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Mass Customization: The Role of Consumer Preference Measurement, Manufacturing Flexibility, and Customer Participation

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Mass Customization: The Role of Consumer Preference Measurement, Manufacturing Flexibility, and Customer Participation

Abstract

Purpose – Existing empirical studies emphasize the role of customer preference measurement accuracy (CPMA) on customized product quality while neglecting the role of manufacturing flexibility. However, the rise of web-based technology has highlighted consumer-manufacturer interaction in mass customization (MC). This paper explores the relationships between CPMA, manufacturing flexibility, customer participation and customized product quality, inspired by module decomposition and integration theory.

Design/methodology/approach – The study carried out a questionnaire survey of 241 directors who are specifically responsible for MC in the apparel industry in China, and tested hypotheses with structural equation modeling (SEM).

Findings – CPMA has a direct positive influence on customized product quality, and an indirect positive effect through manufacturing flexibility. Also, customer participation after placing an order (CPAPO) has a negative moderating effect on the linkage between CPMA and manufacturing flexibility.

Originality/value – First, the essential but unexplored mediating role of manufacturing flexibility is identified, adding knowledge to the consumer-manufacturer interaction literature in MC production. Second, module decomposition and integration are applied to unify consumers and manufacturers into one empirical model, enriched theoretical research on modular theory. Third, this study opens new discussions on the moderating role of customer participation.

Practical implications – Manufacturing flexibility should be improved along with CPMA in MC. Also, disruptions caused by customer participation in the post-design stage should be

noticed. In this context, better consumer service in the early-design stage may be one possible solution.

Key word Mass Customization (MC); Consumer Preference Measurement Accuracy (CPMA); Manufacturing Flexibility; Customized Product Quality; Customer Participation; Modularity

Introduction

Mass customization (MC) is a manufacturing paradigm which combines scale production and customization to produce personalized products at low cost (Pine and Gilmore, 1997; Baranauskas *et al*., 2020). It is considered an important driver of competitive advantages (Salvador *et al*., 2009) and a wide spectrum of related studies have been proposed. However, MC has evolved greatly as new digital technologies, such as web-based configurators, were introduced, and give rise to a full range of new questions (Ceylan *et al*., 2018; Baranauskas *et al*., 2020). One of these issues involves consumer-manufacturer interaction, during which consumers can be integrated into activities of product specification and co-design (Fogliatto *et al*., 2012; Jost and Süsser, 2020). It is found that application of web configuration software has ratcheted up MC, from partial MC production to order-driven and real-time MC production (Fogliatto *et al.*, 2012; Wu *et al.*, 2016), making interactions between consumers and producers timely and feasible (Qi *et al*., 2020). Recently, there have been some articles discussing consumer-manufacturer interaction in MC through theoretical analyses (Jost and Süsser, 2020; Zhang et al., 2020). However, to the best of our knowledge, there is a lack of empirical studies pertaining to relationships between consumers and manufacturers.

From the perspective of consumer-manufacturer interaction, two factors were identified for quality improvement in prior research. Firstly, customer need is emphasized in MC (Huang et al., 2018), and companies need to accurately identify consumer preferences before production by consumer preference measurement (Zipkin,2001). Thus, consumer preference measurement accuracy (CPMA) is critical for MC (Petiot and Dagher, 2010). CPMA refers to the closeness of delivered product's features to consumer's preference system (Ghosh *et al.* 2006; Franke *et al.,* 2009). As to the benefits of CPMA, it is found to be positively related with the customized product quality that consumers can perceive (Jahanshahi *et al*., 2011; Wang, 2013), can maximize their utility (Kramer, 2007), and thereby improve consumer satisfaction (Liang *et al*., 2006). Secondly, for the need to have large-scale supply capacity, manufacturing flexibility is also essential for MC to adapt to unstable conditions created by complex consumer preferences (Ariadi *et al*., 2020). Manufacturing flexibility is characterized by quick response to consumer demand (Nawanir *et al*., 2020). Existing studies indicated that manufacturing flexibility is the key factor to ensure quality stability and efficiency in MC (Nabass and Abdallah, 2019; Pinheiro *et al*., 2020). Thus, the influences of CPMA and manufacturing flexibility on product quality should be both taken into consideration while exploring consumer-manufacturer interaction based MC (Petiot and Dagher, 2010; Qi *et al*., 2020).

