Effects of standardization and innovation on mass customization: An empirical investigation

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ABSTRACT

Mass customization (MC) refers to the capability to produce customized goods for a mass market. Innovation can enhance the flexibility and responsiveness of a company, and standardization enables the company to achieve economies of scale and scope, both of which are necessary for developing MC capability. A conceptual model is proposed to explore the relationships among innovation, standardization, MC capability, and delivery speed. Hypotheses are tested using survey data from 204 manufacturing companies in China. The results show that standardization positively influences innovation. Innovation and standardization positively affect MC capability and are complementary in developing MC capability. Innovation significantly enhances delivery speed. However, the direct effect of standardization on delivery speed is nonsignificant. In addition, innovation and standardization indirectly affect delivery speed through MC capability. This study contributes to the literature by providing empirical evidence on the individual and interactive effects of standardization and innovation in developing MC capability and their joint influence on delivery speed. The results will help managers understand the roles of standardization and innovation in improving organizational capability and performance.

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1. Introduction

Mass customization (MC) aims to offer customized products on a large scale and in a responsive manner so that nearly every customer can find products that satisfy their specific needs at a reasonable price (Anderson and Pine, 1997; Jiao et al., 2003). By aligning a manufacturer with its customer needs (Salvador et al., 2009), MC satisfies the demands for customization efficiently (Jitpaiboon et al., 2013; Kortmann et al., 2014). Mass customizers usually face the challenges of increasing product variety and process complexity (Duray et al., 2000; Salvador et al., 2009). Therefore, delivery speed, which refers to the extent to which a company promptly delivers products in response to customer needs (Calantone and Di Benedetto, 2000), is crucial for mass customizers to create and deliver value to customers (Jitpaiboon et al., 2013; Tu et al., 2001). The purpose of this study is to empirically investigate the roles of standardization and innovation in building MC capability and improving delivery speed. This study addresses the following two research questions. First, what are the individual and interactive effects of standardization and innovation on MC capability? Second, how do standardization, innovation, and MC capability jointly influence delivery speed?

MC capability enables a manufacturer to produce customized products rapidly at a cost comparable to the unit cost achieved with mass production (Tu et al., 2004). Implementing MC requires unique manufacturing systems and operational practices (Salvador et al., 2009). For example, studies have shown that MC capability can be developed through standardized modules (Peng et al., 2011; Tu et al., 2004) and innovative product and process designs (Jitpaiboon et al., 2013; Kristal et al., 2010). Standardization refers to the use of common parts, components, and platforms in research and development (R&D), production, and purchasing (Perera et al., 1999). Innovation is the practice of adopting, integrating, and implementing new knowledge and technologies in product and process development (Manu and Sriram, 1996; Wan et al., 2005). Standardization aims at growth through economies of scale and by increasing productivity and market share, whereas innovation aims at making a manufacturer more profitable and adaptive to market dynamics. Two competing views exist on the relationship between standardization and innovation (Thompson, 1965; Fixson and Park, 2008). Standardization emphasizes the similarity, uniformity, and continuity of behavior and encourages bureaucracy, which may hinder the generation of new and path-breaking ideas

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and thus restrict companies to existing products or technologies (Thompson, 1965; David and Rothwell, 1996). Recently, some researchers argue that standardization allows employees to develop common languages and methodologies that facilitate knowledge distribution and combination, product and process development, and the adaptation of new technologies (Funk and Luo, 2015; Wright et al., 2012), thereby enhancing innovation. Because of the potential mixed effects of standardization on innovation and their major roles in MC (Fogliatto et al., 2012; Salvador et al., 2009), understanding the combined effects of standardization and innovation on MC capability and delivery speed can help manufacturers gain a competitive advantage.

This study can provide insights into the relationship between standardization and innovation and their roles in MC capability development. The results reveal that the interaction between standardization and innovation enhances MC capability and that MC capability carries the effects of standardization and innovation on delivery speed, thereby contributing to the MC literature. Thus, the findings can help managers in manufacturing firms to develop a more clear understanding of the effects of standardization and innovation on organizational capability and performance.

2. Literature review

2.1. Standardization

Standardization is a voluntary process for developing specifications based on the consensus of companies with their stakeholders (Saltzman et al., 2008). Standardization can be investigated at different levels (David and Rothwell, 1996; Perera et al., 1999; Tamura, 2013). As this study investigates the roles of standardization along vertical value chains, a micro-perspective is adopted (Baud-Lavigne et al., 2012). Therefore, this study focuses on company standards at the organization level instead of committee standards at the national level. Company standards emerge with many different formats in organizations and can influence the entire product and process development cycles, ranging from idea generation to product or process launch (Perera et al., 1999; Wright et al., 2012).

