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An Empirical Study of the External Environmental Factors Influencing the Degree of Product Customization

Enrico Sandrin

Postdoctoral research fellow, Department of Management and Engineering, University of Padova, Stradella S. Nicola, 3, 36100 Vicenza, Italy, enrico.sandrin@unipd.it

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Abstract

External environmental factors play a fundamental role in the strategic decisions a company intends to make, which in turn influence the organizational design choices. A widely known key strategic decision in the context of mass customization is the degree of product customization a firm provides to its customers. However, the impact of the external environment on the degree of product customization has yet to be empirically investigated. To narrow this research gap, the present paper empirically examines the impacts of three external environmental factors, namely competitive intensity, heterogeneity of customer demands, and dynamism of customer demands, on the degree of product customization, using survey data from 195 manufacturing plants in three industries and eight countries. Among the three examined factors, the paper identifies the dynamism of customer demands as a key factor that pushes firms to increase the degree of product customization they provide to their customers.

Key words: *Mass customization, Degree of product customization, External environmental factors, Survey research*

1. INTRODUCTION

The mass-customization paradigm has stimulated widespread interest among both practitioners [1] and academic researchers [2, 3] for more than two decades. Mass customization means providing customized products and services that fulfill each customer's idiosyncratic needs without considerable trade-offs in cost, delivery and quality [4-6]. Since the concept of mass customization was first introduced in the literature, different types of mass-customization strategies have been distinguished [5] and, over time, several criteria have been proposed to classify these strategies [e.g., 7, 8]. The most commonly cited criterion, either alone or in combination with others, is the degree of product customization (DPC) a firm provides to its customers [e.g., 5, 9]. The DPC is a key decision for a company pursuing a mass-customization strategy [7] and is related to the point of initial customer involvement along the value chain. Customization occurs in a certain value-chain activity (i.e., design, fabrication, assembly, distribution) when this activity along the value chain is carried out according to the customer's specific needs [10]. A greater DPC means that, for a greater number of customer orders, customers are involved earlier along the value chain [11, 12]. The external environment is of primary importance in determining the strategic decisions a company intends to pursue, which in turn affect the organization's design

choices [13]. The DPC, seen as a strategic decision, plays an important role in the design of an organization that wants to pursue mass customization, as DPC influences all of the organization's subsequent design decisions [8]. As an example, different human resource management practices should be adopted for different DPCs in order to enhance mass-customization capability [14].

Since DPC has a contingency effect on the organization's design decisions with regard to mass customization, it becomes interesting to examine which factors drive the DPC choices and, consequently, condition the effectiveness of certain organizational design decisions in pursuing mass customization.

Mass customization has been recognized as a suitable answer to a highly competitive environment [15, 16] with very heterogeneous and hard-to-predict customer demands [17, 18], and the DPC is a primary decision within a mass-customization strategy [7, 8]. However, there are no empirical studies linking external environmental factors with the strategic decision on the DPC a firm provides to its customers.

Therefore, this paper aims to empirically investigate the links between the DPC that companies offer to customers, and three external environmental factors: competitive intensity, heterogeneity of customer demands, and dynamism of customer demands. Among the three examined factors, this paper

identifies the dynamism of customer demands as a key factor that pushes firms to increase the DPC they provide to their customers.

2. THEORETICAL BACKGROUND AND RESEARCH HYPOTHESES

2.1 Mass Customization and the Degree of Product Customization

The most important strategic decision for a company that wants to pursue a mass-customization strategy regards the point of initial customer involvement along the value chain [7], usually referred to as the DPC the company provides to its customers [11]. The point of initial customer involvement can take place in one of the four activities that compose a generic value chain: design, fabrication, assembly, and distribution. Moving product customization back along the value chain gives rise to five different strategies [10]:

- *No customization*, where the company provides a variety of products (even a large variety) from which the customer can choose, but product customization is not allowed;
- *Customized distribution*, where the only activity influenced by customer requirements is product distribution;
- *Customized assembly*, where customer requirements influence the assembly activities as well as the distribution process, but neither the manufacturing of product components nor the design process;
- *Customized fabrication*, where customer requirements influence the manufacturing of product components as well as all the downstream stages of the value chain, but not the design process;
- *Customized design*, where customer requirements influence the value chain beginning from the design phase.

