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DEVELOPING MASS CUSTOMIZATION CAPABILITY THROUGH SUPPLY CHAIN INTEGRATION

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Abstract

Based on data collected from 292 manufacturing firms located in different countries, our results show that both internal and customer integration contribute positively to MCC. Positive interaction effects are also found between internal and customer integration, and between internal and supplier integration, on MCC. The results suggest that supplier integration play only a complementary role, supporting internal integration in the development of MCC. Overall, the findings demonstrate the pivotal role of internal integration in SCI. Whereas current research into SCI tends to view it as mainly "outward-facing" integration, our results strongly suggest that manufacturing firms should pursue internal integration as the foundation for successful SCI.

1. Introduction

Increasingly competitive markets and the decline of standardized, production-pushed products have forced many manufacturers to meet customer needs by offering more customized products and a greater variety of services on a large scale ([1]). Hence, manufacturers need to develop a key operational capability – mass customization capability (MCC), which is defined as the ability to offer a reliable, high volume of different products to better meet customer demands, without substantial tradeoffs in cost, delivery, or quality ([2]). For many manufacturers today, MCC has become a basic necessity, and the development of this capability among firms is of critical importance ([3],[4]).

As a new manufacturing paradigm, mass customization (MC) has led firms to refocus on their supply chain management (SCM) ([1], [5]). Researchers argue that building the MCC of a manufacturing firm is central to the effective and efficient management of an agile supply chain ([6],[7]). Many companies have implemented supply chain integration (SCI) to enhance their operational capability to meet changing customer requirements. There is a general recognition of the importance of external integration (i.e. with suppliers and customers) and internal integration among manufacturing firms. Over the last decade, researchers have started to examine the relationship between SCI and business performance and the mediating role of manufacturing capabilities Different types of integration might have mixed impacts or synergistic effects on different kinds of operational capabilities. MC requires the combination of several basic operational capabilities ([1],[2]) and SCI to facilitate production, assembly, logistics, and outsourcing decisions.

A number of researchers have observed that the transition to MC is difficult, and requires a comprehensive approach to product and process design, including the configuration of SCM systems ([1]). However, recent literature reviews reveal that previous research offers little insight into the development of MCC or how to make the transition to MC ([5]). The relationship between SCI and MCC is thus an important topic that deserves special attention ([3]). However, there is a lack of empirical research into this area. Hence, the current study investigates the roles of internal, customer, and supplier integration in the development of MCC. It addresses the following questions: What is the overall relationship between SCI and MCC, and what are the relative contributions of different types of integration to MCC? Are there synergistic effects between internal and external integration that a firm can exploit in developing MCC?

2. Literature review and research hypotheses

2.1. Customer integration and MCC

Customer integration refers to the degree to which a firm can strategically collaborate with its customers on managing interorganizational activities and build cooperative relationships. In MC operations, variety is not pushed by manufacturers but rather is driven by customers. Hence, understanding customer needs is a prerequisite for successful MC. Manufacturers need to analyze the heterogeneity of, and changes in, customer needs. This is considered one of major challenges faced by companies in implementing MC. Strategic customer integration builds long-term and collaborative relationships and direct involvement with customers. It allows manufacturers to access customer information, share knowledge, pursue joint development activities, speed up decision processes, reduce lead times, and improve process flexibility.

Therefore, strategic customer integration is critical in helping manufacturers not only to acquire information on customer requirements but also to gain a better understanding of customer preferences and needs, that is, what is preferred and why. Researchers emphasize the importance of providing customers with the opportunity to participate in order to incorporate their voice into the design and production process ([1],[2]). Therefore we propose the following hypothesis:

H1: Customer integration is positively related to MCC.

2.2. Supplier integration and MCC

Supplier integration refers to the degree to which a firm can strategically collaborate with its suppliers to manage interorganizational activities and build cooperative relationships. In MC operations, standardized modularization creates an expanded and greater role for suppliers because it increases the need for collaboration and a long-term commitment between suppliers and manufacturers. Both researchers and practitioners note that suppliers possess valuable knowledge and expertise that is invaluable for MC implementation. Manufacturers need to align what suppliers can deliver with the variety of products that customers want on a timely basis. This requires more information exchange and stronger relationships with suppliers.

