# Defining Product Customization as Form Postponement

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2010-18

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Discussion Paper Series

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## 1. Introduction

Over the past couple of decades, customization based on computer-aided manufacturing has become increasingly important in various industries (Kotha 1995; Lampel and Mintzberg 1996; Feitzinger and Lee 1997; Gilmore and Pine II 1997). This study is intended to explain the relatively recent development of customization, by referring to the postponement-speculation model. There is a great variety of approaches to this model and this paper, in analyzing the subject of customization, focuses on a modified version of Bucklin's postponement-speculation model in relation to inventory management (Bucklin 1965; Bucklin 1966).

The production system that provides a quick and flexible response to customer orders (in terms of customization) is a significant process innovation in the recent development of supply chain management. This system enables companies to reduce inventory costs, thereby reducing the level of risk in their production and distribution operations. The structure can also facilitate competitive advantage, in the form of quick responses to individual customer orders and the generation of higher added value.

However, customization has long been a part of how many industries operate and is not a particularly new concept. For example, buildings are constructed according to an individual specification, and it has been widely known for some time in the construction industry that a quick and flexible response to customer orders is essential for boosting competitive advantage.

In response to the argument that customization is nothing new, it is important to point out that customization in recent years has been characterized by its emphasis on reducing inventory costs and risks and in creating higher added value, even in industries in which the conventional methods of make-to-forecast and mass production have traditionally been employed. In addition, customization in recent years has been characterized by its use of computers in the information processing of orders. These new methods have made it possible to employ customization in industries in which it was previously quite difficult due to cost constraints. Furthermore, large-scale customization using information technology - specifically termed "mass customization" – is a production system that has been shown in many studies to facilitate competitive advantage (Davis and Sasser 1995; Robinson and Elofson 2001).

Additionally, many studies associate mass customization with the postponement strategy of putting off product completion until customer orders are determined (Brown, Lee and Petrakian 2000; van Hoek 2001). However, a firm consensus has not been reached as to how to conceptualize customization as postponement or how to handle it in accordance with the postponement-speculation model. Overcoming the diversity of customization and devising a comprehensive method for explaining this as postponement is still elusive.

Based on a clear recognition of these issues, this study focuses on conceptualizing and dealing with customization as postponement and explains a comprehensive methodology for approaching customization on the basis of Bucklin's postponement-speculation model (Bucklin 1966). By noting these points, the paper also approaches the subject of mass customization using information technology, from the perspective of costs and the business environment and looks at how this improves competitive advantage.

## 2. Conceptual Development of Postponement-Speculation

According to the postponement-speculation model, customization is the process of postponing the determination of final form in production until customer orders are received. By this line of reasoning, customization is therefore a kind of postponement.

Alderson (1950, 1957) referred to postponement as the activity of leaving changes to forms and locations of inventory as late as possible and was the first to show cost-effectiveness through postponement. He presented two reasons for this cost-effectiveness. First, as the form of a product becomes relatively less differentiated, it facilitates distribution of a larger lot size with fewer kinds of products, which leads to more efficient distribution. Second, it is less risky to determine specific forms and create inventories that are more likely to satisfy customer needs, once there is more certainty about what these needs are. In the meantime, Bucklin (1966) defined speculation as creating inventory as early as possible. He explained that postponement involves a certain level of optimization due to the efficiency of speculation and incorporated this into the postponement-speculation model. In this phase, Bucklin’s model focused only on the determination of inventories with regard to the forms and inventories of Alderson’s approach. In addition, according to the model, there was a certain point of equilibrium in the balance between postponement and speculation, in terms of optimizing the cost of distribution. This constituted a model that showed only the most properly optimized macro-distribution structure under competitive conditions; it was not a model that explained competitive advantage.

Following the publication of these studies, there were no notable developments in this field of study for some time. However, in the late 1980s some researchers began to conduct studies about supply chain management, using the postponement-speculation model, which led to a re-evaluation of the concept (Zinn and Bowersox, 1988).

These later studies are characterized by the following two factors: first, the focus was not on postponement as the change of the equilibrium point in distribution costs, as Bucklin (1966) had pointed out, but on postponement as a strategy for creating competitive advantage based on postponed production and distribution systems relative to those used by competitors. This stance focused attention on the improvement of systems within individual companies, not on a change in the entire distribution system. Additionally, recent studies have shown that not every company reaches the optimal level of postponement-speculation through competition; in fact, there are differences among companies in their ability to move to an optimum level, such that only certain companies end up gaining competitive advantage through postponement.