This paper uses modular theory to integrate the relationship among CPMA, manufacturing flexibility and customized product quality. Modularization can be divided into two processes of decomposition and integration (Aoki, 2002). In the decomposition process, products will be decomposed into modules according to product functions and features for consumer to specify their demand (Baldwin and Clark, 2000). This can make consumer preferences measurement options become more clear and transparent, helping to improve CPMA (Kramer, 2007). In the module integration process, consumer preference data will be transmitted to the equipment of each module in the manufacturing plant through the company's database (Zhang *et al*., 2020). Manufacturing flexibility is needed to adjust production line and integrates modules into a complete product (Ariadi *et al*., 2020). Based on module decomposition and integration theory, the mediating role of manufacturing flexibility (integration) in the relationship between CPMA (decomposition) and customized product quality is studied in this research.

In addition, to better reflect consumer-manufacturer interaction, this research involves customer participation as a moderator in the relationship between CPMA and manufacturing flexibility. Customer participation refers to the extent to which customers engage in MC production processes (Hunt *et al*., 2013; Feng *et al*., 2014). Considering the different effects of customer participation at different stages (Fan and Du, 2012), this paper further divides it into participation before placing an order and participation after placing an order, and examines different moderating effects. The proposed model is assessed using large-scale empirical data from 241 MC managers in the apparel industry in China.

Literature review and research hypotheses

This study adopts the theory of module decomposition and integration to explain the relationship between CPMA, manufacturing flexibility and customized product quality. The theory of module decomposition and integration is extended from modular theory (Aoki, 2002), which is widely studied in MC (Da Silveira *et al*., 2001; Ezzat *et al*., 2019). The essential idea of modular theory is that complex processes like MC (Modrak *et al*., 2017) can be divided into simple problems under the rules of modularization (Baldwin and Clark, 2000). Therefore, modularity can be used to solve the contradiction between low-cost and multi-variety in MC (Duray, 2002; Salonen *et al*., 2018). Based on module decomposition and integration theory, relationships between CPMA, manufacturing flexibility, customized product quality and customer participation are discussed below.

Consumer preference measurement accuracy and customized products' quality

In the MC scenario, consumer preference measurement is demand-driven and aims to help people state their personal preference (Ghosh *et al*.,2006; Franke *et al*., 2009). Specifically, companies decompose their product under modular rules and provide a variety of combinations of preference options through configuration software (Kim and Stoel, 2004; Kristjansdottir *et al*., 2018). Based on MC measurement method, CPMA refers to the closeness of delivered product's features to consumer's preference system (Ghosh *et al*. 2006; Franke *et al.,* 2009). Meanwhile, customized product quality refers to consumers' evaluation of their customized products on functionality, usability or design after they receive the final product (Wang, 2013).

Prior research explored the relationship between CPMA and customized product quality. Researchers pointed out that increasing CPMA can deliver more value to consumers (Franke *et al*., 2010). It is found that with higher CPMA, consumers will perceive more product utility (Dellaert and Stremersch, 2005), along with uniqueness and self-expressiveness benefits (Sandrin *et al*., 2017). They will be more pleased and consider that the product is of acceptable or even high quality with higher CPMA (Jahanshahi *et al*., 2011). Also, accurate customer preference data can help companies improve the quality of their products (Brombacher *et al*., 2010) by reducing development costs, therefore leading to successful products (Hauser *et al*., 2014). Based on the above arguments, we hypothesize the following:

H1. CPMA has a significant positive effect on customized product quality.

Mediating effect of manufacturing flexibility

Manufacturing flexibility refers to the capability of a manufacturing system to adapt to external and internal changes, yet continues to produce a variety of products and volumes without compromising performance (Holtewert and Bauernhansl, 2016). Manufacturing flexibility is believed to be critical in MC (Nawanir *et al*., 2020). Based on modular theory, manufacturing flexibility is characterized by the ability to adapt to small-batch and multi-variety customized production through modules integration (Wu *et al*., 2019).

Drawing from modular theory, this research proposes that manufacturing flexibility is positively affected by CPMA. Under clear preference measurement decomposition rules, higher CPMA means modular decomposition of products is more diverse (Kramer, 2007; Dellaert and Stremersch, 2005). This raises the requirements to increase manufacturers' flexibility (Nawanir *et al*., 2020) so that they can reorganize resources to satisfy changing customer needs (Leite and Braz, 2016). Research showed that modular design increases the flexibility of the manufacturing system (Wu *et al*., 2019). Also, from a knowledge-based view, with more decomposed modules, more explicit knowledge will be transferred between modules and tacit knowledge which is hidden in each module will be less (Aoki, 2002). Tacit knowledge is vague; but explicit knowledge can be quickly perceived and applied (Venkitachalam and Busch, 2012). It will be easier for companies to fully understand consumer preference and integrate modules into a complete product (Wang *et al.*, 2013; Qi *et al.*, 2020), increasing the flexibility of manufacturers' production lines. Thus, we hypothesize the effect of CPMA on manufacturing flexibility as follows:

H2. CPMA has a significant positive impact on manufacturing flexibility.

