Industrial Management & Data Systems

Influence of technological innovation capabilities on product competitiveness

Lijun Liu Zuhua Jiang

Influence of technological innovation capabilities on product competitiveness

Lijun Liu and Zuhua Jiang
Department of Industrial Engineering and Management, Shanghai JiaoTong University, Shanghai, China

Received 16 May 2015
Revised 21 August 2015
4 October 2015
27 November 2015
Accepted 6 December 2015

Abstract

Purpose – The purpose of this paper is to shed light on how technological innovation capabilities (TICs) influence the product competitiveness of Chinese manufacturing enterprises and identify the key technological innovation components.

Design/methodology/approach – Quantitative research setting was applied in Chinese Yangtze River Delta. Survey was carried out with 166 responses.

Findings – The study reveals that the firm's strategies capabilities, knowledge resources, fundamental research, application R&D, and manufacturing capabilities have significant influence on the new product development performance and product competitiveness of Chinese manufacturing enterprises. Interestingly, firm's organizational capabilities and human, finance, and material resource have no significant correlation with the product competitiveness.

Practical implications – From a practical perspective, the relationships among TICs enablers, processes, and product competitiveness may provide a clue regarding how firms can promote technological innovation to sustain their competitive advantage. Moreover, the key factors of TICs found in the study are useful for policy makers and managers of Chinese firms to make decision.

Originality/value – This study is one of the first studies to apply the structure equation model method to measure the relationship between TICs and product competitiveness under the background of Chinese manufacturing. The results provide a new framework on the how technological innovation capability influence product competitiveness of Chinese manufacturing firms. From a managerial perspective, this study identifies several crucial TICs factors to support product competitiveness, and discusses the implications of these factors for developing organizational strategies that encourage technological innovation.

Keywords Research and development, Chinese manufacturing, Product competitiveness, Structure equation model, Technological innovation capabilities

Paper type Research paper

1. Introduction

In the competitive advantage theory, Porter (1990) presented that only companies with core competence can gain advantage against the world's best competitors in the background of pressure and challenge. In the long run, it is technological innovation capability (TIC) that forms a major source of competitive advantage (Freeman, 1994). Many studies have shown that technological innovation could bring positive impacts, enhancing the competitiveness of firms (Dierickx and Cool, 1989; Guan, 2002). The ability to introduce new products and adopt new processes in shorter lead time has become an imperative competitive tool (Sen and Egelhoff, 2000). The previous studies

The author is most grateful to National Nature Science Foundation of China (No. 70971085, 71271133), the Research Fund for the Doctoral Program of Higher Education of China (No. 20100073110035), and Innovation Program of Shanghai Municipal Education Commission (13ZZ012) for financial supports that made this research possible.

Industrial Management & Data Systems
Vol. 116 No. 5, 2016
pp. 883-902
© Emerald Group Publishing Limited
0263-5577
DOI 10.1108/IMDS-05-2015-0189

have verified that some resources in TICs are critical factors to support new product introduction and product competitiveness. For example, R&D and resources allocation capabilities are verified as the two most important factors of TICs (Yam, 2004). However, other new factors in TICs, for example, fundamental research and knowledge resource, have not been investigated. Moreover, for Chinese manufacturing, with the increase of labor cost, energy prices, and other production costs, a severe challenge on the sustainable development arrived unexpectedly (Lau *et al.*, 2013). The transformation from low-cost, labor-intensive production strategy to innovation-oriented production strategy is an inevitable tendency. Technological innovation is the only way to gain competitive advantage for Chinese manufacturers. Therefore, how TICs support production competitiveness has attracted attentions from firm's managers to policy makers. Chinese manufacturers need to identify the critical factors in TICs to improve the technological innovation to ensure the competitive advantage of firms. Policy makers need to identify the bottleneck of enterprise's technological innovation in order to properly distribute the national R&D fund. However, only few studies have focussed on the investigation of relationship between TICs and product competitiveness. Research exploring the critical TICs factors supporting product competitiveness is also extremely rare. Our study, described in this paper, investigates the core issues of how TICs influence the product competitiveness of Chinese manufacturing, and identifies the critical factors of TICs that drive the product competitiveness.

According to Guan *et al.* (2006), technological innovation is a process that includes the interaction of many different resources. Successful technological innovation depends on not only the technological factors, but also other critical factors in the areas of manufacturing, such as organization management, strategy planning, knowledge and information, and resources allocation (Chiesa and Manzini, 1998; Yam *et al.*, 2004). They found an inherent connection between a firm's technological resources and its product competitiveness. Earlier studies either confined to the traditional technological innovation strategy analysis framework or mainly focussed on market and financial indicators of product competitiveness (Eisenhardt and Sull, 2001; Karagozoglu and Brown, 1993; Sharma, 2003). They did not explain the formation of how internal mechanism of technological innovation drive product competitiveness. Only in recent years, some researches begin to study the relation of TIC and product competitiveness (Guan and Chen, 2010; Guan *et al.*, 2006; Yam *et al.*, 2011). However, these researchers have not tried an integrative model that explores the effectiveness of TICs from a holistic perspective, and little Empirical verification has been carried out to examine the relationships among TICs enablers, processes, and product competitiveness.

In our study, the function-based TICs assessing framework is used to establish the relationship between TICs and product competitiveness of Chinese manufacturers. By means of questionnaire survey and structure equation model (SEM), the critical factors in the TICs driving the product competitiveness are obtained and the innovative relationship between TICs and product competitiveness is constructed, which can be used to aid the technological investment of firms, and assist the government's funding on the enterprise's technology innovation.

The paper is structured as follows. We first introduce most of the related literature briefly in Section 2. In Section 3 we propose the research model and hypotheses. In Section 4, we explain the data collection details, following which the results of the empirical study are presented in Section 5. Section 6 gives a detailed discussion of the finding. Conclusion, implication and limitation are then outlined in the last section.

2. Theoretical framework

2.1 Technological innovation capability and evaluation

Adler and Shenhar (1990) originally discussed TICs. In their opinion, the framework of organization's technological capability consists of four dimensions, which are technological assets, organizational assets, external assets, and projects. They explained that the purpose of assessing an organization's technological capabilities is to determine its ability to develop and introduce new products that meet market needs, to manufacture these products using the appropriate technologies and processes, to develop new technologies and products to meet future needs, and to quickly respond to unexpected technology updates by competitors and to unforeseen opportunities.