The classification of a manufacturing company based on any one of these five strategies means that all customer orders the company fulfills in a given time period fall into the selected strategy. However, in industrial practice, companies sometimes pursue hybrid strategies [e.g., 19], combining different customization strategies for different customer orders. For instance, this may happen because different items in a company's solution space follow different customization strategies, consistent with Giesberts and van der Tang's [20] notion of assortment hybridity. Consequently, a higher DPC captures the fact that, for a greater number of customer orders, customers are involved at an earlier stage of the value chain [11, 12].

2.2 External Environment

According to Pugh and Hickson [21], an organization is closely influenced by the environment within which it functions, and much of the variation in organizational design choices might be explained by contextual factors, also known as contingency factors. The environment is the physical, technological, cultural, and social context to which every organization must adapt [22]. According to Duncan [23: 314], the environmental factors "are taken

directly into consideration in the decision-making behavior of individuals in the organization." In addition, Duncan [23] indicated that environmental factors influencing individuals' decision making are present both within the boundaries of the organization (i.e., internal environmental factors, such as interpersonal relations of organization members and their interactions with each other) and outside the boundaries of the organization (i.e., external environmental factors, such as customer demands and competitive pressure). The external environment has long been acknowledged as an important contingency factor [e.g., 21, 24], as it influences organizational decisions and is a primary source of uncertainty for companies [16], given that it is not directly under their control. Environmental uncertainty is defined as a general lack of information in the decision-making process [16, 23]. The literature has argued that mass customization is a viable response to an external environment characterized, on the one hand, by strong competitive pressure and, on the other hand, by the increasingly changing and heterogeneous nature of customer demands [5]. However, there is little empirical work that has investigated this claim [16]. To fill this gap, and given that DPC is a fundamental strategic variable in pursuing mass customization, this study empirically investigates the link between three external environmental factors and the strategic choice on the DPC.

Pine [5] defined two main categories of environmental factors that determine market turbulence, which in turn would drive a company's transition from mass production to mass customization: structural factors and demand factors. The structural factors reflect the nature of the industry and, specifically, the competitive intensity faced by a company that operates in a given industry. The demand factors reflect the nature of customer demand and, more specifically, the degree of uncertainty that the company faces in the satisfaction of customer needs. Given that DPC is a key decision with regard to mass customization, the present article considers both structural and demand environmental factors. The structural factors are captured by competitive intensity and the demand factors are captured by the two dimensions of Duncan's [23] perceived environmental uncertainty (i.e., complexity and dynamism) that are been adapted to the case of uncertainty in customer demands (i.e., heterogeneity and dynamism of customer demands). It is worth noting that the three external environmental factors selected in the present study can also represent the three dimensions of Dess and Beard's [25] model (i.e., munificence, complexity, and dynamism). This model has been extensively adopted across many disciplines, including operations management [16]. Therefore, the three external environmental factors that are selected in the present study allow a parsimonious exploration of the dimensions of the three main external environmental factors.

2.2.1 Linking competitive intensity to DPC

Competitive intensity is defined as the level of competition a company faces within its primary industry [16, 26]. This factor has been identified as an important

driver of the decision to implement a mass-customization strategy since the introduction of the mass-customization concept in the literature [5, 27]. In a competitive scenario characterized by increasing global competition, the introduction of new technologies, the reduction of product life cycles, and the growing demand for greater product variety, companies can no longer compete on standardized products and services [15, 16]. This increasing competitive intensity has led to the need to pursue strategies focused on individual customer needs in many industries [7, 16]. Consequently, the following research hypothesis is proposed:

Hypothesis H1: The higher the competitive intensity, the higher the degree of product customization.

