Impacts of supply chain integration on product- and service-oriented mass customisation capability: The role of customer needs

Abstract

Purpose – This study aimed to investigate how different supply chain integrations (i.e. information integration and organisational integration) would impact product- and service-oriented mass customisation capability differently and the moderating role of characteristics of customer needs (i.e. customer need tacitness and diversity).

Design/methodology/approach – From the perspective of information processing theory, we tested our hypotheses using survey data from 277 Chinese manufacturers.

Findings – Our findings indicate that both information and operational integration contribute to product- and service-oriented mass customisation capabilities. Operational integration promotes product-oriented mass customisation capability more, whereas information integration has a greater impact on service-oriented mass customisation capability. In addition, customer need tacitness negatively moderates the impact of operational integration on both product- and service-oriented mass customisation capability. Customer need diversity negatively moderates only the impact of operational integration on service-oriented mass customisation capability.

Practical implications – Managers should focus on not only the position (internal or external) but also the function of supply chain integration when making decisions towards enhancing mass customisation capability. Diverse abilities to integrate with different functions are associated with different mass customisation capabilities.

Originality/value – This study distinguishes between product- and service-oriented mass customisation capabilities and provides novel insights for understanding how to enhance mass customisation capability from a supply chain integration perspective.

Keywords: supply chain integration; mass customisation capability; customer need; moderating effect

1 Introduction

With intensified global competition and increased customer sophistication, firms have been paying more attention to and constantly enhancing mass customisation capability (MCC), which could result in large volumes of customised products without substantial sacrifices having to be made in terms of the delivery process, product quality, and product cost (McCarthy, 2004; Huang et al., 2008; Trentin et al., 2015). Existing studies have extensively explored product mass customisation (MC) and developed a framework of different types, dimensions, enablers, and outcome benefits (e.g. Silveira et al., 2001; Fogliatto et al., 2012; Wang et al., 2016; Sandrin et al., 2018; Ahrens et al., 2019; Qi et al., 2020; Ullah and Narain, 2021). For example, IKEA offers customised furniture solutions of whole-house designs for customers. When customers decide to buy any customised furniture, IKEA combines standardised products with customised modules to meet customers' different needs for customised products.

However, a prominent phenomenon is that a large proportion of firms' customisation solutions appear as product-related services rather than coming with the product itself. Customisation that aims to provide tailor-made product-related services for customers is called service-oriented MCC (Lovelock, 1983; Ding and Keh, 2015). For example, Puma produces sportswear for AC (Associazione Calcio) Milan. Customers can print their names or the names of their favourite athletes on sportswear in Puma's exclusive shops at the time of purchase. In this case, while customers can obtain the same sportswear products, the name printing service is an extra customisation service. Nonetheless, the existing literature does not explicitly distinguish between product- and service-oriented MCC. Since services differ

significantly across products in characteristics, operational strategy, and quality evaluation, it is necessary to differentiate between product- and service-oriented MCC and to explore their different effects.

Moreover, the existing literature indicates that supply chain integration (SCI) can contribute to MCC by linking two vital activities in various areas throughout the supply chain: information and operation. On the one hand, information has been widely treated as one of MCC's enablers and success factors (Silveira et al., 2001; Fogliatto et al., 2012; Tang et al., 2017). From the perspective of information processing theory (IPT), an organisation's ability improves when its information processing capacity satisfies its requirements (Tushman and Nadler, 1978). MCC significantly increases the need for information acquisition and transmission in the supply chain. For example, information on customer demands is needed for new product specifications, quality improvement, and customer co-designs (Fogliatto et al., 2012; Zhang et al., 2015). Information on raw material supplies, market trends, and technology updates from supply chain partners ensures customised product designs, timely production, and precise marketing. Therefore, information integration would increase a firm's information-processing capability, satisfy its increasing information requirements, and ultimately enhance its MCC.

On the other hand, with the flow of information, corresponding operational process interfaces and collaborations are also required to facilitate MCC (Trentin et al., 2012). Previous studies indicate that MC is a 'chain-based concept' whose success largely depends on the readiness and willingness to cooperate among chain members (Silveira et al., 2001; Zhang et al., 2014). For instance, after receiving customers' customised needs through online

platforms, Dell divides these demands into different orders through customer relationship management (CRM) and then sends them to special component manufacturers and raw material suppliers. These well-selected and powerful suppliers can produce components in a short time. Finally, after the product is assembled, a professional express firm sends the products to customers. Dell then feeds customer feedback into a CRM system to enhance its MCC. This operational integration helps focal firms to allocate and configure supply chain members' resources and use them in the design, production, and delivery of MC products or services, which could ultimately improve the manufacturers' MCC. However, there is little evidence of the impact of information and operational integration on MCC.

