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Modularity in building mass customization capability: The mediating effects of customization knowledge utilization and business process improvement

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ABSTRACT

This study investigates the relationships among product/process modularity, organizational learning practices, and mass customization (MC) capability. Drawing on organizational learning theory, we propose that organizational learning practices help to embed the knowledge gained from modular design practices into organizational processes, enhancing MC capability. We empirically test the mediating effects of two organizational learning practices—customization knowledge utilization and business process improvement—on the relationship between product/process modularity and MC capability, using data collected from Chinese manufacturers. We find strong support for the mediating role of organizational learning practices in the relationship between modularity and MC capability. Our findings have implications for management strategies and point to directions for further research in this area.

1. Introduction

In recent decades, mass customization (MC) has played an increasingly important role in satisfying heterogeneous customer needs. Due to the increased diversity in customer requirements, manufacturers are in the process of evolving from mass production to MC. Indeed, MC is being implemented in increasingly more industries, such as the automobile, clothing, computer, food, electronics, and even homebuilding industries (Fogliatto et al., 2012). When successfully implemented, MC benefits manufacturers with competitive advantages in terms of cost, quality, flexibility, and delivery (Kumar, 2004). In the current competitive environment, MC capability is seen as a source of sustained competitive advantage. It is company's ability to produce "varieties of customized products quickly, on a large scale and at a cost comparable to mass-production through technical and managerial innovations" (Tu et al., 2004, p. 152).

Modularity is one of the most popular design practices for MC implementation. The literature highlights the role that modularity in products and processes plays in increasing MC capability (Tu et al., 2004) and improving firm performance (Jacobs et al., 2011). Modular product architecture can help to increase product variety through reconfiguration, reducing time to market and costs through standardization (Lau et al., 2011; Magnusson and Pasche, in press; Persson and Åhlström, 2006; Sanchez, 2000; Ulrich, 1995). A modular process can help a firm to increase flexibility through resequencing and postponement, and reduce costs through standardization (Feitzinger and Lee, 1997; Gualandris and Kalchschmidt, 2013; Van Hoek and Weken, 1998). Various studies have reported the critical role of modularity in MC (Joneja and Lee, 1998; Kumar, 2004; Mikkola, 2007). However, these studies leave partially unexplained, some of the paths through which modularity practices could improve MC capability.

Da Silveira et al. (2001) suggested that MC is a systemic idea involving all aspects of a cycle including product sale, development, production, and delivery. MC capability is also seen as company-wide performance competence (Huang et al., 2008). The effect of modularity on MC capability is not necessarily directly due to the implementation of modular design in the whole organization. For example, Ahmad et al. (2010) argued that modularity is a difficult task that requires multiple function involvement. Conflicts and

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misunderstandings between functions may inhibit the effect of modularity on MC capability. From the perspective of organizational learning, the missing link is the learning process of knowledge conversion in the organization (Nonaka, 1994). This means that companies may need managerial mechanisms to facilitate the use of modular design knowledge for MC capability building.

We have also found that the learning process was very important in bridging modularity efforts and MC capability. One of the companies in our survey, Borche, established MC at its start up. One of the critical issues in the growth of the company was the increased cost of high variety. Managers of the company found that it was not enough to only focus on modular design in implementing MC. The divisions between research and development (R&D), marketing, purchasing, and manufacturing inhibited the modular design efforts. One interesting method the company used was a product 'menu' for the customers. Through the menu, the company could accumulate and reuse customization knowledge, using it to communicate not only with external partners, but also with internal departments. Such behavior helped the company in exploiting modular design efforts.

While previous research has examined how modularity in engineering practices influences MC capability (Joneja and Lee, 1998; Kumar, 2004; Mikkola, 2007), little is known about what managerial mechanisms firms can use to embed the knowledge gained from past modularity practices into organizational processes, enhancing MC capability. To address this research gap, we adopt an organizational learning perspective to examine how such practices help to transform the engineering efforts involved in product/process design into MC capability. We propose that organizational learning practices are intervening factors between modularity and MC capability. We empirically test the mediating roles of two organizational learning practices (customization knowledge utilization and business process improvement) in transforming product/process modularity into MC capability, using data collected from Chinese manufacturers. As a global manufacturing center, China provided a viable context for our research (Jiao et al., 2003). Many Chinese firms are moving from large volume low cost production to mass customization, to meet the diversified needs of different customers (Song and Fiore, 2009).

