performance management, technology alliance management and personnel management (Levin and Barnard 2008).

Learning capability

Learning capability suggests the need for the firm to reflect on previous capabilities, review its experience of success and failure, and learn on how to adapt, manage, and capture relevant knowledge from its past experience. Learning can be captured from the technology management process in two ways: by developing an improved technological capability, and by developing a more effective management process of technological change (Cotec 1998). Thus, there are two types of learning in technology management: technological learning in order to capture and accumulate technological competence and organizational learning to develop organizational routines for managing the process of technological change (Cotec 1998). Key elements in learning capability include structured and challenging reflection on

the process, conceptualizing, experimentation and capturing of previous experience (Cotec 1998).

Our model thus aims to provide a more comprehensive understanding of the TMC concept by encompassing all core activities relevant to our research setting. The proposed TMC model appears to be more feasible and pragmatic, as it incorporates these four sub-capabilities, which can be used by any firms.

Social capital

The notion of social capital has been discussed extensively in the literature since the mid-1980s. Social capital is gaining prominence as a concept that provides a foundation for describing and characterizing a firm's set of relationships (Inkpen and Tsang 2005; Cuevas-Rodríguez, Cabello-Medina, and Carmona-Lavado 2014), as it argues that the networks of firm relationships constitute a valuable resource for firm development (Adler and Kwon 2002; Suseno and Pinnington 2017). Social capital can be conceptualized as the actual and potential resources provided by and derived from firms' social relations. We follow a narrow view in which the notion of social capital is confined to describing firms' social relationships.

A great majority of studies have proposed that social capital entails beneficial outcomes (e.g. Florin, Lubatkin, and Schulze 2003; Zahra 2010; Maurer, Bartsch, and Ebers 2011; Chin and Liu 2015; Chin et al. 2017; Suseno and Pinnington 2017). For example, Yli-Renko, Autio, and Sapienza (2001), employing a sample of 180 entrepreneurial high-technology ventures, point out that social capital facilitates external knowledge acquisition in key customer relationships. Florin, Lubatkin, and Schulze (2003), in their longitudinal study of 275 US ventures that went public, find that social capital provides ventures with a durable source of competitive advantage by leveraging the productivity of their resource base. Zahra (2010) shows how social capital enables family firms to assemble the resources (especially knowledge) necessary for successful adaptation.

The importance of social capital as a determinant of innovation has received much attention (Landry, Amara, and Lamari 2002; Alguezaui and Filieri 2010). From knowledge based view, innovation is considered as a process with its implementation resting upon knowledge resources (Leiponen and Helfat 2010). The social network created by social capital can establish rich communication channels and increase the social interactions. This consequently creates opportunities for knowledge acquisition from both internal and external sources to support innovation activities (Molina-Morales and Martínez-Fernández 2010; Maurer, Bartsch, and Ebers 2011). For example, social capital has been generally perceived as the resources that can be derived from a set of ties to achieve specific goals (Suseno and Pinnington 2017, 2018). Many researchers prove that social capital can stimulate intra-organizational knowledge sharing for the generation of new ideas (Manning 2010; Cuevas-Rodríguez, Cabello-Medina, and Carmona-Lavado 2014). In addition, social capital can also facilitate the creation of inter-organizational networks, which may facilitate firms to access unavailable knowledge and further improve their innovation capabilities (Wu 2008; Martínez-Cañas, Sáez-Martínez, and Ruiz-Palomino 2012).

While service-oriented manufacturing business requires more complex processes to integrate goods and services and therefore involves more value co-creation activities with suppliers and customers (Lin, Pekkarinen, and Ma 2015; Chin et al. 2017, 2016), it is imperative

for manufacturing firms to nurture social capital to enhance cooperation and coordination among business stakeholders. Such a service culture is more likely to help manufacturers in fostering guanxi-based social capital that enhances the establishment of trust and networks (Redding 2005; Rowley and Redding 2014). In short, social capital is indeed a valuable asset that stems from accessing various resources available through social relationships (Krause, Handfield, and Tyler 2007; Pérez-Luño et al. 2011).