To clarify the above issues, this study focuses on information integration and operational integration and the coexistence of product- and service-oriented MCC to address the following research questions: What are the impacts of information integration and operational integration on product- and service-oriented MCC? Are the impacts the same for information integration and operational integration on the two types of MCC? Moreover, the primary purpose of manufacturing is to satisfy customers' diversified needs. However, tacitness and diversity in customer needs both increase MCC's uncertainty and difficulty and then induce information processing problems, which would probably influence the need and effectiveness of the integration of various functions in supporting MCC (Jean and Kim, 2020; Zhang and Xiao, 2020). Therefore, we treat tacitness and diversity as moderators. To gain a more comprehensive understanding of the effects of different integrations on different MCC types, based on IPT, we empirically tested the main hypotheses using survey data from 277 Chinese manufacturers in several industries. The moderated regression analysis results support the

positive but diversified impetus of information integration and operational integration on the two types of MCC. These findings contribute to the existence of service-oriented MCC (e.g. Kaplan and Haenlein, 2006; Silvestro and Lustrato, 2015) and provide a more comprehensive understanding of the effectiveness of SCI of various functions in enhancing MCC under different customer needs situations.

2. Literature Review and Hypotheses

2.1 A product-oriented vs service-oriented MCC perspective

Existing literature mainly focuses on firms' MCC in product manufacturing and treats MCC as a multi-dimensional construct comprising four aspects: high volume, cost efficiency, quick responsiveness, and consistent quality (Huang et al., 2008; Tu et al., 2001; Wang et al., 2016). High-volume and high-quality customisation inevitably lead to increased costs and lead times. Controlling costs and lead time adversely harms the implementation of high-volume and high-quality maintenance in customisation. Thus, the simultaneous achievements of these seemingly contradictory capabilities are complex and challenging. Researchers suggest that manufacturers exert modularity and quality management in production (Tu et al., 2004; Kristal et al., 2010), implement advanced information and manufacturing technology (Fogliatto et al., 2012; Peng et al., 2011; Tang et al., 2017), conduct learning and innovation (Huang et al., 2008; Wang et al., 2016), integrate supply chain partners or internal functions (Zhang et al., 2019; Liu et al., 2012), and skilfully manage the workforce (Ullah and Narain, 2021) to increase product-related MCC.

The concept of service-oriented MCC is relatively new and was not developed until recently, when people realised that 'product MC' often appears, and service-oriented MCC is

experienced by customers in the product-related service area (Koch and Inanc, 2015). For example, Borche, a professional Chinese manufacturer of injection moulding equipment, provides a customised solution to each customer who orders injection moulding equipment on kinetic energy allocation, wastewater treatment, plant layout planning, and maintenance schemes, among others. It is through these diversified services that customers feel customisation. Accordingly, service-oriented MCC is the ability to provide product-related, tailor-made services for customer benefits without substantial trade-offs in cost, delivery, or quality performance (Lovelock, 1983; Ding and Keh, 2015). It is facilitated by accurate information about customer needs and creative employees' ideas towards service designs (Keh et al., 2013). The latest information technologies are vital for service MCC because they facilitate firms to build internal and external communication and learning channels to couple customer and service operations (Silvestro and Lustrato, 2015). Unlike physical products, service consumption occurs simultaneously with service production, and customers are involved in the process (Wang et al., 2019). Thus, customisation or adaption in services based on customers' diversified requirements is critical to differentiate themselves from competitors. Thus, ongoing process experiments, timely trials, error testing, and whole process modifications are more prominent in customising services than in the products themselves (Koch and Inanc, 2015).

2.1 Adding the integration lens

According to the SCI literature, firms depend on an efficient and effective flow of information and coordination of operational practices and procedures with supply chain partners to satisfy customer needs (Durach and Wiengarten, 2020; Huo, 2012; Liu et al.,

2016; Wang and Feng, 2022; Wiengarten et al., 2019). However, integrating activities in various areas, such as information integration and operational integration, has received relatively less attention. *Information integration* refers to the degree to which a focal firm strategically manages the direct and real-time flow of information related to material procurement, production techniques, customer needs, market trends, inventory levels, and delivery plans, among others, with supply chain partners (Kulp et al., 2004; Lai et al., 2012; Liu et al., 2016). The existing literature regards information integration as the foundation of SCI (Cao and Zhang, 2011; Kulp et al., 2004; Lai et al., 2012; Liu et al., 2016; Tang et al., 2017). As suggested by IPT, firms should fit their information-processing needs with their information-processing capability to improve performance (Galbraith, 1973; Srinivasan and Swink, 2018). Both product- and service-oriented MC increase the uncertainty and difficulty of forecasting customer demand, scheduling production, and ensuring delivery (Kulp et al., 2004; Lai et al., 2012). They naturally increase firms' information needs with respect to customer needs, market trends, and competitive forces. By implementing information technology and facilitating timely, accurate, and sufficient information exchange among supply chain partners, information integration can satisfy a firm's information needs by increasing its information-processing capability (Srinivasan and Swink, 2015; Yu et al., 2021). When a firm's information-processing capability meets its information-processing needs, it achieves maximum performance. As indicated by Lee (2000), without the implementation of information integration, 'few gains can be made in overall supply chain integration' (p. 33).