Researchers subsequently presented various multiple dimensions frameworks to evaluate a firm's TICs. For instance, Christensen (1995) classified TICs into science research asset, process innovation asset, product innovation asset and esthetics design asset. These assets correlate with internal accumulation, experimental acquirement and disquisition. He commented that the combination of more than one of these assets is essential for the success of industrial innovation. Chiesa and Manzini (1998) developed a TIC framework including several significant elements. The framework focusses on core processes and enabling processes to support technological innovation. Other areas such as learning, organizing and strategic planning are central to a firm's innovation capability and should be stressed. Yam *et al.* (2004) presented an innovation model including both a capability perspective and a performance perspective. These elements are then grouped under seven capability dimensions. A functional approach is adopted in each dimension, except learning capability, represents a separate function of the organization – R&D, manufacturing, marketing, organizing, resource allocation and strategic planning. Guan *et al.* (2006) proposed an innovation framework for evaluating a firm's technological innovation performance and competitiveness. The framework includes seven capability dimensions, namely, learning capability; R&D capability; manufacturing capability; marketing capability; resource exploiting capability; organizational capability and strategic capability. These seven TICs dimensions constitute the basic components of innovation including technology, production, management and market, etc. In recent years, many researchers evaluate TICs under uncertainty. Wang *et al.* (2008) presented a simple and suitable method to identify the primary criteria influencing TICs at hi-tech firms. The approach adopts a fuzzy measure and non-additive fuzzy integral method, by which can obtain valuable information about hierarchical TIC framework. Verdu *et al.* (2012) evaluated the technological innovation in high-tech firms, using environmental uncertainty as a moderating variable. Cheng and Lin (2012) proposed the approach of adopting trapezoid fuzzy numbers and extending a technique for ordering performance by similarity to address the evaluation of TICs. The hybrid method is a suitable and effective method for identifying and analyzing the competitiveness in the context of uncertainty.

The TICs assessing approaches can be divided into four types, the asset approach (Christensen, 1995), the process approach (Chiesa and Manzini, 1998; Burgelman *et al.*, 2004), the output-based approach (Romijn *et al.*, 2002) and the functional approach (Yam *et al.*, 2004; Guan, 2006). The asset and process approaches are more difficult to understand than the functional approach. The output approach can point out the level of innovation performance, but generally cannot indicate the specific factors which are responsible for the performance of TICs (Lau *et al.*, 2013). Yam *et al.* (2011) explained that the functional approach has two advantages. At first, it is easy to understand, and second, it facilitates the multi-informants approach for the survey. Therefore, the functional approach is adopted widely in the TICs evaluation of manufacturing and service industries (Lau *et al.*, 2013; Tseng *et al.*, 2015).

2.2 New product development performance

New product development is necessary process and foundation for firm survival and competitive advantage (Hsu and Fang, 2009; Feng and Wang, 2013). Griffin posited that about 32.4 percent of company sales are generated by new products (Griffin, 1997).

Many researchers were committed to the relationship between NPD performance and TICs. Hsu and Fang (2009) analyzed the relationship between intellectual capital and NPD performance. The results show that human capital and relational capital actually improve NPD performance through organizational learning. Lai and Lin (2012) discussed the relationship between knowledge management and NPD performance. This study explored the correlation of variables knowledge management, technological innovation and NPD performance in the machine tools industry. Chen *et al.* (2015) presented the relationship between team characteristics and NPD performance under different levels of technological turbulence.

The previous literatures focussed on the relationship between new product development performance and the individual factor of TICs, such as, intellectual capital, knowledge management, R&D team, etc. However, the study on the relationship between NPD performance and TICs framework is rare.

2.3 Product competitiveness

Luo (2010) defined product competitiveness of a firm as a degree to which the firm's product offerings are perceived to have a superior fitness for use, free of deficiencies, and conformance to requirements relative to its competing firms. According to the previous literature (Oral and Reisman, 1988; Powell and Dent-Micallef, 1997), seven factors of product competitiveness at firm level were identified. They are, market share, sales growth rate, export rate (the export volume/sales volume), profit growth rate, productivity growth rate, new product rate (new product sales/total sales), and innovation rate (the number of new products/total number products). These seven indicators not only represent an enterprise's existing competitive advantage, but also reveal its development potential.

A firm's competitive advantage originates from the possession of special resources, for example, innovation capability, and cannot be imitated and substituted (Guan *et al.*, 2006). These resources ensure an enterprise's superior position in strategy, technology, and management. TIC is beneficial for an enterprise's development and contributes to the improvement of competitiveness (Langerak and Hultink, 2008).

2.4 Relationship between TICs and production competitiveness

The study of Guan *et al.* (2006) confirmed a close internal relationship between TICs and competitiveness. Their inherent relationship makes the score of constant returns to scale is closer to one in the DEA model. The results indicate there is plenty of room for enterprises to improve competitiveness through technological innovation. Lai and Lin (2012) linked the benchmarking tool to a knowledge-based system for performance improvement. Kocoglu *et al.* (2012) focussed on learning, R&D, and manufacturing capabilities. They studied the interrelationships between the three TICs dimensions and technological learning, and the influence of technological learning on innovation and firm performance. In recent years, some studies focus on the relationship between TICs and competitiveness aiming at specific country or region, for example: France (Boly *et al.*, 2014), Hong Kong (Yam *et al.*, 2011), Vietnam (Lang *et al.*, 2012). However, research on the relationship between TICs and production competitiveness based on the latest data of Chinese manufacturing is rare.

3. Research model and hypotheses

Figure 1 illustrates the general framework of research model. Following the approach proposed by Rajagopalan *et al.* (1993), the analytical framework of our study comprises three aspects: enablers, processes, and outcomes. "Enablers" are the factors of TICs foster the competitiveness of product and firm. The "processes" dimension refers to how factors of TICs promote the product competitiveness. A product development process includes many phases: concept development, feasibility testing, product design, development process, pilot production, and final production (Takeuchi and Nonaka, 1986). In the product development process, TICs are specialized and segmented: the R&D engineers selected the appropriate design; the production engineers put it into shape; and other functional specialists carry the baton at different stages of the process. The "outcomes" dimension reveals the effects of the NPD effectively achieved on the product competitiveness (Lin, 2007a, b).

In our study, the functional approach is adopted to analyze the relationship between TICs and product competitiveness. Furthermore, under the background of Chinese manufacturing (e.g. many Chinese manufacturing firms are far from the modern management frontier, and would find the asset concept or process concept difficult to comprehend), some factors in the functional approach may be not applicable to represent Chinese enterprise's TICs (Yam *et al.*, 2004). However, others factors that are not mentioned in the functional approach may be important for Chinese manufacturing enterprise. Therefore, an exploratory study was conducted to evaluate the existing factors and explore other context-specific factors. In total 12 semi-structured interviews were conducted in the Shanghai municipality. All of interviewees came from the R&D departments of manufacturing firms. They worked in the auto or telecommunications equipment manufacturing enterprises. Seven of them were directors of R&D department,

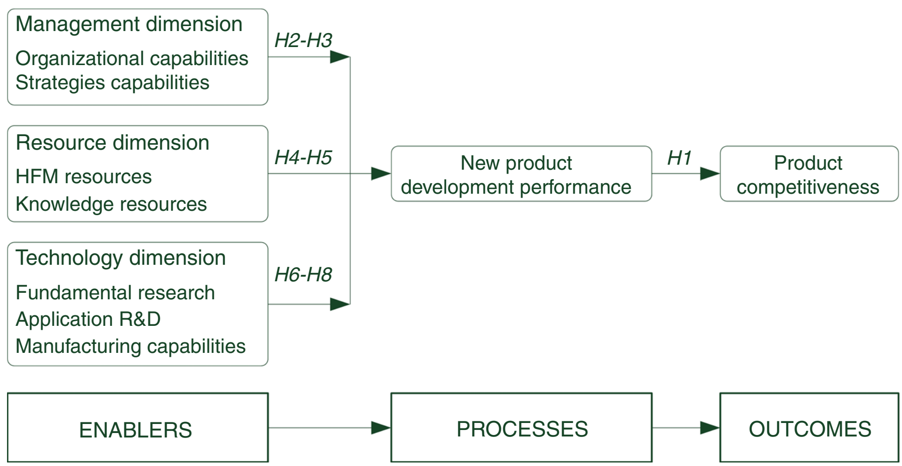

Figure 1.
Research model

and five of them were senior engineers in the R&D department. They had an average of 25.7 years of working experience in the industry.