NPD performance

Product innovation is a critical component of China's manufacturing firms to bring innovative products to market ahead of their competitors. As such, NPD is important for firms. Existing research has highlighted that NPD performance is a multidimensional construct (Hsu and Fang 2009; Lazzarotti, Manzini, and Mari 2011), with various indicators to measure NPD performance (see Table 1).

As shown in Table 1, we argue that NPD is related to the efficient balance and control of time, cost, quality and profit margins, as well as the effective maintenance of coordination with suppliers, customers and all related stakeholders. Viewed from this angle, relative to traditional manufacturers, service-oriented firms are more obliged to cope with far more complicated interpersonal relationships within and outside organizations in NPD processes, with service operations needing better communicative competences for performing service-related tasks (Tao et al. 2017). The synergistic value-creation mechanism between production and service is believed to guide China's manufacturing firms to design more modern, comprehensive solutions and to propel continuous product innovation to cater to ever-changing customer demands (Gao et al. 2011). As such, it is particularly critical to discuss the TMC-NPD associations in the context of service-oriented manufacturing in China's context.

Table 1. The measures of NPD performance.

Researchers	Indexes
Souder (1988)	(1) NPD cycle; (2) NPD cost; (3) prototype development proficiency; (4) design change frequency; (5) the technology performance of R&D; (6) the commercialization performance of R&D; (7) market effects
Calantone, Schmidt, and Song (1996)	(1) the ratio of investment (ROI); (2) the investment growth rate (GROI); (3) ratio of sales (ROS); (4) sales growth rate (GROS); (5) market share and growth rate
Song and Parry (1997)	(1) overall profit; (2) new product sales compared with competitors; (3) profit rate for new product compared with competitors; (4) new product success compared with the expected profit
Atuahene-Gima and Ko (2001)	(1) market share; (2) sales and customer use; (3) sales growth; (4) profit objectives
Liu, Chen, and Tsai (2005)	(1) new product life cycle; (2) new product sales and profits; (3) time to market for new product
Wang (2009)	(1) quality and speed to market; (2) number of major customer; (3) market share rate; (4) widening customer choice and expectation; (5) flexibility; (6) number of new products or processes; (7) number of patent; (8) fee of research; (9) index of productivity; (10) trademark; (11) information system; (12) competitive priorities of responsiveness; (13) capability of employees; (14) output merit of employees; (15) skill training of employees

Hypotheses development

TMC and NPD performance

NPD is the process of transforming business opportunities into tangible products (Jeong, Pae, and Zhou 2006; Rauniar and Rawski 2012) while TMC is the managerial knowledge embedded in the organization that is available to support the realization of product innovation (Díaz-Díaz, Aguiar-Díaz, and De Saá-Pérez 2008; Wu et al. 2014). TMC addresses the effective identification, selection, acquisition, exploitation and protection of technological resources needed to facilitate product innovation (Cetindamar, Phaal, and Probert 2009), and it can ensure technological resources are effectively linked to product innovation requirements (Gaimon 2008). Therefore, it can be inferred that TMC has an impact on NPD performance.