In addition to information sharing, the previous literature indicates that firms should have a higher level of coordination to exchange decisions, knowledge, and resources (Lee, 2000). *Operational integration* refers to the extent to which a firm coordinates with supply chain partners to manage intra- and inter-organisational processes in decision making, production, service provision, and product flow to meet customer requirements and automatically execute supply chain activities (Sanders, 2007). As a collaborative strategy of firms, operational integration aims to manage the fluent flow of products, capital, and information from upstream suppliers to end users (Lai et al., 2012). To achieve this, firms must collaborate with supply chain partners to deploy their resources and capacities (Flynn et al., 2010; Liu et al., 2016). Finally, operational integration enhances firms' capability to respond to technological and market changes (Lai et al., 2012), which is vital for MCC.

Operational and information integration often provide firms with a unique competitive advantage. To win over other competitors, Borche provides each customer with a customised and integrated solution with its core equipment. In doing so, Borche shares information with each customer to know their purposes for the equipment, future production plans, production capacities, and plant environments. Simultaneously, it communicates with various upstream suppliers to capture the market trends and latest technologies of kinetic energy allocation and wastewater treatment, as well as the production and supply conditions of the needed components. Then, Borche conducts collaborations along the supply chain to achieve its MCC. On the upstream side, by integrating suppliers into its components purchase process, Borche and suppliers can work together to design kinetic energy allocation and wastewater treatment systems for customers and provide after-sale services for customers. On the

downstream side, Borche works with each customer to conduct equipment installation, production tests, kinetic energy and wastewater treatment system allocation, and maintenance training, among others. Lastly, various internal units of Borche are also needed to collaborate closely to conduct the design and production process while supporting the provision of external information and operational integration.

2.3 Effects of information and operational integration on product- and service-oriented MCC

Both product- and service-oriented MC are characterised by a high degree of uncertainty and customisation of customer needs (Kulp et al., 2004; Lai et al., 2012). Every pending and customised order denotes an accurate communication of information related to customer-specific needs of products and services and timely information sharing about the design, production, and delivery of products and services with suppliers and between internal units (Piller et al., 2004). Thus, product- and service-oriented MC increase a focal firm's information processing needs. Information integration is an effective approach to improve a firm's information-processing capability (Srinivasan and Swink, 2015). When a focal firm can timely and efficiently share information with suppliers and customers, it can capture customers' specific needs accurately and then coordinate processes well in material procurement, design, production, and delivery to satisfy their needs (Tu et al., 2001; Piller et al., 2004). According to IPT, when the increased information needs produced by product- and service-oriented MC are satisfied well by information integration, a better MCC can be achieved, as indicated by previous studies. Lee et al. (2000) find that information integration with customers is necessary for MCC by enabling firms to deal efficiently with the

subsequent intensity and complexity of customer needs. Yassine et al. (2004) suggest that information integration with suppliers benefits MCC. Thus, we hypothesize the following:

H1*: Information integration has positive impacts on (a) product-oriented and (b) service-oriented MCC.*

Operational integration can also benefit product- and service-oriented MCC. First, when a focal firm has a high level of operational integration, it is more likely to allocate various intra- and inter-organisational processes in material procurement, design, production, and the delivery process to meet the production needs of small-batch customised products or services. Unlike mass production, MC requires different operational resources and processes to produce various kinds of customised products or services. Operational integration allows focal firms to monitor and deploy scarce and valuable resources across the supply chain. Second, operational integration facilitates the timely adjustment of operational processes and the reconfiguration of components to meet customers' diversified needs. In product- or service-oriented MC, manufacturers must continuously monitor customers to obtain feedback about products and services and then configure and modify supply chain activities to improve their MCC. Operational integration allows focal firms to incorporate customer needs such as desired features into operational processes such as production, planning, and control of products or services so that the design and component configuration of products and services can be changed timely (Peng et al., 2011; Koch and Inanc, 2015). This coordination is critical for decomposing complex customer specifications into a standard interface of components that will satisfy customers' demands (Tu et al., 2004). Moreover, operational integration also helps reduce conflicts with supply chain partners and promotes joint efforts in cost and inventory reduction, which result in better MCC. By contrast, the absence of operational

integration can have negative consequences on MCC, such as long lead times for customer orders and poor utilisation of resources (Barnett et al., 2004). Consequently, we propose the following:

H2*: Operational integration has positive impacts on (a) product-oriented and (b) service-oriented MCC.*

We anticipate that operational integration would be relatively more effective in promoting product-oriented MCC than information integration. This is largely determined by the differences between products and services. Both product- and service-oriented MC require a great amount of resources, information, and coordination. Compared with services, a product is tangible, and the realisation of its performance requires physical materials and parts to be assembled and tested before customers' purchase, as well as the coordination and cooperation of production and operation between firms. Thus, after knowing customers' diversified needs via information gathering, product-oriented MCC lays a high requirement on firms' capability to design products; acquire and reorganise raw materials, resources, and organisational capabilities to produce such products; and complete product performance tests before delivery to customers. As indicated by Barnett et al. (2004, p. 626), product-oriented MCC requires a reduction in size and an increase in model variety, leading to a lower level of resource efficiency and a higher level of resource configuration. Therefore, operational integration, as opposed to information integration, enables firms to reallocate and share their limited resources, thereby helping them to meet customer needs better (Sadiq et al., 2018; Sheng et al., 2021b). Therefore, operational integration (e.g. resource allocation and operational process configuration) is more important than information integration for product-oriented MCC.