Because of the multidimensional requirement for product variety, flexibility, cost, and delivery, mass customizers face a complex and dynamic operational environment. Whether or not they can respond to the changes in the environment and adjust operations is determined by the efficiency and effectiveness of the whole supply chain ([2],[3]). Where there is a long-term and cooperative relationship, information can flow freely across the supply chain to help manufacturers design better quality components that are more suited to customized demands, implement more cost-efficient production, minimize the possibility of errors, and facilitate initiatives for process improvements that can create added value ([1],[2]). Finally, supplier integration can help manufacturers gain critical knowledge that affects their core competence in MCC. Therefore, we propose the following hypothesis:

H2: Supplier integration is positively related to MCC.

2.3. Internal integration and MCC

Internal integration refers to the degree to which the different internal functions of firms are able to strategically collaborate and coordinate intraorganizational activities and decisions and build integral relationships with one another. MC demands quick and effective organizational responses in product development, production, and delivery in accordance with current customer needs. Internal integration facilitates the translation of customer demands into specific designs, processes, and physical goods, which leads to a connected and more coordinated response to marketplace changes and disruptions. It also requires the breaking down of the traditional functional "silo approach" and close coordination among the functional areas. Without effective internal integration, the complexity and variety of MC will cause many problems due to the conflicting interests of the different departments. For example, the marketing department might put too much emphasis on customer demands and overcommit to requirements without considering whether the products can be designed and manufactured efficiently and effectively. Design engineers might be interested in adding functions and features that are considered extraneous by customers. The manufacturing department might focus on cost reduction and efficiency and not care about customer needs, while the accounting department might not be able to estimate the variety-related portion of manufacturing overhead.

Internal integration provides the critical mechanisms inside the organization that strategically link up different functions and decision making. It plays a central role in the creation of manufacturing effectiveness, cost efficiency, process effectiveness, and product flexibility, which are essential for the development of MCC ([1],[3]). Researchers have consistently observed that cross-functional integration and knowledge sharing present one of the greatest challenges to the implementation of MC. Given the wealth of evidences of the importance of internal integration for MCC, we propose the following hypothesis:

H3: Internal integration is positively related to MCC.

2.4. Interaction effects among customer, supplier, and internal integration on MCC

Although it is widely recognized that effective supply chain integration involves customer, supplier, and internal integration, there is a surprising lack of research into the relationships among these different types of integration and whether their contributions to manufacturing capabilities are simply additive or synergistic. The few empirical studies that have investigated the relationships among the different types of integration tend to examine only specific aspects, and yield mixed results. We argue that the relationships among customer, internal, and supplier integration and their possible synergistic effects on MCC constitute an important issue that should be examined more carefully. The need to quickly provide products that are configured to customer requirements is becoming increasingly important in today's competitive environment. In MC operations, the value of customer integration depends largely on whether the manufacturer can understand customer demands and translate them into technical specifications and effective actions within the company; that is, both customer and internal integration are required. Customer integration can provide only the basic input about customer requirements, which are expressed in terms of product quantity, cost, functionality, quality, characteristics, aesthetics, and delivery ([1]). However, these requirements are not specified in terms of engineering, production, and material/component requirements that the internal company staff and workers can follow and develop into actions. Only through a process of information sharing, analyzing, interpreting, translating, and problem-solving interactions can ill-defined concepts and terms be translated into technical production specifications, plans, and schedules that can be easily understood and communicated inside the organization. This leads to a shared understanding of customer demands and a shared goal of how to fulfill such demands. However, this is often a complex and difficult process that requires the simultaneous integration of internal functions with external interfaces and strategic integration with customers and suppliers.

The linkage of customer with internal integration not only facilitates short-term operations but also has a strategic, long-term effect, building the organization's core competence and competitive capabilities. By building a direct, business-to-business integrative channel between the customer and the manufacturer, customer needs, preferences, and constraints can be shared directly deep within the organization among the different functions. In a similar vein, we argue that supplier integration together with internal integration can optimize the efficiency and effectiveness of business operations, enhance knowledge sharing, promote organizational learning, and aid in building new capabilities among manufacturers. Supplier knowledge of innovations in component design, technologies, and equipment and experience of logistics networks will enrich the basic understanding of product, process, and supply chain activities and provide innovative improvements ([2]). Such external knowledge, if effectively shared throughout the organization, can also help to remedy inefficiencies in the existing operations. Moreover, the integration of external supplier knowledge into internal operations can also lead to strategic improvements in the organization's MCC. For instance, knowledge about improvements in the functionality and characteristics of component production gives manufacturers vital knowledge for modular design of products and processes. Conversely, the production department may find a new way to aggregate parts production based on some innovation of the components, which can greatly increase the batch volume and decrease costs. However, if this knowledge is not shared with the design engineers in the company, then they will be unaware of the opportunity to use the same module to fulfill other demands, and the value of external supplier knowledge will be greatly reduced. When a manufacturer has an efficient internal integration infrastructure that enables the assimilation of supplier knowledge, it can more easily exploit the capabilities of its suppliers to find ways to improve the degree of customization, lower prices, or cut production lead times.