More specifically, the searching capability of TMC deals with acquiring technology information (Kostoff 2012). It highlights that firms with strong searching capability can quickly identify new technological trends, respond to technology changes and master the state-of-art technologies, which may enable them to better understand the market and its dynamics. The technology information obtained by searching capability serves as the foundation of NPD strategy formulation (Cooper and Edgett 2010), which is the critical factor of successful undertaking NPD projects. After acquiring new technological information from external sources, the selecting capability of TMC helps to interpret the exact meaning of the acquired knowledge, identifies how new and prior knowledge interacts, and incorporates novel knowledge into knowledge base (Li et al. 2012). The integration of this accumulated knowledge as part of the NPD process can help firms to develop attractive new product concept (Martín-de Castro et al. 2013), which is important for the introduction of new products. Form resource-based view, successful NPD requires the use and redistribution of technological resources (Kim, Shin, and Min 2016). The implementation capability of TMC is concerned with appropriately distributing and effectively embedding technological resources within the NPD process (Wu, Liu, and Yu 2016). This implementation capability also offers supportive routines to employ various technological resources (Levin and Barnard 2008; Oerlemans, Knoben, and Pretorius 2013; Phaal, Farrukh, and Probert 2013), which ensures the achievement of NPD performance. Finally, the learning capability of TMC highlights the importance of recording information from past product development projects, and this consequently influences performance (Sherman, Berkowitz, and Souder 2005). Firms possessing learning capability can accumulate experiences from the NPD procedure (Nguyen, Chen, and De Cremer 2017), by integrating extant knowledge with different methods (Kim and Atuahene-Gima 2010). This means that learning capability increases the possibility of developing a structured NPD process, which may accelerate the strategic use of resources for NPD performance. We therefore hypothesize:

H1: TMC and NPD performance are significantly and positively related.

H1a: Searching capability is significantly and positively related to NPD performance.

H1b: Selecting capability is significantly and positively related to NPD performance.

H1c: Implementation capability is significantly and positively related to NPD performance.

H1d: Learning capability is significantly and positively related to NPD performance.

TMC and social capital

TMC is directly relevant to acquisition, assimilation and transformation of technological resources embedded in the internal and external network into the NPD process (Badawy 2009; Cetindamar, Phaal, and Probert 2009), demonstrating the close correlation between TMC and social capital. Following this logic, the sub-capabilities of TMC – searching capability, selecting capability, implementation capability and learning capability all exert impact on social capital. Searching capability monitors the external environment which includes establishing routines for the systematic scanning of existing and emerging technologies. Searching capability also involves developing an awareness of the technological information which are, or may be, important to the business (Wu, Liu, and Yu 2016). In the scanning process, it is important for organizations to utilize their searching capability to develop reliable and effective communication channels within and across organizational boundaries, as a source of social capital. Selecting capability involves the choice of technological information that should be supported and promoted (Shehabuddeen, Probert, and Phaal 2006). Selecting capability further enables firms to establish frequent communication within the organization in order to gather ideas and select useful information, which facilitates social interactions. Implementation capability invokes cross-functional integration (Wu, Liu, and Yu 2016), which may promote the development of social ties. This may facilitate collaborative behaviours and collective action, and thus develops connections among actors and a common set of goals for the organization. Learning capability is also important to the development of social capital. The organizational learning process consists of the acquisition, dissemination and use of knowledge (Bhatti, Larimo, and Coudounaris 2016). The learning mechanisms may have a positive impact on social capital by increasing the internal group cohesion and co-ordination (Sun and Anderson 2010). Moreover, learning capability also facilitates the external interactions with the external environment for technology transfers and R&D collaboration (Huikkola, Ylimäki, and Kohtamäki 2013). We therefore hypothesize:

H2: TMC and social capital are significantly and positively related.

H2a: Searching capability is significantly and positively related to social capital.

H2b: Selecting capability is significantly and positively related to social capital.

H2c: Implementation capability is significantly and positively related to social capital.

H2d: Learning capability is significantly and positively related to social capital.

The role of social capital

Combining the technology management and social capital literatures with NPD theory leads to the assertion that social capital plays an important role in the relationship between TMC and NPD performance. NPD is a complex activity, which requires new knowledge being applied to commercial ends (Cankurtaran, Langerak, and Griffin 2013). Firms can search and select internal and external technological knowledge across boundaries, and reinterpret and transform the acquired knowledge through effective TMC (Wu, Liu, and Yu 2012, 2016). This is important since NPD requires knowledge flow to perform useful actions to solve problems related to concept development, technological development and commercial development (Frankort 2016). In the process of TMC generating technological knowledge,

social capital provides first mover benefits in terms of the level of technological knowledge that is available and/or the timeliness with which it is available (Maurer, Bartsch, and Ebers 2011).