Through the interviews, majority factors were identified (i.e. manufacturing, resource, management, strategic). However, some factors reported by interviewees were different from factors in existing literature. The factors with more availability and accessibility acquired more support by interviewees. For example, interviewees did not consider market capability as a factor of TICs. In their opinion, the market performance of products was the result of TICs. In addition, under the background of Chinese enterprise's management system, the human, finance, and material (HFM) resources were added into the TICs framework. In addition, R&D capabilities were divided into two parts of fundamental research and application R&D based on the suggestion of interviewees. Finally, the factors of TICs are divided into three dimensions, named management dimension, resource dimension, and technology dimension. The research model is shown in Figure 1:

H1. NPD performance has a positive correlation on the product competitiveness.

The organizational capabilities have long been recognized as an important role in the successful outcome of innovation in research and development process (Omar *et al.*, 2001). Koski *et al.* (2012) pointed out that the management factors, such as company culture, support for idea generation, multifunctional teaming to encourage innovative behavior, different management control mechanisms and performance based reward systems affect the innovation performance of the companies. Therefore, firm's organization and management will affect product innovation and competitiveness. Thus:

H2. Organizational capabilities have a positive correlation on the new product development.

The position of R&D strategies is to improve operational performance through competitive comparisons, product improvement, substitute product analysis, and product enhancement (Cooper, 1984; Sharma, 2003). Sharma (2003) presented that R&D strategies had been accorded the second highest importance after operations strategies in the organization. Therefore, the R&D strategies capabilities have received a high priority in the recent years (Kuckertz *et al.*, 2010; Hooshangi *et al.*, 2013). Thus:

H3. Strategies capabilities have positive correlation on the new product development.

HFM is a specific item with Chinese characteristic. HFM is a general concept which includes of human resource, finance resource, and material resource. HFM is a necessary support to the process of technological innovation (Yang, 1998). Thus:

H4. HFM resources have positive correlation on the new product development.

With global economy has shifted from a manufacturing-based value system to a knowledge-based one, more and more enterprises devote substantial resources into initiating and maintaining enterprise knowledge systems in order to exploit knowledge of their employees (Deken *et al.*, 2012; Nerkar, 2003). Knowledge, information and experience of individual and organization are crucial for product R&D and innovation (Link *et al.*, 2007; Ho and Kuo, 2013). Thus:

H5. Knowledge resources have positive correlation on the new product development.

Fundamental research or basic research is research carried out to increase understanding of fundamental principles. It does not intend to yield immediate practical benefits. Nevertheless, it stimulates new ways to think about deviance that has the potential to revolutionize and dramatically improve how practitioners deal with a problem.in the long term. It is the fundamental of many commercial products and applied research. The world class industrial laboratories, such as: Bell Labs, DuPont Experimental Station, Thomas J. Watson Research Center, Google X Lab, are committed to technology revolution and rapid product development (Zhao and Guo, 2003; Liu and He, 2011). Thus:

H6. Fundamental research has a positive correlation on the new product development.

Application R&D is different from fundamental research, the latter usually requires large amount of resources and undertake greater risks. Therefore, Chinese domestic enterprises prefer to the application development (Sun, 2010). Furthermore, the market demand and high-quality labors are major drivers of application development in China. The results of application development are well suited for the demand of customers. Therefore, the quickly application development will provide more right product to respond market demand. Thus:

H7. Application R&D has a positive correlation on the new product development.

Manufacturing capabilities indicate a firm's ability to transform R&D results into final product. Manufacturing capabilities, such as advanced manufacturing technology (Guan and Ma, 2003), product quality level (Wang *et al.*, 2008), commercialization success rate (Yam *et al.*, 2004), production staff quality level (Yam *et al.*, 2004), and product cycle time (Guan and Ma, 2003), are assessed subjectively. Manufacturing capabilities are the crucial resource of new product development. Thus:

H8. Manufacturing capabilities have positive correlation on the new product development.

4. Research method

4.1 Sample and data collection

As the technical innovation process of a firm involves personnel belonging to the areas of technology management and technology development, the people coming from different technological departments participated in the questionnaire survey. Correspondingly, the unit of analysis is the technical expert of R&D department, rather than the company (Hong *et al.*, 2013; Salerno *et al.*, 2015). The Yangtze River Delta involving Shanghai municipality, Jiangsu and Zhejiang province is the largest and most dynamic economic zone in China. It plays an increasingly important role in technology development and economic growth in China. The state-certified enterprise technology center (SCETC) awarded by the Chinese government has strong technological innovation capability, remarkable innovation performance, and important demonstration effect. The R&D capability of SCETC is stronger than other enterprises' technology departments in China. Accordingly, a large-scale questionnaire survey was conducted to SCETC in Yangtze River Delta. There are 136 SCETC in Yangtze River Delta (up to 2013), which account for 20 percent of SCETC in China.

The sample is a simple random sampling drawn from the population of 120 enterprises (because 16 SCETC belong to the joint venture, and not included in the questionnaires), for the number of enterprises and experts is medium in size (Yen-Ku, 2013). Furthermore, 400 of sampling number are adequate according to Moore *et al.* (2006). In order to ensure unbiased results of random sampling and operational convenience, we provided the predetermined number of sampling in each enterprise and the number was four. Four experts including one technical manager and three senior technical experts were required to fill the questionnaires each firm. And then the total sampling number is 480, which is near 400. Of the 480 questionnaires distributed, 166 completed and usable questionnaires from 48 firms were returned, representing a response rate of 34.6 percent. Following the advice of Armstrong and Overton (1977), we checked the nonresponse bias to ensure that no major difference exists in the responses. Table I reports the statistics description of those respondents, including industry type, location; personal education level, working experience, and position.

4.2 Measures

In our study, items used to operationalize the constructs were adapted from previous studies. All constructs were measured using multiple items. Each item is measured in a seven-point Likert scale. That is, respondents are required to present their answers with scores of 1 to 7 (e.g. 1 = extremely unimportant, and 7 = extremely important). The items and corresponding descriptions are listed in Table II.