This study focuses on the company standards on product components and platforms (Anderson and Pine, 1997; Jiao and Tseng, 2000). These standards can be used to facilitate coordination among internal departments and with external partners (Perera et al., 1999; Baud-Lavigne et al., 2012). Company standards allow a manufacturer to decompose complex products into submodules, which can be shared, swapped, and used in multiple product lines (Fixson and Park, 2008), reducing transaction costs and fostering specialization (Funk and Luo, 2015). The standards enable a manufacturer to achieve economies of scale and scope and reduce costs by customizing one component without changing the overall product design or the designs of other components of the product (Baud-Lavigne et al., 2012). By maximizing the number of standard components, creating standard interfaces among them, and using product platforms, a manufacturer can produce compatible modules concurrently and reassemble or modify the modules into different functional forms (Peng et al., 2011; Tu et al., 2004). Standardization thus can benefit manufacturers by simplifying operations and reducing production complexity and inventory levels (Fredriksson and Gadde, 2005; Jiao et al., 2003). Researchers have argued that standardization can improve MC capability by facilitating the implementation of modularity-based manufacturing practices (i.e., product modularity, process modularity, and dynamic teaming) (Tu et al., 2004) and product configurator (Peng et al., 2011) and by mitigating the negative effects of product variety on internal operations (Duray et al., 2000).

2.2. Innovation

Innovation refers to new applications of knowledge, methods, and skills that can generate enhanced products and processes to meet customer demands and market needs (Kim et al., 2012; Wan et al., 2005). Innovation enables manufacturers to transform value propositions and improve agility and flexibility (Tongur and Engwall, 2014), and therefore, the manufacturers can quickly respond to changes in environments and benefit from market dynamics, which are fundamental for their competitiveness (Manu and Sriram, 1996; Lim et al., 2013). Innovations can take different forms such as upgrades, extensions, and major changes in existing products and processes (Kim et al., 2012).

This study focuses on product and process innovation. Product innovation refers to changes at the end of providing products, whereas process innovation is defined as changes in the methods of producing products (Kim et al., 2012). Product and process innovation require manufacturers to learn and develop new knowledge (Lin et al., 2012; Nonaka, 1991). Researchers have argued that innovation has a major role in MC because new products and processes allow a manufacturer to efficiently manage a wide variety of products (Da Silveira et al., 2001). For instance, Kristal et al. (2010) propose that continuous improvement is a prerequisite to and the solution for improving the operational competence in MC. Jitpaiboon et al. (2013) discover that process innovation can provide variety, custom fit, high-performance, and speed that customers expect and therefore enhance MC capability.

2.3. MC capability

MC capability can be defined as the ability to offer a relatively high-volume of product options for a relatively large market that demands customization, without substantial tradeoffs in cost, delivery, and quality (Huang et al., 2008). MC capability has four aspects: (1) customizing products while maintaining high-volume, (2) customizing products without substantially increasing costs, (3) responding to customization demands quickly, and (4) customizing products with consistent quality.

High-volume customization refers to the ability to aggregate individual customer needs into the large-batch production of common parts (Tu et al., 2001). As markets become increasingly segmented, mass customizers must aggregate customer demands to produce high-volumes of products across their fixed asset bases to achieve economies of scope and scale (Peng et al., 2011). Customization cost efficiency refers to the ability to provide customized products at a price similar to the unit price achieved using mass production (Tu et al., 2001). MC considerably increases operational uncertainty and complexity. Controlling operation costs is a challenge for mass customizers (Jiao et al., 2003). Customization responsiveness refers to the ability to reduce the total lead time for product customization (Huang et al., 2008). In general, customers must wait longer if they want personalized products. Increasing the agility of a production process is a major concern for mass customizers. Customization quality refers to the ability to manage and guarantee the quality level of every customized product (Huang et al., 2008). Mass customizers usually face the challenge of ensuring consistent quality when product variety increases considerably. Thus, manufacturers must implement advanced and innovative technologies and systems for delivering products that meet individual customer needs at nearly mass production efficiency (Salvador et al., 2009). For example, researchers have found that MC capability can be developed through time-based manufacturing practices (Tu et al., 2001), organizational learning (Huang et al., 2008), quality management (Kristal

et al., 2010), information technology (Peng et al., 2011), and supply chain integration (Jitpaiboon et al., 2013).

Researchers have acknowledged that standardization as well as product and process innovation are indispensable in MC implementation in conceptual studies. For example, Da Silveira et al. (2001) argue that MC products must be modularized with standardized interfaces and MC processes require rapid product development and innovation capabilities. Salvador et al. (2009) propose that MC requires not only standardized process designs but also innovation toolkits in solution space development. Fogliatto et al. (2012) argue that MC enablers include both standardized product platforms that are shared by a set of products and the adoption of new manufacturing and information technologies. However, the majority of existing empirical studies focus only on the individual effects of standardization and innovation on MC capability development (Duray et al., 2000; Tu et al., 2004; Huang et al., 2008; Wang et al., 2014); their combined effects on MC capability have been generally unexplored.