Furthermore, in order to achieve successful NPD performance, firms should combine internal and external sources of technological knowledge (Prabhu, Chandy, and Ellis 2005). TMC establishes the close ties to build social capital that is characterized by mutual feelings of attachment and trust (Prashantham and Dhanaraj 2010; Suseno and Pinnington 2017, 2018). The network relationships established by TMC facilitate firms to exploit existing internal knowledge and also explore external technological knowledge beyond firm-specific competencies. Consequently, firms investing in TMC are more likely to have broader social networks, and thereby tend to outperform competitive rivals in their product innovation activities (Chiang and Hung 2010).

In addition, NPD also needs coordination to enhance formal and informal communication since product innovation activities are executed in the different functional groups. TMC can coordinate the activities that constitute the product innovation process and provide the infrastructure for supporting functional integration (McFadyen and Cannella 2004). In this way, TMC facilitates and leverages interaction relationships by reducing the transaction costs through social capital, which consequently improves the efficiency of the development of new products. We therefore hypothesize that:

H3: Social capital mediates the effects of TMC on NPD performance.

Methods

Sample

Based on the literature and background as discussed above, we designed a structured and closed-type questionnaire that asked respondents to rate their business units on TMC, social capital and NPD performance. The questionnaire was first developed in English and then translated into Chinese. In order to ensure accuracy, the Chinese version was subsequently retranslated into English by a third party. We carefully checked the two versions of English questionnaire and agreed that there was no substantial difference between them in the meanings of the items. Moreover, to detect potential problems in the questionnaire, a pre-test was run with a small sub-sample of 20 respondents, including professors and managers who are familiar with innovation management field. After the pre-test, the questionnaire was revised again to make sure that there were no problems for the respondents in completing it.

We sent the questionnaire to 150 Chinese service-oriented manufacturing firms. We asked senior managers to complete the questionnaire since senior managers have a more comprehensive understanding of TMC, social capital and NPD performance. Completed questionnaires were returned in sealed envelopes or as e-mail file attachments. 130 firms responded to this questionnaire. Of these responses, 122 were valid (after eliminating those cases with missing data). This sample was sufficient to allow statistical analysis at the firm level.

Measures

The survey questionnaire comprises four parts. The first three parts assess TMC, social capital and NPD performance, respectively, using a 5-point Likert scale with 1 = strongly disagree, 3 = neutral and 5 = strongly agree. The fourth part of the questionnaire is related to various descriptive information about each firm.

We designed scale measures to assess the four capabilities of TMC. By reorganizing the routines from Levin and Barnard's (2008) technology management framework, we developed 3 items to assess searching capability, 10 items to assess selecting capability, and 7 items to assess implementation capability. We also used four items that describe technology management adapted from Cotec's (1998) study, to assess learning capability. The measurement items of TMC are shown in Table 2.

In addition, we used the scale from Maurer and Ebers (2006) and Inkpen and Tsang (2005) to measure the social capital. A sample item is 'The team members of NPD project communicate very often with each other'. Drawing from previous research, we developed three items to assess NPD performance: the NPD cycle (NPDP1) (Liu, Chen, and Tsai 2005; Souder 1988), the return on investment (NPDP2) (Calantone, Schmidt, and Song 1996; Song and Parry 1997) and the market share (NPDP3) (Souder 1988; Calantone, Schmidt, and Song 1996; Atuahene-Gima and Ko 2001). These items were assessed for each firm relative to its competitors.

We also included two control variables, namely firm size (FS) and type of industry (TOI). It is important to control for FS, measured by number of employees, because of the impact a firm's employees as its resources can influence the firm's NPD performance (Hitt, Hoskisson, and Kim 1997; Swan and Allred 2003; Devaraj, Hollingworth, and Schroeder 2004). TOI is an important control variable because of the influence it exerts on TMC (Wu et al. 2010). The respondents in this study were from high-technology and non-high-technology industries, which were controlled for in our model using dummy variables for each industry type.