5. Data analysis

5.1 Data analysis strategy

A suitable data analysis strategy is desired to test the hypothesized multiple causal relationships in the research model. In our study, structural equation modeling is employed to analyze the experimental data due to its advantages over multiple regression. First, SEM is able to conduct the relationship between each indicator and its corresponding latent variable. However, multiple regression could only deal with observed variables (Musil *et al.*, 1998). Second, SEM is efficient for a series of multiple regression equations to be estimated simultaneously. Traditional multiple regression and path analysis could only estimate path coefficients through a series

Variable	Categories	Number of cases	Frequency (%)
Type of companies	Auto manufacturing	19	39.6
	Ordinary machinery	18	37.5
	Shipping manufacturing	3	6.3
	Telecommunications equipment	8	16.6
Location of companies	Shanghai	24	50.0
	Jiangsu	13	27.2
	Zhejiang	11	22.8
Job position of respondents	Department manager	32	19.3
	Senior engineer	120	72.3
	Engineer	14	8.4
Working experience in current company (years) of respondents	< 5	12	7.2
	5-10	44	26.5
	10-15	56	33.7
	15-20	31	18.7
	> 20	23	13.9
Education of respondents	Postgraduate	63	38.0
	Bachelor degree	87	52.4
	Technical school	16	9.6

Table I.
Statistics information of companies and respondents

Construct	Item	Description	References
Product competitiveness	PC1	Sales of the new products	Adapted from Powell and Dent-Micallef (1997) and Oral and Reisman (1988)
	PC2	Market share of the new products	
	PC3	Profit of the new products	
NPD performance	NPDP1	Successful new products projects	Adapted from Karagozoglu and Brown (1993)
	NPDP2	Independent intellectual property rights	
	NPDP3	Technological change and revolution of new products	
Organizational capabilities	OC1	Company culture encourage for innovation	Adapted from Koc (2007) and Koski *et al.* (2012)
	OC2	Reward system for technical innovation	
	OC3	The management mechanism focussing on the technology	
	OC4	Organizational structure	
Srategies capabilities	SC1	Firm's new product orientation and commitment	Adapted from Cooper(1984)
	SC2	Firm's technology orientation for new product	
	SC3	Firm's new product market orientation	
HFM resources	HFM1	The number of R&D staffs	Adapted from Ministry of science and technology of the People's Republic of China (2008)
	HFM2	The quality of R&D staffs	
	HFM3	The value of technology development equipment	
	HFM4	R&D funds	
Knowledge resources	KR1	Comprehensive product development database	Adapted from Mohrman *et al.* (2003), Fri (2003) and Smith *et al.* (2005)
	KR2	Competitor's product database	
	KR3	Knowledge base of employees' experience and lesson in R&D	
	KR4	Knowledge and Information exchange and sharing platform	
Fundamental research	FR1	The capital investment of fundamental research	Adapted from Mowery and Sampat (2005) and Cohen *et al.* (2002)
	FR2	The number of fundamental research projects	
	FR3	The number of fundamental research staffs	
Application R&D	ARD1	The capital investment of application R&D	Adapted from Sun (2010)
	ARD2	The number of application R&D projects	
	ARD3	The number of application R&D staffs	
Manufacturing capabilities	MC1	Advanced manufacturing technology	Adapted from Guan and Ma (2003) and Wang *et al.* (2008)
	MC2	Product quality level	
	MC3	Commercialization success rate	

Table II. Construct measures

of separate regressions. SEM is regarded as a hybrid model with two components: the measurement model and the structural model. The measurement model shows the hypothesized relationships between latent variables and their indicators. The structural model is the path model, which links the independent and dependent latent variables (Zhang and Ng, 2012, 2013). Kline's (2005) two-step modeling method is followed in this study, i.e., measurement model with confirmatory factor analysis (CFA) first and then structural model with path analysis. The software of SPSS 19 and AMOS 17.0 are used to process the SEM analysis.

5.2 CFA

CFA aims to validate indicators underlying each latent construct and test the measurement model fit (Kline, 2005; Zhang and Ng, 2013). Hair *et al.* (2010) and

Cai *et al.* (2012) suggested that construct validity should be assessed by examining factor loadings of indicators, composite reliability and average variance extracted (AVE). Table III shows that the factor loadings are from 0.660 (MM2) to 0.958 (MC2), higher than the minimum acceptable level of 0.5 (Hair *et al.*, 2010). All the composite reliabilities exceed the cut-off level of 0.7 suggested by Hair *et al.* (1998). Concerning AVE, a threshold of 0.5 is recommended by researchers (Fornell and Larcker, 1981; Hair *et al.*, 2010; Zhang and Ng, 2012). All the AVE values are acceptable.

According to Fornell and Larcker (1981), the discriminant validity is acceptable when the square root of every AVE of each construct is larger than any correlation among any pair of the constructs. Table IV shows that all values of the square root of AVE are above 0.70 and are larger than all other cross-correlations. This indicates that the variance explained by the respective construct is larger than the measurement error variance. The discriminant validity is acceptable.

5.3 Path analysis

To test the hypotheses in the research model, a structural model is developed as shown in Figure 2.

Construct	Item	Cronbach's α	Factor loading	Composite reliability	AVE
PC	PC1	0.872	0.701	0.873	0.699
	PC2		0.947		
	PC3		0.841		
NPDP	NPDP1	0.801	0.754	0.802	0.572
	NPDP2		0.736		
	NPDP3		0.779		
OC	OC1	0.832	0.834	0.839	0.569
	OC2		0.660		
	OC3		0.674		
	OC4		0.830		
SC	SC1	0.914	0.873	0.914	0.780
	SC2		0.866		
	SC3		0.909		
HFM	HFM1	0.871	0.752	0.873	0.633
	HFM2		0.896		
	HFM3		0.718		
	HFM4		0.805		
KR	KR1	0.887	0.868	0.889	0.669
	KR2		0.870		
	KR3		0.802		
	KR4		0.722		
FR	FR1	0.945	0.939	0.944	0.850
	FR2		0.907		
	FR3		0.922		
ARD	ARD1	0.919	0.913	0.920	0.793
	ARD2		0.862		
	ARD3		0.896		
MC	MC1	0.904	0.774	0.908	0.767
	MC2		0.958		
	MC3		0.886		

Table III.
Construct validity and reliability

	PC	NPDP	OC	SC	HFM	KR	FR	ARD	MC
PC	0.836								
NPDP	0.513	0.756							
OC	0.119	0.213	0.754						
SC	0.367	0.167	0.276	0.883					
HFM	0.273	0.139	0.384	0.301	0.796				
KR	0.221	0.267	0.251	0.662	0.429	0.818			
FR	0.318	0.582	0.389	0.431	0.378	0.154	0.922		
ARD	0.326	0.517	0.432	0.467	0.291	0.482	0.526	0.891	
MC	0.406	0.582	0.382	0.490	0.318	0.372	0.481	0.632	0.876