We particularly consider delivery speed as a performance indicator. In the MC context, delivery speed reflects the time required to deliver customized products and reorganize production processes in response to customization requests (Chen and Paulraj, 2004; Tu et al., 2001). Product and process innovation can reduce product development and manufacturing lead times, enabling manufacturers to promptly fulfill customer requirements (Kortmann et al., 2014). Manufacturers using company standards can streamline operations, reducing the lead time from purchasing to delivery (Calantone and Di Benedetto, 2000). Therefore, we argue that standardization and innovation are positively associated with MC capability and delivery speed. Fig. 1 shows the conceptual model.

3. Hypothesis development

Company standards contribute to product and process innovation by creating compatibility standards (Fixson and Park, 2008), which represent openness and promote collaboration between internal employees and cooperation with external partners. Employees can become more creative and less likely to resist changes and new ideas if they have common understandings of product components and platforms (Funk and Luo, 2015; Perera et al., 1999). Company standards improve product innovation by facilitating concurrent and collaborative product development (Baud-Lavigne et al., 2012). They enable product developers to simultaneously attempt different combinations of modules with low-costs and develop new products through trial and error learning at both component and architecture levels (Henderson and Clark, 1990; Mikkola, 2006). Furthermore, manufacturers can standardize product interfaces and platforms to reduce production variety and complexity (Wright et al., 2012). This assists R&D

Fig. 1. Conceptual model. Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

personnel in developing a deeper understanding of existing processes and technologies, detecting potential problems, and discovering improvement opportunities and ideas for new process designs, which accelerate process innovation (Manu and Sriram, 1996). Thus, we propose the following hypothesis:

H1. Standardization is positively associated with innovation.

MC implementation requires advanced manufacturing and information technologies and novel product and process designs (Da Silveira et al., 2001; Peng et al., 2011). The capabilities to create entirely new products or improve certain dimensions of products are crucial for developing MC capability (Jitpaiboon et al., 2013; Kristal et al., 2010). Product innovation helps manufacturers design modules that can be shared by multiple product families and recombined quickly (Wang et al., 2014). Process innovation makes manufacturing processes more flexible and efficient (Huang et al., 2008) and reduces costs through supply chain optimization (Kortmann et al., 2014). Innovative process designs are required by mass customizers to compete in business environments characterized by short product life cycles and heterogeneous and volatile demands (Jiao et al., 2003; Fogliatto et al., 2012). Thus, we propose the following hypothesis:

H2a. Innovation is positively associated with MC capability.

By adopting new technologies and investing in R&D, manufacturers can develop new components, modules, and platforms to reduce the lead times in supply chains (Chen and Paulraj, 2004; Lim et al., 2013). Innovative product designs can shorten the lead time for product trial and launch (Kim et al., 2012; Li and Tellis, 2016). Process innovation can accelerate new product development, purchasing, manufacturing, and delivery processes by helping manufacturers discover production problems, isolate potential quality problems, and avoid potential mismatches among different components or between product features and customer demands early (Panayides, 2006; Tongur and Engwall, 2014). Therefore, fewer design changes are required in the manufacturing and purchasing processes. Moreover, Panayides (2006) finds that innovativeness is positively associated with logistics service quality that includes quick delivery. Thus, we propose the following hypothesis:

H2b. Innovation is positively associated with delivery speed.

Standardization in components and platforms can help manufacturers reduce design costs because modules can be shared among various product families (Da Silveira et al., 2001). Manufacturers can also reduce production costs and complexity associated with increasing product variety when company standards are widely used because they can be leveraged to achieve economies of scale and scope (Anderson and Pine, 1997; Perera et al., 1999). Manufacturers can purchase parts, components, and equipment in large quantities if they are standardized (Duray et al., 2000). The costs for managing purchasing and suppliers can also be reduced because company standards can be used as the benchmark of quality management. In addition, standardized interfaces and platforms can facilitate recombining and rearranging modules (Fogliatto et al., 2012). With standardized designs, a product development team can reduce the lead time by developing new products concurrently (Baud-Lavigne et al., 2012). Therefore, company standards can reduce costs and improve flexibility and responsiveness when manufacturers customize products. Thus, we propose the following hypothesis:

H3a. Standardization is positively associated with MC capability.

Using standardized components and platforms can reduce the lead times for product development and component purchasing
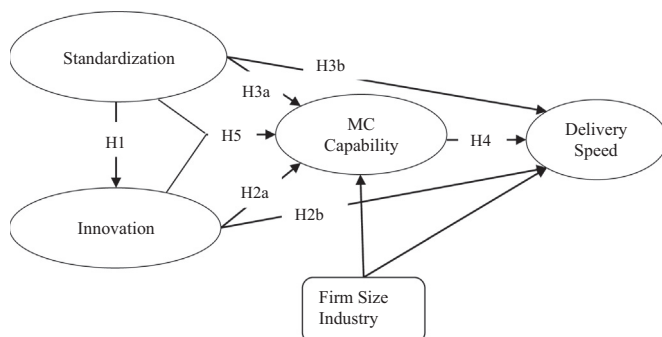
and avoid stock-out (Jiao and Tseng, 2000). Company standards can also expedite R&D processes and design modifications (Baud-Lavigne et al., 2012; Fredriksson and Gadde, 2005). Using standardized components can avoid production problems and ensure the quality of products because of learning effects, thereby reducing lead times. Moreover, company standards can improve delivery speed by improving process effectiveness and increasing forecast accuracy (Chen and Paulraj, 2004; Funk and Luo, 2015). The reduction in lead times can also be attributed to the increased proficiency of shop floor workers who can learn to assemble standardized components quickly (David and Rothwell, 1996). Thus, we propose the following hypothesis:

H3b. Standardization is positively associated with delivery speed.

MC capability can improve the operational efficiency of manufacturers and allow them to promptly fulfill customer needs (Kortmann et al., 2014; Tu et al., 2001). MC is characterized by greater flexibility and responsiveness in production and supply chain processes and therefore can shorten lead times (Jiao et al., 2003). Close relationships exist between time-based manufacturing and quality management practices and MC capability, and therefore, MC features enhanced consistent quality and quick delivery (Kristal et al., 2010; Tu et al., 2001). In addition, implementing MC is associated with timely information sharing both within and beyond organizational boundaries, which accelerate information processing and decision making (Jitpaiboon et al., 2013). This enables manufacturers to improve forecasts, synchronize production and delivery, and coordinate decisions; therefore, manufacturers can promptly respond to customer requests (Huang et al., 2008; Calantone and Di Benedetto, 2000). Thus, we propose the following hypothesis:

H4. MC capability is positively associated with delivery speed.

Mass customizers face a competitive and dynamic environment that requires them to provide customized products at reasonably low-costs (Duray et al., 2000; Fogliatto et al., 2012). Standardization and innovation are complementary in developing MC capability because they are associated with the capabilities of mass production and customization, both of which are critical for MC (Anderson and Pine, 1997). Manufacturers may face difficulties if either of the two practices is missing in MC capability development. For example, manufacturers may incur increasing costs when they focus excessively on innovation to differentiate their customized products from those of their competitors (Da Silveira et al., 2001). Similarly, if manufacturers place excessive emphasis on obtaining cost advantages through standardization, they may ignore the changes in customer preferences that require new modules, product platforms, or solution spaces (Kortmann et al., 2014). Process innovation introduces new elements in manufacturing processes, machinery, equipment, and technologies, which help manufacturers customize products by recombining standardized modules quickly (Kim et al., 2012; Lim et al., 2013). Innovative product designs ensure that standardized modules can fulfill customization requirements and can be configured rapidly with low-costs (Salvador et al., 2009). Company standards enable employees to learn these innovations and incorporate them into MC efficiently and effectively. In addition, company standards increase component separability, combinability, and commonality (Tu et al., 2004; Mikkola, 2006), which help manufacturers develop new products by improving the linkages among components and develop new processes by postponing production or redesigning push–pull boundary. Therefore, the interaction between standardization and innovation can enhance MC capability. Thus, we propose the following hypothesis:

H5. The interaction between innovation and standardization is positively associated with MC capability.

4. Research design

4.1. Data collection and sample

To test the proposed hypotheses, manufacturing companies were randomly selected from the Pearl River Delta (PRD) region of China. Since the "open-door policy", the PRD region has rapidly become a major destination for foreign investment and a modern manufacturing base that is often called "the world's factory". It is one of the fastest growing regions in China and is increasingly important in global supply chains (Wang et al., 2015). Experiences in collaborating with Western partners help manufacturing companies in the PRD region gain capabilities to develop new products and processes based on their own concepts and designs and create company standards (Li and Tellis, 2016). In addition, many manufacturers in the PRD compete through customization and quick response. The majority of them have adopted the MC philosophy because they face cost pressures from changing business environments, such as increasing material and labor costs, Chinese Yuan appreciation, and decreasing foreign market demands. Thus, the PRD region provides a unique context for exploring the roles of standardization and innovation in developing MC capability.

According to the suggestions of Frohlich (2002), we relied on the professors who have social connections with companies to collect data. We used the list provided by the Industrial Research Institute of a university in the PRD region as the sampling frame for selecting manufacturing companies. To increase the response rate, selected companies were first called to identify qualified respondents and confirm their participation in the survey (Frohlich, 2002). We also verified that a selected company was suitable for this research. The questionnaire was then sent through mail or e-mail. According to Boyer et al. (2002), these methods for data collection yield equivalent results if the questionnaire is developed appropriately.

