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Impact of Modular Design on NPD Practices and Firm Performance

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ABSTRACT

Previous research has recognized the importance of new product development (NPD) practices and its impact on firm performance. This study investigates the impact of modular product design adoption on new product development practices and firm performance. A conceptual model capturing the relationships among a firm's modular design adoption, NPD knowledge sharing, customer involvement, NPD performance, and market performance was empirically tested. The results provide support for the contention that the effect of modular design on NPD practices and firm performance is positive and significant. Managerial and theoretical implications are discussed.

KEYWORDS: Modular design, NPD knowledge sharing, Customer involvement, NPD performance, Market performance

INTRODUCTION

NPD is a cornerstone of competitive strategy because the ability to develop and rapidly launch successful new products is a critical cornerstone of the competencies that support sustained business growth in the best firms. In light of the fact that product innovations are critical in securing a firm's competitive advantage in global markets, successful NPD is crucial and needs to be innovatively and steadily developed (Chen, Kang, Xing, Lee, & Tong, 2008). To create a sustainable competitive advantage requires the firm to develop unique and difficult-to-replicate capabilities (Teece, 2007). With increased global competition, growing uncertainties, and an environment characterized by instantaneous changes, the capabilities of innovation management and modular design adoption have become essential for firms to possess. Innovation management and design modularity are enablers for firms to sustain competitive advantage in a rapidly changing environment (Chen & Huang, 2009; Subramaniam & Youndt,

2005). In order to quickly customize and adapt to changes in market trends and customer preferences, firms need to become increasingly flexible to ensure efficient utilization of scare resources (Sadovnikova, Pujari, & Mikhailitchenko, 2016). Thus, it is reasonable to argue that firms need to adopt modular design to remain competitive in today's global marketplace.

Many previous studies focused on a wide variety of NPD issues; however, NPD success related to modular design adoption has received limited attention (Fixson, 2005). There exist gaps in the literature regarding the process, determinants, and outcome of modular design adoption and its impact on NPD and firm performance. This study intends to fill part of this gap by investigating the impact of modular design adoption on new product development practices and performance. Specifically, this study develops and tests a conceptual model capturing the relationships among modular design adoption, knowledge sharing, customer involvement, NPD performance, and market performance. It is postulated that modular design adoption influences NPD knowledge sharing and consumer involvement leading to NPD performance and market performance.

LITERATURE REVIEW

Modular design adoption can provide firms NPD agility that can be considered as a dynamic capability. Dynamic capabilities of the firm can be viewed as "bundles of specific skills, procedures, and processes that can leverage resources into competitive advantage" (Baker & Sinkula, 2005). Dynamic capabilities, such as NPD agility, enable the firm to quickly and effectively respond to market trends and customer preference changes (Kock & Gemünden, 2016; Roberts & Grover, 2012). This dynamic perspective allows the firm to be both reactive and proactive in updating to environmental changes by building, leveraging, and reconfiguring its capabilities (Eisenhardt & Martin, 2000; Sanchez, 2004). By applying resource-based theory, capabilities should be valuable, difficult to produce, rare and non-substitutable (Day 1994). These dynamic capabilities enable the firm to create, deploy and protect the intangible assets that support superior long-run financial performance (Teece, 2007). Although dynamic capabilities are perceived as the firm's capacity to reconfigure its resource base, the dynamic capability view also focuses on the firm's ability to integrate, build and reconfigure internal and external competences to address the rapidly changing global environment (Vogel & Güttel, 2013).

Modular Design

Innovation is the process of creating, acquiring, sharing and/or utilizing knowledge (Huang, Wu, Lu, & Lin, 2016) and as such is a major determinant in a firm's competitive advantages. In fact, the development of new products and services through innovation processes is essential for continued firm financial performance (Allen, Adomdza, & Meyer, 2015). In developing new products, products are considered to include both physical elements and functional elements (Ultrich & Eppinger, 2008). Firms need to determine the product architecture that represents how physical elements and functional elements are integrated and linked to form a product. Modular design is a special form of product architecture that allows a high degree of independence between main components of a product (Press & Geipel 2010). Firms adopting modular designs can deploy a physical element containing one or more functional elements in their entirety. In addition, linkages between components and functions are well defined in modular design. Thus, firms adopting the modular design can define and communicate more clearly the component interfaces and how components function and interact in a product in the

new product development processes. This clear description and communication of product design specifications can facilitate knowledge sharing within and between new product development teams and customer involvement in the new product development process. Based on these discussions, the following hypotheses are presented.

Hypothesis 1: Modular design will have a positive effect on (a) NPD knowledge sharing and (b) customer involvement in NPD of a firm.