Table IV. Discriminant validity

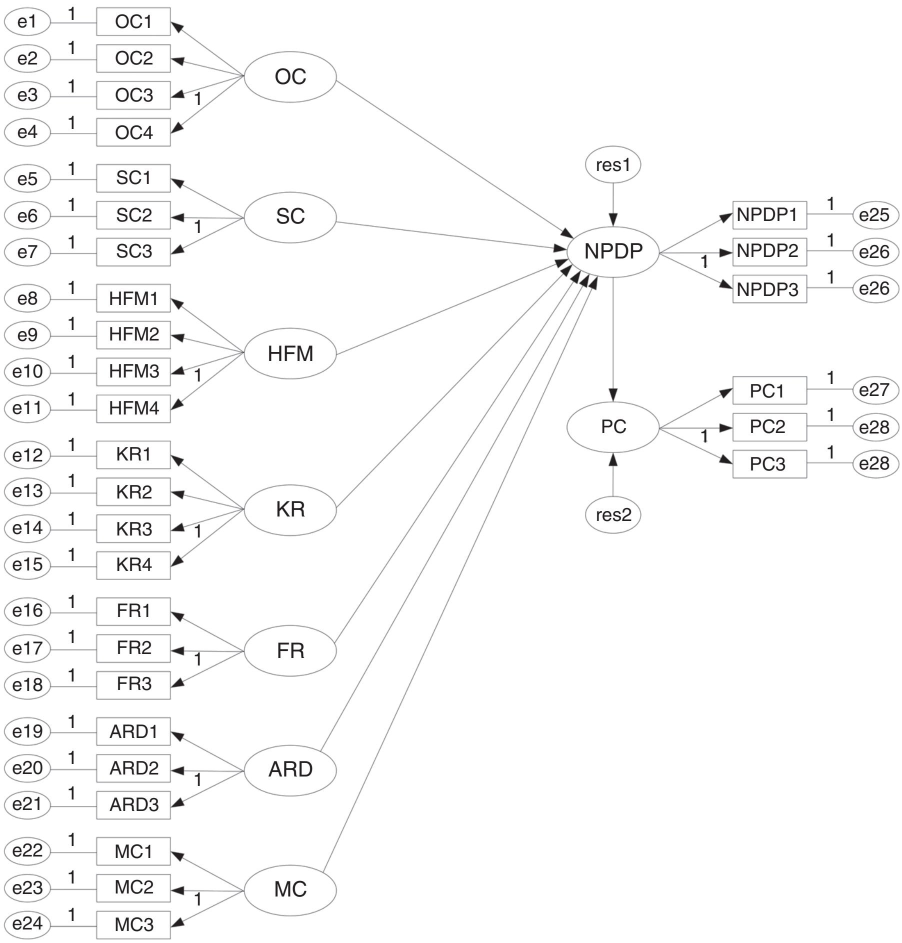

Figure 2. Original structural model

The overall model fit is assessed by absolute fit measures (χ^2/df, RMSEA), and incremental fit measures (NNFI, CFI) as recommended by Hair *et al.* (2010) and Schermelleh-Engel *et al.* (2003). Table V shows that all the goodness-of-fit indices are unsatisfactory. SEM results suggest that the original model should be rejected because several goodness-of-fit indices fail to achieve the desired values. Accordingly, an alternative structural model should be developed. Modification indices in AMOS output are referred to modify the structural model. The revised structural model is shown in Figure 3.

Compared to the original model, the revised model incorporates correlated relationships between constructs and between error items. Table VI indicates that all the fit measures accomplish the acceptable level of values. The revised model is supported by achieving adequate fit.

Table V. Goodness-of-fit indexes for original structure model

Type of fit measures	Index	Calculation of measures	Acceptable level	Acceptability
Absolute fit measures	χ^2/df	3.762	⩽3	Not accepted
	RMSEA	0.129	⩽0.10	Not accepted
Incremental fit measures	NNFI	0.807	⩾0.90	Not accepted
	CFI	0.865	⩾0.90	Not accepted

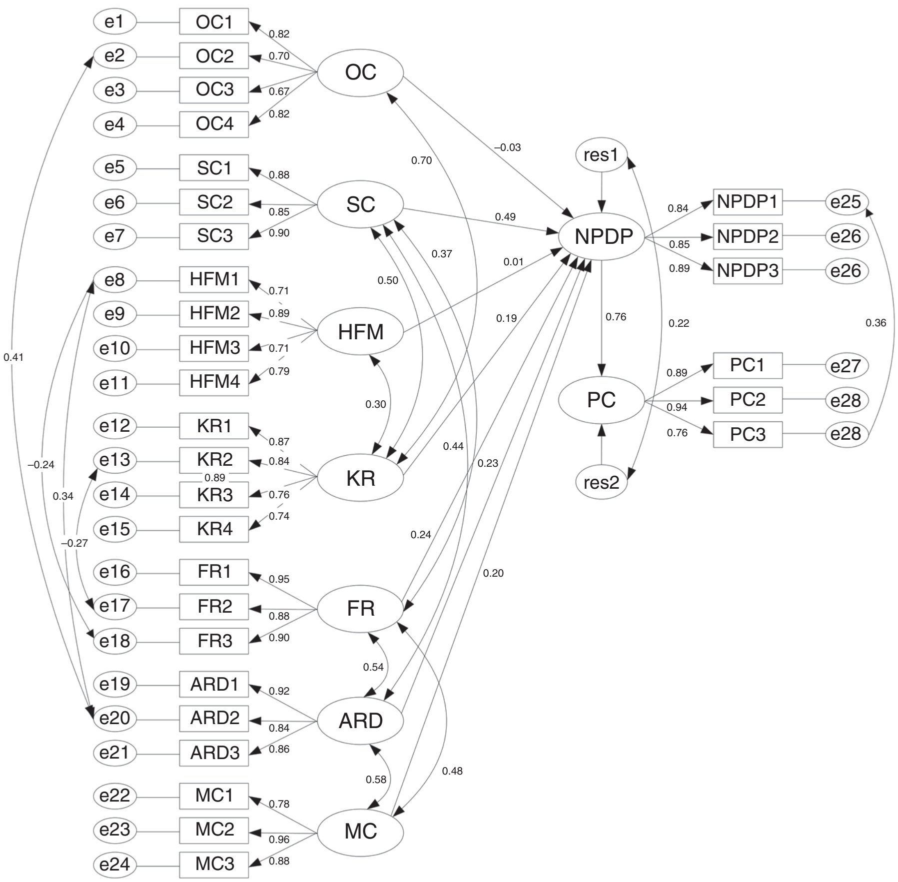

Figure 3. Revised structure model

5.4 Hypotheses testing

The results of hypotheses testing are summarized in Table VII. SEM results uncover that NPD performance has the significant impact on product competitiveness (path coefficient 0.762, $p < 0.001$). Strategies capabilities (path coefficient 0.484, $p < 0.001$), knowledge resources (path coefficient 0.189, $p < 0.01$), fundamental research (path coefficient 0.242, $p < 0.001$), application R&D (path coefficient 0.228, $p < 0.01$) and manufacturing capabilities (path coefficient 0.197, $p < 0.01$) positively impact NPD performance. However, organizational capabilities (path coefficient −0.029, $p = 0.716$) and HFM resources (path coefficient 0.008, $p = 0.894$) have no significant relationships with NPD performance. The plausible reasons for such results are explained in the next section.

6. Discussion

The results imply that NPD performance is an important resource for improving the product competitiveness of Chinese manufacturers. The results also indicate that new product development is mainly determined by firm's strategies capabilities, knowledge resources, fundamental research, application R&D and manufacturing capabilities rather than the organizational capabilities and HFM resources of enterprises.

More specifically, firm's strategies capabilities exert the strongest influence on the new product development. The finding indicates that new product development of

Type of fit measures	Index	Calculation of measures	Acceptable level	Acceptability
Absolute fit measures	χ^2/df	2.151	⩽3	Accepted
	RMSEA	0.084	⩽0.10	Accepted
Incremental fit measures	NNFI	0.909	⩾0.90	Accepted
	CFI	0.921	⩾0.90	Accepted

Table VI. Goodness-of-fit indexes for revised structure model

Path (hypotheses)	p-value	Path coefficient	Result
New product development performance → product competitiveness (*H1*)	0.000	0.762**	Supported
Organizational capabilities → new product development performance (*H2*)	0.716	−0.029	Not supported
Strategies capabilities → new product development performance (*H3*)	0.000	0.484**	Supported
HFM resources → new product development performance (*H4*)	0.894	0.008	Not supported
Knowledge resources → new product development performance (*H5*)	0.006	0.189*	Supported
Fundamental research → new product development performance (*H7*)	0.000	0.242**	Supported
Application R&D → new product development performance (*H8*)	0.003	0.228*	Supported
Manufacturing capabilities → new product development performance (*H6*)	0.002	0.197*	Supported

Notes: *$p < 0.01$; **$p < 0.0001$

Table VII. Summary of hypotheses testing results

Chinese manufacturers is not solely affected by resources and technological factors – it also relies heavily on firm's explicit R&D strategies and technological developing direction (Teece, 1986).