A total of 745 questionnaires were sent in the end of 2009. In a 2-month period, calls were made to remind the respondents. Finally, 250 questionnaires were returned. After data cleaning, the questionnaires of 204 respondents were retained and used for further analysis. The response rate is 27.4%. Of the 204 questionnaires, 123 were collected through mail and 81 through e-mail. We performed a t test to assess the response bias between the two groups. The results show no significant difference in the number of employees ($t=0.889$, $p > 0.1$). Early and late responses on the number of employees were also compared. The results show that the t statistic is not significant between the 127 early responses and the 77 late responses ($t=0.275$, $p > 0.1$), indicating that nonresponse bias is not a major concern in this study. Approximately 88% of the respondents held the posts of general manager or functional director. The remaining respondents were in charge of daily operations in design, marketing, or manufacturing. A pilot study of 10 manufacturers in the PRD region shows that they were qualified respondents for this research. The characteristics of the responding companies are listed in Table 1.

4.2. Measures

The questionnaire was designed in English and then translated into Chinese. Its accuracy was verified through back translation. Each construct was measured using multiple items on a 7-point Likert scale (1=totally disagree; 7=totally agree). The scales were adopted or adapted from the literature and are listed in Table 2. Six items were used to measure the four aspects of MC capability (Huang et al., 2008; Tu et al., 2001). Standardization was also

Table 1

Respondent characteristics.

	N	%		N	%
1. Industry			2. Number of employees		
Appliances	26	12.7	Less than 100	10	4.9
Non-metallic mineral products	26	12.7	101–500	42	20.6
Fabricated metal products	23	11.3	501–1000	51	25.0
Automotive or parts	20	9.8	1001–5000	74	36.3
Chemicals and pharmaceutical	24	11.9	More than 5000	27	13.2
Industrial machinery and equipment	19	9.3	3. Ownership		
Computer and electronics	17	8.3	State-owned	33	16.2
Food and beverage	12	5.9	Privately-owned	97	47.5
Rubber and plastics	10	4.9	Foreign-owned	52	25.5
Textiles and apparel	8	3.9	Joint venture	22	10.8
Miscellaneous	19	9.4			

Table 2

Measurement model.

Measurement items	Factor loading
Mass customization capability (α=0.907, C.R.=0.929, AVE=0.68)[*]	
We can customize products on a large scale.	0.806
We can add product variety without increasing cost.	0.808
We can set up for a different product at low-cost.	0.757
We can customize products while maintaining a large volume.	0.886
We can add product variety without sacrificing product quality.	0.874
We can respond to customization requirements quickly.	0.825
Innovation (α=0.874, C.R.=0.906, AVE=0.62)	
Our company seeks for innovativeness in both production and product-related services.	0.817
Our company tries to be creative on products or services.	0.810
Our company develops new products or new technologies continuously.	0.769
Our company invests a lot in production process innovation.	0.741
Our company usually takes the lead in the market to launch new products or services.	0.837
Our company is willing to develop new products even if the market potential is still uncertain.	0.734
Standardization (α=0.817, C.R.=0.867, AVE=0.52)	
We try to utilize standardized parts as many as possible when we design new products.	0.741
Most of parts we used are in the product categories of our suppliers, so we have no need to order customized parts.	0.655
Most of parts we used are purchased from multiple suppliers.	0.722
When we develop new products, we try to do serial design.	0.752
We can easily add or remove additional functions by adding or removing parts.	0.713
Our products can be categorized into serial products based on a few platforms.	0.742
Delivery speed (α[**]=0.777, C.R.=0.941, AVE=0.89)	
We have advantage in fast delivery	0.939
We have advantage in lead time (from purchasing to delivery)	0.947

[*] α: Cronbach's alpha; C.R.: composite reliability; AVE: average variance extracted.

[**] Correlation coefficients.

measured by six items, which were adapted from Anderson and Pine (1997), Jiao and Tseng (2000), and Fredriksson and Gadde (2005). The first three items are related to standardized components; the others are related to product platforms. The measures of innovation were adapted from Manu and Sriram (1996). Six items were used to measure product and process innovation. Two items were used to gauge delivery speed and were adapted from Chen and Paulraj (2004) and Calantone and Di Benedetto (2000). In addition, the questionnaire has a section for collecting data on the company's demographic profile, including industry sector,

ownership, and firm size.

Two control variables, industry sector and firm size, were included in the analysis (Huang et al., 2008; Peng et al., 2011). The available technologies, clockspeed, and competition intensity in a given industry may affect managerial decisions on MC and the operational performance of companies (Anderson and Pine, 1997). Large companies may have higher MC capability because they have fewer resource constraints (Huang et al., 2008). The number of employees was used to measure firm size. Both industry sector and firm size were measured using dummy variables.

5. Analysis and results

5.1. Measurement model

According to the sample size, model complexity, and requirement for testing the interaction effect, partial least squares (PLS) is used for data analyses (Peng and Lai, 2012). PLS has been widely used in empirical MC research (e.g., Jitpaiboon et al., 2013; Kortmann et al., 2014). A PLS model can be assessed on the basis of the estimates of path loadings and R^2 values. Path loadings indicate the strength of the relationships between constructs and R^2 values indicate the predictive power (Peng and Lai, 2012). SmartPLS software (version 2.0.M3) is used to assess the measurement and structural models. Bootstrapping estimation procedure is employed to examine the significance of factor loadings in the measurement model and path coefficients in the structural model (Peng and Lai, 2012).