Reliability, validity and common method bias

We calculated Cronbach's α coefficient for each construct. The Cronbach's α values of TMC, social capital and NPD performance are 0.786, 0.772, 0.793, respectively, indicating that the constructs have acceptable reliability.

The questionnaire was formed based on an extensive review of previous research. We also asked a panel of our pilot study respondents, i.e. professors and managers in our pretest stage, to review the indicators and the scope of the content of the questionnaire. They verified that the indicators and the contents of the questionnaire accurately represent the measurement objective, thus establishing the content validity.

We performed confirmatory factor analysis (CFA) to check the unidimensionality of the constructs using AMOS 16.0 with maximum likelihood estimation. A measurement model included all of our proposed constructs, and each item was allowed to load only on its proposed construct. The results of this assessment showed that χ^2/degrees of freedom = 2.683, $p < 0.01$; goodness of fit index = 0.935; comparative fit index = 0.920; normed fit index = 0.876 and root mean square error of approximation = 0.052, indicating that it was a very good model fit. Convergent validity, the extent to which the measurement items represent the

Table 2. The measurement index of TMC.

Construct	Items
Searching capability (SHC) adapted from Levin and Barnard (2008)	My firm scans the external environment, including technologies, competitors, suppliers, customers, regulators, etc. (SHC1)
	My firm analyzes its technological capability, including technologies, patents, copyrights, trademarks, standards, etc. (SHC2)
	My firm investigates the market and technical feasibility of an idea (SHC3)
Selecting capability (STC) adapted from Levin and Barnard (2008)	My firm chooses creative process to develop new product/process (STC1)
	My firm plans the progression of technology to be developed by R&D (STC2)
	My firm determines what technologies current and future customers want (STC3)
	My firm develops a plan for future direction of product line/platform (STC4)
	My firm evaluates portfolio of R&D projects to achieve desired balance along different dimensions (STC5)
	My firm develops its plan and budget (STC6)
	My firm determines the role of various technologies in business units (STC7)
	My firm determines if a programme/project should be funded (STC8)
	My firm determines how to fund R&D efforts (STC9)
	My firm determines when a new set of products/technologies/markets warrant the formation of a new business unit (STC10)
Implementation capability (IC) adapted from Levin and Barnard (2008)	My firm designs, staffs, and manages projects (IC1)
	My firm shifts ownership of artefact and accompanying knowledge (IC2)
	My firm absorbs and adapts a technical artefact and accompanying knowledge (IC3)
	My firm provides supports to adopters of technology (IC4)
	My firm measures and manages performance (IC5).
	My firm identifies, develops and manages strategic partnerships and consortia (IC6)
	My firm manages intellectual property (patents, copyright, trademarks, and standards) (IC7)
Learning capability (LC) adapted from Cotec (1998)	My firm capture experience honestly (LC1)
	My firm makes the structured and challenging reflection on technology management process (LC2)
	My firm captures and codifies the lessons learned into frameworks and eventually procedures to build on lessons learned (LC3)
	My firm has the willingness to try and manage things differently next time, to see if the lessons learned are valid (LC4)

construct, was confirmed as each path loading was greater than twice its associated standard error.

Discriminant validity was tested through inter-factor correlations. All inter-factor correlations were reasonably low and within an acceptable range. A more rigorous test of discriminant validity was carried out by checking the average variance extracted (AVE). AVE was calculated through the square root of the average communality and confirmed because the square root of the AVE was greater than all other cross-loadings, ranging between 0.716 and 0.783, as shown in Table 3.

Table 3. Interfactor correlations.