In our study, fundamental research is identified as a critical impetus of NPD performance of Chinese manufacturing enterprises. The finding indicates that fundamental research is attracting the attention of more and more Chinese manufacturers. Fundamental research, especially the research on new technology and new material, can bring about revolutionary products, which are the pursuit of more and more Chinese manufacturers.

Application R&D also significantly affects new product development of Chinese manufacturers. The result is supported by Sun (2010), who indicated that Chinese domestic enterprises prefer to application development. The market demand and the availability of quality labor are the major drivers of application development in China.

In addition, knowledge resources also have significant influence on NPD performance of Chinese manufacturers. The result is supported by Miller *et al.* (2007), who presented that "the use of interdivisional knowledge positively affects the invention on subsequent technological developments." In the era of knowledge economy, a firm must continually acquire the diverse and novel knowledge, which will serve as the seed for future technological innovation and development (Fri, 2003; Smith *et al.*, 2005). According to the results of our study, knowledge resources are urgent need for today's Chinese manufacturers.

It is interesting that the organizational capabilities have no significant correlation with NPD performance of Chinese manufacturers. This result discords with the findings of many prior empirical studies (Gallivan, 2001; Langerak and Hultink, 2008; Nambisan *et al.*, 1999). Several plausible explanations can be suggested for this phenomenon by comparing this study with previous studies. First, the characteristics of respondents may account for this phenomenon. Table II indicates that all of the respondents come from the R&D department of enterprises and many of them are senior experts in the department. With more attention paid to technical activities, they may be less concerned with the organizational management than the enterprise's top managers. Second, the management mechanism of Chinese firms is lagging behind that of many foreign competitors. For instance, Chinese firm's bureaucratic culture constrains many organizational changes and firm cannot fully exploit the technologically potential (Gallivan, 2001; Nambisan *et al.*, 1999). Therefore, we consider that the value of organizational capabilities for promoting technology innovation and new product development has not been revealed, which should be particularly noteworthy for Chinese manufacturing enterprises.

An unexpected finding is that HFM resources have no significant correlation with the NPD performance of Chinese manufacturing enterprises. The result discords with other researchers' findings (Yang, 1998). Because HFM resource is a concept with Chinese characteristics, the review of existing literature reveals limited attention paid to such factor. One possible reason is suggested to explain the phenomenon. Though HFM is the key fundamental resource for technological innovation, the result shows that firm's HFM resource is not the bottleneck of enterprise's technological innovation, with Chinese government and enterprise providing continual R&D capital investment (Gu *et al.*, 2006; Chen *et al.*, 2007). As a result, HFM resource has no significant correlation with technological innovation and new product development. It seems to be a fruitful area for future research to explore the mechanisms explaining such phenomenon.

7. Conclusion and limitation

This study applies the SEM method to shed light on how TICs influence the product competitiveness in the background of Chinese manufacturing. From a managerial perspective, this study identifies several TICs factors essential to successful product competitiveness. The results indicate that firm's strategies capabilities, fundamental research, application R&D and manufacturing capabilities significantly influence NPD performance and further influence product competitiveness. Contrary to expectation, organizational capabilities and HFM resource do not make significant contribution to new product development.

The research findings provide some managerial implications for Chinese policy maker and manufacturers to improve production competitiveness through enhancing TICs. Policy makers may be interested in that HFM resources have not significant correlation with technological innovation and new product development nowadays. Meanwhile, fundamental research is recognized as a critical impetus for new product development performance. It seems that more fundamental research investment should be taken into account for policy makers. To Chinese manufacturers, the importance of R&D strategies should be emphasized in business management. R&D strategy can point out the right direction for improving enterprise's competitiveness advantage. Successful R&D strategies could impulse firm to continuously exploit new business opportunities in the fluctuating worldwide competition. Because R&D is a typical knowledge-intensive task, knowledge resource is also beneficial to new product development and product competitiveness. The knowledge of experts and organization should be effectively managed for solving innovative problem and making effective decisions (Piorkowski *et al.*, 2012; Shankar *et al.*, 2012). Knowledge resource, especially tacit knowledge and individual empirical knowledge, should be paid enough attention to in Chinese firm's management practice.

This study has its own limitations. However, the limitations also provide directions for future research. At first, the so-called product competitiveness is a complex concept. For example, profit is a key factor of product competitiveness. However, profit equals price subtracting unit cost, where price is affected by external competition, not just by the capability of the factory. Therefore, one of the limitations of the study is that only internal factors of the potential influential factors in TIC are examined, and therefore only a portion of the variance of the dependent variables in the research model is explained. Future studies could elaborate the research model with additional factors. Additionally, our findings are based on R&D departments' perceptions and what they had chosen to reveal in the survey or interview, and therefore the results may not be applicable to other regions due to different working practice and different cultural characteristics. Future studies could extend the survey to the whole company including multiple parties.

References

Adler, P.S. and Shenhar, A. (1990), "Adapting your technological base: the organizational challenge", *Sloan Management Review*, Vol. 32 No. 1, pp. 25-37.

Armstrong, J.S. and Overton, T.S. (1977), "Estimating nonresponse bias in mail surveys", *Journal of Marketing Research*, Vol. 14 No. 3, pp. 396-402.

Boly, V., Morel, L., Assielou, N.D.G. and Camargo, M. (2014), "Evaluating innovative processes in French firms: methodological proposition for firm innovation capacity evaluation", *Research Policy*, Vol. 43 No. 3, pp. 608-622.

Cai, S., Goh, M., de Souza, R. and Li, G. (2012), "Knowledge sharing in collaborative supply chains: twin effects of trust and power", *International Journal of Production Research*, pp. 1-17.

Chen, J., Neubaum, D.O., Reilly, R.R. and Lynn, G.S. (2015), "The relationship between team autonomy and new product development performance under different levels of technological turbulence", *Journal of Operations Management*, Vol. 33-34, January, pp. 83-96.

Chen, Y., Li, X. and Bai, P. (2007), "How market structure influence R&D input: an empirical analysis on China's manufacture's panel data", *Nankai Economic Studies*, No. 1, pp. 135-145.

Cheng, Y.-L. and Lin, Y.-H. (2012), "Performance evaluation of technological innovation capabilities in uncertainty", *Procedia-Social and Behavioral Sciences*, Vol. 40, pp. 287-314.

Chiesa, V. and Manzini, R. (1998), "Profiting from the virtual organisation of technological innovation: suggestions from an empirical study", *International Journal of Technology Management*, Vol. 15 No. 1, pp. 109-123.

Christensen, J.F. (1995), "Asset profiles for technological innovation", *Research Policy*, Vol. 24 No. 5, pp. 727-745.

Cohen, W.M., Nelson, R.R. and Walsh, J.P. (2002), "Links and impacts: the influence of public research on industrial R&D", *Management Science*, Vol. 48 No. 1, pp. 1-23.