Confirmatory factor analysis (CFA) is conducted to examine the measurement model. The results are presented in Table 2. Reliability is assessed in terms of Cronbach's α and composite reliability (Fornell and Larcker, 1981). The composite reliabilities range from 0.867 to 0.941 and Cronbach's α values range from 0.777 to 0.907, which are above the recommended threshold value of 0.70 (Fornell and Larcker, 1981), suggesting adequate reliability.

Content validity is established by conducting a comprehensive literature review and a careful evaluation of constructs by academics and practitioners during the pilot test. Convergent validity is evaluated using the CFA results. As shown in Table 2, all item loadings are higher than 0.7, except one item whose value is slightly lower. The t statistics are significant at the $p < 0.001$ level, suggesting adequate convergent validity at the item level (Fornell and Larcker, 1981). In addition, the average variance extracted (AVE) is used to assess convergent validity. Table 3 shows that all AVE values are above the recommended value of 0.5 (ranging from 0.52 to 0.89), suggesting adequate convergent validity at the construct level. Discriminant validity is assessed by comparing the square root of the AVE of each construct against its correlations with other constructs (Fornell and Larcker, 1981). Table 3 shows that the correlations are smaller than the square roots of the AVE, suggesting adequate discriminant validity for all constructs.
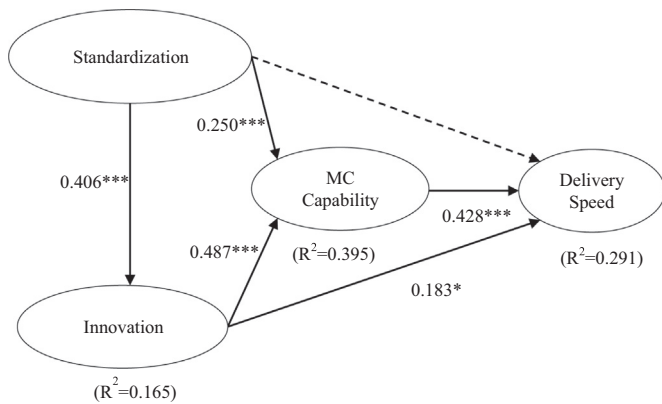
Because we used one informant to answer the self-reported questionnaire, common method variance (CMV) may be a concern. When designing the questionnaire, the scales were randomly

Table 3

Correlation, mean, and standard deviation.

	Mean	S.D.	1	2	3	4
1 Standardization	4.77	1.070	(0.72)[a]			
2 Innovation	5.42	0.974	0.406[**]	(0.79)		
3 MC capability	5.11	1.118	0.434[**]	0.567[**]	(0.83)	
4 Delivery speed	5.50	1.098	0.222[**]	0.392[**]	0.516[**]	(0.94)

[a] Square root of AVE is on the diagonal in parentheses.

[**] $p < 0.01$.

Note: * p<0.05; ** p< 0.01; *** p<0.001

Fig. 2. Results of statistical analysis.

Fig. 3. Interaction effect of standardization and innovation on MC capability.

placed in different sections of the questionnaire, and we also differentiated instructions for different scales to reduce the potential consistency of respondents (Frohlich, 2002), thus reducing CMV (Podsakoff et al., 2003). We assess CMV by using the following methods. First, Harman's single factor test is conducted by including all items in principal component factor analysis (Podsakoff et al., 2003). There is no evidence of CMV because no single factor accounts for most of the covariance. Second, partial correlation method is used (Podsakoff et al., 2003). The first factor from principal component factor analysis is used in the PLS model as a control variable. The results suggest the absence of CMV because the control variable does not significantly change the variance explained in the dependent variables. Third, the correlation matrix reveals that the highest correlation between the constructs is 0.567. Pavlou et al. (2007) suggest that CMV is unlikely if no excessively high-correlations (>0.9) exist. The results of these tests suggest that CMV is not a major concern.

5.2. Structural model

The results of the structural model are shown in Fig. 2. The standardized coefficients for the control variables range from 0.094 to 0.158, and none of them is statistically significant. The model explains 39.5% of variance (R^2) in MC capability and 29.1% of variance in delivery speed. The results show that standardization significantly and positively affects innovation ($b=0.406$, $p<0.001$). Both innovation ($b=0.487$, $p<0.001$) and standardization ($b=0.250$, $p<0.001$) significantly and positively affect MC capability. The effect of innovation on delivery speed is significant ($b=0.183$, $p<0.05$). MC capability also significantly and positively affects delivery speed ($b=0.428$, $p<0.001$). However, the effect of standardization on delivery speed is nonsignificant ($b=0.040$, $p>0.1$). Therefore, H1, H2a, H2b, H3a, and H4 are supported, but H3b is not supported.