This research also proposes that manufacturing flexibility has a positive effect on customized product quality. This is because companies with manufacturing flexibility can adapt to small-batch and multi-variety customized production (Wu *et al*., 2019), thus can produce reliable and high-quality products (Nawanir *et al*., 2020). Also, with high manufacturing flexibility, each module has high independence and adjustability. Once a module failure occurs in production, it can be repaired and solved by means of replacement, removal or isolation in real time, without affecting other parallel modules' operations (Baldwin and Clark, 2000). This allows flexible production lines to reduce the company's possibility of making mistakes and reduce the cost of rework due to production errors (Wiengarten *et al*, 2017), contributing to improvement of customized product quality (Ullah and Narain, 2020). Thus, we propose that:

H3. Manufacturing flexibility has a significant positive impact on customized product quality.

Also, manufacturing flexibility is an ability which can absorb knowledge from preference measurement and then creates an additional indirect and positive impact on business performance (Pinheiro *et al*., 2020). This means customized product quality partly comes from accurate measurement of consumer preference, satisfying consumers' personalized needs, while also needing flexible manufacturing to ensure the stability of product quality. Combining the above argument for the relationship between CPMA and manufacturing flexibility, and the relationship between manufacturing flexibility and customized product quality, we propose that:

H4. Manufacturing flexibility plays a mediating role between CPMA and customized product quality.

Moderating effect of customer participation

Customer participation refers to the extent to which customers engaged in MC production processes (Hunt *et al*., 2013; Feng *et al*., 2014). To customize their desired products, customers propose their requirements by selecting module options and communicating with company service staff. Customers with a high level of participation will respond more positively during MC production (Ceylan *et al.,* 2018). Considering that customer participation at different stages may display different effects (Fan and Du, 2012), this paper divides it into participation before placing an order (CPBPO) and participation after placing an order (CPAPO), referring to Yan *et al*.'s (2020) classification of early-design stage and post-design stage.

External condition changes will affect company's MC production strategies, that is, the relationship between product configuration software design and production integration (Zhang *et al.*, 2020). Before placing an order, problems often arise such as insufficient consumer experience and unfamiliarity with the use of product configuration software (Hauser *et al*, 2014). A high level of CPBPO can help the company obtain more information about customers

(Atakan *et al*., 2014) and improve production adjustments based on this information (Yang and Zhang, 2018). After placing an order, customer participation often means requirements for demand changes, such as design modifications of important personalized parts or order changes, etc. (Yan *et al*., 2020). Companies accepting consumers' requests at this stage will have to implement major revisions and thus incur higher processing costs (Xiao *et al*., 2005). Therefore, CPAPO has caused actual interference to the production process, and has a negative moderating effect. Hence,

H5. Customer participation in different stages moderates the linkage between CPMA and manufacturing flexibility in different ways, such that (a) CPBPO has a positive moderating effect and (b) CPAPO has a negative moderating effect.

In summary, this paper builds a theoretical model shown in Figure 1.

—— Insert Figure 1 here——

Research methodology and data collection

Sampling

A structured questionnaire survey was conducted. The samples were clothing companies engaged in MC business in China. The respondents were heads of these companies, including the managers of customized factories, sales managers, and heads of customized stores who were able to answer questions on behalf of their companies. The apparel industry was chosen for data availability and accuracy. Due to the early and extensive development of MC in the apparel industry, data is easier to collect (Yao and Xu, 2018). Also, consumers are clear and familiar with the preference options in the apparel industry, which helps to avoid the ambiguity problem and reduce the bias (Kramer, 2007).

We partnered with two professional MC companies in the apparel industry. They offered help in introducing our research team to the apparel industry communication platform which includes most of the MC companies with their main persons in charge in China's clothing market. After these managers were contacted, this research distributed and collected electronic questionnaires by "Questionnaire Star", which is widely used for questionnaire surveys in China.

Data collection procedures

The questionnaire in this study came from mature scale tables and was combined with actual business scenarios. A pre-survey was conducted to ensure the question items are stated clearly and are understandable. A total of 101 respondents were randomly chosen and were asked to give feedback about the questionnaire. One problem appeared which dealt with the misunderstanding of manufacturing flexibility measurement scales. Based on the pre-survey results and discussions with three apparel experts, we refined the measurement scales and then formed the final questionnaire.

