

The effect of country level factors on the trade-off between cost and flexibility in mass customization

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Abstract

Insufficient attention has been paid to both the relationship between mass customization capability and operational performance and the contingency factors affecting this relationship. We propose a model that conceptualizes the relationship between mass customization capability, flexibility performance, and cost performance. The hypotheses are empirically tested using data collected from 5th round of GMRG and secondary data obtained from World Bank and UNIDO. The results show that mass customization capability positively impacts both flexibility performance and cost performance. In addition, national logistics performance and a country's risk level impact the relationship between mass customization capability and cost performance in different ways.

Keywords: Mass Customization Capability, Country Level Factors, Trade-off

Introduction

The added value provided by manufacturing continues to attract the attention of both academics (e.g., Kortmann et al., 2014) and practitioners (e.g., UNIDO, 2014). Investments to establish or improve manufacturing capabilities can be substantial. Hence, it is crucial to make the right choices. Mass customization capability (MCC) has become an important competitive factor to overcoming the trade-off between cost and flexibility for meeting customer needs in a cost-efficient manner (Zhang et al., 2014). A number of studies (e.g., Jin et al., 2014) have called for further studying the relationship between capabilities and performance in a manufacturing context. Additionally, recent studies (e.g., Wiengarten et al., 2013) have called for more empirical research into the influencing role of contextual factors on capabilities, and in turn on operational performance. Particularly, Sandrin et al. (2014) requests research on contingency factors that moderate the relationship between mass customization (MC) and relevant variables.

Following this call, we adopt a contingency lens and address the gaps described above.

We explore the impact of MCC on the trade-off between cost and flexibility performance and the influencing role of the two country level factors, Logistics Performance Index (LPI) and World Risk Index (WRI), on this relationship. In doing so, we assume that the match of organizational resources with the corresponding environmental context will lead to an improved performance, while believing that there is no universal set of choices that is optimal for all businesses (Sousa and Voss, 2008).

Accordingly, we posit the following research questions:

RQ1. Does MCC really overcome the trade-off between cost performance and flexibility performance?

RQ2. Do country's LPI and WRI moderate the relationship described in RQ1?

Literature review and research hypotheses

MCC definition and trade-off

Competitive performance in manufacturing is typically measured in relation to improvements in cost, quality, dependability and flexibility. Regardless the existence of trade-offs (Skinner, 1974) or synergies (Ferdows and De Meyer, 1990) between these performance measures, there is considerable agreement that investments in manufacturing practices lead to improved competitive performance (Caniato et al., 2013). Plants can achieve specific capability and performance gains by investing in specific manufacturing practices (Narasimhan et al., 2005). Squire et al. (2006) contributed to this debate by showing that customization can lead to significant decrease in other types of performance. To the best of our knowledge, there is no other empirical research that analyzes the impact of MC or MCC on competitive performance. As product life cycles shorten and competitive pressures intensify, MC, as an emerging paradigm, is turning out to be increasingly important (Huang et al., 2008). We use the definition of Tu et al. (2001) for MCC as the capability to provide high product variety and customization with operational performance level that are comparable to those of a mass producer, without considerable trade-offs in cost, quality, and delivery. Other similar definitions and descriptions of MC also occur in the literature. Pine (1993) argues that MC is where a customer can avail of flexibility, rapid delivery, good quality at a reasonable cost.

Impact of MCC on FP and CP

The relationship between competitive performance priorities and manufacturing capabilities is central to much of the conceptual work in manufacturing strategy (Ward et al., 1998). Nevertheless, there has been limited empirical testing of the relationship, particularly in the context of MCC. While the scholarly debate continues about how manufacturers address these priorities in order to build capabilities and which, if any, contingencies apply (Cleveland et al., 1989), there is some consensus that once firms have reached higher levels of capability, further improvement is only possible via significant investments in practices and major breakthroughs to proceed them to the next level (Schoenherr et al., 2012).