Factors	1	2	3	4	5	6
Searching capability (1)	0.726					
Selecting capability (2)	0.235***	0.762				
Implementation capability (3)	0.213***	0.322***	0.783			
Learning capability (4)	0.282***	0.226***	0.358***	0.716		
Social capital (5)	0.223***	0.218***	0.211***	0.402***	0.756	
NPD performance (6)	0.142***	0.313****	0.227***	0.249**	0.343***	0.761

Note: Square-root AVE of the corresponding construct is displayed in the diagonal.
Significance levels: ***$p < 0.01$.

Table 4. The regression analysis of the relationships among TMC, social capital and NPD performance.

Model	Model 1	Model 2
Dependent variables	NPD performance	Social capital
Independent variables		
SHC	0.221**	0.262**
STC	0.332***	0.247**
IC	0.241**	0.233**
LC	0.263**	0.321***
Control variables		
TOI	0.126	0.153
FS	0.097	0.106

Significance levels: **$p < 0.05$, ***$p < 0.01$.

We used Harman's (1967) one-factor test to examine common method bias. The rationale behind the test is that if common method bias is a serious problem in the data, then all the measures would tend to load on a single factor when both the independent and dependent variables are entered into factor analysis. The results showed a six-factor structure, which explained 78% of the variance. No single factor was apparent in the unrotated factor structure, with the first factor accounting for about 24% of the total variance. Thus, a single factor did not emerge; nor there was a general factor accounting for the majority of the covariance in the variables. These results suggest that common method bias is not a significant problem in the data-set.

Results

We tested the hypotheses using SPSS 20.0 to run multiple regression analysis. The results for H1 and H2 are shown in Table 4, and the results for H3 are shown in Table 5.

The relationship between TMC and NPD performance

In Model 1, searching capability, selecting capability, implementation capability and learning capability are the independent variables and NPD performance the dependent variable. All four capabilities of TMC are significant and positively related to NPD performance, thus supporting all of H1 (H1a–H1d). Model 1 further shows that selecting capability is more significantly related with NPD performance ($\beta = 0.332$, $p < 0.01$), compared with selecting capability ($\beta = 0.221$, $p < 0.05$), implementation capability ($\beta = 0.247$, $p < 0.05$) and learning

Table 5. The multiple-regression analysis results.

Model	Model 3	Model 4	Model 5
Dependent variables	NPD performance	Social capital	NPD performance
Independent variables			
TMC	0.896***	0.606***	0.372**
Social capital			0.519***
Control variables			
TOI	0.083**	0.213	0.102**
FS	0.093	0.188	0.094

Significance levels: **$p < 0.05$, ***$p < 0.01$.

capability ($\beta = 0.263$, $p < 0.01$). This implies the comparative importance of selecting capability to NPD performance.

The relationship between TMC and social capital

In Model 2, searching capability, selecting capability, implementation capability and learning capability are the independent variables and social capital is the dependent variable. All four capabilities of TMC are significant and positively related to social capital, thus supporting all of H2 (H2a–H2d). Learning capability ($\beta = 0.321$, $p < 0.01$) in comparison to searching capability ($\beta = 0.262$, $p < 0.05$), selecting capability ($\beta = 0.247$, $p < 0.05$) and implementation capability ($\beta = 0.233$, $p < 0.05$) has the most significant and the greatest influence on social capital. This implies a greater importance of learning capability to social capital in comparison to the effects of the other three sub-capabilities of TMC on social capital.

The role of social capital in the relationship between TMC and NPD performance

Following the procedure of Baron and Kenny (1986), we employed multiple regression analysis to test whether social capital plays a mediating role in the relationship between TMC and NPD performance. First, we analyzed the relationship between TMC and NPD performance (Model 3). Second, we analyzed the relationship between TMC and social capital (Model 4). Then, social capital was entered into Model 5, and the significance of the coefficients was examined.