In the formal research, two screening processes were used to control the quality of the survey. First, the questionnaire was set to disallow private forwarding links so that only the contacted respondents by the research team could answer the questionnaire. Second, the research team double checked the background of the respondents using open information on the platform to confirm the respondents were qualified and questionnaire answers were effective. The entire survey period lasted for one month, and 303 questionnaires were collected during the formal research. After verification, 79.53% of them were confirmed effective, resulting in a usable sample of 241questionnaires. Table 1 represents the sample profile. The main reasons for invalid questionnaires were as follows: all the questionnaires were filled in "totally agree", or the answers were arranged very regularly but didn't make sense, or the researcher's verification of background information showed that the respondent is not in the clothing customization industry, etc.

—Insert Table 1 here —

Measures

A seven-point Likert-type scale ranging from totally disagree (1) to totally agree (7) has been used to measure the items of the questionnaire (Appendix). In particular, there are 6 measurement items for CPMA (Dellaert and Stremersch, 2005; Ghosh *et al*., 2006). Since the way to measure consumer preference is set by companies, we refer to "extent of MC" and "level of heterogeneity" from Dellaert and Stremersch (2005) and "closeness" from Ghosh *et al*. (2006). Manufacturing flexibility is measured through 9 measurement items, mainly based on the literature of Miller and Roth (1994), Chen *et al.* (2013), including the degree of flexibility and response to manufacturing plants, as well as the degree of optimizing production processes. There are 5 measurement items for customized product quality adapted from Nielsen and Brunoe (2014). Finally, CPBPO and CPAPO are measured based on the scale of Fang *et al.*, (2008) and a total of 7 measurement items are formed.

Common Method Variance (CMV)

Procedural and statistical remedial methods were adopted to deal with CMV due to the self-reported measures used in this study (Podsakoff *et al*., 2012; Kock *et al*., 2021). Procedurally, the design of the questionnaire was amended after receiving feedback from pre-survey and revised after discussing with three industry experts for clarity and reliability. Also, respondents were informed that the survey would remain anonymous and confidential (Podsakoff *et al*., 2012). Statistically, Harman's single-factor test was employed. The first factor explained 45.64%, which was below the threshold level of 50% (Chumg *et al*., 2016). In addition, we added a common method factor into the measurement model to perform confirmatory factor analysis (CFA) (Podsakoff *et al*., 2003; Flynn *et al*., 2010). The outcome suggested that CMV only accounted for 31.3% of the covariance among the measures (Lindell and Whitney, 2001), and marginal improvement in the model fit indices was rather small (RMSEA by 0.01, CFI by 0.01 and NFI by 0.01), thus indicating that our survey was not affected by CMV (Podsakoff *et al*., 2003).

Reliability and Validity

Firstly, Cronbach's α coefficient was used to test the reliability of the measurement. Results showed that Cronbach's α coefficient of the five variables in the formal survey questionnaire, i.e., CPMA, CPBPO, CPAPO, manufacturing flexibility and customized product quality, were 0.911, 0.83, 0.876, 0.937 and 0.883, all of which reached acceptable levels (Hair *et al*., 2014). Secondly, the Kaiser-Meyer Olkin (KMO) value was 0.928, significantly higher than the threshold of 0.70, and the *p*-value of the Barlette's sphere test was equal to 0.000, meaning the questionnaire data was suited for factor analysis (Williams *et al*., 2010). Therefore, we used exploratory factor analysis (EFA) for structural validity analysis, and the software automatically identified five factors, corresponding with the five variables which were expected by this research. Thirdly, this study tested the convergent validity and discriminative validity by performing confirmatory factor analysis (CFA). The results of convergent validity showed that the Average Variance Extracted (AVE) values were all greater than 0.5, and the Composite Reliability (CR) values were all higher than 0.7 (Fornell and Larcker, 1981). The discriminative validity results (Table 2) also showed that the square root of AVE of each factor was greater than the inter-construct squared correlation (Fornell and Larcker, 1981), indicating that the discriminability of the variables was very good.

