

Absorptive capacity and mass customization capability

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Abstract

Purpose

The purpose of this paper is to investigate the effects of a manufacturer's absorptive capacity (AC) on its mass customization capability (MCC).

Design/methodology/approach

The authors conceptualize AC within the supply chain context as four processes: knowledge acquisition from customers, knowledge acquisition from suppliers, knowledge assimilation, and knowledge application. The authors then propose and empirically test a model on the

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relationships among AC processes and MCC using structural equation modeling and data collected from 276 manufacturing firms in China.

Findings

The results show that AC significantly improves MCC. In particular, knowledge sourced from customers and suppliers enhances MCC in three ways: directly, indirectly through knowledge application, and indirectly through knowledge assimilation and application. The study also finds that knowledge acquisition significantly enhances knowledge assimilation and knowledge application, and that knowledge assimilation leads to knowledge application.

Originality/value

This study provides empirical evidence of the effects of AC processes on MCC. It also indicates the relationships among AC processes. Moreover, it reveals the mechanisms through which knowledge sourced from customers and suppliers contributes to MCC development, and demonstrates the importance of internal knowledge management practices in exploiting knowledge from supply chain partners. Furthermore, it provides guidelines for executives to decide how to manage supply chain knowledge and devote their efforts and resources in absorbing new knowledge for MCC development.

Keywords: Knowledge application, Knowledge acquisition, Absorptive capacity, Knowledge assimilation, Mass customization capability

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Introduction

Mass customization (MC) is a competitive strategy that aims at providing enough product and service variety so that almost every customer finds exactly what he/she wants at a reasonable price (Pine, 1993). Manufacturers' demands for MC are growing in response to shortening product life cycle and increasing global competition (Da Silveira et al., 2001). At the same time, achieving MC is a challenge for many manufacturing firms since MC may increase the costs, uncertainty, and complexity of manufacturing processes and a manufacturer's dependency on supply chain partners (Lai et al., 2012). To align a manufacturer with customer needs, MC demands not only advanced manufacturing and information technologies, but also unique operational capabilities (Salvador et al., 2009). It involves major changes to resource configurations and calls for constant improvement in products and processes (Pine, 1993). Many manufacturers find determining the required changes a challenge and often rely on their customers and suppliers to assist in designing new products and processes (Lai et al., 2012; Zhang et al., 2014). Thus, knowledge learned from supply chain partners plays an important role in MC (Huang et al., 2008).

Some previous studies argue that a firm's absorptive capacity (AC) plays critical roles in collaborative innovation and inter-organizational relationships (Lane and Lubatkin, 1998; Nagati and Rebolledo, 2012) and has significant influences on competitive advantage (Lane et al., 2006; Volberda et al., 2010). However, outside of the research that looks at broadly defined alliances, few studies address the effects of AC on complex supply chain management processes (Lane et

al., 2006). Hence, important questions on the mechanisms through which AC and knowledge sourced from supply chains contribute to MC remain unanswered (Huang et al., 2008; Kotha, 1995). This study develops and empirically tests a conceptual framework that relates AC to the development of MC capability (MCC). Our study addresses two major research questions:

RQ1. What are the effects of a manufacturer's AC on its MCC?

RQ2. How does knowledge sourced from customers and suppliers contribute to MCC development?

2. Theoretical background and research hypotheses

2.1. MCC

MCC can be defined as the capability to offer a reliably high volume of different products for a relatively large market and adjust product and process designs according to customer demands quickly, without substantial trade-offs in cost, delivery, and quality (Liu et al., 2006; Tu et al., 2001). It includes the capabilities of high-volume customization, customization cost efficiency, customization responsiveness, and customization quality (Liu et al., 2006; Tu et al., 2001).

Researchers have identified different types of MC (Da Silveira et al., 2001) and investigated the benefits and challenges associated with MC adoption (Liu et al., 2012). Large-scale surveys have been conducted to explore the impacts of various practices and tools on MCC (e.g. Huang et al., 2010; Kristal et al., 2010; Peng et al., 2011; Tu et al., 2001, 2004).

Supply chain management practices are important MC enablers. For example, Huang et al. (2008) find that both internal and external learning from supply chains contribute to MCC development and that their effects are mediated by effective process implementation. Lai et al. (2012) reveal that internal integration has not only a significant, direct effect on MCC, but also an indirect effect through customer integration. However, although they find that customer integration improves MCC directly, supplier integration appears to have no significant effects. Previous studies also document that customers and suppliers play critical roles in MC and that a manufacturer must learn from them and use their knowledge for MCC development (e.g. Kristal et al., 2010; Zhang et al., 2014). However, there is limited large-scale empirical research that investigates how knowledge sourced from customers and suppliers is processed and absorbed for MCC development.

2.2. AC

AC, which describes a firm's ability to acquire, assimilate, and exploit external knowledge (Cohen and Levinthal, 1990), has been widely applied in exploring inter-organizational learning and knowledge transfers within strategic alliances (Flatten et al., 2011; Lane et al., 2006). Researchers have proposed various processes for capturing the richness and multidimensionality of AC (Lane et al., 2006; Todorova and Durisin, 2007; Tu et al., 2006; Zahra and George, 2002). Rather than using indirect proxies such as research and development (R & D) intensity or prior relevant knowledge (Cohen and Levinthal, 1990; Tsai, 2001), the process-based view conceptualizes AC as a broad set of organizational learning processes and mechanisms (Flatten et al., 2011; Volberda et al., 2010). For example, Zahra and George (2002) suggest that four distinct but complementary processes compose a firm's AC, including acquisition, assimilation,

transformation, and exploitation. Todorova and Durisin (2007) further argue that assimilation and transformation are alternative processes and propose that AC processes include recognize the value and acquire, assimilate and transform, and exploit. The relative view of AC argues that the relationship between two firms may influence what and how much knowledge is transferred (Lane and Lubatkin, 1998). A firm's AC is not absolute, but rather varies with inter-organizational learning contexts and across different partners (Nagati and Rebolledo, 2012; Volberda et al., 2010). Hence, a firm's AC is relationship-specific and affected by both whom it collaborates with and how the learning processes are managed. Therefore, AC depends not only on a firm's direct interfaces with external knowledge sources, but also on its internal processes through which knowledge is processed and distributed across subunits (Cohen and Levinthal, 1990; Hult et al., 2004).