The remainder of this paper is organized as follows. Section 2 develops the theoretical models and hypotheses. Sections 3 and 4 present the research methodology and results of statistical analyses. In Sections 5 and 6, the implications of the results and the study's limitations are discussed. Section 7 summarizes the purpose and key findings of the paper.

2. Theoretical background and hypotheses

2.1. Theoretical background

Modularity was initially used to control variety and increase interchangeability in a turbulent environment (Starr, 1965). The principles of modularity have been extended from product design to process design, and even to whole manufacturing system design. Product modularity is the extent to which a product is separated into standardized modules that can be easily recombined into different product features or shared across different product lines (Schilling, 2000). Process modularity is the extent to which the production process is separated into standardized modules that can be easily re-sequenced into new processes that fulfill the requirements of producing new product features (Feitzinger and Lee, 1997).

MC can be understood from a range of perspectives, including strategy (Pine and Davis, 1999), marketing (Piller and Muller, 2004), engineering (Bateman and Cheng, 2006; Tseng and Jiao, 1998), and operations management (Huang et al., 2010; Liu et al., 2006, 2010; Tu et al., 2004). This study adopts an operations management perspective and focuses on MC capability, the ability of a firm to provide a high volume of customized products or services in a short delivery time and at a reasonably low cost (Tu et al., 2001, 2004). Based on a thorough literature review, Tu et al. (2001) divided MC capability into three components: customization cost-effectiveness, customization volume effectiveness, and customization responsiveness.

Organizational learning is "the development of insights, knowledge and association between past actions, the effectiveness of those actions, and future actions" (Fiol and Lyles, 1985). We define customization knowledge utilization as a firm's effort to learn from past customization experiences (Zollo and Winter, 2002) and to use the knowledge gained to improve future business. Business process improvement is a firm's effort to make improvements in organizational processes using lessons learned from past experiences, and to build the mechanisms to implement such improvements (Kale et al., 2002). From an organizational learning perspective, customization knowledge utilization and business process improvement represent a firm's efforts in internal learning. They are organizational learning practices that create a permanent change in organizational knowledge through experiential learning (Holmqvist, 2004). Customization knowledge utilization enables firms to apply and combine knowledge gained or generated by satisfying their customers. Business process improvement focuses on internally generated knowledge and extends that knowledge to the whole organization. According to organizational learning theory, these two action-based learning practices have significant effects on a firm's capabilities (Kale and Singh, 2007). MC producers often face a complex and dynamic environment and need changes in their production systems or technology. Learning and knowledge creation enable companies to deal with such environments and adapt quickly (Fiol and Lyles, 1985). Organizational learning has been identified as a key determinant in building MC capability (Hirschhorn et al., 2001; Pine et al., 1993) and has been illustrated by case-based evidence (Kotha, 1995, 1996). Huang et al. (2008) empirically validates the positive effects of internal and external learning on MC capability development. They argue that learning practices can help companies to create tacit knowledge embedded in processes, which in turn increases MC capability.

Organizational learning theory provides a theoretical rationale for the relationships between modularity, organizational learning practices, and MC capability. The core tenet of organizational learning theory is to develop skills and capabilities through both intra-organizational and inter-organizational learning (Ignatius et al., 2012; Lin et al., 2012). We argue that customization knowledge utilization and business process improvement are important organizational learning practices that can help a firm exploit modular design knowledge to enhance its MC capability. Modularity design knowledge alone may not increase MC capability, but must be incorporated into organizational processes and combined with other departmental knowledge to take effect. Nonaka (1994) suggested that the role of knowledge can be amplified by four modes of knowledge conversion, socialization, externalization, internalization, and combination. To maximize the value of modularity in product and process design, companies need to adopt managerial mechanisms to convert the knowledge embedded in the minds of product and process engineers. Knowledge from different departments also needs to be interpreted, combined, or shared by the whole organization (Slater and Narver, 1995). This is referred to as the mediating effect of modularity on MC capability, where the mediators in this study are customization knowledge utilization and business process improvement. We thus propose that modularity in products/processes promotes learning through customization knowledge utilization and business process improvement, and subsequently enhances MC capability. However, the literature lacks an empirical examination of these mediating effects on MC capability.