2.2.2 Linking demand heterogeneity to DPC

With regard to uncertainty in customer demand, it is worth noting that the uncertainty of the environment has two fundamental dimensions: the complexity of the environment and the dynamism of the environment [23]. Environmental complexity is defined by Duncan [23] as the number of environmental factors to consider in the decision-making process. The more complex the environment, the higher the number of factors to consider and, consequently, the greater the uncertainty perceived by the decision maker. An important driver of the complexity of the environment in which a company operates is the heterogeneity of the customer demands served by that company, namely the extent to which the demands of its customers are differentiated. A higher level of heterogeneity in customer demands means a higher variety of customer wants and needs. Therefore, companies are increasingly pushed to segment the market into small groups, to the extreme of having a market of one, which is the aim of mass customization. It follows that the heterogeneity of customer demands can only be met by providing a greater degree of product customization [5]. Consequently, the following research hypothesis is suggested:

Hypothesis H2: The higher the heterogeneity of customer demands, the higher the degree of product customization.

2.2.3 Linking demand dynamism to DPC

According to Duncan [23], the second dimension of environmental uncertainty is the dynamism of the environment, defined as the rate of change of the factors to be considered in decision making. The more dynamic the environment [16], the more quickly and unpredictably a greater number of factors change [25] and, consequently, the greater the uncertainty perceived by the decision maker. An important driver of the dynamism of the environment in which a company operates is the dynamism of the customer demands served by that company, defined as the rate of change in demand [16, 28]. When the demand is stable over time, a company is able to predict customer demands, and its product offerings will be able to meet customer needs without having to design tailor-made products [16, 29]. On the other hand, when customer needs and wants change quickly and constantly, the demand

forecast, for example in terms of sales variety and volume, becomes an increasingly harder and sometimes unmanageable task. As a consequence, companies are forced to increase the degree of product customization to meet unforeseen demands from customers and, therefore, to design and manufacture new products not yet incorporated into the solution space of the company. Accordingly, the following research hypothesis is proposed:

Hypothesis H3: The higher the dynamism of the customer demands, the higher the degree of product customization.

2.3 Control variables

The fact that some companies serve an industrial market, rather than end consumers, was included as a control variable in the model that was empirically tested. Supplying an industrial market is shown in the literature as a factor that pushes a higher degree of product customization [30]. Effectively, companies that respond to the market with an engineer-to-order (ETO) mode, thus offering a very high degree of customization, are typically companies that serve industrial customers that make complex and highly engineered products [31] and provide capital goods such as those in the machinery and equipment industries [32].

With the discussion of a control variable included in this study, the presentation of the research framework is complete. The proposed model, linking the competitive intensity, the heterogeneity of customer demands, the dynamism of customer demands, and the DPC is graphically depicted in Figure 1.

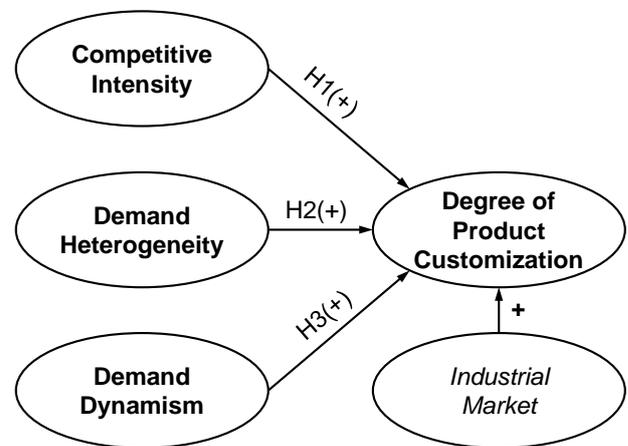


Figure 1. Conceptual model that links three external environmental factors to the degree of product customization, controlling for the industrial market