We propose that AC includes both relationship-specific and firm-level processes. Considering the supply chain context, we conceptualize AC as the processes of knowledge acquisition from customers, knowledge acquisition from suppliers, knowledge assimilation, and knowledge application (Cohen and Levinthal, 1990; Todorova and Durisin, 2007; Zahra and George, 2002). Knowledge acquisition from customers/suppliers refers to a firm's ability to both identify and acquire the customer/supplier knowledge that is critical to operations (Todorova and Durisin, 2007; Zahra and George, 2002). This can be achieved through different routines and mechanisms such as real-time information sharing, special meetings or surveys, and interactions (Hult et al., 2004; Jansen et al., 2005). Knowledge assimilation is defined as a firm's routines and procedures for analyzing, interpreting, and understanding external information and combining it with internal knowledge (Todorova and Durisin, 2007; Zahra and George, 2002). A manufacturer can

assimilate external knowledge through various practices such as group learning, collaborative problem solving, knowledge sharing routines, and training programs (Hult et al., 2004; Jansen et al., 2005; Tu et al., 2006; Zahra and George, 2002). Knowledge application refers to the processes by which firms exploit knowledge by incorporating assimilated knowledge into their daily operations to create new knowledge and commercial outputs, and predict future trends (Cohen and Levinthal, 1994; Lane et al., 2006). ;A manufacturer can exploit knowledge by applying employees' suggestions and ideas on process improvement, new product development, and future trend forecasting (Zahra and George, 2002).

2.3. Research hypotheses

2.3.1. The direct effects of knowledge acquisition on MCC

Knowledge acquisition processes can help a manufacturer to obtain customer demands, such as those related to aesthetic design and product functionality, and supplier operational knowledge (e.g. inventory levels, production plans, and delivery schedules) (Lau et al., 2010). Based on common platforms, components and modules can be configured quickly according to customers' choices on certain features such as colors, styles, and flavors, reducing both total customization costs and lead times (Tu et al., 2004; Zhang et al., 2014). Customer knowledge can also enhance the efficiency and effectiveness of MC tools, such as product configurators or choice manuals, and hence improve customization quality and responsiveness (Salvador et al., 2009; Trentin et al., 2012b). Supplier operational knowledge can support postponement and modularity by synchronizing production (Tu et al., 2004; Yeung et al., 2007). It also enhances manufacturers' process flexibility and responsiveness by reducing supply uncertainties and total lead times. Hence, a manufacturer can develop agile supply networks to source appropriate and accurate

supplies for the timely production and delivery of customized products based on supplier knowledge.

Such knowledge is often transferred in standard formats through interaction routines and information systems automatically, and can be understood and integrated with a manufacturer's current knowledge base and operations easily (Zahra and George, 2002). It is explicit, codified, simple, and constrained by existing solution spaces (Nonaka, 1994). A solution space provides a list of options and pre-defined components that determine what is offered to customers and the additional costs associated with customization (Piller, 2004; Salvador et al., 2009). It represents the degrees of freedom built into a given manufacturer's production system (von Hippel, 2001). Hence, such knowledge does not need to be processed, assimilated, or applied and can contribute to MCC directly (Huang et al., 2008; Trentin et al., 2012a). Therefore, we propose the following hypotheses (Figure 1):

H1a. Knowledge acquisition from customers improves MCC directly.

H1b. Knowledge acquisition from suppliers improves MCC directly.

2.3.2. The indirect effects of knowledge acquisition on MCC through knowledge application

A manufacturer can learn feedback and opinions on current products and processes, and improvement suggestions from customers and suppliers (Nagati and Rebolledo, 2012). It allows the manufacturer to identify the heterogeneity of and changes in customer needs and how to improve supply chains (Lau et al., 2010). However, such knowledge does not directly enhance

MCC, as it may often be partially tacit and not consistent with the manufacturer's past experiences and current operations (Zahra and George, 2002). Hence, the acquired feedback and suggestions must be applied to adjust product designs and manufacturing processes according to the changes in environments, which improves current solution spaces (Huang et al., 2008; Kristal et al., 2010).

Knowledge application processes enable a manufacturer to persistently improve products, processes, and systems to realign solution spaces with environments (Patel et al., 2012; Tsai, 2001). For example, feedback from customers and suppliers helps a manufacturer to identify new ways to modify current solution spaces to fulfill customized demands at low costs quickly (Liu et al., 2006). Improvement suggestions that acquired from customers and suppliers enhance supply chain collaboration; thus, supply chain members can optimize their operations at the global level, thereby improving supply chain responsiveness and flexibility (Yeung et al., 2009; Zhang and Huo, 2013). Long-term forecasting helps a manufacturer make facility and equipment investments and create product platform designs that allow it to prepare for future changes in customer needs (Cohen and Levinthal, 1994). Hence, knowledge application transforms tacit knowledge acquired from customers and suppliers into operational competence that improves MCC (Salvador et al., 2009). Therefore, we propose the following hypotheses:

H2a. Knowledge acquisition from customers improves MCC indirectly through knowledge application.

H2b. Knowledge acquisition from suppliers improves MCC indirectly through knowledge application.