Secondly, attention focused not only on Bucklin's model of the postponement of inventory determination but also on customization and make-to-order as postulated by Alderson (1957). However, this caused the primary focus to be drawn away from Bucklin's approach of considering the optimal degree of postponement from the one-dimensional perspective of delivery time, and moved towards a more complex and diverse perspective. In this context, discussion emphasized the qualitative differences involved in postponement and their patterns (Ernst and Kamrad 2000; Yang, Burns and

Backhouse 2004; Boone, Craighead and Hanna 2007), rather than the best optimization level of postponement-speculation.

Zinn and Bowersox (1988) classified postponement into five categories: labeling, packaging, assembly, manufacturing and time. Other than the time category, these are all examples of form postponement, where the form of different products can be based on customer orders. Van Hoek (1997) largely grouped form postponement into either assembly postponement, involving products with different formulation and peripherals, or labeling/packaging postponement, involving products with standard formulation but different peripherals.

In addition, Pagh and Cooper (1998) focused on form postponement from the perspective of make-to-order and considered direct distribution also to be a form of logistics postponement. Based on these combinations of postponement, they presented the following four patterns of postponement strategy: the full speculation strategy; the logistics postponement strategy; the manufacturing postponement strategy; and the full postponement strategy.

Meanwhile, Waller, Dabholkar and Gentry (2000) differentiated customization and make-to-order; that is, they focused on the strategy of not making products until customer orders were received as an example of make-to-order without customization. They regarded make-to-order in itself as an object of postponement, and looked at customization as a separate factor that further affected costs, both as the result of the costs of storing inventory and as the result of delivery lead times that changed along with the postponement.

These arguments about diverse types of postponement raise two separate points.

The first is whether it is possible to consider various activities, such as labeling, packaging, assembly and manufacturing, as differences in the *degree* of postponement in addition to being distinct *types* of postponement; for example, whether it is possible to express the postponement of packaging as representing a greater degree of postponement than the postponement of labeling.

The second point is how to approach the difference between customization and make-to-order. Make-to-order, as a system, can exist with or without customization. Customization involves postponing the decision about what form the final product will take, while make-to-order *without* customization is simply postponement of the creation of certain products on the assembly line. These two patterns have different meanings as far as postponement is concerned. They should be regarded not as a one-dimensional form of postponement but as two separate aspects of postponement in their own right.

As a means of addressing these differences in the qualitative diversity of postponement, this study takes the perspective of quantitative, not qualitative, measurement of postponement to explain customization as postponement. Based on this approach, this paper describes how decision-making about customization as a kind of postponement is undertaken. In observing decision-making based on the quantitative measurement of postponement levels, the study examines a modified version of Bucklin's postponement-speculation model, in relation to customization.

## 3. Characteristics of Bucklin-type Postponement-Speculation Model

Bucklin (1966) considered that speculative inventories increase the average inventory cost per unit of product, but that they also facilitate an overall cost reduction by shortening delivery times. By this line of reasoning, in assessing how much speculative inventory to hold, it is desirable to minimize the two costs that are affected by the level of speculative inventories. This leads to a rational evaluation of the entire cost of distribution involving manufacturers, distributors and consumers.

As noted above, Bucklin's postponement-speculation model leads to a degree of postponement that facilitates minimization of costs in the entire supply chain. The model is characterized by two cost curves that show contrasting changes according to the degree of postponement in relation to the overall cost.

The average inventory cost curve is premised on the positioning of the most ideal inventory sites and the choice of distribution structure. When the optimal degree of postponement is determined, the most suitable inventory locations and distribution structure are chosen. That is, the cost curve is based on centralized or decentralized inventories and direct or indirect distribution in logistics (Twede, Clarke and Tait 2000). By using this simulation, the cost curve that traces the lowest cost at a certain postponement level can be selected. In this way, with upstream postponement (defined as centralized inventories and direct distribution) and downstream postponement (defined as decentralized inventories and indirect distribution) as secondary points, the primary focus is placed on the determination of time postponement.

Bucklin's postponement-speculation model is limited to inventory postponement-speculation, but this study focuses on a modified version that can be applied to form postponement-speculation. This modified model takes the characteristics set out in the following paragraphs from Bucklin's original model.

First, the model expresses postponement-speculation by means of a one-dimensional variable and considers increasing the degree of postponement to be the same as lowering the degree of speculation; full speculation is defined as zero postponement (Waller, Dabholkar and Gentry 2000).

Second, the model is based on cost curves showing two different shapes according to different degrees of postponement. One of them is the cost curve concerning process efficiency and the other is the risk and uncertainty cost curve. As postponement levels rise, the former increases and the latter decreases.

Third, the minimal cost point is specified on the basis of the total of these costs and the optimum degree of postponement is determined at that point. That is, the postponement strategy is intended to facilitate postponement at the most suitable level rather than maximize postponement for its own sake. A company that has achieved the optimum level can enjoy competitive advantage until its competitors reach the same level.