—Insert Table 2 here —

Data analysis and findings

Structural model results

Structural Equation Modeling (SEM) was conducted for data analysis using IBM SPSS AMOS Graph version 24. Table 3 obtains the regression coefficients of the empirical model. Test results show that CPMA has a direct positive effect on customized product quality (β = 0.393, $p < 0.001$), providing support for H1. Also, CPMA has a significant positive effect on manufacturing flexibility (β= 0.65, $p < 0.001$), in support of H2. In addition, it is found that manufacturing flexibility is positively associated with customized product quality (β = 0.473, $p < 0.001$). Hence H3 is supported. The model fit indices result as follows: χ^2/df =1.92 <3, RMSEA=0.063 < 0.08, CFI=0.958 > 0.9, NFI=0.918 > 0.9, RFI=0.903 > 0.9, IFI=0.958 > 0.9, TLI=0.95 > 0.9, etc. These results demonstrate a highly appropriate model fit and fulfilled the criteria proposed by Hair *et al*. (2010).

—— Insert Table 3 here——

Tests of mediating effects

This paper used the Process program proposed by Hayes and Scharkow (2013) to conduct Bootstrap analysis and bias-corrected 95% confidence intervals were examined for evidence of mediation. Results show that the lower and upper limits of the 95% confidence interval of the mediation effect are 0.206 and 0.393, and the interval does not contain 0 (Table 4), indicating the mediation effect is significant. From a numerical point of view, the total effect of CPMA on the customized product quality is 0.541, of which the direct effect is 0.275, and the indirect effect after mediation by manufacturing flexibility is 0.266. This implies that part of the effects of CPMA on customized product quality are indirectly affected by manufacturing flexibility. Thus, H4 is supported.

—— Insert Table 4 here ——

Tests of moderating effects

The moderated mediation model developed by Andrew F. Hayes (Hayes, 2013) was used to explore the moderating effect. Two moderators were added in the SEM model and the results were shown in Table 5. Results of Model 2 show that the cross-term coefficient of CPMA and CPBPO is significantly negative (β = -0.095, $p < 0.05$). This does not support H5a and the reason will be explored in the discussion. While the results of Model 3 show that the cross-term coefficient between CPMA and CPAPO is -0.1(β = -0.1, $p < 0.05$), indicating that CPAPO negatively affects the linkage between CPMA and manufacturing flexibility. Hence H5b is supported.

——Insert Table 5 here ——

Additional tests

To further test moderation effect, the bootstrap method (Hayes, 2013) was used to test the mediating effect at different levels of the moderating variable (less than one standard deviation, average value, and above one standard deviation). The results obtained are noted in Table 6.

Tests show that before the order is placed, the 95% confidence intervals were [0.152, 0.332], [0.120, 0.247] and [0.054, 0.200] when CPBPO were at low, average and high levels respectively, indicating that when CPBPO increases, the mediation effect tends to weaken. The results confirm that mediation effect of manufacturing flexibility exists significantly and moderation effect of CPBPO was significantly negative, which does not support H5a.

Likewise, after the order is placed, the 95% confidence intervals were [0.168, 0.377], [0.135, 0.273] and [0.070, 0.213] when CPAPO were at low, average and high levels respectively. Therefore, the mediation effect of MF exists significantly and moderation effect of CPAPO was significantly negative. As CPAPO increases, the mediation effect tends to weaken, thus confirming that H5b is supported.

—— Insert Table 6 here ——

Discussion

This research constructed a theoretical model of CPMA on customized product quality, mediated by manufacturing flexibility and moderated by customer participation, and then carried out a questionnaire survey on MC managers. Empirical data from 241 managers and SEM model were used to verify the theoretical framework. Results of the study revealed several interesting findings.

First, CPMA and manufacturing flexibility are positively related to customized product quality separately, implying both CPMA and manufacturing flexibility are important factors for customized product quality. This is consistent with previous research. CPMA can help to improve customized product quality (Brombacher et al., 2011; Jahanshahi et al., 2011) and manufacturing flexibility is one of the critical requirements to uphold high volume and consistent quality in MC (Ariadi et al., 2020; Nawanir *et al*., 2020).

Second, the mediating role of manufacturing flexibility is identified. The empirical results confirmed that CPMA is positively related to manufacturing flexibility. This means when companies decompose a product into modules to obtain CPMA, the manufacturing flexibility of the production process will change accordingly. Also, results show that manufacturing flexibility mediates between CPMA and customized product quality, meaning CPMA not only has a direct influence on customized product quality, but also has an indirect effect on customized product quality through the mediation of manufacturing flexibility. This explains the phenomenon that although some companies can better understand customer needs, they still cannot improve the final product quality due to manufacturing capability limitations. Special attention should be paid to the mediating role of manufacturing flexibility.