2.3.3. The indirect effects of knowledge acquisition on MCC through knowledge assimilation and knowledge application

A manufacturer can also learn innovative knowledge such as new product concepts and ideas, new materials and their applications, competitors' inventions, and market and technology development trends from customers and suppliers through special meetings, surveys, and interactions (Lau et al., 2010). Such knowledge can radically change a manufacturer's operations and help it to develop new solution spaces (von Hippel, 2001). In this case, the similarity between external knowledge and a manufacturer's existing knowledge base is low; thus, the manufacturer requires internal processes and capabilities to understand, interpret, and transform external knowledge within its operational context (Volberda et al., 2010). For example, new product ideas may relate to several internal functional departments; thus, a manufacturer requires special procedures for employees to share those ideas (Liu et al., 2012). To analyze how new market trends and technological knowhow influence operations, employees from different departments must form learning and problem-solving groups to develop a shared understanding and internalize acquired knowledge by combining it with their existing knowledge (Hult et al., 2004; Nonaka, 1994).

Knowledge assimilation processes enable a manufacturer to analyze and interpret acquired knowledge and create new knowledge, thereby enhancing its knowledge base and employees' skills (Zahra and George, 2002). For example, through group learning, employees can transform

market and technology trends and new product ideas learned from partners into strategic plans for new product and process development (Jansen et al., 2005). Group learning also allows employees from multiple functional units to process information together and make joint decisions that help them incorporate everyone's ideas and expertise into product and process designs (Hult et al., 2004; Trentin et al., 2012a). Problem-solving groups help employees to tackle the conflicts caused by interdependency or different interests among functional departments (Liu et al., 2012). Knowledge sharing and training programs distribute information widely in a manufacturer, enabling employees to develop a common understanding of the quality, functionality, characteristics, and aesthetics demanded by customers and how to adjust facilities and processes to satisfy them quickly (Kotha, 1995; Pine, 1993). They also enable the manufacturer to record knowledge in standard and systematic formats such as manuals, reports, meeting memos, and standard operating procedures (Hult et al., 2004). Moreover, working in teams also provides informal means for employees to distribute knowledge (Tu et al., 2006). Such externalized knowledge enables employees to improve processes, design new products, renew forecasting, and redefine solution spaces to meet environmental contingencies (Nonaka, 1994; Patel et al., 2012). Hence, the innovative knowledge sourced from suppliers and customers is converted into a manufacturer's own language and can be applied to improve its operations.

MC solution spaces rely on a manufacturer's product design elements to define the degree of customization offered and on its manufacturing capabilities to develop stable yet flexible and responsive processes (Piller, 2004; von Hippel, 2001). To realize the value of knowledge, a manufacturer must exploit and leverage it by implementing it to new product and process development (Salvador et al., 2009). Knowledge assimilation increases managers' cognitive

understanding and knowledge of solution spaces (Todorova and Durisin, 2007). However, it is the improved products, processes, and operational capabilities rather than knowledge that lead to new solution spaces and enhance MCC (Huang et al., 2008; Lai et al., 2012). Thus, accumulating more knowledge does not necessarily improve MCC, and its value is determined by how it is used to change a manufacturer's strategic and operational behaviors (Tu et al., 2006; Volberda et al., 2010). Knowledge application processes improve a manufacturer's operations and long-term forecasting, which contribute to MCC development (Pine, 1993). Hence, sourced innovative knowledge is only "raw materials" or inputs, and a manufacturer must assimilate and apply it to realize its value for MCC (Hult et al., 2004). Therefore, we propose the following hypotheses:

H3a. Knowledge acquisition from customers improves MCC indirectly through knowledge assimilation and knowledge application.

H3b. Knowledge acquisition from suppliers improves MCC indirectly through knowledge assimilation and knowledge application.

3. Research design and methodology

3.1. Questionnaire design

Based on the relevant literature, a survey instrument was designed to measure a manufacturer's MCC and AC within the supply chain context. In addition, the questionnaire outlined the firm's demographic profile, including information about industry, ownership, size, and location. A multiple-item, seven-point Likert-type scale (1="strongly disagree"; 7="strongly agree") was

used for all constructs. The scales, which consist of 22 measurement items, are listed in the Appendix.

Six items were used to measure four aspects of MCC. We adopted four items from Liu et al. (2006) to measure a manufacturer's capability of customizing products while maintaining high volume, without significantly increasing costs, and with consistent quality. Two new items related to adjusting product and process designs according to customer demands were used to measure process flexibility and customization responsiveness, which is the capability "to reorganize production processes quickly in response to customization requests" (Tu et al., 2001, p. 204).

Knowledge acquisition from customers was measured by four items related to the routines and procedures of customer interactions, such as real-time information sharing, special meetings, and surveys (Zahra and George, 2002). These were developed based on the studies by Jansen et al. (2005) and Hult et al. (2004) and were adapted to the supply chain context. Similar items were used to capture knowledge acquisition from suppliers. Knowledge assimilation was measured by four items related to the mechanisms and processes used to analyze, convert, and distribute knowledge within a firm (Todorova and Durisin, 2007). Two items gauging group learning and knowledge distribution were adapted from Jansen et al. (2005), and we added two new items on problem solving and training based on Zahra and George (2002). Knowledge application was also measured by four items related to the routines and capabilities of incorporating knowledge into operations (Zahra and George, 2002). One item about knowledge exploitation was adapted from Jansen et al. (2005). Two new items related to product and process improvement and new

product development (Zahra and George, 2002) and another item related to forecasting (Cohen and Levinthal, 1994) were added to capture the operations management context.

Industry, ownership, and plant size were included as control variables in our analysis and were measured by categorical variables (Liu et al., 2006). The available technologies and competition intensity in a given industry may affect managers' decisions on management practices (Lai et al., 2012). The industry was measured by three dummy variables representing four industries. Depending on their ownerships, manufacturing firms in China have different histories and various cultures that may influence their supply chain management and manufacturing philosophies (Zhao et al., 2006). The five ownership types were measured by four dummy variables. Large firms are more likely to have higher MCC than small firms due to their additional resources (Liu et al., 2006). Hence, we also controlled plant size, which was measured by five dummy variables according to the number of employees. The details of the control variables are shown in Table I.