3. METHOD

3.1 Data description

The empirical test of the conceptual model is performed on data taken from the third round of the High Performance Manufacturing (HPM) project, a large-scale survey aimed to investigate manufacturing practices, processes, and performance [33]. Twelve different questionnaires were developed by HPM researchers,

which were directed to as many different respondent categories. By dividing the survey items between the twelve questionnaires, information was obtained from the respondents who were most knowledgeable. The use of multiple respondents permitted an investigation of different aspects of the operations of the companies involved in the study. In addition, the use of multiple respondents and multiple items enhances the reliability and validity of the perceptual measures [34]. The respondent categories included production workers, supervisors, and various managers, such as the production control manager, the human resources manager, and the plant manager.

To maximize the response rate, HPM researchers first solicited participation from manufacturing plants and then sent the questionnaires to those plants that had agreed to participate. In return for participation, each plant received a detailed report comparing its manufacturing operations profile to those of other plants in its industry. With this approach, the response rate was approximately 65% in each country, thus reducing the need to check for non-response bias [4, 35]. Additional details of the data collection procedures can be found in Schroeder and Flynn [33].

Table 1. Sample profile of industries and countries included in the study

COUNTRY	INDUSTRY ^a			Total
	E	M	A	
Austria	9	5	2	16
Finland	13	4	10	27
Germany	7	9	16	32
Italy	10	10	7	27
Japan	9	11	6	26
South Korea	6	8	8	22
Sweden	7	8	7	22
USA	8	8	7	23
Total	69	63	63	195

^aE = Electronics, M = Machinery, A = Auto suppliers

Because there were missing responses to the survey items necessary to determine the DPC, which were missing completely at random according to Little's test, 43 plants were removed from this study. The sample used in this study consists of 195 plants from three industries (machinery, electronics, and automotive suppliers) and eight countries (USA, Japan, South Korea, Austria, Finland, Germany, Italy, and Sweden). The sample profile is reported in Table 1.

3.2 Measures

The external environmental drivers were measured through reflective scales with one or more items. For each item, respondents indicated the extent to which they agreed or disagreed with the corresponding statement on

a seven-point Likert scale anchored at the extremes of "strongly disagree" (1) and "strongly agree" (7). Two items reflecting the competitive pressure in the company's industry measured the competitive intensity scale (Competitive Intensity). A single reverse-coded item that captures the homogeneity of customer needs measured the heterogeneity of customer demands (Demand Heterogeneity). Two items measured the dynamism of customer demands (Demand Dynamism) covering, on one hand, the fact that the needs and demands of customers change very quickly and, on the other hand, the fact that product demand is unstable and unpredictable. Finally, the DPC was measured by an objective measure adapted from Liu et al.'s [12] measure of "degree of make-to-order" and defined by equation (1). The DPC measure captures Lampel and Mintzberg's [9] conceptualization of a continuum of strategies, ranging from zero (no customization) to one (pure customization). The DPC is measured as the weighted average of the percentages of customer orders that, at a given plant, fall into the following five strategies: customized design (CDE%), customized fabrication (CF%), customized assembly (CA%), customized distribution (CDI%), and no customization (NC%). The four activities in the value chain where initial customer involvement can take place are weighted, from zero to four, according to their position in the value chain (i.e., distribution, assembly, fabrication, and design), where zero is no product customization and four is customized design.

$$DPC = \frac{CDE\% \times 4 + CF\% \times 3 + CA\% \times 2 + CDI\% \times 1 + NC\% \times 0}{400} \quad (1)$$

Finally, supplying industrial customers (Industrial Market) was measured using a dummy variable equal to one if the company provides its products to the industrial market (see Table 2).