Cooper, R.G. (1984), "The strategy-performance link in product innovation", *R&D Management*, Vol. 14 No. 4, pp. 247-259.

Deken, F., Kleinsmann, M., Aurisicchio, M., Lauche, K. and Bracewell, R. (2012), "Tapping into past design experiences: knowledge sharing and creation during novice-expert design consultations", *Research in Engineering Design*, Vol. 23 No. 3, pp. 203-218.

Dierickx, I. and Cool, K. (1989), "Asset stock accumulation and sustainability of competitive advantage", *Management Science*, Vol. 35 No. 12, pp. 1504-1511.

Eisenhardt, K.M. and Sull, D.N. (2001), "Strategy as simple rules", *Harvard Business Review*, Vol. 79 No. 1, pp. 106-119.

Feng, T. and Wang, D. (2013), "Supply chain involvement for better product development performance", *Industrial Management & Data Systems*, Vol. 113 Nos 1-2, pp. 190-206.

Fornell, C. and Larcker, D.F. (1981), "Evaluating structural equation models with unobservable variables and measurement error", *Journal of Marketing Research*, Vol. 18 No. 1, pp. 39-50.

Freeman, C. (1994), "The economics of technical change", *Cambridge Journal of Economics*, Vol. 18 No. 5, pp. 463-514.

Fri, R.W. (2003), "The role of knowledge: technological innovation in the energy system", *The Energy Journal*, Vol. 24 No. 4, pp. 51-74.

Gallivan, M.J. (2001), "Organizational adoption and assimilation of complex technological innovations: development and application of a new framework", *SIGMIS Database*, Vol. 32 No. 3, pp. 51-85.

Griffin, A. (1997), "Modeling and measuring product development cycle time across industries", *Journal of Engineering and Technology Management*, Vol. 14 No. 1, pp. 1-24.

Gu, L., Zhang, Z. and Kang, J. (2006), "Patent and R&D resources: the input-output analysis of china innovation", *Journal of Industrial Engineering and Engineering Management*, Vol. 20 No. 1, pp. 147-151 (in Chinese).

Guan, J. (2002), "Comparison study of industrial innovation between China and some European countries", *Production and Inventory Management Journal*, Vol. 43 Nos 3-4, pp. 30-46.

Guan, J. and Chen, K. (2010), "Measuring the innovation production process: a cross-region empirical study of China's high-tech innovations", *Technovation*, Vol. 30 No. 5, pp. 348-358.

Guan, J. and Ma, N. (2003), "Innovative capability and export performance of Chinese Firms", *Technovation*, Vol. 23 No. 9, pp. 737-747.

Guan, J.C., Yam, R.C.M., Mok, C.K. and Ma, N. (2006), "A study of the relationship between competitiveness and technological innovation capability based on DEA models", *European Journal of Operational Research*, Vol. 170 No. 3, pp. 971-986.

Hair, J., Black, B., Babin, B. and Anderson, R. (2010), *Multivariate Data Analysis 7th*, Pearson Prentice Hall, Upper Saddle River, NJ.

Ho, L.-A. and Kuo, T.-H. (2013), "How system quality and incentive affect knowledge sharing", *Industrial Management & Data Systems*, Vol. 113 No. 7, pp. 1048-1063.

Hong, J.-T., Yang, X.-Y. and Chen, J.-F. (2013), "An empirical research on the relationship among knowledge management, knowledge competence and core competence", *Journal of Shanghai Jiaotong University*, Vol. 47 No. 3, pp. 444-449.

Hooshangi, S., Arasti, M.R., Hounshell, D.A. and Sahebzamani, S. (2013), "Evolutionary learning methodology: a case study of R&D strategy development", *Technological Forecasting and Social Change*, Vol. 80 No. 5, pp. 956-976.

Hsu, Y.-H. and Fang, W. (2009), "Intellectual capital and new product development performance: the mediating role of organizational learning capability", *Technological Forecasting and Social Change*, Vol. 76 No. 5, pp. 664-677.

Karagozoglu, N. and Brown, W.B. (1993), "Time-based management of the new product development process", *Journal of Product Innovation Management*, Vol. 10 No. 3, pp. 204-215.

Kline, R. (2005), *Principles and Practice of Structural Equation Modeling*, Guilford, New York, NY.

Koc, T. (2007), "Organizational determinants of innovation capacity in software companies", *Computers & Industrial Engineering*, Vol. 53 No. 3, pp. 373-385.

Kocoglu, I., Imamoglu, S.Z., Ince, H. and Keskin, H. (2012), "Learning, R&D and manufacturing capabilities as determinants of technological learning: enhancing innovation and firm performance", *Procedia – Social and Behavioral Sciences*, Vol. 58, October, pp. 842-852.

Koski, H., Marengo, L. and Makinen, I. (2012), "Firm size, managerial practices and innovativeness: some evidence from Finnish manufacturing", *International Journal of Technology Management*, Vol. 59 Nos 1-2, pp. 1-2.

Kuckertz, A., Kohtamäki, M. and Droege gen. Körber, C. (2010), "The fast eat the slow – the impact of strategy and innovation timing on the success of technology-oriented ventures", *International Journal of Technology Management*, Vol. 52 No. 1, pp. 175-188.

Lai, Y.-L. and Lin, F.-J. (2012), "The effects of knowledge management and technology innovation on new product development performance – an empirical study of Taiwanese machine tools industry", *Asia Pacific Business Innovation and Technology Management Society* Vol. 40, pp. 157-164.

Lang, T.M., Lin, S.H. and Vy, T.N.T. (2012), "Mediate effect of technology innovation capabilities investment capability and firm performance in Vietnam", *Procedia – Social and Behavioral Sciences*, Vol. 40, pp. 817-829.

Langerak, F. and Hultink, E.J. (2008), "The effect of new product development acceleration approaches on development speed: a case study", *Journal of Engineering and Technology Management*, Vol. 25 No. 3, pp. 157-167.

Lau, A.K.W., Baark, E., Lo, W.L.W. and Sharif, N. (2013), "The effects of innovation sources and capabilities on product competitiveness in Hong Kong and the Pearl River Delta", *Asian Journal of Technology Innovation*, Vol. 21 No. 2, pp. 220-236.

Lin, H.-F. (2007a), "Effects of extrinsic and intrinsic motivation on employee knowledge sharing intentions", *Journal of Information Science*, Vol. 33 No. 2, pp. 135-149.

Lin, H.F. (2007b), "Knowledge sharing and firm innovation capability: an empirical study", *International Journal of Manpower*, Vol. 28 Nos 3-4, pp. 315-332.

Link, A.N., Siegel, D.S. and Bozeman, B. (2007), "An empirical analysis of the propensity of academics to engage in informal university technology transfer", *Industrial and Corporate Change*, Vol. 16 No. 4, pp. 641-655.

Liu, X. and He, Y. (2011), "Basic research is the source of industrial core technological innovation in China", *China Soft Science*, Vol. 4, pp. 104-117 (in Chinese).

Luo, X. (2010), "Product competitiveness and beating analyst earnings target", *Journal of the Academy of Marketing Science*, Vol. 38 No. 3, pp. 253-264.

Miller, D.J., Fern, M.J. and Cardinal, L.B. (2007), "The use of knowledge for technological innovation within diversified firms", *Academy of Management Journal*, Vol. 50 No. 2, pp. 307-325.