The English version of the questionnaire was first developed and subsequently translated into Chinese by a professor. The Chinese version was then translated back into English by another professor. This translated English version was then checked against the original English version for any discrepancies, and adjustments were made to reflect the original meanings of the questions in English. The questionnaire was pilot tested using a sample of 13 firms before its full-scale launch. The researchers discussed the questions face-to-face with managers after they filled out the questionnaire and clarified the meanings of the questions with them. When any confusion arose, the wording of the questions was modified.

3.2. Sampling and data collection

We conducted the survey in China for two reasons. First, Chinese manufacturers are increasingly important in global supply chains since western companies outsource their operations to China. Understanding how Chinese manufacturers develop AC and MCC will help western companies to select capable partners to optimize their global supply chains (Zhao et al., 2006). Second, China, as an emerging economy, is characterized by underdeveloped institutional infrastructures and lack of well-established legal systems to protect intellectual property (Wang et al., 2011; Zhou and Poppo, 2010). In addition, many Chinese manufacturers begin competing through customizing and localizing foreign competitors' products or developing new applications for imported technologies. They are transiting from mass production to MC to gain competitive advantage in global markets because of the pressures from the changing business environments. However, there is very little empirical evidence of how Chinese manufacturers develop MCC through learning from supply chain partners. Hence, Chinese manufacturers provide a unique research opportunity to explore AC and MCC (Flatten et al., 2011). Firms from the textile and apparel, electrical appliance, electronics and communication equipment, and automobile industries were selected since MC is a common practice in these industries (Liu et al., 2006; Pine, 1993). The Pearl River Delta, the Yangtze River Delta, the Bohai Sea Economic Area, and the Central China comprise the four areas selected.

After pilot testing the questionnaire, it was decided that we had to call firms to find out who is the best informant that is knowledgeable on knowledge management routines and processes and familiar with product designs, production processes, and supply chain management. Potential

key informants include supply chain managers, production managers, R & D managers, presidents, senior executives, and directors. We used the database provided by CSMAR Solution (<http://csmar.gtadata.com/>) as the sampling frame and 1,460 manufacturing firms were randomly selected from the database after controlling the region and industry. Selected firms were contacted by telephone to identify the names and contact information of the most suitable informants. We then mailed the questionnaire along with a cover letter highlighting the objectives of the research to them. Follow-up telephone calls were made to improve the response rate. Respondents were also contacted to clarify any missing data in their responses.

Because of an incorrect address or recipient, 133 questionnaires were returned unopened. We finally collected 276 usable questionnaires. Hence, the response rate is 20.8 percent, which is comparable with the response rates of previous similar studies (e.g. Tu et al., 2001, 2006).

Detailed information on the sample demographics is shown in Table I. Early and late (after four or more calls) responses on demographic characteristics, including industry, ownership, annual sales, and number of employees were compared with the t-test showing no significant differences, indicating that non-response bias does not appear to be a major concern in this study (Armstrong and Overton, 1977).

Since we obtained data from a single survey, common method variance might be a concern. We performed a Harman's one-factor (or single-factor) test of common method bias on the AC and MCC variables using an exploratory factor analysis (Podsakoff and Organ, 1986). The results show six distinct factors with eigenvalues above or near 1.0, explaining 69.1 percent of the total

variance. Moreover, the first factor does not explain the majority of the total variance. Therefore, we conclude that common method bias is not a significant threat in our study.

4. Results of statistical analyses

Partial least squares (PLS) is chosen for the data analyses (Chin, 2010). We use SmartPLS 2.0 M3 software to assess the measurement and structural models. We also apply a bootstrapping estimation procedure, in which 500 random samples of observations with replacements are generated from the original data set, to examine the significance of the scale factor loadings in the measurement model and that of the path coefficients in the structural model (Chin, 1998).

4.1. Measurement model

We conduct a confirmatory factor analysis (CFA) using PLS (Chin, 2010). The CFA results are then used to analyze the reliability, convergent validity, and discriminant validity of the multiple-item scales (Henseler et al., 2009). The composite reliabilities in our measurement model range from 0.851 to 0.911 (Table II), which are all above the recommended threshold value of 0.70 (Nunnally and Bernstein, 1994), thus suggesting adequate reliability.

We assess convergent validity in terms of the average variance extracted (AVE) (Chin, 2010). Table II shows that all of the AVE values are above the recommended value of 0.50 (ranging from 0.587 to 0.720), thereby demonstrating adequate convergent validity (Fornell and Larcker, 1981). In addition, all item loadings are greater than 0.7 except for one that is slightly lower, and the t-statistics of factor loadings are all significant at the $p < 0.01$ level, which also suggest adequate convergent validity (Henseler et al., 2009).

Discriminant validity is assessed by comparing the square roots of the AVE of each construct with the correlations between the focal construct and every other construct, with a square root higher than the correlation with other constructs suggesting discriminant validity (Henseler et al., 2009). A comparison of all of the correlations and square roots of the AVEs on the diagonal indicates adequate discriminant validity for all constructs (Table III). In addition, the loading of each indicator is greater than all of its cross-loadings, which indicates discriminant validity on the indicator level (Chin, 1998).