4. RESULTS

The statistical method used to perform the data analysis for this study was partial least squares structural equation modeling (PLS-SEM) [36]. The main reason for using PLS-SEM rather than covariance-based structural equation modeling (CB-SEM) (such as LISREL) is that the estimation of CB-SEM may include some identification criticalities in the measurement model. The minimum condition of identifiability in a CB-SEM measurement model is that the number of non-redundant elements in the covariance matrix of the variables is greater than or equal to the number of parameters to be estimated [37]. In the model analyzed in this study, there are variables modeled by a single item. This fact violates the minimum condition of identifiability and it is necessary to arbitrarily constrain some parameters; in the specific case, to arbitrarily constrain the measurement error variance of the non-objective variable measured by a single item. Since the PLS-SEM technique is free from identification constraints, it is possible to estimate causal models without the constraints that the CB-SEM involves [38]. Therefore, to overcome the identification problems that would occur in the case of CB-SEM, PLS-SEM was used

in the data analysis, which is also advantageous with respect to the multiple regression because it is able to estimate models containing latent constructs reflected and/or formed by multi-item scales [36, 38]. SmartPLS 2.0.M3 was used to evaluate the measurement model and the structural model. A bootstrapping estimation procedure, in which 500 random observation samples were generated from the original data set, was used to analyze the significance of the scale factor loading in the measurement model and the significance of the path coefficients in the structural model [38]. Before analyzing the data with PLS-SEM, all the variables were standardized across countries and industries in order to rule out their potential effects, in line with several previous studies [e.g., 19, 39, 40-42].

4.1 Measurement model

The PLS-SEM assessment initially focused on the evaluation of the properties of the measurement model such as reliability, unidimensionality, convergent validity, and discriminant validity [43].

Table 2. Measurement items and PLS-SEM results for the measurement model

Measurement item	Std factor loading
Competitive intensity (PE, PM, PS)* CR = 0.86, AVE = 0.75	
CI1: We are in a highly competitive industry	0.72
CI2: Our competitive pressures are extremely high	1.00
Demand Heterogeneity (PD, PE, PS)*	
DH1: All of our customers desire essentially the same products (reversed coded)	1.00
Demand Dynamism (PD, PE, PS)* CR = 0.70, AVE = 0.57	
DD1: The needs and wants of our customers are changing very fast	0.45
DD2: The demand for our plant's products is unstable and unpredictable	0.97
Degree of Product Customization (PE)*	
DPC1: See equation (1)	1.00
Industrial Market (PD)*	
IM1: Industrial market	1.00

** Respondent codes (PD: member of product development team; PE: process engineer; PM: plant manager; PS: plant superintendent)*

The reliability of the scales was assessed in terms of the composite reliability (CR) [43]. The composite reliability values of the multi-item scales of the measurement model are 0.86 and 0.70, which are equal and higher than the recommended threshold of 0.70 [44], respectively, demonstrating adequate reliability of the measurement scales.

The unidimensionality and convergent validity of the multi-item scales were evaluated in terms of average variance extracted (AVE) [43]. The AVE values of the multi-item scales of the measurement model are 0.75 and 0.57, both of which are above the recommended threshold of 0.50, which demonstrates adequate convergent validity. Moreover, all the factor loading of these scales are significant and greater than 0.5, with the exception of an item of the construct Demand Dynamism that is slightly below this threshold, again confirming adequate unidimensionality and convergent validity [37, 38, 45].

Discriminant validity of the scales was assessed by comparing the square root of the AVE of each construct with the correlations between the focal construct and every other construct. Discriminant validity is indicated when the square root of the AVE of one construct is greater than the correlation between that construct and the other constructs [43]. Table 3 shows the correlations between the constructs and the square roots of the AVEs. The comparison between the square roots of the AVEs, shown on the diagonal of the matrix, and the inter-correlations between this construct and the others, shown off the diagonal of the matrix, suggests discriminant validity for each construct.