Like Model 1, the results for Model 3 confirm that TMC has a significant positive effect on NPD performance when TMC is the only variable. When social capital is entered into this model in Model 5, both TMC and social capital have significant positive effects on NPD performance. In comparing the coefficients for TMC in Models 3 and Model 5, we find that the direct effect of TMC on NPD performance decreases when social capital is incorporated ($\beta = 0.896$ decreases to $\beta = 0.372$). Moreover, the effect of TMC on social capital and the effect of social capital on NPD performance are significant. These results indicate that social capital mediates the effect of TMC on NPD performance.

We also used the Sobel test to examine the statistical significance of the indirect relationship between TMC and NPD performance through social capital. The result of the Sobel test statistic (t) is 3.772, with the one-tailed probability being 0.0001626 and the two-tailed probability being 0.0003183. This indicates that social capital indeed plays an intermediary role in the relationship between TMC and NPD performance. Thus, H3 is supported.

Discussion

Our results show that TMC has a significant and positive effect on NPD performance, confirming that TMC is an important capability that should be incorporated in the product innovation process of firms. One of our respondents, a successful service-oriented manufacturer in China, is a sample case that illustrates the importance of TMC for NPD. Since its inception, the firm has focused on improving TMC, such as scanning and choosing word-leading hydroelectric technologies, implementing distribution and incentive regulations. The firm has accumulated more than fifty years of TMC, providing it with a solid foundation to consistently implement successful product innovations (Wu, Yu, and Wu 2012).

Our study further indicates that the four sub-capabilities of TMC – searching capability, selecting capability, implementation capability and learning capability – all exert positive and significant effects on both NPD performance and social capital. However, the effectiveness of each sub-capability differs. Selecting capability is more significantly related to NPD performance because it deals with strategic issues (Levin and Barnard 2008; Cetindamar, Phaal, and Probert 2009). Selecting capability requires the firm to choose strategic analyses to identify the strengths and weaknesses of firms. The evaluation of the firm's internal strengths and weaknesses creates a solid foundation for product innovation strategy and product innovation plan. Learning capability has the most significant and greatest influences on social capital, and it provides the basis for the development of social capital. Learning capability accumulates relevant organizational success by reinforcing intra- and inter-organizational social interactions. As such, firms with high level of learning capability may leverage their past experience to bring the organization's members together around a shared vision internally (Akgün et al. 2007) and promote strategic alliances externally (Li et al. 2014). Following this argument, we found that learning capability greatly accelerates the development of social capital.

Our findings also shed lights on the role social capital plays in the process of TMC in influencing NPD performance. Our results indicate that TMC can directly and indirectly affect NPD performance through social capital, suggesting that Chinese service-oriented manufacturing firms should strengthen their TMC and social capital simultaneously to achieve better NPD performance. With some traditional product-focused technological capabilities becoming redundant and obsolete (Motohashi and Yun 2007), we argue that it is necessary for Chinese service-oriented manufacturing firms to develop their capabilities for newer innovative products. In this context, the transformation of industry requires firms to emphasize more on TMC as well as social capital (Gebauer, Gustafsson, and Witell 2011). Social capital should therefore be viewed as a key resource that can enable firms to develop TMC and further facilitate NPD. In other words, social capital is needed to develop technological competences that may be better developed by service-oriented manufacturing firms to attain a competitive advantage.

Although this study presents several important points regarding the effect of TMC on NPD from social capital perspective, it also suffers from some limitations. We only incorporate social capital as a mediator in analyzing the relationship between TMC and NPD performance. Thus, our research model can be advanced by investigating the mediating effects of other types of capital such as human capital and cultural capital on the TMC-NPD relationships.

In addition, other environmental characteristics, such as technological turbulence (Gaimon, Hora, and Ramachandran 2017), may potentially have an impact on TMC, social

capital, and NPD performance. Future studies could therefore explore various other environmental characteristics, which would provide a more comprehensive interpretation of our research results.