4.2. Structural model

PLS is also used to examine the structural model, and the results are presented in Figure 2. This model explains 31.7 percent of the MCC variance (R^2). As indicated by the path coefficient, knowledge acquisition from customers ($b=0.210$, $p < 0.01$) has a significant influence on MCC, supporting H1a. However, the effect of knowledge acquisition from suppliers on MCC is insignificant, which does not support H1b. The results show that knowledge acquisition from customers and suppliers significantly affect knowledge application ($b=0.275$, $p < 0.01$ and $b=0.273$, $p < 0.01$), which leads to MCC ($b=0.352$, $p < 0.01$). We apply Sobel's Z-test to assess the significance of indirect effects (Lai et al., 2012). The indirect effects of knowledge acquisition from customers and suppliers on MCC through knowledge application are calculated by multiplying the path coefficients from knowledge acquisition from customers and suppliers to knowledge application and from knowledge application to MCC. The indirect effect of knowledge acquisition from customers is $0.275 \times 0.352 = 0.097$ ($p < 0.01$), and that of knowledge acquisition from suppliers is $0.273 \times 0.352 = 0.096$ ($p < 0.01$). Hence, both H2a and H2b are supported. The indirect effects of knowledge acquisition from customers and suppliers on MCC

through knowledge assimilation and knowledge application are similarly calculated. Knowledge assimilation has a strong effect on knowledge application ($b=0.393$, $p < 0.01$) and its indirect effect on MCC via knowledge application is $0.393 \times 0.352 = 0.138$ ($p < 0.01$). Hence, the indirect effect of knowledge acquisition from customers on MCC through knowledge assimilation and application is $0.325 \times 0.138 = 0.045$ ($p < 0.05$), and that of knowledge acquisition from suppliers on MCC through knowledge assimilation and application is $0.337 \times 0.138 = 0.046$ ($p < 0.05$), thus providing support for both H3a and H3b.

5. Discussion and conclusions

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The results of our analyses indicate that both customers and suppliers are important knowledge sources for MCC development (Huang et al., 2008). Customers can provide knowledge about unfulfilled demands, product features and functions, and market trends, which help a manufacturer to come up with new product and process ideas and thereby helps the manufacturer to define a solution space (Kristal et al., 2010; Zhang et al., 2014). To develop an appropriate production system that supports the solution space, the manufacturer often relies on suppliers' knowledge of operational processes, advanced information and manufacturing technologies, and new components or materials (Lai et al., 2012). The manufacturer's prior relevant knowledge, such as customer preferences and manufacturing practices and technologies, also facilitates the processing and absorption of sourced knowledge (Cohen and Levinthal, 1990; Tu et al., 2006). Hence, MC's success requires a manufacturer to integrate knowledge from customers, suppliers, and internal sources.

Our findings also show that the knowledge sourced from supply chains improves MCC in three ways: directly, indirectly through knowledge application, and indirectly through knowledge assimilation and application. However, the direct impact of the knowledge sourced from suppliers on MCC is insignificant. Supplier knowledge is mainly related to the production system supporting solution spaces and cannot provide manufacturers with the information as to how they can customize and configure products according to customer requirements within current solution spaces (Trentin et al., 2012b; von Hippel, 2001). Hence, the value of supplier knowledge on MCC is realized by improving product, process, supply chain, and solution space designs; therefore, such knowledge must be implemented and integrated into operations and can only become effective in enhancing MCC after it is assimilated and applied.

The analysis shows that plant size does not significantly influence MCC, which is consistent with existing empirical results (Huang et al., 2010; Kristal et al., 2010; Lai et al., 2012). To further investigate the effects of plant size, the whole sample is divided into six groups based on the number of employees (Table I) and ANOVA is used to compare mean values of MCC across these groups. The results show that the MCC's mean values are not significantly different ($F=0.445$; $p > 0.1$). We also conduct a regression analysis in which MCC is used as the dependent variable and dummy variables representing plant size are used as independent variables. We find that only 0.8 percent of the MCC variances can be explained by plant size and none of the coefficients of the independent variables is significant. These results further show that plant size does not affect MCC. Large manufacturers are more likely to have additional resources to deploy for the implementation of MC tools and practices, and to achieve multiple

operational priorities simultaneously (Huang et al., 2008; Liu et al., 2006). However, they also tend to have past investments in productive but inflexible manufacturing assets, established structural constraints, and hierarchical and centralized organizational structures, which hinder MCC development (Huang et al., 2010; Rungtusanatham and Salvador, 2008). Hence, plant size may have mixed effects on MCC. We also test a model in which plant size is used as control variables for all constructs (i.e. MCC and AC processes) in Figure 1 using PLS. The results show that plant size does not significantly change the relationships reported in Figure 2. This indicates that both large and small firms can benefit from implementing AC processes for MCC development.

Chinese manufacturers are lack of advanced technological capabilities but have developed sophisticated and flexible supply chains (Breznitz and Murphree, 2011). Moreover, the inadequate legal system cannot protect them from unlawful or unfair competitive behaviors, such as copyright piracy and counterfeiting (Zhou and Poppo, 2010). Chinese manufacturers may find it difficult or expensive to follow formal legal processes and rely on contracts to protect intellectual property (Wang et al., 2011). Hence, they will not invest in radical technological breakthroughs; instead, they tend to focus on incremental innovation which mainly involves copying and reverse engineering foreign products and technologies and developing new features to fulfill local demands (Breznitz and Murphree, 2011). To provide customized products with low costs, Chinese manufacturers need knowledge about local customer demands and how to optimize supply chains; therefore, customers and suppliers become very important sources of knowledge (Hult et al., 2004). In addition, Chinese manufacturers must localize product features by changing the designs of foreign products, and adjust manufacturing processes accordingly,

which rely on knowledge assimilation and application. Therefore, AC plays a critical role for Chinese manufacturers to imitate foreign products and mass customize them to satisfy local customers.