Fourth, the model focuses on time postponement and is based on the premise that, with regard to upstream and downstream postponement, as defined above, the most rational choice is made to achieve a certain degree of time-postponement. That is, the optimal degree of time-postponement measured by certain criteria is based on the most rational inventory locations and distribution structures in logistics.

Some researchers have conducted studies on postponement strategies that combine both geographical dimensions and upstream/downstream dimensions in relation to form postponement such as customization (van Hoek 1999). For example, Feitzinger and Lee (1997) focused on Hewlett-Packard's printer manufacturing operations. As its chosen method of customization, the company conducted the final assembly process at its distribution centers in many parts of the world and distributed the products to customers from these centers. Feitzinger and Lee (1997) explain that the point of product differentiation was moved geographically closer to consumers, that is, postponed. However, Twede, Clarke and Tait (2000) approached decentralized inventories in terms of logistics speculation and regarded Hewlett-Packard's customization as a "postponement strategy" combining manufacturing postponement and logistics speculation.

In any example like this, the most important point of process innovation is the approach based on time postponement, which facilitates customization with a fast response to customer orders. The choice of centralized or decentralized methods of conducting the final assembly process is directly related to the process innovation that has the lowest cost. In addition, the choice of direct distribution results from the necessity of directly negotiating with customers. In these senses, place postponement and upstream/downstream postponement, which involve the choice of centralized or decentralized inventories and direct or indirect distribution, are determined rationally on the premise of a certain level of time postponement (cf. Rabinovich and Evers 2003).

## 4. Customization as Form Postponement

### 4.1. The Difference between Make-to-order and Customization

In the postponement-speculation model, bringing forward activities to an earlier point is called speculation while delaying activities until a later point is called postponement. If this formula is applied to make-to-forecast, the method of starting production “earlier”, before customer orders are actually received, can be regarded as speculation and make-to-order, which is the pattern of starting production “later”, after customer orders are actually received, can be considered as postponement. By the same token, the pattern of determining product specifications and making standardized products “earlier”, before customer orders are actually received, is speculation; and the pattern of making customized products “later”, after customer orders are actually received, is postponement. That is, both make-to-order and customization can be looked upon as postponement.

To determine the point at which to start taking action for customer orders is to consider how to flexibly respond to the needs of individual customers. That is, make-to-order and customization can be defined as flexibly responding to the needs of individual customers when they are specified, by setting the determination of product forms at as late a point of time as possible.

However, it is necessary to note the difference between make-to-order and customization. With regard to product manufacturing, the two patterns of make-to-forecast and make-to-order exist on the basis of the relative positions of customer orders and the production initiation point. In addition, the pattern of make-to-order is categorized into make-to-order of standardized products and customization (make-to-order of customized products). Customization depends on the criteria for different product specifications for each customer order. The following two ways realize different product specifications for each customer order.

The first customization method is to assemble parts in the assembly line, in response to individual customer orders, on the basis of prior designs. Mass-customization means providing customized products for many customers on the basis of these efficient operations. The second method is to design specific products, one by one, in response to each customer order. This latter method can reflect customer needs even in the product development process, including the design operation, which enables the needs to be reflected throughout the entire production process. The former method, on the other hand, can reflect customer needs only in the final assembly process.

If these two patterns are integrated as postponement methods, the combination of make-to-order and customization can be categorized into the following three patterns: (1) make-to-forecast of standardized products; (2) make-to-order of standardized products; and (3) customization (make-to-order of customized products). An important point is how to set each postponement level for make-to-order and customization. For example, make-to-order of standardized products is postponement on the basis of production, but it is speculation on the basis of customization.

### 4.2. Continuous Measurement of Customization

The next focus is how to continuously measure customization as form postponement. The continuous scale of the length of delivery time was used in Bucklin’s postponement level of inventories, but customization cannot be represented in terms of length of time. This is because, in the process of customization, the point at which the form of a product is specified is determined by whether it is before or after customer orders are actually received and it has no relation to length of time. Therefore, in order to convert the time categories of 'before' and 'after' customer orders into continuous variables, levels of customization are measured by two scales: product ratios and process ratios.

Product ratios show the percentage of customized products over the entire product range. For instance, if customized products make up half of all customer orders and standard products constitute the remaining half, the product ratio of postponement is 50% (cf. Baligh and Richartz 1967).

Process ratios deal with production and procurement costs relating to individual customer orders as a proportion of the overall production and procurement costs. This means that the process ratio is the cost percentage associated with the customization process of a certain product, that is, the percentage of production, procurement and design costs that are affected by individual customer needs (cf. Yang and Burns 2003).