To further explore the mechanisms through which standardization and innovation improve delivery speed, we examine the indirect effects of standardization and innovation on delivery speed through MC capability by using bootstrapping (Preacher and Hayes, 2008). The results show that the bias-corrected 95% confidence interval for the indirect effect of standardization on delivery speed through MC capability is (0.148, 0.362) and that for the indirect effect of innovation on delivery speed through MC capability is (0.163, 0.398). Thus, both standardization and innovation significantly improve delivery speed through MC capability.

To test the interaction effect, we follow the procedure suggested by Little et al. (2006). The items for the interaction of
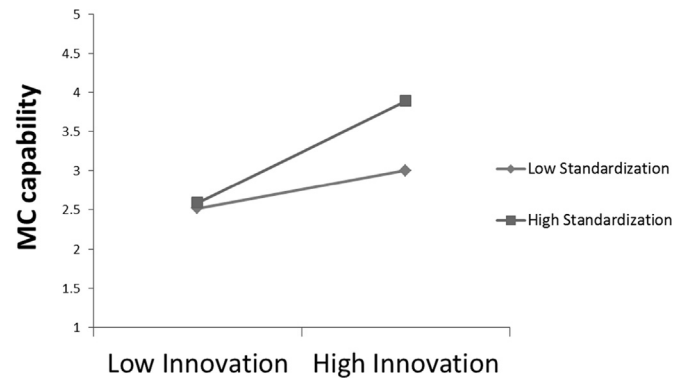
standardization and innovation are calculated by cross multiplying the standardized items of each construct. We find that the interaction between standardization and innovation positively and significantly affects MC capability ($b=0.204$, $p<0.01$). Thus, H5 is supported. We plot the interaction effect in Fig. 3 according to the method suggested by Aiken and West (1991).

6. Discussion

6.1. Implications to theory

This study contributes to the literature in three ways. First, the results reveal that company standards significantly and positively affect product and process innovation, which is consistent with existing empirical evidence (Fixson and Park, 2008; Wright et al., 2012). Standardization is often investigated at the macro-level, and studies have usually focused on the socioeconomic and technical factors that lead to industrial or national standards and the implications on public policies (Blind, 2013; Saltzman et al., 2008). This study contributes to the standardization literature by employing a micro-perspective and providing insights into the relationships between company standards and product and process innovation (Blind, 2013). Some researchers argue that standardization may have negative effects on innovation (Thompson, 1965; David and Rothwell, 1996). This study provides empirical evidence that this conventional wisdom deserves second thought for manufacturing companies in China. Compared with Western manufacturers, Chinese manufacturers lack competence and skills for developing cutting-edge inventions and rely on inward technology licensing (Wang et al., 2015). Chinese manufacturers tend to develop new products and processes by reverse engineering and localizing Western products and adapting existing technologies to Chinese markets (Breznitz and Murphree, 2011; Lim et al., 2013). These innovations focus on the linkages among core components or modules and usually do not overturn the core design concepts of a technology or a product (Henderson and Clark, 1990). Company standards build a foundation for such innovations because they assist manufacturers in adjusting functions or subsidiary parameters of a component (Henderson and Clark, 1990). Moreover, company standards help manufacturers rapidly adjust and adapt supply chains in response to changes in product designs and customer demands (Baud-Lavigne et al., 2012). Innovations made by Chinese manufacturers are usually compatible with dominant designs, and focus on developing new features, functions, or benefits for existing products and processes, which depend on the exploitation of existing knowledge (Breznitz and Murphree, 2011). Standardization enables manufacturers to systematically formalize and record past experiences and knowledge, improving their knowledge base and the ability to assimilate and

apply knowledge (Lin et al., 2012). Therefore, company standards enhance product and process innovation in Chinese manufacturers. This study thus elucidates the context where standardization positively affects innovation.

Second, this study contributes to the MC literature by demonstrating that standardization and innovation positively affect MC capability both individually and interactively. Empirical evidence has been provided on the positive effects of modularity (Peng et al., 2011; Tu et al., 2004) and knowledge management (Huang et al., 2008; Wang et al., 2014) on MC capability development. Although company standards facilitate implementing modularity, standardization can directly affect the entire value chain, including inbound and outbound logistics, operations, technology, and procurement (Perera et al., 1999; Mikkola, 2006), of a company. Similarly, although organizational learning provides inputs for innovation, knowledge alone is not innovation and new product and process development requires other tangible and intangible resources (Nonaka, 1991; Kim et al., 2012). This study provides empirical evidence that manufacturers can implement MC by adopting company standards and developing new products and processes, enhancing the present knowledge on the antecedents of MC capability. In addition, we find that standardization and innovation are complementary in developing MC capability. Existing literature has reported that implementing MC requires complementary manufacturing practices (Fogliatto et al., 2012). The present study provides empirical evidence that standardization and innovation have synergistic effects and are co-specialized capabilities in MC capability development. Complementarity may develop from the positive effects of company standards on product and process innovation in Chinese manufacturers. The findings thus indicate that when standardization improves innovation, their combined use improves MC capability.