On the other hand, services are intangible and require relatively less physical resource allocation and process configuration than products. A significant feature of such services is their perishability (Hong et al., 2010; Kaplan and Haenlein, 2006). Services cannot be inventoried in advance, and they must be consumed at the time of production. Service-oriented MCC will have more ongoing process experiments, timely trial and error testing, and whole-process modifications (Koch and Inanc, 2015). To meet each customer's unique requirements and improve the flexibility and agility of responses, timely and accurate information on market demands and technology breakthroughs is required for service-oriented MCC. (Koch and Inanc, 2015). Thus, continuously gathering information on customers' needs, service experience feedback, market trends, and technology breakthroughs is more important than operational integration for enhancing service-oriented MCC. Taken together, operational integration is likely to contribute more to product-oriented MCC, whereas information integration may benefit service-oriented MCC more. Here, we hypothesize the following:

H3: *(a) Operational integration has a greater impact on product-oriented MCC than information integration, while (b) information integration has a greater impact on service-oriented MCC than operational integration.*

2.4 Moderating role of the characteristics of customer needs

Operational and information integration can enhance firms' MCC to meet customer needs. However, when the characteristics of customer needs differ, it may increase the difficulty of obtaining and processing information for firms, thus affecting operational and information integration. The literature has highlighted tacitness and diversity as the main attributes of customer needs (De Luca and Atuahene-Gima, 2007; Jean and Kim, 2020; Zhang et al., 2015; Zhang and Xiao, 2020). Tacitness means that customer needs are highly hidden and hard to

understand and measure, thus inducing higher information processing difficulty. Diversity means that customer needs differ greatly from each other; hence, there is a high degree of uncertainty and complexity. To obtain a comprehensive understanding of customer needs, focal firms require more information-processing efforts. Therefore, tacitness and diversity both increase MC's uncertainty and difficulty, thereby inducing information processing problems. We will further explore the moderating roles of these factors.

2.4.1 Customer need tacitness

Customer need tacitness represents the difficulty of accurately capturing and documenting customer needs (Nonaka, 1994). In practice, customers often communicate their needs to firms in written form. In this process, customers are able to express their current needs, but have difficulty expressing their potential needs (Leonard, 2007). Although this situation may be due to the limitation of the written form, it is difficult for firms to identify and collect the needs of their customers accurately. According to the results of knowledge transfer studies, tacit knowledge is harder to transfer than explicit knowledge and requires more personal interactions and a relatively extended period to achieve (Nonaka, 1994; Yang et al., 2019). As a result, for firms, customer need tacitness increases the difficulty in accurately identifying customer needs and weakens their information processing capabilities, which can lead to a lack of information about customer needs, thus reducing their MCC.

Information integration is used to exchange information throughout the supply chain (Lai et al., 2012; Liu et al., 2016). Suppose that information on customer needs is hard to document in written form. In this case, the extent of information distortion is amplified, and the accuracy of the information on customer needs cannot be guaranteed. Moreover, advanced

digital technologies typically facilitate information integration. Such information transfer is fast and involves more minor personal interactions. As a kind of explicit knowledge, customers need tacitness requires more personal interactions and a more extended period (Nonaka, 1994; Yang et al., 2019). Thus, information integration's information-processing capability cannot match the information-processing needs to be created by customer need tacitness. Customer need tacitness may cause inefficiency in information integration. Accordingly, the impetus of information integration on product- and service-oriented MCC will be mitigated. Here, we propose the following:

H4O*: Customer need tacitness negatively moderates the impacts of information integration on (a) product-oriented and (b) service-oriented MCC.*

In the process of product- or service-oriented MC, operational integration aims to help manufacturers integrate the necessary operational processes and resources along the supply chain to facilitate the production of high-volume and customised products or services for customers (Cao and Zhang, 2011). Customer need tacitness increases the uncertainty in capturing customer needs. Therefore, firms are often unable to accurately capture customer needs (Boon-itt and Wong, 2011). As a result, even if resources and operational processes are sufficiently allocated, they cannot develop customised products or services that meet customers' needs. Accordingly, the efficiency of operational integration declines, causing redundancy of efforts and waste of resources.

Second, a high level of operational integration emphasises standardisation in supply chain coordination that would ignore sufficient flexibility (Barnett et al., 2004; Kulp et al., 2004). With a high level of tacitness, firms that implement operational integration may find it challenging to modify their standardised routines to adjust the process changes required by

tacit needs (Zhang and Xiao, 2020). Specifically, such a mismatch between operational integration and customers' tacit needs is likely to result in solutions that may be market-wise efficient, yet operational-wise ineffective. For instance, even if the customer's tacit needs may appeal to the market, firms may lack the resources and manufacturing skills necessary. As a result, high tacitness levels may lead to severe setbacks in both product- and service-oriented MC that would ultimately weaken MCC. In summary, we hypothesise the following:

***H4I**: Customer need tacitness negatively moderates the impacts of operational integration on (c) product-oriented and (d) service-oriented MCC.*

2.4.2 Customer need diversity

First, customer need diversity implies that customers possess an extensive range of preferences for products and services, and one customer's needs could significantly differ from another's (Zhang and Xiao, 2020; Sheng et al., 2021a). This suggests that firms need to identify and collect customer needs in a timely and accurate way to obtain a comprehensive understanding of the needs and provide customised products and services that could meet customer needs. Thus, the requirement for information processing increases when customer diversity is high. Information integration can effectively accelerate information gathering and increase the efficiency of void interference and distortion in information transfer. If a manufacturer uses its compatible information integration system to exchange information, it can more promptly and precisely detect shifts in customer needs (Srinivasan and Swink, 2015; Yu et al., 2018). Thus, information integration can satisfy the need for manufacturers' greater amount of information when customer needs for diversity increase. According to IPT, the fit between information-processing needs and capability can enhance product- and service-oriented MCC.