This study contributes to the literature in three ways. First, although researchers have emphasized the importance of suppliers in MC (Tu et al., 2001), the empirical findings on suppliers' roles in MCC development are mixed (Huang et al., 2008; Lai et al., 2012). Our results indicate that Chinese manufacturers rely on supplier knowledge to improve operations and develop supply chain capabilities for MC. Chinese manufacturers usually compete through imitating, reverse engineering, and localizing foreign products for local customers (Breznitz and Murphree, 2011). Hence, supplier knowledge must be assimilated and applied according to local customers' special requirements, and thus it only enhances MCC indirectly in China. Therefore, suppliers may not be able to contribute to MCC if there are no appropriate supporting practices, such as group learning and problem solving, knowledge sharing and training routines, cross-functional product development, and continuous improvement programs, for knowledge absorption. In addition, researchers provide only anecdotal evidence about how to develop MCC in China. This study provides empirical evidence on the positive relationship between AC and MCC and how knowledge sourced from customers and suppliers improves MCC in China, thus extending the current theory.

Second, our analysis reveals the importance of knowledge assimilation and application in converting the knowledge sourced from customers and suppliers into MCC in China. Due to the lack of R & D capabilities, Chinese manufactures rely on the conversion and integration of

external knowledge to create new knowledge. Our results shed light on the knowledge creation processes by identifying the mechanisms through which knowledge obtained from customers and suppliers is absorbed for MCC development according to the tacitness of knowledge. In particular, the acquired explicit knowledge can be used to develop MCC directly. To create new knowledge for MC, the acquired tacit knowledge must be socialized, externalized, and combined with existing knowledge through application, or assimilation and then application (Nonaka, 1994; Kotha, 1995). Such results enable Chinese manufacturers to select the suitable way to process and absorb external knowledge to enlarge their knowledge bases for MCC development. Hence, this study broadens our understanding of how knowledge is created within a manufacturer in China.

Third, Volberda et al. (2010) argue that the majority of empirical AC studies use indirect measures and unidimensional operationalizations that are not able to address AC's process dimensions (Flatten et al., 2011; Lane et al., 2006). By integrating the relative and process-based views of AC, this study conceptualizes and measures AC using both relationship-specific and firm-level components that truly assess the multidimensional nature of AC. In addition, China is lack of well-established institutional infrastructure to protect innovations and thus manufacturers tend to use external knowledge and resources, rather than investing in internal R & D, for MC (Zhou and Poppo, 2010). Hence, internal knowledge assimilation and application is driven by knowledge acquisition from external sources. We thus suggest that researchers take the relationships among the AC process components into account when investigating the antecedents and consequences of AC in China.

The results indicate that Chinese manufacturers could develop MCC through improving AC. We suggest Chinese managers to invest in information technologies and systems and apply supply chain management practices to acquire knowledge from customers and suppliers. For example, enterprise resource planning and product configurator could be used to facilitate real-time information sharing and co-design of products and processes with customers and suppliers. To facilitate the interactions, and build relationships, with suppliers and customers, Chinese managers could implement customer and supplier integration and joint performance measures, and organize special meetings, such as focus groups and brainstorming sessions, and social activities, such as new product exhibitions, workshops, and seminars. We also suggest Chinese managers to invest in internal sociotechnical systems to improve knowledge assimilation and application. For example, collaboration software and applications could be applied to support group learning and problem solving. To ensure both managers and workers have the desired skills to process knowledge, Chinese manufacturers could keep high standards for recruiting, provide task-related training programs, and regularly rotate employees between different functions. Formal routines and procedures could also be developed to facilitate cross-functional and leader-subordinate communications and meetings, which assist employees to discuss the impact of acquired knowledge on internal operations and make joint decisions. This study also helps western managers to select and develop Chinese partners to source manufacturing and supply chain capabilities and knowledge about Chinese customers. When selecting a Chinese supplier for MC, western managers could evaluate its processes, practices and systems for knowledge acquisition, assimilation and application, such as the mechanisms and technologies used to interact with partners, and the procedures and programs implemented for exploring and

exploiting knowledge. Collaborating with partners with high levels of AC could help western companies to customize products designed in the west for the mass market in China.

While this study makes significant contributions to the academic literature and practices, it also has limitations that open up avenues for future research. First, this study measures supply chain knowledge using the processes and routines through which it is absorbed and assumes that tacit and explicit knowledge are transferred in chunks. Future research may investigate how the properties of knowledge, such as tacitness and innovativeness, influence the effects of AC processes on organizational capability development. Second, the AC process model proposes that contingent factors, such as trust, regions of appropriability, and power, may influence not only the relationships among AC processes but also how they affect outcomes (Todorova and Durisin, 2007; Zahra and George, 2002). Future studies could explore how social capital and institutional environments influence AC and its effects on manufacturer's capability development. Last but not least, although this study provides some interesting findings on the relationships between AC and MCC in China, we cannot ascertain whether these relationships are the same in other countries with different business and cultural environments. Future research could examine cross-country differences.

References

1. Armstrong, J. and Overton, T. (1977), "Estimating nonresponse bias in mail surveys", *Journal of Marketing Research* , Vol. 14 No. 3, pp. 396-402.
2. Breznitz, D. and Murphree, M. (2011), *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China* , Yale University Press, New Haven, CT.
3. Chin, W.W. (1998), "The partial least squares approach to structural equation modeling", in Marcoulides, G.A. (Ed.), *Modern Methods for Business Research* , Lawrence Erlbaum Associates, Mahwah, NJ, pp. 295-336.
4. Chin, W.W. (2010), "How to write up and report PLS analyses", in Vinzi, V.E. , Chin, W.W. , Henseler, J. and Wang, H. (Eds), *Handbook of Partial Least Squares: Concepts, Methods and Applications* , Springer, Berlin, pp. 655-690.
5. Cohen, W.M. and Levinthal, D.A. (1990), "Absorptive capacity: a new perspective on learning and innovation", *Administrative Science Quarterly* , Vol. 35 No. 1, pp. 128-152.
6. Cohen, W.M. and Levinthal, D.A. (1994), "Fortune favors the prepared firm", *Management Science* , Vol. 40 No. 2, pp. 227-251.
7. Da Silveira, G. , Borenstein, D. and Fogliatto, F.S. (2001), "Mass customization: literature review and research directions", *International Journal of Production Economics* , Vol. 72 No. 1, pp. 7-13.
8. Flatten, T. C. , Engelen, A. , Zahra, S.A. and Brettel, M. (2011), "A measure of absorptive capacity: scale development and validation", *European Management Journal* , Vol. 29 No. 2, pp. 98-116.