From the seminal works of Skinner (1969) to recent studies (Yeung et al., 2013), operational Cost Performance (CP) has been identified as one of the important competitive priorities. Better CP from lower manufacturing costs permits manufacturers to have higher margins and simultaneously be more price-responsive (Rosenzweig et al., 2003). Åhlström and Westbrook (1999) and Zhang et al. (2011), however, highlight increasing cost as one of the most important dangers for MC. Previous researches (Zhang et al., 2003) reported flexibility as an important competitive performance. Although the importance of flexible manufacturing practices has been vastly examined in the literature, the relation between flexibility as a competitive performance and product variety or MC

has been neglected (Oke, 2013). Adapting Upton's (1994) definition of flexibility, we regard flexibility as "the ability to change or react with little penalty in time, effort, cost or performance" of a manufacturing plant. We are investigating plant level flexibilities. Volume and variety dimensions of flexibility are known as Flexibility Performance (FP) (Zhang et al., 2003, Robb Dixon, 1992). According to Hill (2011), MC is a business model that uses a routine approach to efficiently create a high variety of products or services in response to customer-defined requirements. Da Silveria et al. (2001) suggest that increasing global competition and shorter product life cycles have led to an increased demand for MC. MCC is a construct with contradicting impact on costs: on the one hand, it is expensive because it takes "the best of the craft era"; on the other hand, it is affordable because it takes "the best of the production era" (Fralix, 2001). Squire et al. (2006) report that there are trade-offs between customization and manufacturing costs and delivery lead times. MC provides increased levels of product variety which in turn results in expensive changes in manufacturing and other processes. We argue that MCC underpin the ability to adapt to such changes cost effectively. To meet specific customer demands in a cost-efficient way, companies are exploring different paths to develop MCC. A number of potential solutions to the development of MCC, including changes in the manufacturing process and product design, have been proposed (e.g., Feitzinger and Lee, 1997). Accordingly, we posit the following hypotheses:

H1: MCC has a positive impact on cost performance.

H2: MCC has a positive impact on flexibility performance.

Developing a contingency perspective

There is a considerable body of empirical evidence to support the relationship between investing in best practices and company performance (Flynn et al., 1995). However, Sousa and Voss (2008) have cautioned against a "one size fits all" approach. They argue that there is considerable scope for developing operations management (OM) theory through adopting a contingency perspective. Taking a contingency perspective in this work, the match of business context with the relationship between both MCC and CP and MCC and FP is examined. In addition, we follow the call of recent studies (e.g., Lo et al., 2013) demanding for additional empirical research into the influencing role of contextual factors on capabilities, and in turn on operational performance. Huang et al. (2008) and Sandrin et al. (2014), in particular, claim that there is a need for research on contingency factors that moderate the relationship between MC and relevant variables for MC. We specifically address this gap by investigating the possible moderating role of the two country level factors, namely LPI and WRI.

Moderating effect of LPI on the relationship between MCC and CP and FP

Logistical capability is typically defined in terms of managing flows of information and materials (Stank et al., 2005); it includes but it is not limited to warehousing, transportation, cross-docking, electronic information sharing, and supply chain visibility. Arvis et al. (2010) define the macro-level national logistical capabilities as the breadth and quality of logistics services and infrastructure available to plants located in that country. Wiengarten et al. (2013) expand this definition to include infrastructure elements as cost and quality of physical transportation infrastructure (such as ports, roads, and airports), and supportive customs (such as encouraging regulation and speed of customs procedures).

In our study we address the quality of the national logistical capabilities in the country where the plant is located. Some authors (e.g., Zacharia et al., 2011) claim that because of access to national logistical capabilities from their logistics environment many firms no

longer consider traditional logistical activities of customs clearance, transportation, and warehousing as core activities. Likewise, Wiengarten et al. (2013) reports that the presence and quality of such national logistical capabilities can have a significant effect on how organizations manage their supply chains and coordinate with their supply chain partners. As the global competitiveness report from the World Economic Forum points out, different countries' investments in infrastructure and institutions lead to differences in the supporting environment for firms in those countries (Wiengarten et al., 2013). Likewise, inherent cross-border trade and globalization make national logistical capabilities even more crucial Kinra and Kotzab (2008). As such, plants with access to cost-efficient high quality logistical capabilities can often allocate fewer internal resources to certain logistics tasks and/or outsource these tasks. Consequently, more internal resources can be allocated to avoid the trade-off between MCC, CP, and FP. Besides, in countries with predictable customs clearance and good roads, transport should be better and delivery times will be both shorter and more certain. Shorter and more certain delivery times positively influence MCC (Kotha, 1995). In the same way, cheaper access to logistical capabilities positively influences raw material and total product cost and volume and variety flexibility. Therefore, logistical capability empowers the relationship between MCC, CP, and FP. Correspondingly, better transport and shorter and more certain delivery times improves response to changes in delivery due dates. Logistical capabilities are measured using the "Logistical Performance Index" developed and measured by the International Trade Department of The World Bank. Accordingly we hypothesize:

H3a: The higher the level of LPI, the higher the effect of MCC on CP.

H3b: The higher the level of LPI, the higher the effect of MCC on FP.