Third, customer participation moderates the linkage between CPMA and manufacturing flexibility. In particular, CPAPO has a significant negative moderating effect due to the disturbance on the existing production line caused by customers' modification requirements after an order is placed. This confirms the negative effect of post-order customer participation on MC. The more module options, the greater the disturbance. Meanwhile, CPBPO has a negative but insignificant moderating effect, which is supposed to be positive in H5a. The reason may be the characteristics of the apparel industry. As the descriptive results show, the average education level of customer service staff is not high. This may decrease the effectiveness of customer participation, failing to avoid uncontrollable factors in production and inability to improve interactions between customers and factories as postulated by H5a. Our explanation can be supported by former research. It has been found that human resources are a crucial ingredient (Kakati, 2002). Company's effective personnel management could reduce coordination costs (Cai *et al.*, 2017) and help the organization in managing the problems which occurred in a high-variety mix of products (James and Mondal, 2019; Ullah and Narain, 2020).

Theoretical contributions

First, this research fills an important gap in MC literature, especially the consumer-manufacturer interaction literature (Fogliatto *et al.*, 2012; Ullah and Narain, 2018). Previous studies have shown that both CPMA and manufacturing flexibility have important effects on MC product quality, however few studies have combined the two in a theoretical model (Liu *et al.*, 2018; Petiot and Dagher, 2010; Qi *et al.*, 2020). This paper investigated the underlying mechanism of CPMA on customized product quality, and discovers the significant relationships between CPMA and manufacturing flexibility. The direct effect of CPMA on customized product quality is consistent with prior research (Franke *et al.*, 2010), but we also found the indirect effect achieved through the improvement of manufacturing flexibility.

Second, this study enriched theoretical research on modular theory. Modular theory is widely applied in MC (Ezzat *et al.*, 2019; Liu *et al.*, 2019), but we dig deeper into module decomposition and integration (Aoki, 2002) to empirically investigate the interactions in MC. Earlier empirical literature was conducted from consumer perspective and manufacturer perspective separately due of their differing research objects and research basis. CPMA is studied by issuing questionnaires to consumers while manufacturing flexibility is used by surveying the corporate milieu's perspective (Hauser et al., 2014; Zhang *et al.*,2019). This paper finds that module decomposition and integration theory can be used to unify these two perspectives into one empirical model, and this can be construed as a new method in dealing with consumer-manufacturer relationship problems in future research.

Last, this study found the negative moderating effect of customer participation on the effect of CPMA to manufacturing flexibility after the customization order is placed, responding to the calls on consumer participation research to gain a deeper understanding of how customers react to customization (Mustak et al., 2016; Ceylan et al., 2018).

Managerial implications

This research offers some seasonable managerial suggestions. First, companies need to attribute more value to the role of manufacturing flexibility. The trend of digitalization is driving partial-MC into real-time MC, making the interaction between consumers and manufacturers more important. When companies try to adjust the consumer measurement method for higher quality products, they must realize that the manufacturing flexibility of the production line should also be improved accordingly, so that manufacturing flexibility can better play its intermediary role in quality improvement. Coordination ability between marketing and manufacturing should be enhanced. Advanced digital technologies like 5G, big data, smart manufacturing technology, etc. can be applied to help companies achieve better consumer-manufacturer interaction.

Second, CPAPO is found to have a negative moderating effect on consumer-manufacturing interaction, implying that companies need to properly handle the inevitable interference to the production line caused by post-order customer participation. One possible solution is that companies can improve their customer service to obtain more information before production to avoid post-order adjustments. Research found that consumer preference can be easily observed by experienced salesmen (Alavi *et al.*, 2016), which can improve companies' MC service ability (Yang and Zhang, 2018). Also, technologies such as AI customer service can be used as supplements to MC service, helping companies strengthen communication with customers in the order generation stage at a reasonable cost, thereby reducing production disruptions caused by modifications in the post-order stage.

Moreover, this research also has broad and important contributions to society. Our research focuses on quality improvement in MC products and explores the role CPMA, manufacturing flexibility and consumer participation. These findings on the one hand, can serve as references for companies' adjustment of production in their digital transformation. If the successful experience is widely implemented, it can alleviate the quality decline problem encountered by traditional industries in the MC transformation, helping traditional industries achieve sustainable development and efficiency improvement. On the other hand, consumers can derive benefits from MC production improvement, not only through their diverse needs being satisfied, but also through quality improvement of their customized products, thereby improving consumer welfare in society.