9. Fornell, C. and Larcker, D.F. (1981), "Evaluating structural equation models with unobservable variables and measurement errors", *Journal of Marketing Research* , Vol. 18 No. 1, pp. 39-50.
10. Henseler, J. , Ringle, C.M. and Sinkovics, R.R. (2009), "The use of partial least squares path modeling in international marketing", in Sinkovics, R.R. and Ghauri, P.N. (Eds), *Advances in International Marketing* , Emerald, Bingley, pp. 277-319.
11. Huang, X. , Kristal, M.M. and Schroeder, R.G. (2008), "Linking learning and effective process implementation to mass customization capability", *Journal of Operations Management* , Vol. 26 No. 6, pp. 714-729.
12. Huang, X. , Kristal, M.M. and Schroeder, R.G. (2010), "The impact of organizational structure on mass customization capability: a contingency view", *Production and Operations Management* , Vol. 19 No. 5, pp. 515-530.
13. Hult, G.T.M. , Ketchen, D.J. Jr and Slater, S.F. (2004), "Information processing, knowledge development, and strategic supply chain performance", *Academy of Management Journal* , Vol. 47 No. 2, pp. 241-253.
14. Jansen, J.J.P. , Van Den Bosch, F.A.J. and Volberda, H.W. (2005), "Managing potential and realized absorptive capacity: how do organizational antecedents matter?", *Academy of Management Journal* , Vol. 48 No. 6, pp. 999-1015.
15. Kotha, S. (1995), "Mass customization: implementing the emerging paradigm for competitive advantage", *Strategic Management Journal* , Vol. 16 No. S1, pp. 21-42.
16. Kristal, M.M. , Huang, X. and Schroeder, R.G. (2010), "The effect of quality management on mass customization capability", *International Journal of Operations & Production Management* , Vol. 30 No. 9, pp. 900-922. ,

17. Lai, F. , Zhang, M. , Lee, D.M.S. and Zhao, X. (2012), “The impact of supply chain integration on mass customization capability: an extended resource-based view”, *IEEE Transactions on Engineering Management* , Vol. 59 No. 3, pp. 443-456.
18. Lane, P.J. and Lubatkin, M. (1998), “Relative absorptive capacity and interorganizational learning”, *Strategic Management Journal* , Vol. 19 No. 5, pp. 461-477.
19. Lane, P.J. , Koka, B.R. and Pathak, S. (2006), “The reification of absorptive capacity: a critical review and rejuvenation of the construct”, *Academy of Management Review* , Vol. 31 No. 4, pp. 833-863.
20. Lau, A.K.W. , Yam, R.C.M. and Tang, E.P.Y. (2010), “Supply chain integration and product modularity: an empirical study of product performance for selected Hong Kong manufacturing industries”, *International Journal of Operations & Production Management* , Vol. 30 No. 1, pp. 20-56. ,
21. Liu, G. , Shah, R. and Schroeder, R.G. (2006), “Linking work design to mass customization: a sociotechnical systems perspective”, *Decision Sciences* , Vol. 37 No. 4, pp. 519-545.
22. Liu, G. , Shah, R. and Schroeder, R.G. (2012), “The relationships among functional integration, mass customisation, and firm performance”, *International Journal of Production Research* , Vol. 50 No. 3, pp. 677-690.
23. Nagati, H. and Rebolledo, C. (2012), “The role of relative absorptive capacity in improving suppliers’ operational performance”, *International Journal of Operations & Production Management* , Vol. 32 No. 5, pp. 611-630. ,
24. Nonaka, I. (1994), “A dynamic theory of organizational knowledge creation”, *Organization Science* , Vol. 5 No. 1, pp. 14-37.

25. Nunnally, J.C. and Bernstein, I.H. (1994), *Psychometric Theory* , McGraw-Hill, New York, NY.
26. Patel, P.C. , Terjesen, S. and Li, D. (2012), “Enhancing effects of manufacturing flexibility through operational absorptive capacity and operational ambidexterity”, *Journal of Operations Management* , Vol. 30 No. 3, pp. 201-220.
27. Peng, D.X. , Liu, G. and Heim, G.R. (2011), “Impacts of information technology on mass customization capability of manufacturing plants”, *International Journal of Operations & Production Management* , Vol. 31 No. 10, pp. 1022-1047. ,
28. Piller, F.T. (2004), “Mass customization: reflections on the state of the concept”, *International Journal of Flexible Manufacturing Systems* , Vol. 16 No. 4, pp. 313-334.
29. Pine, B.J. (1993), *Mass Customization: The New Frontier in Business Competition* , Harvard Business School Press, Boston, MA.
30. Podsakoff, P.M. and Organ, D.W. (1986), “Self-reports of organizational research: problems and prospects”, *Journal of Management* , Vol. 12 No. 4, pp. 531-544.
31. Rungtusanatham, M.J. and Salvador, F. (2008), “From mass production to mass customization: hindrance factors, structural inertia, and transition hazard”, *Production and Operations Management* , Vol. 17 No. 3, pp. 385-396.
32. Salvador, F. , De Holan, P.M. and Piller, F. (2009), “Cracking the code of mass customization”, *MIT Sloan Management Review* , Vol. 50 No. 3, pp. 71-78.
33. Todorova, G. and Durisin, B. (2007), “Absorptive capacity: valuing a reconceptualization”, *Academy of Management Review* , Vol. 32 No. 3, pp. 774-786.