Third, our results reveal the mechanisms through which standardization and innovation improve delivery speed. The findings show that MC capability is positively associated with delivery speed, which is consistent with extant findings on MC's performance consequences. Studies have reported that MC capability improves value to customers (Tu et al., 2001) and operational efficiency (Kortmann et al., 2014), both of which are related to delivery speed. Here, this study demonstrates that standardization only indirectly affects delivery speed through MC capability. This indicates that applying company standards alone may not directly improve operational performance. The finding is consistent with the arguments of the capability building theory, which proposes that companies must transform engineering practices into routines before having capabilities (Ethiraj et al., 2005). Thus, manufacturers must embed and integrate company standards into operational processes to develop MC capability (Huang et al., 2008; Fogliatto et al., 2012), which then improves delivery speed. This study thus contributes to the literature by revealing that manufacturing firms must implement company standards and MC simultaneously to improve delivery speed. By contrast, innovation contributes to delivery speed both directly and indirectly through MC capability. This is because new product and process designs can directly improve routines, processes, and procedures, which positively affect both MC capability and operational performance, including delivery speed (Calantone and Di Benedetto, 2000; Jitpaiboon et al., 2013). Therefore, this study contributes to the MC literature by providing empirical evidence that MC capability carries the effects of standardization and innovation on delivery speed.

6.2. Implications to practice

Our results also provide guidelines for manufacturers on developing MC capability and improving delivery speed in China.

First, manufacturers should implement company standards on components and the interfaces among the components. When developing new products, managers should apply serial product design based on a few platforms. Manufacturers could source standardized parts from suppliers' existing catalogs and from multiple suppliers. Managers should understand that using standardized parts in product design and purchasing can enhance product and process innovation. Second, manufacturers should invest in innovation by employing approaches such as importing advanced technology and equipment from Western competitors, applying product configurator, and hiring global talent. In addition, managers should develop new processes and products even when market potential is uncertain. Manufacturers can develop and implement a knowledge management system for recording experiences and best practices and facilitating information processing and decision making. Managers should pay more attention to human resource management practices, such as training and job rotation, to motivate employees to create and share tacit knowledge (Nonaka, 1991). Special routines or programs, such as cross-functional design, brainstorming, and continuous improvement, can also be implemented to encourage employees to apply their knowledge to improve innovation. Third, managers should apply standardization and innovation simultaneously because they complement each other in developing MC capability. In particular, managers can apply company standards when designing new products and processes and ensure that product and process innovations are compatible with company standards on product components and platforms. In addition, managers can implement manufacturing practices that improve MC capability, such as time-based manufacturing practices, quality management, organizational learning, and supply chain integration and collaboration, to improve delivery speed. Although product and process innovation can directly increase delivery speed, managers should understand that MC capability also carries the effects of standardization and innovation on delivery speed. Therefore, we suggest that managers implement standardization, innovation, and MC simultaneously.

7. Conclusions

This study empirically investigates the impact of standardization and innovation on MC capability and delivery speed. Based on a sample of 204 Chinese manufacturers, we find that standardization has a significant and positive effect on innovation. Standardization and innovation positively affect MC capability both individually and interactively. MC capability and innovation improve delivery speed. In addition, standardization and innovation have indirect effects on delivery speed via MC capability.

This study has limitations, which provide avenues for future research. First, this study is conducted in China. Future studies can examine the research model in other countries with different cultural, business, and institutional environments to increase the generalizability of the findings. Second, we use a questionnaire survey with a 7-point Likert scale. This method may entail measurement errors and cannot establish causal relationships among standardization, innovation, MC capability, and delivery speed. Future studies can use longitudinal objective data and in-depth case studies to validate the findings. Third, this study focuses on company standards. Investigating the roles of committee standards in the context of Chinese manufacturers, such as whether committee standards are a significant mediator in relation to productivity and innovation alongside manufacturing methods and customer demands, would be a valuable topic. Fourth, we conceptualize innovation as both product and process innovation and measure innovation by using subjective measures, which are major limitations. Future studies can investigate the different

effects of product and process innovation on MC capability and use objective measures, such as R&D investments or the number of patents, to gauge innovation. Fifth, standardization and innovation may not always be complementary in enhancing MC capability, and we have not investigated the conditions under which they are complementary in this study. Future research can explore the contingencies that influence the joint effects of standardization and innovation. Finally, delivery speed is measured subjectively and we do not investigate the optimal delivery speed, which depends on market and product characteristics. Our study can be extended by using objective measures, such as the percentage of improvement in delivery time, to gauge delivery speed and by exploring the optimal delivery speed in the MC context and the influences of market conditions and product features.

Acknowledgments

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