Second, diverse customer needs may cause conflicts and disagreements among supply chain partners due to increased difficulty and workload in decision making and resource allocation (Shou et al., 2017; Sheng et al., 2021a). Information integration helps manufacturers address these conflicts and reach an agreement by providing sufficient and accurate information to support decision making and conflict resolution (Srinivasan and Swink, 2015). Consequently, the process of product- and service-oriented MCC can be executed more efficiently. Thus, we hypothesize the following:

H5O: *Customer need diversity positively moderates the impacts of information integration on (a) product-oriented and (b) service-oriented MCC.*

With a higher level of customer need diversity, firms require more types of customised products or services and more types of allocations in resources and operational processes. However, with limited resources and types, this may mitigate the quality of operational integration. The difficulty of process allocation increases, and the amount of resources in each product or service category is reduced (Zhang and Xiao, 2020). In addition, with increased operational integration, firms are increasingly able to provide standardised services and products; however, standardised designs do not fully meet the diverse needs of customers (Schmitz and Ganesan, 2014; Zhang and Xiao, 2020). Therefore, diversity tends to make information processing more difficult, which makes coordination and cooperation in operations more difficult, and thus affects the effect of product- and service-oriented MCC.

In addition, when customer need diversity increases, the number of orders for various products or services will also increase (Zhang and Xiao, 2020). Since different types of products or services require various resources and operational processes, with an increase in product or service types, conflict between resource allocation and operational integration is

inevitable. Flynn et al. (2010) indicated that when a decision on resource allocation conflicts with another, opposition to such a decision emerges. Accordingly, it is necessary to make more efforts to solve the conflicts between resource allocation and operational integration. In addition, the efficiency of resource usage and operational integration is harmed. If operational integration cannot make the best use of supply chain resources, its contribution to product- and service-oriented MC will be limited. In summary, we expect the following:

H5I: *Customer need diversity negatively moderates the impacts of operational integration on (c) product-oriented and (d) service-oriented MCC.*

3 Research Methods

3.1 Measurement scales

We developed a questionnaire based on the above literature review and insights from interviews we conducted. First, to obtain practical insights, we conducted in-depth interviews with eight executives of our EMBA students. We raised the following interview questions: Is supply chain integration beneficial to enhance MCC? How does supply chain integration affect MCC? What kinds of integration are more important for enhancing MCC? Could firms benefit from supply chain integration and is this affected by the characteristics of customer needs? We developed the initial questionnaire in English and used the translation and back-translation method. Then, we asked the eight executives to check the measures and made revisions following their suggestions. Next, we performed a pilot study with ten top managers, who were not included in our final analysis. We used a 7-point Likert scale with 1 = ‘strongly disagree’ and 7 = ‘strongly agree’ for all measures. The scales are presented in Appendix A.

Information and operational integration. Information integration was evaluated using four items adapted from Liu et al. (2016). Operational integration was measured using seven items adapted from Liu et al. (2013) and Liu et al. (2016).

Characteristics of customer need. Customer needs tacitness was assessed using four items adapted from Zhang and Xiao (2020). Customer need diversity was evaluated using three measures adapted from Zhang and Xiao (2020).

MCC. Product-oriented MCC was measured using six items adapted from Huang et al. (2008). Service-oriented MCC was measured using six items adapted from Huang et al. (2008) and Liu et al. (2018).

Control variables. Firm age, firm size, ownership type, industry type, and competitive intensity were chosen as control variables. We measured firm age using the natural logarithm of the number of years since the firm was established and firm size using the natural logarithm of the number of employees. We evaluated ownership type using two dummy variables, with state-owned and collective enterprises as the base. We measured industry type using a dummy variable (1 = high-tech industries, 0 = otherwise). Competitive intensity was measured using four items adapted from Jaworski and Kohli (1993).

3.2 Sampling and data collection

To collect representative data, we strategically selected five provinces in China (Guangdong, Jiangsu, Shandong, Shaanxi, and Inner Mongolia). Guangdong and Jiangsu, located in the Pearl River Delta and Yangtze River Delta, respectively, exhibit the highest level of industrial development. Shandong is located in the Bohai Coastal Region and reflects an average level of industrial development. Shaanxi and Inner Mongolia are located in north-

western China and reflect a relatively lower level of industrial development. These provinces reflect different levels of industrial development in China and can ensure the external validity of our findings.