Ministry of science and technology of the People's Republic of China (2008), "State-certified enterprise technology center management method", available at: www.most.gov.cn/ztzl/gjzctx/ptzckjcx/200802/t20080222_59226.htm

Mohrman, S.A., Finegold, D. and Mohrman, A.M. Jr (2003), "An empirical model of the organization knowledge system in new product development firms", *Journal of Engineering and Technology Management*, Vol. 20 Nos 1-2, pp. 7-38.

Moore, D.S., Notz, W.I. and Notz, W. (2006), *Statistics: Concepts and Controversies*, Macmillan, New York, NY.

Mowery, D.C. and Sampat, B.N. (2005), "Universities in national innovation systems", *The Oxford Handbook of Innovation*, pp. 209-239.

Musil, C.M., Jones, S.L. and Warner, C.D. (1998), "Structural equation modeling and its relationship to multiple regression and factor analysis", *Research in Nursing & Health*, Vol. 21 No. 3, pp. 271-281.

Nambisan, S., Agarwal, R. and Tanniru, M. (1999), "Organizational mechanisms for enhancing user innovation in information technology", *MIS Quarterly*, Vol. 23 No. 3, pp. 365-395.

Nerkar, A. (2003), "Old is gold? The value of temporal exploration in the creation of new knowledge", *Management Science*, Vol. 49 No. 2, pp. 211-229.

Omar, A.-M., NEIL, D. and Malcolm, K. (2001), "An investigation into the relative success of alternative approaches to the treatment of organizational issues in systems development projects", *Organization Development Journal*, Vol. 19 No. 1, pp. 31-48.

Oral, M. and Reisman, A. (1988), "Measuring industrial competitiveness", *Industrial Marketing Management*, Vol. 17 No. 3, pp. 263-272.

Piorkowski, B.A., Gao, J.X., Evans, R.D. and Martin, N. (2012), "A dynamic knowledge management framework for the high value manufacturing industry", *International Journal of Production Research*, Vol. 51 No. 7, pp. 2176-2185.

Porter, M.E. (1990), "The competitive advantage of nations", *Harvard Business Review*, Vol. 68 No. 2, pp. 73-93.

Powell, T.C. and Dent-Micallef, A. (1997), "Information technology as competitive advantage: the role of human, business, and technology resources", *Strategic Management Journal*, Vol. 18 No. 5, pp. 375-405.

Rajagopalan, N., Rasheed, A.M. and Datta, D.K. (1993), "Strategic decision processes: critical review and future directions", *Journal of Management*, Vol. 19 No. 2, pp. 349-384.

Salerno, M.S., Gomes, L.A.d.V., Silva, D.O.d., Bagno, R.B. and Freitas, S.L.T.U. (2015), "Innovation processes: which process for which project?", *Technovation*, Vol. 35 No. 1, pp. 59-70.

Schermelleh-Engel, K., Moosbrugger, H. and Müller, H. (2003), "Evaluating the fit of structural equation models: tests of significance and descriptive goodness-of-fit measures", *Methods of Psychological Research Online*, Vol. 8 No. 2, pp. 23-74.

Sen, F.K. and Egelhoff, W.G. (2000), "Innovative capabilities of a firm and the use of technical alliances", *IEEE Transactions on Engineering Management*, Vol. 47 No. 2, pp. 174-183.

Shankar, R., Mittal, N., Rabinowitz, S., Baveja, A. and Acharia, S. (2012), "A collaborative framework to minimise knowledge loss in new product development", *International Journal of Production Research*, Vol. 51 No. 7, pp. 2049-2059.

Sharma, B. (2003), "R&D strategy and Australian manufacturing industry: an empirical investigation of emphasis and effectivness", *Technovation*, Vol. 23 No. 12, pp. 929-937.

Smith, K.G., Collins, C.J. and Clark, K.D. (2005), "Existing knowledge, knowledge creation capability, and the rate of new product introduction in high-technology firms", *Academy of Management Journal*, Vol. 48 No. 2, pp. 346-357.

Sun, Y. (2010), "Foreign research and development in China: a sectoral approach", *International Journal of Technology Management*, Vol. 51 No. 2, pp. 342-363.

Takeuchi, H. and Nonaka, I. (1986), "The new new product development game", *Harvard Business Review*, Vol. 64 No. 1, pp. 137-146.

Teece, D.J. (1986), "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy", *Research Policy*, Vol. 15 No. 6, pp. 285-305.

Tseng, M.-L., Lin, Y.H., Lim, M.K. and Teehankee, B.L. (2015), "Using a hybrid method to evaluate service innovation in the hotel industry", *Applied Soft Computing*, Vol. 28 No. 3, pp. 411-421.

Verdu, A.J., Tamayo, I. and Ruiz-Moreno, A. (2012), "The moderating effect of environmental uncertainty on the relationship between real options and technological innovation in high-tech firms", *Technovation*, Vol. 32 No. 9, pp. 579-590.

Wang, C.-H., Lu, I.-Y. and Chen, C.-B. (2008), "Evaluating firm technological innovation capability under uncertainty", *Technovation*, Vol. 28 No. 6, pp. 349-363.

Yam, R., Guan, J.C., Pun, K.F. and Tang, E.P. (2004), "An audit of technological innovation capabilities in Chinese firms: some empirical findings in Beijing, China", *Research Policy*, Vol. 33 No. 8, pp. 1123-1140.

Yam, R., Lo, W., Tang, E.P. and Lau, A.K. (2011), "Analysis of sources of innovation, technological innovation capabilities, and performance: an empirical study of Hong Kong manufacturing industries", *Research Policy*, Vol. 40 No. 3, pp. 391-402.

Yang, H. (1998), "An empirical analysis of technological innovation capability evaluation index", *Statistical Research*, Vol. 1, pp. 53-58 (in Chinese).

Yen-Ku, K. (2013), "Organizational commitment in an intense competition environmentnull", *Industrial Management & Data Systems*, Vol. 113 No. 1, pp. 39-56.

Zhang, P. and Ng, F.F. (2012), "Attitude toward knowledge sharing in construction teams", *Industrial Management & Data Systems*, Vol. 112 No. 9, pp. 4-4.

Zhang, P. and Ng, F.F. (2013), "Explaining knowledge-sharing intention in construction teams in Hong Kong", *Journal of Construction Engineering and Management*, Vol. 139 No. 3, pp. 280-293.

Zhao, L. and Guo, G. (2003), "Changing traditions in the US corporate laboratories", *Studies in Science of Science*, Vol. 1, pp. 25-29 (in Chinese).

Further reading

Fan, P. (2006), "Catching up through developing innovation capability: evidence from China's telecom-equipment industry", *Technovation*, Vol. 26 No. 3, pp. 359-368.

Fontana, R., Geuna, A. and Matt, M. (2006), "Factors affecting university – industry R&D projects: the importance of searching, screening and signalling", *Research policy*, Vol. 35 No. 2, pp. 309-323.

Plewa, C., Troshani, I., Francis, A. and Rampersad, G. (2012), "Technology adoption and performance impact in innovation domains", *Industrial Management & Data Systems*, Vol. 112 Nos 5-6, pp. 748-765.

Corresponding author
Zuhua Jiang can be contacted at: zhjiang1966@126.com