Determining Factors of NPD Performance

Previous studies have prescribed what constitutes best practice in NPD and have suggested normative strategies leading to NPD success. In this study, three factors, modular design, NPD knowledge sharing, and customer involvement, are postulated to influence NPD performance are identified.

Modular design facilitates continuous modification of products and generation of product variations and creates critical capability of responding to market uncertainties. Modular design provides firms with important dynamic capabilities and allowing firms to become more flexible and agile in new product development and introduction. NPD agility can provide a firm with a wide variety of potential competitive actions and feasible responses to environmental changes and to control risk (Benaroch, 2002; Benaroch, Lichtenstein, & Robinson, 2006; Fichman, 2004; Sambamurthy, Bharadwaj, & Grover, 2003). NPD agility allows the firm to actively respond to new market opportunities as those opportunities occur. A flexible firm adopting modular design can improve firm performance by exercising these various options. An effective implementation of these options can offer a firm increased revenues, profitability, cost avoidance, and market growth (Sambamurthy, et al., 2003; Tallon & Pinsonneault, 2011). Firms can improve NPD performance by developing the ability to design and manufacture modular products (Salvador & Villena, 2013). Firms can design products that have standard components, create product platforms for incremental product modifications, and ensure that each product feature can be changed by modifying only one module. Thus, modular design positively affects NPD outcomes because it can reduce design iterations among design teams.

A positive relationship exists between knowledge sharing and firm innovation capability (Lin, 2007). A firm with proficiency in generating, sharing, and utilizing knowledge is more likely to be unique and have a high level of innovation capability. In addition, empirical evidence supports the view that a firm with knowledge management capability will use resources more efficiently and thus, will be more innovative (Darroch, 2005). Knowledge management capability has significant impact on a firm's innovation (Ju, Li, & Lee, 2006). Taken together, it is predicted that significant direct relationship will exist between NPD knowledge sharing and NPD performance. A positive relationship was found between knowledge application and firm effectiveness (Gold, Malhotra, & Segars, 2001). Knowledge utilization has a significant and positive direct relationship to product innovation performance (Zhang, Di Beneditto, & Hoenig, 2009). Also, retrieving and utilizing information from past projects has been found to influence new product performance (Lynn, Reilly, & Akgun, 2000). Thus, it is expected that knowledge sharing leads to better NPD performance since strong knowledge management involves higher degrees of market intelligence gathering, dissemination and implementation.

Customer involvement has been the main focus in NPD studies (Ritter & Walter, 2003). Customer involvement refers to the extent a customer participates in new product development of a supplier from the idea stage to the prototype testing stage (Brown & Eisenhardt, 1995). An

organization strong in customer influence would be driven more by the demand in rapidly changing or uncertain markets. Taken in this light, firms involved in new conceptual products would require more customer input. Thus, the change could be as drastic as changing the entire market the organization competes within requiring substantial customer input to ensure success. These discussions lead to the following hypotheses.

Hypothesis 2: A firm's (a) modular design, (b) NPD knowledge sharing, and (c) customer involvement will have a positive effect on NPD performance.

Market Performance as a Consequence of NPD Performance

NPD performance would be measured by goals set forth at the beginning of the project, such as, new product success. NPD performance depends on a firm's ability to assess market trends, identify and select the right new technological developments and advances, and to commercialize the right new technologies and patents into successful new products. NPD performance allows a firm to proactively compete with new products and, thus, enhances business performance (Li, et al. 2005; Song, et al. 2005).

Past research suggests a strong linkage between various types of innovation activities and company performance (Hult, Hurley, & Knight, 2004). Other research suggests a positive relationship between product innovation performance and business performance (Hult, Hurley, & Knight, 2004; Hog & Ha, 2009; Menguc & Auh, 2006; Zhang & Duan, 2010). Based on the aforementioned discussions, the following hypothesis is presented.

Hypothesis 3: NPD performance will have a positive effect on a firm's market performance.

RESEARCH DESIGN

Sample and Data Collection

A mail survey was employed in this study using a key informant approach. Respondents for the study were top executives of manufacturing firms from three industry groups. Three industry groups that include chemicals and allied products (SIC 28), non-electrical machinery (SIC 35), and electronic and other electric equipment (SIC 36) were selected to provide a range of technical complexity in the sample. Using a systematic random sampling procedure, a total of 1350 firms were selected based on a computerized mailing list. A total of 218 usable questionnaires were received, resulting in a response rate of 16.2 percent.

Description of the Measures

The modular design measure captures the degree of modular design adoption by a firm using a three-item 5-point rating scale. The knowledge sharing measure captures the level of knowledge sharing within and between project teams. A four-item 5-point scale was used. Customer involvement and NPD performance were measured by 5-point rating scales. Market performance was measured by a 7-point itemized rating scale. Table 1 shows mean and standard deviation values for these constructs. Mean values ranged from 2.13 to 4.15. The control variables included in the study are firm size and the respondent's years of working in their present position.