In China, local governments may establish economic development zones and assign agencies to provide operational services in these zones (Zhu et al., 2019). With the help of these agencies, we obtained a list of manufacturing firms. We then randomly selected 120 firms in each province. Subsequently, we contacted the firms to introduce our research purpose and promised them anonymity if they participated and the final research report. After contacting, 346 firms agreed to participate in our research. We divided the questionnaire into two parts: A and B. Each firm identified two informants to complete the questionnaire (one for Part A and another for Part B). The two informants were asked to answer independently. Informants of Part A answered questions on firms' characteristics, competitive intensity, customer need tacitness, customer need diversity, and information integration. Informants of Part B answered questions on operational integration, product-oriented MCC, and service-oriented MCC. We also provided two reminders explaining the significance of completing the questionnaire. A total of 277 valid questionnaires were received, with a response rate of 46.2%. Then, we first compared the firm size, firm age, ownership type, and industry type between the responding and non-responding firms. There was no significant difference. Further, no significant difference was found between the early and late responses in all variables. Thus, non-response bias was not serious in our study.

Among the 554 responding informants, 61.2% were CEOs, general managers, and vice presidents, while 38.8% were operations directors. Operations directors were executive-level

managers who were actively engaged in the strategic decisions of their firms. Hence, they were expected to be knowledgeable and suitable in answering the questions. The informants had worked 7.32 years on average in their current firms. These firms included diverse industries, such as machinery, electrical machinery and equipment, communication and computer-related equipment, chemical and related products, instruments and related products, and metal products. The sample characteristics are presented in Table 1.

[INSERT TABLE 1 ABOUT HERE]

3.3 Reliability and validity

The results in Table 2 indicate that the Cronbach's alpha and composite reliability (CR) values of the seven constructs were all above 0.80, indicating favourable internal consistency. The fit index of the measurement model from confirmatory factor analysis (CFA) was satisfactory: $\chi^2(506) = 1149.80$, RMSEA = 0.066, NNFI = 0.97, CFI = 0.97, SRMR = 0.043. As Table 2 shows, each factor loading was significant. Thus, this study has acceptable convergent validity. Moreover, the average variance extracted (AVE) values of seven constructs were above 0.5, providing further evidence for convergent validity.

To assess discriminant validity, we compared the square root of the AVE value for each construct with its correlations with other constructs. The results in Table 3 reveal that the square root of AVE value of each construct was larger than the correlations (Hair et al., 2006), which suggests that discriminant validity is satisfactory.

[INSERT TABLE 2 AND 3 ABOUT HERE]

3.4 Common method bias

We employed several approaches to check the possibility of common method bias (CMB). First, exploratory factor analysis (EFA) results indicated that seven factors with an eigenvalue above 1 were generated. These seven factors accounted for 82.2% of the total variance, whereas the first factor accounted for only 17.5%. Second, we performed CFA for Harman's single-factor analysis (Podsakoff et al., 2012). Compared with the measurement model, the model fit indices became worse (χ^2/df = 13.65, RMSEA = 0.28, NNFI = 0.67, CFI = 0.69, and SRMR = 0.21). Thus, different factors should be considered. Finally, we re-examined the measurement model by including a method factor (Podsakoff et al., 2012). In this model, we specified that the method factor was not correlated with the other seven constructs. The model fit indices only marginally improved compared with the seven-factor model (ΔRMSEA = -0.005; ΔCFI = 0.01; ΔSRMR = -0.006). The method factor accounted for only 1.5% of the total variance (Hair, 2006). Based on our analysis of the techniques used to check for CMB, we conclude that it was unlikely to be a serious concern.

4 Analysis and Results

Hierarchical moderated regression analysis was conducted to test the hypotheses. To mitigate the influence of multicollinearity, the independent variables and moderators were mean-centred before generating the interaction terms. The regression analysis results are shown in Table 4. As shown in Models 2 and 6, information integration is positively related to both product-oriented MCC ($\beta = 0.197$, $p < 0.01$) and service-oriented MCC ($\beta = 0.403$, $p < 0.001$). Thus, both H1a and H1b are supported.

[INSERT TABLE 4 ABOUT HERE]

Models 2 and 6 in Table 4 indicate that operational integration is positively related to product-oriented MCC ($\beta = 0.364$, $p < 0.001$) and service-oriented MCC ($\beta = 0.132$, $p < 0.05$). These findings empirically support H2a and H2b.

T-test results suggest that the impact of operational integration on product-oriented MCC is higher than that of information integration ($p < 0.1$), and the impact of information integration on service-oriented MCC is higher than that of operational integration ($p < 0.01$). Thus, H3a and H3b are supported.

Models 3 and 7 in Table 4 show that the interaction between information integration and customer need tacitness has insignificant impacts on product- ($\beta = -0.005$, $p > 0.1$) and service-oriented MCC ($\beta = 0.005$, $p > 0.1$), lending no support to H4Oa and H4Ob. In addition, Models 3 and 7 in Table 4 indicate that the interaction between operational integration and customer need tacitness has negatively significant impacts on product- ($\beta = -0.195$, $p < 0.01$) and service-oriented MCC ($\beta = -0.179$, $p < 0.01$), providing support to H4Ic and H4Id.