Limitations and future research

This research has some limitations which can be addressed in further research. First, the research is mainly conducted from a static perspective. However, in real business, there are certain dynamic adjustments and mutual adaptations between the consumer preference measurement process and the manufacturing process, which makes the mechanism more complex. Follow-up research can explore this issue more comprehensively from a dynamic perspective. Second, questionnaires are answered by companies' managers, which will lead to relatively higher customized product quality due to the company's self-reporting bias. This is limited by the survey objectives and survey cost. If customized product quality can be measured from the perspective of consumers, more accurate conclusions can be drawn. Third, other MC industries (Calegari *et al*., 2018; Kanama, 2018) are also experiencing new development with ICT technology. Future research can explore whether the findings apply in other industries in other countries.

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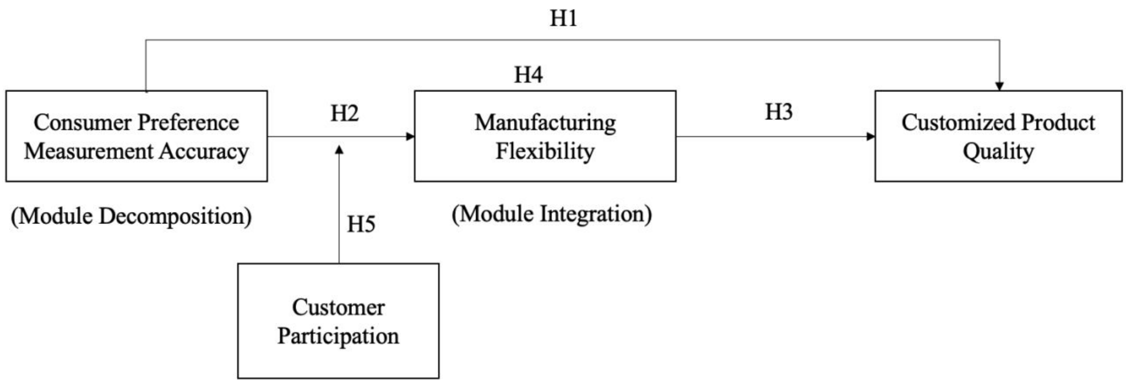

Figure 1 : Theoretical model of this research

Table 1: Respondents and their working companies' characteristics

Demographics	No. of participants	% of participants
Gender		
Male	114	47.30
Female	127	52.70
Education level		
University or graduate	63	26.64
Some college	82	34.02
High school or less	96	39.83
age		
19 -25	33	13.69
26-35	122	50.62
36-45	71	29.46
45 or above	15	6.22
Company age		
0-10 years	135	56.02
11-20 years	88	36.51
Above 21 years	18	7.47
Company size		
1- 50 people	102	42.32
51 – 500 people	87	36.10
Above 501 people	52	21.58
Company annual revenue		
0 - 10 million	130	53.94
10 – 100 million (excluding 10 million)	60	24.90
100 – 200 million (excluding 100 million)	33	13.69
Above 200 million	18	7.47

Table 2：Discriminative validity：Pearson correlation coefficient and square root of AVE

	Mean	SD	CPMA	CPBPO	CPAPO	MF	CPQ
Consumer preference measurement accuracy (CPMA)	5.29	1.206	0.793				
Customer participation before placing an order (CPBPO)	5.09	1.376	0.52***	0.789			
Customer participation after placing an order (CPAPO)	4.62	1.498	0.367***	0.577***	0.818		
Manufacturing flexibility (MF)	5.69	1.094	0.607***	0.524***	0.452***	0.792	
Customized product quality (CPQ)	5.71	1.061	0.615	0.508***	0.397***	0.688***	0.779

Notes: The square root of AVE is on the diagonal of the table, while the off-diagonals represents the correlations; * p<0.05, ** p<0.01, *** p<0.001

Table 3：Structural equation model regression results

X-> Y	Non-standard coefficient	*z*	SE	*p*	Standard coefficient
CPMA -> CPQ	0.307	5.361	0.057	***	0.393
CPMA -> MF	0.575	8.744	0.066	***	0.650
MF -> CPQ	0.418	6.046	0.069	***	0.473

Notes: * $p<0.05$, ** $p<0.01$, *** $p<0.001$;
CPMA: consumer preference measurement accuracy, CPBPO: customer participation before placing an order, CPAPO: customer participation after placing an order, MF: manufacturing flexibility, CPQ: customized product quality

Table 4：Bootstrap analysis results of mediation effect

			95%CI	
	Effect	**SE**	**LLCI**	**ULCI**
Total effect	0.541		0.355	0.793
Direct effect	0.275	0.064	0.149	0.400
Indirect effect	0.266	0.047	0.206	0.393