Another opportunity for future research is by considering research samples from other countries. The sample used in this study was taken only from China. However, different countries may have different TM practices (Choi et al. 2012); for example, the U.S. has a comparative advantage in project management while Spain focuses on intellectual property, and these different practices may lead to different results. Future research can therefore be conducted in other countries to further contribute to our understanding of how TMC is associated with NPD performance across different countries.

Implications

The study offers several theoretical contributions. First, this study provides theoretical grounds and empirical evidence for positing the influence of TMC on NPD performance. In particular, our results indicate that TMC is an antecedent of NPD performance. We also verify that each of the four sub-capabilities of TMC – searching capability, selecting capability, implementation capability and learning capability – has different impacts on NPD performance. The examination of each of these sub-capabilities of TMC on NPD performance through incorporating social capital perspective has not been extensively addressed in previous studies (Cetindamar, Phaal, and Probert 2009; Wu, Yu, and Wu 2012). In this way, our study provides a distinctive potential for firms to capture values from TMC in order to stimulate NPD performance.

Second, this study contributes to the social capital literature by demonstrating the effect of TMC on social capital. Prior social capital studies have been primarily focused on investigating social networks (Arregle et al. 2007; Alguezaui and Filieri 2010), with TMC rarely being mentioned. Our study theoretically and empirically confirms that TMC has a significant positive effect on social capital, and that social capital is further influenced by all four sub-capabilities of TMC. This contributes to the social capital theory by uncovering an important new direction on how firms develop social capital and technology management.

Third, this study identifies the mediating role of social capital in the relationship between TMC and NPD performance, which expands our understanding of how TMC affects NPD performance. This also provides an important supplement to the technology management research. Although previous research provides hints on the influence of TMC on innovation, our study confirms such assertion by showing that social capital indeed plays an important role. By examining the mediating role of social capital, this study reveals the underlying mechanism of the TMC-NPD performance relationship.

As for the managerial implications, this study provides new insights into the technology management practices of Chinese service-oriented manufacturing. In a service-oriented industry, technology management and the delivery of service offerings must closely interact (Santamaría, Jesús Nieto, and Miles 2012). Our findings highlight the importance of TMC in modern manufacturing systems, such that firms with stronger TMC are more likely to achieve better NPD performance. Firms should thus strengthen their TMC by simultaneously promoting their searching, selecting, implementation and learning capabilities. Our results further show that selecting capability has a stronger relationship to NPD performance than the other three capabilities and thus technology managers should place more emphasis to

this aspect of TMC. We have also indicated that firms can develop their selecting capability through developing information interpretation, identifying key signals, and designing strategies and plans.

This study has demonstrated that a partial effect of TMC on NPD performance is exerted through social capital. This implies that managers should pay particular attention to fostering the firm's social capital so as to maximize the outcomes of their TMC efforts. Most importantly, in order to obtain the benefits from TMC, it is worth noting that managers should emphasize the linkage between TMC and social capital, with a special focus on learning capability because this capability has a more significant relationship with social capital than the other three sub-capabilities of TMC.

Conclusion

In recent years, technology management research has attracted increasing attention in academic discussions and practical applications. However, there has been a scarcity of research examining the influence of TMC on NPD performance in China's service-oriented manufacturing. To fill this research gap, the current research examines the impact of TMC on NPD performance, and further explores the mediating effect of social capital. Overall, our study demonstrates that TMC is an important antecedent of NPD and social capital, and each of the four sub-capabilities of TMC – searching capability, selecting capability, implementation capability and learning capability, exerts significant impacts on NPD performance and social capital. The outcomes of this study further offer contributions to the technology management literature, and provide interesting directions for future studies.

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Notes on contributors

Weiwei Wu is a Professor of Business Administration at School of Management, Harbin Institute of Technology, Harbin, China.

Yexin Lu is a doctoral student of Business Administration at School of Management, Harbin Institute of Technology, Harbin, China.

Tachia Chin is a Professor of Human Resource Management at School of Management, Hangzhou Dianzi University, Hangzhou, China.

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