Moderating effect of WRI on the relationship between MCC and CP and FP

The World Risk Index (WRI) is a tool used to assess and estimate the disaster risk of a country. It indicates the risk exposure of a country based on four components: vulnerability to natural hazards, susceptibility, coping capacities, and adaptive capacities. Higher WRI indicates higher risk. The aim of the index is to demonstrate that a multitude of different factors such as the political and institutional structures, the state of infrastructure or the nutrition situation, economic and environmental conditions of a country determine whether a natural hazard will turn into a disaster (Welle et al., 2012). In response to increasing calls to use more secondary data in OM research, Kaupp et al. (2014) used WRI to examine the impact of country level factors on supply chain risk management and operational performance. Specifically, Gualandris and Kalchschmidt (2014) highlight the very limited work on supply chain risk conditions and MC enablers. In relation to MCC, it could be expected that plants operating in countries with high risks would invest more in MCC enablers to cope with risks than those operating in more stable environments. In countries associated with high levels of risks, more resource is needed to achieve MCC and less number of resources will be available to overcome the trade-off between operational performances. As a result, the impact of MCC on CP and FP would be not as strong as the impact in more stable countries. Besides, achieving CP and FP in high risk countries with unhealthy economical condition and high inflation rates is more challenging. Accordingly we hypothesize:

H4a: The higher the level of WRI, the lower the effect of MCC on CP.

H4b: The higher the level of WRI, the lower the effect of MCC on FP.

The literature review identified several research gaps. This section presents our conceptual model. This model is operationalized in terms of constructs and the relationships between the dependent and independent variables are expressed as research

hypotheses. The conceptual model is used to empirically investigate the research propositions (see Figure 1).

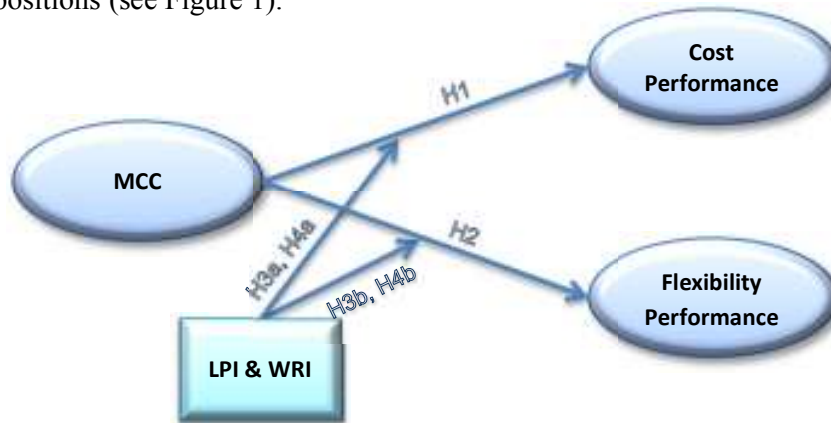


Figure 1 – The conceptual research model

Research Methodology

We utilize the data collected between 2013 and 2014 as part of the fifth round of manufacturing research conducted by Global Manufacturing Research Group (GMRG). Standardized survey instruments have been developed over a number of years and administered by GMRG members in their respective country. Almost 800 responses have been collected, representing 14 countries in most regions of the world. The benefits of using this dataset are: the data comes from a multinational study, the sample size is large enough to carry out rigorous analysis of the data, and the unit of analysis is the manufacturing plant, which increases the contextual validity of the results. Following a rigorous approach, we only considered records for which no data were missing for all our variables. This led to a dataset of 490 records. In addition, we utilize the World Bank's 2014 LPI report and the United Nation's 2014 WRI. Table 1 provides an overview of the dataset in terms of country of origin, company size, and industry.

Table 1 – Sample overview ($n = 490$)

Country	n	%	Industry	n	%	No. of employees	n	%
Australia	23	5	Food & Kindred	58	12	≤ 50	152	31
Croatia	110	22	Fabricated Metal	52	11	51 - 100	107	22
Hungary	35	7	Electronic and Electrical	42	9	101 - 500	169	34
India	58	12	Rubber and Plastic	40	8	501 - 1000	34	7
Ireland	29	6	Apparel & Textile	28	6	> 1000	28	6
Poland	76	16	Lumber & Wood	26	5			
USA	83	17	Chemical & Allied	25	5			
Vietnam	76	16	Machinery & Computer	22	4			
			Other	197	40			

Measures

Constructs are measured using plant level data. Choosing the plant as the unit of analysis avoids problems that arise from multiple plants operating in different ways under one business unit (Caniato et al., 2013). Manufacturing practices are typically implemented at the plant level (Fynes, 1999). Ramdas (2003) argues that plant level impact of product variety and MC is understudied.