Finally, as full supply chain integration requires the linking of customer, internal, and supplier integration, we expect the widest arc of integration to have a holistic, synergistic impact on MCC. At the same time, because the effects of supply chain integration on MCC must work through internal integration, there is no reason to expect the interaction between supplier and customer integration to have an effect on MCC. Therefore, we propose the following hypotheses:

H4a: There is a significant interaction effect between customer integration and internal integration on MCC.

H4b: There is a significant interaction effect between supplier integration and internal integration on MCC.

H4c: There is a significant interaction effect among customer integration, supplier integration, and internal integration on MCC.

3. Research methodology

3.1. The sample

The database used in this research is taken from the third round of the High Performance Manufacturing (HPM) project, which was conducted by a team of collaborative researchers in North America, Europe, and Asia. The database includes 292 mid- to large-size manufacturing plants (each with at least 100 employees) from nine countries (the U.S., Finland, Japan, South Korea, Australia, Italy, Germany, Sweden, and China). The sample includes plants in the electronics, machinery, and automobile supply industries in each of these countries. A stratified design was used to randomly select an approximately equal number of plants from each country and industry.

3.2. Measurement validation

We conducted exploratory factor analysis to assess the unidimensionality of the constructs. In each case, an eigenvalue greater than 1.00 was used to determine which factors would be retained, and a factor loading cutoff of 0.60 was used to ensure that each item or measure loaded on a common factor and contributed significantly to its score. The results of principal component factor analysis with varimax rotation, which show that all items met the cut-off criteria. Cronbach's alpha was used to evaluate construct reliability. The reliability of the scales met the threshold value of a Cronbach's alpha greater than 0.70, as recommended by Flynn et al. (1990).

Content validity was established by a literature review of the key concepts and a series of plant visits, during which we conducted structured interviews with a number of managers. Then, we constructed a confirmatory factor analysis (CFA) model using the LISREL 8.54 program to assess convergent validity. In the model, each item was linked to its corresponding construct, and the covariances among those constructs were freely estimated. The resulting model fit indices are $\chi^2(113) = 255.91$ ($p < 0.001$), non-normed fit index (NNFI) = 0.94, comparative fit index (CFI) = 0.95, standardized root mean square residual (RMR) = 0.058, and root mean square error of approximation (RMSEA) = 0.067, the values of which are all better than the threshold. The item loadings are all positive and greater than 0.50, and the critical ratio for each loading is significant, indicating the convergent validity of the items. Finally, we built a constrained CFA model for each possible pair of latent constructs in which the correlation between each paired construct was fixed to 1. We compared this model with the original unconstrained model in which the correlations among constructs were freely estimated. A significant difference in the chi-square statistics between the fixed and unconstrained models indicates high discriminant validity. In our study, the differences were significant at the 0.01 level, and thus discriminant validity was verified.

4. Analysis and results

We employed a hierarchical moderated regression approach to assess the effects of SCI on MCC. Model 1 included only the control variables, and Model 2 combined the control variables with the main effects of customer, supplier, and internal integration. Models 3 and 4 added the interaction terms, which were computed as the cross-products of the mean-centered scores for supplier and customer integration with internal integration, respectively. Model 5 considered the interaction between customer and supplier integration. Finally, Model 6 tested the complete three-way interaction effect of customer, supplier, and internal integration on MCC. The variables were mean centered to minimize potential multicollinearity problems associated with cross-product terms. Analysis of the variance inflation factors revealed no serious multicollinearity problems in any of the regression models. Residual analyses suggested that one case was an outlier. Therefore, we deleted it and report the regression results of the remaining cases. The sign and significance of the coefficients for the independent variables indicate support or non-support for the hypothesized effects. We also compared each model with its nested models to examine the incremental change in R^2 due to additional independent variables.