Table 3. Inter-construct correlations and discriminant validity

	Correlations (PLS-SEM results)				
	1	2	3	4	5
1 - Competitive Intensity	0.87				
2 - Demand Heterogeneity	0.02	1			
3 - Demand Dynamism	0.19	0.06	0.75		
4 - DPC	0.03	-0.02	0.20	1	
5 - Industrial Market	-0.06	0.00	-0.02	0.12	1

Note: The square root of the average variance extracted (AVE) is shown on the diagonal of the matrix in bold; the inter-construct correlation is shown off the diagonal.

4.2 Structural model

The first step in the assessment of the structural model is the examination for collinearity. Potential multicollinearity effects were examined with collinearity diagnostics for each predictor construct. The values of tolerance are all above 0.9 and variance inflation factors

(VIFs) are all around one, thus ruling out multi-collinearity problems. The next step of the structural model assessment is the assessment of the structural model path coefficients. The path coefficients of the structural model and their statistical significance are reported in Table 4.

Table 4. PLS-SEM structural model path coefficient estimates

Path	Path coefficient ^a
Competitive Intensity -> DPC	-0.003 NS
Demand Heterogeneity -> DPC	-0.033 NS
Demand Dynamism -> DPC	0.209 ***
Industrial Market -> DPC	0.127 *

^aLevels of significance (NS: not significant at $p < 0.10$; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$)

As shown by the path coefficients (Table 4 and Figure 2), the impact of the dynamism in customer demands on DPC is positive and statistically significant ($b = 0.209, p < 0.01$). On the other hand, the impact of the competitive intensity and the heterogeneity of customer demands on DPC is not statistically significant.

As regards the impact of the control variable on DPC, companies that serve industrial customers provide a higher DPC ($b = 0.127, p < 0.10$).

The predictive power of the structural model was assessed by the coefficient of determination (R^2), and the model explains 6% of the variance (R^2) of DPC. In addition, the predictive relevance was evaluated by the Stone-Geisser's Q^2 for the dependent variable DPC. The Q^2 of DPC was greater than zero, therefore the model has predictive relevance.

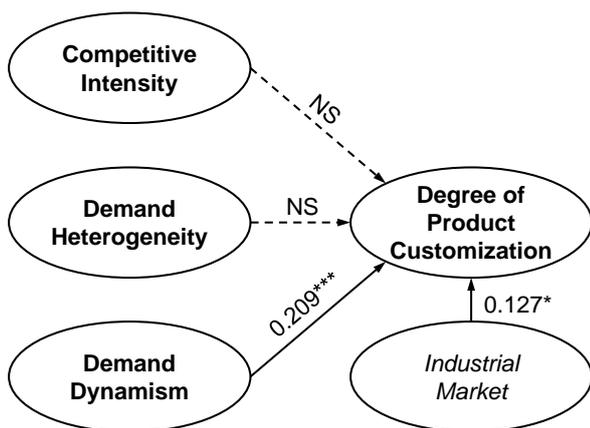


Figure 2. PLS-SEM structural model

The results of the present analysis show that the dynamism of customer demands is a crucial external environmental factor in the adoption of a higher DPC, which supports only hypothesis H3. The results do not provide empirical support for hypotheses H1 and H2,

since no significant path coefficients exist between competitive intensity and DPC, and between heterogeneity of customer demands and DPC.

5. DISCUSSION AND CONCLUSION

The DPC that a firm provides to its customers is widely recognized as a key strategic decision in the context of mass customization [e.g., 7, 8]. However, previous studies on the effect of external environmental factors on the decision to pursue mass customization have not empirically investigated the link between the external environment and decisions regarding the DPC a firm provides to its customers [5, 16]. To narrow this gap, the present paper developed and empirically tested hypotheses on the impact of three external environmental variables (competitive intensity, demand heterogeneity and demand dynamism) on the DPC to be provided to customers, using an international sample of 195 manufacturing plants from three industries.