MCC. Based on the literature (Liu and Deitz, 2011, Zhang et al., 2011, Salvador et al., 2009) we measured MCC using seven items. Respondents were asked to indicate their agreement with the statements assessing their plant's MCC (1 = strongly disagree, 7 =

strongly agree). These 7 items are: being highly capable of large-scale product customization, easily adding significant product variety without increasing cost, customizing products while maintaining high volume, adding product variety without sacrificing quality, being highly capable of responding quickly to customer requirements, and producing high volume and high variety of products.

CP, FP. We use Power et al. (2010) measures to measure both CP and FP. They measured CP based on labor costs, total product costs, and raw material costs. As for FP, based on the work of Robb Dixon (1992) and Zhang et al. (2003) the OM literature has considered volume and variety dimensions of flexibility as FP. Recently, Power et al. (2010) defined FP as a combination of output volume, product mix (variety), and delivery flexibility. We choose to adopt the latter as it contains the former measures. Respondents were asked to indicate on a scale from 1 to 7 the level of agreement with the statements assessing their plant's CP and FP.

Reliability

Reliability of the measurements was assessed by conducting Exploratory Factor Analysis (EFA) using IBM SPSS Statistics 20 to assess the reliability of the measures. We employed EFA to test the unidimensionality of the scales, followed by Cronbach's alpha and composite reliability for assessing construct reliability. EFA with Maximum Likelihood method and Promax rotation with Kaiser Normalization was used. The reliability (internal consistency) was tested and all constructs had a minimum of 0.728 indicating reliable measures.

Factor analysis and structural equation model

Validity of the measurements was conducted by Confirmatory Factor Analysis (CFA) using AMOS to assess the validity of the measures. The results are presented in Table 2 in terms of Cronbach alpha, factor loadings, t-values, standard errors and R²'s. Using Hu and Bentler (1998) goodness of fit values, the comparison indicated that the model is satisfactory (CFI=0.956, RMSEA=0.066, NFI=0.937, IFI=0.956, RFI=0.920, SRMR=0.041). The ratio of chi-square (195.544) to degrees of freedom (62) has achieved the minimum. Subsequently, based on the previous studies using GMRG data (e.g., Lee et al., 2015), we controlled for Plant Size and proceeded our proposed Structural Equation Model (SEM). Goodness of fit measures are also satisfactory for the SEM model (CFI=0.952, RMSEA=0.063, NFI=0.930, IFI=0.953, RFI=0.913, SRMR=0.041). The ratio of chi-square (213.721) to degrees of freedom (73) has achieved the minimum. To examine content and face validity, we involved numerous OM scholars at the development stage of the survey. In addition, we assured that all items used are well grounded in the corresponding OM literature. To check convergent validity (i.e., the extent to which indicators of a specific construct "converge" or share a high proportion of variance), we calculated construct loadings and standard error. Each coefficient is greater than twice its related standard error (Anderson and Gerbing, 1988). The factor loadings reach from 0.52 to 0.92 and the t-statistics of the factor loadings are all significant at the $p < .001$ level. Convergent validity is generally achieved, if a construct has either a loading of indicators of at least 0.5, a significant t-value ($t > 2.0$), or both. Accordingly, our model meets the required quality criteria for convergent validity. To check the discriminant validity (i.e., the extent to which a construct is truly distinct from other constructs), we calculated inter-factor correlations. Our results indicated that all inter-factor correlations were in an acceptable range. Moreover, we tested the reliability (internal consistency) of our constructs. With a minimum value of 0.728, reliable measures are given. Finally, we evaluated the variance that is linked to the measurement method rather than to its

constructs by re-running the CFA with an additional unmeasured factor. The constructs continued to load on their initial assigned latent variables. Hence, we concluded that common method variance is insignificant in this dataset (Podsakoff et al., 2003).

Table 2 – Measurement characteristics

Construct/Variable	Loading	t-value	S.E.	R²
Mass Customization Capability ($\alpha = 0.898$)				
Capable of large-scale product customization	.72	72.11	.069	.57
Easily adding significant product variety without increasing cost	.74	67.09	.067	.59
Customizing products while maintaining high volume	.86	74.28	.065	.69
Adding product variety without sacrificing quality	.81	80.67	.063	.61
Capability for responding quickly to customization requirements	.85	80.29	.063	.70
Producing a high volume of products	.52	77.33	.066	.31
Producing a high variety of products	.71	72.05	.069	.50
Cost Performance ($\alpha = 0.778$)				
Labor unit costs	.76	80.50	.055	.53
Total product unit costs	.83	83.11	.054	.73
Raw material unit cost	.61	91.31	.049	.39
Flexibility Performance ($\alpha = 0.813$)				
Response to changes in delivery due dates	.63	101.46	.052	.48
Production volume flexibility (increase/decrease volume)	.92	102.48	.051	.76
Production variety flexibility (increase/decrease product mix)	.74	94.60	.053	.57

Results

In relation to plant size, we tested whether or not results of the proposed model were consistent across different plant size. Table 3 reports the results of the significance tests associated with the paths.