In Model 1, Australia is used as the base to control for country effects, and the auto supply industry is used as the base to control for industry effects. Model 1 is statistically significant, which indicates that country, industry, and plant size account for a small but marginally significant amount of the variance in MCC ($p < 0.05$). The base model shows that plant size is not associated with MCC. Few differences are found among countries in terms of MCC, and among industries, the electronics industry has much higher MCC than the auto supply industry. Model 2 reveals that SCI accounts for a significant amount of variance in MCC (an incremental R^2 of 0.158, $p < 0.01$). Specifically, both customer and internal integration have statistically significant and positive influences on MCC. Hence, Hypotheses 1 and 3 are supported. However, supplier integration does not have a statistically significant impact on MCC. Thus, Hypothesis 2 is rejected.

Comparing the results for Model 3 with those for Model 2, the positive and significant interaction between customer and internal integration reveals that customer integration not only improves MCC directly but also enhances the impact of internal integration. Therefore, Hypothesis 4a is supported. Model 4 reveals that the interaction between supplier and internal integration significantly affects MCC (an incremental R^2 of 0.013, $p < 0.05$). Thus, Hypothesis 4b is also supported. In addition, our results suggest that although supplier integration does not affect MCC directly, it has an indirect effect through enhancing the impact of internal integration.

The results of the hierarchical regressions support our argument that SCI works through internal integration and there is thus no reason to expect an interaction between customer and supplier integration (Model 5). In addition, we do not find a significant three-way interaction effect of customer, supplier, and internal integration on MCC (Model 6). Therefore, Hypothesis 4c is rejected.

5. Discussion and conclusions

This study investigates the effects of different types of integration on MCC. The results show that both internal and customer integration are positively associated with MCC. However, there is no direct relationship between supplier integration and MCC. In addition, there are significant interaction effects between internal integration and both types of external integration (customer and supplier) on MCC. These results show that different types of integration work interactively in the development of MCC, an important issue that researchers need to explore further.

Studies have also reported interaction effects between external and internal integration, but they do not distinguish between customer and supplier integration. In this study, we find that different types of integration have synergistic effects on MCC. Moreover, there is an interesting overall pattern in the emerging relationships, with internal integration playing the central role. In addition to its significant, direct effect on MCC, internal integration also has significant two-way interaction effects with customer integration and with supplier integration on MCC. Finally, unless internal integration plays a linking role, there is no reason to expect a significant interaction effect between customer and supplier integration, as shown by our results.

Our results support the general contention that SCI is important in building manufacturing capabilities Whereas previous research has generally examined SCI at an overall macro level, this study provides a detailed investigation into how various types of integration might work together to contribute to MCC. We find that internal integration plays a pivotal role in helping to reap the overall benefits of SCI. We draw attention to this result because current SCI research tends to de-emphasize the role of internal integration, and considers SCI to constitute mainly “outward-facing” activities . Our results suggest, however, that internal integration should serve as the foundation of SCI.

Our results have practical implications for executives and managers of manufacturing firms. The development of MCC is a very important manufacturing strategy given today’s competitive environment, and requires consistency between internal and external integration. Our results indicate that managers interested in building MCC should start with internal integration. Without a good foundation characterized by strong internal integration mechanisms, other investments in supply integration might be wasted.

References

[1] Pine, B.J. 1993. Mass customization: The new frontier in business competition, Harvard Business School Press, Boston, MA.

[2] Liu, G., Shah, R. and Schroeder, R.G. 2006. Linking work design to mass customization: A sociotechnical systems perspective, Decision Sciences, 37(4): 519-545

[3] Duray, R., Ward, P.T., Milligan, G.W. and Berry, W.L. 2000. Approaches to mass customization: Configurations and empirical validation, Journal of Operations Management, 18: 605-625.

[4]Zipkin, P. 2001. The limits of mass customization, MIT Sloan Management Review, 42(3): 81-87.

[5] Huang, X., Kristal, M.M. and Schroeder, R.G. 2008. Linking learning and effective process implementation to mass customization capabilities, Journal of Operations Management, 26: 714-729

[6] Feitzinger, E. and Lee, H.L. 1997. Mass customization at Hewlett-Packard: The power of postponement, Harvard Business Review, Jan-Feb 1997: 116-121

[7] Da Silveira, G., Borenstein, D. and Fogliatto, F.S. 2001. Mass customization: Literature review and research directions, International Journal of Production Economics, 72: 1-13.