34. Trentin, A. , Forza, C. and Perin, E. (2012a), “Organisation design strategies for mass customisation: an information-processing-view perspective”, *International Journal of Production Research* , Vol. 50 No. 14, pp. 3860-3877.
35. Trentin, A. , Perin, E. and Forza, C. (2012b), “Product configurator impact on product quality”, *International Journal of Production Economics* , Vol. 135 No. 2, pp. 850-859.
36. Tsai, W. (2001), “Knowledge transfer in interorganizational networks: effects of network position and absorptive capacity on business unit innovation and performance”, *Academy of Management Journal* , Vol. 44 No. 5, pp. 996-1004.
37. Tu, Q. , Vonderembse, M.A. and Ragu-Nathan, T.S. (2001), “The impact of time-based manufacturing practices on mass customization and value to customer”, *Journal of Operations Management* , Vol. 19 No. 2, pp. 201-217.
38. Tu, Q. , Vonderembse, M.A. , Ragu-Nathan, T.S. and Ragu-Nathan, B. (2004), “Measuring modularity-based manufacturing practices and their impact on mass customization capability: a customer-driven perspective”, *Decision Sciences* , Vol. 35 No. 2, pp. 147-168.
39. Tu, Q. , Vonderembse, M.A. , Ragu-Nathan, T.S. and Sharkey, T.W. (2006), “Absorptive capacity: enhancing the assimilation of time-based manufacturing practices”, *Journal of Operations Management* , Vol. 24 No. 5, pp. 692-710.
40. Volberda, H.W. , Foss, N.J. and Lyles, M.A. (2010), “Absorbing the concept of absorptive capacity: how to realize its potential in the organization field”, *Organization Science* , Vol. 21 No. 4, pp. 931-951.
41. Von Hippel, E. (2001), “Perspective: user toolkits for innovation”, *Journal of Product Innovation Management* , Vol. 18 No. 4, pp. 247-257.

42. Wang, L. , Yeung, J.H.Y. and Zhang, M. (2011), “The impact of trust and contract on innovation performance: the moderating role of environmental uncertainty”, *International Journal of Production Economics* , Vol. 134 No. 1, pp. 114-122.
43. Yeung, J.H.Y. , Selen, W. , Zhang, M. and Huo, B. (2009), “The effects of trust and coercive power on supplier integration”, *International Journal of Production Economics* , Vol. 120 No. 1, pp. 66-78.
44. Yeung, J.H.Y. , Selen, W. , Zhou, D. and Zhang, M. (2007), “Postponement strategy from a supply chain perspective: cases from China”, *International Journal of Physical Distribution & Logistics Management* , Vol. 37 No. 4, pp. 331-356.
45. Zahra, S.A. and George, G. (2002), “Absorptive capacity: a review, reconceptualization, and extension”, *Academy of Management Review* , Vol. 27 No. 2, pp. 185-203.
46. Zhang, M. and Huo, B. (2013), “The impact of dependence and trust on supply chain integration”, *International Journal of Physical Distribution & Logistics Management* , Vol. 43 No. 7, pp. 544-563. ,
47. Zhang, M. , Zhao, X. and Qi, Y. (2014), “The effects of organizational flatness, coordination, and product modularity on mass customization capability”, *International Journal of Production Economics* , Vol. 158, pp. 145-155.
48. Zhao, X. , Flynn, B.B. and Roth, A.V. (2006), “Decision sciences research in China: a critical review and research agenda – foundations and overview”, *Decision Sciences* , Vol. 37 No. 4, pp. 451-496.
49. Zhou, K.Z. and Poppo, L. (2010), “Exchange hazards, relational reliability, and contracts in China: the contingent role of legal enforceability”, *Journal of International Business Studies* , Vol. 41 No. 5, pp. 861-881.

Appendix.

Measurement items

Knowledge acquisition from customers

AfC1: We have special mechanisms to gain customers' operational information (e.g. production plan, inventory level) in real time.

AfC2: We periodically organize special meetings with customers (e.g. focus groups, brainstorming sessions) to find out what products are needed in the future.

AfC3: We frequently poll our customers to assess the quality of our products.

AfC4: We have formal routines and standard operating procedures to guide employees' interactions with customers.

Knowledge acquisition from suppliers

AfS1: We have special mechanisms to gain suppliers' operational information (e.g. production plan, inventory level) in real time.

AfS2: We periodically organize special meetings with suppliers (e.g. focus groups, brainstorming sessions) to find out what products are needed in the future.

AfS3: We frequently poll our suppliers to assess the quality of our products.

AfS4: We have formal routines and standard operating procedures to guide employees' interactions with suppliers.

Knowledge assimilation

ASS1: We regularly organize learning groups to discuss the consequences of new knowledge.

ASS2: We have special mechanisms to solve conflicts when employees have different understandings and interpretations of new knowledge.

ASS3: We have special procedures for employees to share knowledge and practical experiences.

ASS4: We have special training programs that help employees grasp new knowledge.

Knowledge application

APP1: Our employees frequently make product and process improvement suggestions based on new knowledge.

APP2: We periodically review our long-term forecasting (e.g. market trends and technology development) based on new knowledge.

APP3: We have systematic procedures for implementing new knowledge to develop new products.

APP4: We constantly consider how to better exploit knowledge.

MCC

MCC1: We are highly capable of large-scale product customization.

MCC2: We can easily add significant product variety without increasing costs.

MCC3: We can customize products while maintaining high volume.

MCC4: We can add product variety without sacrificing quality.

MCC5: We can adjust our process design according to customer demand without significantly increasing costs.

MCC6: We can adjust our product design according to customer demand without significantly increasing costs.