We show the significant moderating effects in Figures 2 and 3. Figure 2 suggests that operational integration has a greater positive influence on product-oriented MCC when the degree of customer need tacitness is lower ($\beta = 0.438$, $p < 0.001$) than when it is higher ($\beta = 0.146$, $p < 0.1$). Figure 3 shows that operational integration has a greater positive influence on service-oriented MCC when the degree of customer need tacitness is lower ($\beta = 0.276$, $p < 0.001$) than when it is higher ($\beta = -0.020$, $p > 0.1$).

[INSERT FIGURE 2 and 3 ABOUT HERE]

Models 4 and 8 in Table 4 reveal that the interaction between information integration and customer need diversity has insignificant impacts on product- (β = -0.023, p > 0.1) and service-oriented MCC (β = -0.102, p > 0.1). Thus, H5Oa and H5Ob are not supported. Further, Models 4 and 8 in Table 4 also indicate that the interaction between operational integration and customer need diversity has an insignificant impact on product-oriented MCC (β = -0.061, p > 0.1), while it has a negatively significant impact on service-oriented MCC (β = -0.146, p < 0.05). Thus, H5Ic is not supported, but H5Id is. We also show the significant moderating effects in Figure 4. Figure 4 suggests that operational integration has a greater positive influence on service-oriented MCC when the degree of customer need diversity is lower (β = 0.196, p < 0.05) than when it is higher (β = -0.045, p > 0.1).

[INSERT FIGURE 4 ABOUT HERE]

5 Conclusion and discussion

5.1 Conclusion

From the lens of information processing theory, this study investigates how information integration and organisational integration impact product- and service-oriented MCC differently, and the moderating role of characteristics of customer need. Specifically, the empirical results show that both information and operational integration can work as information processing tools to benefit manufacturers' MCC. Our survey data shows that 9.4% of respondents had both high levels of product and service customisation. Thus, MC exists in both product- and service-related fields because of the inseparability between a product and its related services, which is also confirmed by our empirical findings. Lastly, in terms of customer need characteristics, the results suggest that customer need tacitness

negatively moderates the impacts of operational integration on the product- and service-oriented MCC. Moreover, customer need diversity negatively moderates the impact of operational integration on service-oriented MCC.

5.2 Theoretical implications

This study makes significant contributions to both the MCC and SCI literature. First, this study introduces a new theoretical lens by examining MCC from an information-processing perspective. Taking the IPT, we re-conceptualised MCC as information processing tasks and revealed that both product- and service-oriented MCC are positively influenced by the focal firm's information and operational integration, two necessary information processing tools, while the effects are distinct. To produce products in high variety and small batches, information about new product designs, prototypes, and manufacturing techniques must be shared quickly along the supply chain. More importantly and difficultly, rapid, accurate, and low-cost configurations in physical materials, production processes, production equipment, and personnel must be achieved to realise actual manufacturing. In contrast, since services are invisible and perishable, they possess high price elasticity and low customer loyalty. To attract customers, firms must innovate continuously and radically to create brand-new customised services for customers. In doing so, information about customers' changing needs, suppliers' capability updates, market trends, and technology breakthroughs are needed in a timely manner, while the need to allocate tangible assets and arrange operational procedures is relatively less. Consequently, product-oriented MCC is more significantly promoted by operational integration, whereas service-oriented MCC improvement is more prominent in information integration.

Second, to the best of our knowledge, the current study is the first to distinguish between product- and service-oriented MCC. Previous studies on the existence of product- and service-oriented MC have been controversial. Some scholars consider that MC should only exist in the product because of the intangible and inseparable nature of services (Kaplan and Haenlein, 2006). Others argue that product-oriented MC itself is a service, since the process of customisation is indeed a service (Silvestro and Lustrato, 2015). The basic assumption of these two views is that products and services are independent of each other. However, in today's market, products and services are intertwined. Products require marketing, after-sales, trial use, maintenance, and other-related services, while services require physical facilities and tangible goods to operate and deliver them. Thus, any form of MCC is likely to have both product- and service-related facets. Accordingly, it is both theoretically and practically rational to distinguish between product- and service-oriented MCC.

Third, our research provides alternative perspectives concerning the roles of the characteristics of customer needs, in terms of tacitness and diversity, on the effectiveness of integration in product- and service-oriented MCC (Lai et al., 2012). Previous studies have shown that firms can benefit from tacit customer needs as a positive factor that moderates the relationship between the customer as a data provider and new product performance (Zhang and Xiao, 2020). Their study suggests that organisations must involve customers more deeply in data analytics when customer needs are highly tacit. This argument is consistent with our study's positive direct effect of customer need tacitness on product-oriented MCC. Exploring customer need tacitness allows firms to generate creative ideas for product innovation. Customer need tacitness implies that customers' real needs are highly hidden, which makes

them difficult to capture and express. In the logic of information processing, customer need tacitness increases the difficulty and uncertainty and undermines the effectiveness of MCC's information processing task. As a result, the information-processing capability provided by the same amount of information and operational integration will no longer meet the requirement of MCC's information-processing needs.