Table 3 – Results of the significance test of the SEM model

Path	Path coefficient	S.E	p-Value	Hypothesis test
MCC→CP	.367	.039	***	Supported H1
MCC→FP	.294	.041	***	Supported H2
Plant size→CP	-.041	.000	.387	Control variable
Plant size→FP	.028	.000	.568	Control variable

*** p < .001.

For H1, the standardized path coefficient from MCC to CP was significant ($\beta=.367$, $p<.001$), providing support for H1. Likewise, the standardized path coefficient from MCC to FP was significant ($\beta=.294$, $p<.001$), providing support for H2. H3 proposed that LPI will moderate the relationship between CP (H3a) and FP (H3b), such that the relationship is stronger when having high levels of LPI. The results show that the beta coefficient of interaction term (MCC and LPI) was significant for H3a ($\beta=-.176$, $p<.001$) but in the opposite direction i.e., the relationship is weaker when having high levels of LPI. The results show that the beta coefficient of interaction term (MCC and LPI) was not significant for H3b (FP). H4 proposed that WRI will moderate the relationship between CP (H4a) and FP (H4b), such that the relationship is weaker when having high levels of WRI. The results show that the beta coefficient of interaction term (MCC and WRI) was significant for H4a ($\beta=-.127$, $p<.05$) but in the opposite direction i.e., the relationship is stronger when having high levels of WRI. The results show that the beta coefficient of interaction term (MCC and WRI) was not significant for H4b (FP).

Discussion

Our findings address the research gaps in the literature. The results indicate a positive impact of MCC on cost and flexibility performance supporting the overcoming of a trade-off between cost and flexibility. Our results support the argument that there is a synergy between CP and FP. There are a variety of possible explanations for this. One is the emergence and implementation of advanced manufacturing technologies. Another explanation is that in order to build MCC, plants have to invest in manufacturing practices that empower product variety, product volume flexibility and product delivery with a cost comparable to mass production. As a consequence, once plants reach the acceptable level of MCC, their CP and FP are enhanced to some levels. Therefore, we argue that the results support “sandcone model” (Kasra and Thurnheer, 2011). In addition to the role of moderators, we posited that higher levels of LPI and lower levels of WRI will positively moderate the relationships between MCC and CP and FP. But our results did not confirm this; namely: (1) LPI and WRI moderate the relationship between MCC in the opposite way of what we initially hypothesized; (2) LPI and WRI do not moderate the relationship between MCC and CP and FP. One of the explanations for number (1) is that in countries with high levels of logistical capabilities and low levels of risk, plants might rely on external available sources and are able to enhance their MCC easier. On the other hand, in countries with low levels of logistical capability and high levels of risk, enhancing MCC, plants have to focus and invest their available internal and limited external sources in a most effective way. Besides, small enhancement in MCC and improvement in CP and FP will be both significant and noticeable in countries with low LPI and high WRI. Furthermore, uncertainty regarding logistical services and exposure to risk leads plants with MCC to take a better care of their business and prevent trade-offs from happening. As for number (2), one of the reasons is that flexibility is a complex construct and we still do not have a solid explanation of how to achieve flexibility (Kalchschmidt et al., 2010) and contingency factors involved. Likewise, comparing to CP, measuring and controlling FP is harder. CP measures directly impact the bottom-line of the company but the effect FP is not evident. Finally, we argue that there is a human side to flexibility which LPI and WRI do not consider/interact. We suggest future studies to consider country level factors that take into account human side, for example education level.

Conclusion

Our study is limited by the use of cross-sectional and single respondent data from non-random sample to test the hypotheses. To the best of our knowledge, the present study is the first to underpin the impact of MCC on CP and FP and the possible moderating variables. It develops and empirically tests a conceptual model, which is grounded on integrating the reasoning of contingency theory. By identifying the circumstances or variables that have an intervening effect on the investment-capability-performance relationship, we contribute to both the academic and practitioner community with potentially compelling answers to the question of *why* developing capabilities are or are not always successful.

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