Notes: LLCI refers to the lower limit of the estimated 95% interval，ULCI refers to the upper limit of the estimated 95% interval

Table 5：Test results of two moderating effects of H5a and H5b

	Mode 1	Model 2	Model 3
	CPQ	**MF**	**MF**
constants	1.510***	0.220	0.188
	-4.303	-0.217	-0.203
CPMA	0.275***	0.855***	0.882***
	-4.293	-4.262	-5.459
CPBPO		0.704***	
		-3.263	
CPAPO			0.725***
			-3.368
CPMA*CPBPO		-0.095**	
		(-2.431)	
CPMA*CPAPO			-0.100***
			(-2.797)
MF	0.483***		
	-6.663		
Obs	241	241	241
R^2	0.535	0.461	0.470
Adjusted R^2	0.529	0.452	0.461
***F* value**	F (2,238)=137.076, p=0.000	F (3,237)=67.540, p=0.000	F (3,237)=70.009, p=0.000

Notes: * $p<0.05$, ** $p<0.01$, *** $p<0.001$;

CPMA: consumer preference measurement accuracy, CPBPO: customer participation before placing an order, CPAPO: customer participation after placing an order, MF: manufacturing flexibility, CPQ: customized product quality

Table 6：Indirect effects of mediating variables

	Indirect effects	SE	95%LLCI	95%ULCI
Moderated variable a: CPBPO				
Low level（-1SD）：3.719	0.242	0.046	0.152	0.332
Average：5.095	0.179	0.032	0.12	0.247
High level（+1SD）：6.472	0.116	0.038	0.054	0.200
Moderated variable b: CPAPO				
Low level（-1SD）：3.119	0.275	0.053	0.168	0.377
Average：4.617	0.203	0.035	0.135	0.273
High level（+1SD）：6.115	0.130	0.037	0.070	0.213

Notes: CPBPO: customer participation before placing an order, CPAPO: customer participation after placing an order

Appendix：Scale items、Standardized loadings and Convergent validity

Constructs and measurement Items	Standardized loadings
Customer Preference Measurement Accuracy (CPMA)（Dellaert and Stremersch, 2005; Ghosh et al., 2006）（AVE:0.629, CR:0.91, Cronbach α:0.911）	
Our company provides many category options for suit customization	0.759
Our company provides many sub-options under each category option	0.770
The options provided by our company can accurately capture customer needs	0.859
The category options has high heterogeneity	0.682
The sub-options under categories options has high heterogeneity	0.741
Heterogeneity of options can basically accurately capture the needs of different customers	0.861
Manufacturing Flexibility (MF) (Miller and Roth, 1994; Chen et al., 2013)（AVE:0.623, CR:0.832, Cronbach α:0.83）	
When receiving unexpected customer requests, the factory can respond quickly	0.705
Normally, the factory can deliver on time	0.710
Normally, the production cycle of each suit in a factory is short	0.629
Normally, the factory's delivery rate is high	0.752
The factory will continue to adjust equipment to improve production efficiency	0.868
The factory will continue to optimize the content of each job to improve work efficiency	0.903
The factory will continue to optimize flow operations to eliminate work bottlenecks	0.857
The factory will continue to take measures to improve the ability to respond to abnormal production	0.834
The factory will develop some special tools to improve work efficiency	0.762
Customized Product Quality (CPQ) (Nielsen and Brunoe, 2014)（AVE:0.67, CR:0.886, Cronbach α:0.876）	
After customers purchase customized suits, they are satisfied with the first delivery and almost no need to modify	0.748
After customers purchase customized suits, the return and exchange requirements are very low	0.767
After customers buy customized suits, the complaint rate is very low	0.843
After customers purchase customized suits, there is a high percentage of repeat purchases	0.764
After customers buy customized suits, they will recommend your company to friends	0.775
Customer Participation Before an Order (CPBPO) (Fang, 2008)（AVE:0.627, CR:0.938, Cronbach α:0.937）	
When customers place an order, they frequently communication with our customer service staff	0.704
When customers place an order, they provide us with a lot of information related to their needs	0.720
When customers place an order, they spend a lot of time and energy in determining the details of customization	0.717
Customer Participation After an Order (CPAPO) (Fang, 2008)	

(AVE:0.607, CR:0.885, Cronbach α:0.883)	
After customers place an order, they will still actively contact our customer service staff for other needs	0.824
After customers place an order, they still frequently communicate with our customer service staff	0.873
Customers spend a lot of time and energy in the process of modifying the suit samples	0.835
Customers always give us feedbacks on fitting and modification in time after receiving the suit samples	0.628