The analysis results presented in the previous section empirically support only the hypothesis that the dynamism of customer demands is an environmental factor that determines an increase in DPC (H3). When a company faces extremely changeable, unstable, and unpredictable customer demand, characterized by increasing requests for new and differentiated products, the company is forced to wait for the customer's order before beginning the design of the product. In such a context, the accuracy of demand forecasting tends to deteriorate heavily, resulting in poor performances such as higher inventory costs, stock-outs, and lower customer satisfaction. As a consequence, a very dynamic demand does not allow the company to design all the possible variants of the product that the customer may require in advance. On the other hand, the analysis conducted in this study does not support the hypothesis that competitive intensity (H1) and demand heterogeneity (H2) drive an increase in DPC. Indeed, in a highly competitive market or in a market characterized by heterogeneous demands that is stable over time, customer demands can be forecasted and can be fulfilled by offering high product variety in products designed entirely in advance.

The results of the present paper are not necessarily in contrast with the claim that mass customization is a suitable answer to a highly competitive environment [15, 16] with very heterogeneous and hard-to-predict customer demands [17, 18]. This paper suggests that providing a higher DPC is a suitable answer for companies that have to cope with increasing dynamism in customer demands. On the other hand, companies that face high competitive intensity or a heterogeneous customer demand will more likely embrace mass customization without the need to provide a high DPC, for example, without allowing customer involvement in the fabrication or design phase.

From a managerial standpoint, the present paper demonstrates that the external environment should be carefully considered when the decision on the point of initial customer involvement along the company's value chain is made. The results of the paper also suggest that high product customization is a suitable answer

only when customers are asking for this type of customization, as in the case of dynamic customer demands. If the firm does not face a highly dynamic customer demand but provides a very high DPC, the firm should consider the possibility of reducing the DPC it provides to its customers. Future research could explore methods and solutions for assessing the dynamics of customer demand and reducing the DPC in cases where it was excessive compared to the dynamism of customer demands.

While contributing to both the academic literature and managerial practice, this study is not without limitations, which could be addressed in future research. The first limitation is related to the cross-sectional nature of the data set used in this study, which limits the ability to explore the causal relationship between external environmental drivers and DPC. Therefore, a future research opportunity is to design a longitudinal study to assess these causal relationships over time. A second limitation of this study is derived from the use of secondary data to measure the constructs of interest. Therefore, future research should design an ad-hoc questionnaire for investigating the relationship between the environmental drivers and DPC, thus allowing the use of more articulated scales, and should include a greater number of items for measuring the constructs of competitive intensity, demand heterogeneity, and demand dynamism.

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Empirijska studija uticaja faktora okruženja na stepen kastomizacije proizvoda

Enrico Sandrin

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Apstrakt

Uticaj faktora iz okruženja ima veoma važnu ulogu u donošenju strateških odluka kompanija, koje sa druge strane utiču na izbor organizacionog modela. Ključnu stratešku odluku u kontekstu kastomizovane industrijske proizvodnje predstavlja stepen kastomizacije proizvoda koji kompanija omogućava svojim potrošačima. Međutim, uticaj faktora okruženja na stepen kastomizacije proizvoda prema individualnim zahtevima potrošača tek treba da se istraži empirijski. Kako bi se smanjio ovaj istraživački jaz, u ovom radu je ispitan empirijski uticaj tri faktora okruženja na stepen kastomizacije proizvoda: intenzitet konkurentnosti, heterogenost zahteva potrošača i dinamika zahteva potrošača. Korišćeni su podaci prikupljeni iz upitnika sprovedenog u 195 proizvodnih sistema iz tri različite industrije i osam zemalja. Od tri ispitivana faktora, utvrđeno je da dinamika zahteva potrošača predstavlja ključni faktor koji podstiče kompanije da omoguće veći stepen kastomizacije proizvoda svojim potrošačima.

Ključne reči: Kastomizovana industrijska proizvodnja, stepen kastomizacije proizvoda, faktori okruženja, anketa