Meanwhile, similar to previous research, our result shows that customer need diversity decreases the customer's impact as a data analyst on new product innovation. (e.g. De Luca and Atuahene-Gima, 2007; Zhang et al., 2015; Zhang and Xiao, 2020). However, the direct effects of customer need diversity on product- and service-oriented MCC were both positive in our study. On the one hand, as indicated by a previous study, increased diversity of customer needs implies a greater degree of external uncertainty and complexity, which makes it more possible that firms will further enhance operational integration with supply chain partners (Sheng et al., 2021b). With increased operational integration, the firm's product- and service-oriented MCC will also increase. On the other hand, increased diversity means that customers' needs differ significantly from each other. This means that the workload and uncertainty of information gathering, information-based resource allocation, and operational process configuration will largely increase. Thus, to provide better MC services, firms need more information on the specifications, details, and categories of services (Jean and Kim, 2020). From the perspective of IPT, with increased information process capacity, it would enhance product- and service-oriented MCC.

Except for the above significant moderation effects, most of the hypothesised moderation effects (i.e. H4Oa, H4Ob, H5Oa, H5Ob, and H5Ic) are not supported. We believe that while

customer need diversity and tacitness may make operational integration more difficult from the perspective of physical production and supply chain partner collaboration, they would not affect the effectiveness of information integration. IPT suggests that information integration could improve the information-processing capability of organisations and thus meet the increasing information-processing needs well. Lee et al. (2000) found that information integration can help firms effectively address the intensity and complexity of customer needs. Thus, diversity and tacitness may simply make it more difficult to collect data on customer needs, but they do not affect the reinforcing effect on MCC t is generated after information collection and processing. Furthermore, customer need diversity and tacitness are likely to increase the need for information integration and thus indirectly enhance product- and service-oriented MCC, rather than exhibiting a moderating effect. This finding is similar to our empirical results.

5.3 Managerial implications

For positive relationships between information and operational integration with MCC, managers should rethink MCC from an information-processing task perspective. Diverse abilities to increase information processing capabilities are associated with different MCCs. For service-oriented MCC, timely and accurate information is more critical. Abilities to facilitate the timely and accurate transfer of market demands, technology breakthroughs, and secret know-hows benefit service-oriented MCC more. For product-oriented MCC, information-based resource allocation and configuration are more critical. The ability to coordinate various operational processes in analysis, design, development, and deployment contributes more to product-oriented MCC. These inspire managers that, in today's

commercial environment, digital transformation and the application of digital information technology have become development trends in many industries. For firms that engage in MC production, digital transformation should be carried out to improve their ability of information acquisition, processing, and application so as to offer better customised products and services and gain continuous competitive advantage.

It is also notable that firms should be aware that the positive effects of both information and operational integration become insignificant when customer needs and customer need diversity interact. Managers should note that they must reduce *tacit customer needs and customer need diversity to allow* information and operational integration, so as *to facilitate mass customisation. W*e suggest that managers establish a measuring system to quantify different degrees of *tacit customer needs and customer need diversity.*

Managers can also learn from the results for the different effects of information integration and operational integration on product- and service-oriented MCC. Information on customer needs and organisational resources should be allocated and implemented according to the domain of firms' MCC. In pursuing either product-oriented or service-oriented MCC, when information processing capabilities are sufficient and available, firms can foster integration in both information and operations, particularly when market competition is expected to be fierce or they need to make full use of resources. However, in the presence of the current fierce market competition and slower economic growth, most firms do not have the ability to provide abundant resources for information processing. In the case of information-processing capability constraints, more integration in operational processes is more beneficial for

product-related MCC. For service-related areas, firms need to fully exploit MCC's potential and place their central focus on cultivating information integration.

Finally, in practice, managers must be aware of the impact of customer need tacitness and diversity. Although not all the negative moderation effects are significant, customer need tacitness and diversity do hinder the exertion of integration effectiveness. In this case, we suggest that besides enhancing information integration with upstream and downstream supply chains to ensure that focal firms can obtain timely and accurate information, firms should also focus on CRM. CRM is a traditional but very effective technique to maintain constant contact with customers and obtain real customer experience and customer needs information. This will decrease the difficulty of information processing in the presence of customer need tacitness and diversity.

5.4 Limitations and future research

It is worth noting some limitations of our study. First, although we propose a coexistence of product- and service-oriented MCC, the empirical verification of the conceptual model is based on data collected from manufacturers in the context of China. Further studies should be conducted to revalidate our findings in service sectors and other contexts. Second, we employed well-established and widely used scales to measure SCI and customer need characteristics, which are largely determined by managers' experiences. Although CMB has been assessed as unlikely an issue, future research can explore how SCI affects MCC over time using a longitudinal approach. Third, two types of SCI (i.e. information integration and operational integration) were included in our study as antecedents for MCC. However, the dynamics between the two types of SCI remain unknown. Information integration likely

affects operational integration, or vice versa. An investigation into these dynamics may generate a more comprehensive understanding of SCI's type and effectiveness in MCC. Fourth, we used a well-established scale to measure the subjective experience of customer need for diversity. Although this subjective measurement is widely used, which could not completely avoid potential CMB, we hope future research could create a more objective measurement and provide more robust evidence for our findings. Finally, although we provide some possible explanations for the unsupported hypotheses, future research is encouraged to explore why the expected impacts do not occur.