RESULTS

Confirmatory Factor Analysis

The measurement properties were assessed in one confirmatory factor analysis (CFA). Confirmatory factor analysis results of the measurement items are presented in Table 1. Table 1 shows means, standard deviations, composite reliabilities, average variance extracted, factor loadings, and goodness of fit indices. The fit indices showed that the model resulted in a good fit to the data (χ^2 = 224.03, d.f. = 109, normed fit index (NFI) = .92, comparative fit index (CFI) = .96, root mean square residual (RMSR) = .064). All the items loaded significantly on the expected constructs indicating convergent validity of the measures. The composite reliabilities for the four scales ranged from .63 to .87, with factor loadings ranging from .52 to .93 ($p < .01$). The average variance extracted ranged from .50 to .77. The discriminant validity was assessed by the chi-square difference tests that were performed for all possible pairs of constructs. The correlations between constructs ranged from .01 to .77. In all pairs of constructs, the critical value was exceeded indicating discriminant validity. The CFA results suggest that all measurement scales have adequate reliability and validity.

Table 1: Confirmatory Factor Analysis Results

	Number of Items	Mean	SD	Composite Reliabilities (CR)	Average Variance Extracted (AVE)	Lambda Coefficients
Modular Design	3	2.24	1.09	0.80	.62	.52 - .84
NPD Knowledge Sharing	4	2.56	0.88	0.63	.50	.65 - .80
Customer Involvement	3	2.13	1.15	0.87	.77	.80 - .93
NPD Performance	4	3.32	0.90	0.80	.51	.59 - .79
Market Performance	3	4.15	1.57	0.84	.72	.73 - .91
Note: Fit Indices: χ^2 / d.f. = 224.03 / 109; Normed Fit Index (NFI) = 0.92; Comparative Fit Index (CFI) = 0.96; Root Mean Square Residual (RMSR) = 0.064.						

Hypotheses Testing

Data were analyzed by path analysis using LISREL 8.8. In testing the path model, the summated scores of the scale items were used as indicators of the construct. The fit indices indicate a good fit of the model for the data. The chi-square for the model is 38.87 with 12 degrees of freedom. The goodness of fit index (GFI) is .95 with comparative fit index (CFI) of . 90. The root mean square residual (RMSR) is .076.

The path coefficient from modular design to NPD knowledge sharing is significant. The path coefficient of .36 ($p < .01$) indicates that modular design positively influences NPD knowledge sharing. This result provides support for the Hypothesis 1a. The path from modular design to customer involvement is positive and significant with the path coefficient of 0.67 ($p < .01$). Hypothesis 1b is supported by the results.

The path from modular design to NPD performance is positive and significant ($\beta = 0.23$, $p < .01$). The result shows positive effect of modular design on NPD performance supporting Hypothesis 2a. The path from NPD knowledge sharing to NPD performance is positive and significant ($\beta = 0.26$, $p < .01$). These results provide support for Hypothesis 2b. The path from

customer involvement to NPD performance is not significant ($\beta = 0.01$, $p > .05$) providing no support for Hypothesis 2c. The path from NPD performance to market performance is positive and significant ($\beta = 0.15$, $p < .05$). This result provides support for Hypothesis 3.

DISCUSSION

Our research is designed to answer the following questions: how do the modular design adoption impact the firm's NPD knowledge sharing and customer involvement and how these three factors affect the firm's NPD performance and market performance? A summary of this study's findings follows. First, it was found that a significant positive relationship between modular design and knowledge sharing as well as between modular design and customer involvement exists. Second, a positive relationship is found between knowledge sharing and NPD performance as well as between modular design and NPD performance. Third, it was also found that a significant positive relationship between NPD performance and market performance exists.

The study makes an interesting contribution to the literature in that it identifies the causal relationships among modular design architecture, knowledge sharing, and performance. While modular design is able to directly improve NPD performance, it has an indirect effect on NPD performance through knowledge sharing. This suggests that firms should promote NPD knowledge sharing and ensure that their knowledge management practices can enhance their ability to generate more successful new products in the market.

This study has some limitations that offer avenues for future research, thus care should be taken in interpreting the results. Cross-sectional data was used in testing our hypotheses. The model tested was recursive. In the model, relationships were captured by one-way causal paths. A recursive model, when tested with cross-sectional data, might not capture the dynamic and interactive nature of NPD. Therefore, future research should employ longitudinal studies incorporating non-recursive relationships. In addition, the study's results may be somewhat biased due to the fact that the sample was composed primarily of three industry groups. For practical reasons, our sample was limited in scope and did not allow for industry-specific analysis. Future research could explore and shed light on the identified relationships within targeted industries.

REFERENCES

References available upon request.