For example, if customer orders affect the entire process of product design, the choice of all parts and materials and the assembly line, the product will be completely customized and the process ratio of postponement is 100%. In contrast, if product design is undertaken before customer orders are placed and flexiblility in manufacturing, in response tocustomer orders, is limited to the final process, the process ratio of this product is comprised of the production cost of the final process as a proprotion of the overall production, procurement and design costs.

Therefore, the variety of postponement, such as labeling, packaging, assembly, and manufacturing, which Zinn and Bowersox(1988) presented, can be considered as differences in *degrees* of postponement, measured by process ratios, rather than *qualitative differences* of postponement. For the customization of packaging only, the

the packaging cost as a proportion of the overall cost determines its postponement level and this postponement level is smaller than that of the customization of the entire production process.

The choice of product ratios and process ratios as postponement levels depends on industrial competition characteristics and corporate strategies. For example, in a situation where there is a wide variety of customer needs, customization creates a substantial difference for competitive advantage and product ratios work well as a scale. On the other hand, process ratios are more effective where significant customization through production process innovation is required without undermining customer satisfaction.

## 5. Determination of the Optimal Degree of Postponement

### 5.1. Two Cost Curves

It is necessary to consider two cost curves to determine which is more accurate for measuring the optimal level of customization with regard to the Bucklin-type postponement-speculation model.

These curves are illustrated by the cost function of $C=f(p)$ with the postponement level $p$ set as an independent variable. The cost $C$, which is a dependent variable, considers not only manufacturers' costs but also the costs involved in the entire supply chain, including customers' procurement costs and suppliers' production costs. The optimal level of customization in the entire supply chain can be determined by the total of these costs.

To achieve optimization throughout the entire supply chain, manufacturers do not always need to control the activities of customers and suppliers, and the best conditions can be obtained by competition. That is, the model is based on the assumption that each company in the supply chain controls its own activity to form a more efficient system.

The Bucklin-type postponement-speculation model distinguishes between two contrasting costs according to the degree of postponement. His model of inventories involves the cost of moving goods to the buyer and the cost incurred by the buyer in holding an inventory (Stern and El-ansary, 1988). However, the model of customization involves the processing cost of production tasks (production costs) and the costs concerning demand uncertainty (uncertainty costs). That is, production costs and uncertainty costs are devised as primary costs that change along with the postponement level, and other cost conditions are determined independently from the postponement level. Evaluating the sum of these two costs makes it possible to obtain the postponement level with the lowest average cost.

Based on these premises, the following section examines the form of two cost curves that illustrate the changes in those costs according to the postponement level of product ratios and process ratios.

## 5.2. Cost Curves Concerning the Product Ratios of Customization

### 5.2.1 Production Costs

With regard to the relationship between product ratios of customization and production costs, the higher the ratios are, the more production costs will increase. Two factors can affect this mechanism. The first is the inevitable effect of make-to-order on customization. In make-to-order, its difficulty in predicting customer orders is likely to raise the production cost. When a large number of orders are concentrated on a particular period of time, manufacturers are required to have proper production capability for handling the bulk of these orders. In contrast, when there are only a small number of orders, they have much surplus capacity for production. By this line of reasoning, the higher product ratios become, the more difficult it is to produce goods in line with production plans, which leads to higher production costs.

The other factor is the effect of lower production efficiency due to the stream of diverse products in the assembly line of customization. Customization is the method of flexible response to individual customer orders of various product specifications. This undermines the economy of scale in the production operation and requires a higher level of production costs.

Furthermore, it is expected that the higher product ratios become, the higher the increase rate of production costs will become. This is because the greater diversity of products made to order in the assembly line requires a higher level of expertise in production capability. In addition, the process of customization after receiving customer orders requires a lot of time. In general, in situations in which customers are less tolerant of having to wait longer to receive their product, manufacturers face strong time pressures and are obliged to employ quicker production methods, which escalates costs (Zinn and Bowersox 1988). In particular, in industries where a huge number of orders concentrate on a particular period of time, manufacturers are more likely to reach the limit of their production capability, which causes a sharp increase in production costs. As a result, generally speaking, the production cost curve, which depicts the rate of increase in production costs in relation to the product ratios of customization, is likely to show a rising, concave-up shape.

### 5.2.2 Uncertainty Costs

Uncertainty costs are intended to deal with the uncertainty of customer demand in the case of standardized products that do not involve customization. In this scenario, manufacturers are burdened with the costs and risks of diverse inventories resulting from a great variety of customer orders, as well as with costs associated with predicting demand for customer orders (Yang, Burns and Backhouse 2004). In addition, the uncertainty cost on the part of customers includes opportunity cost due to the supplier's failure to provide goods that meet their needs, as well as other costs for additional processing by the customers.

Uncertainty costs usually emerge in relation to the production of standardized products, as opposed to where full customization is employed, as customization provides products in response to individual customer orders. As the product ratios of standardized goods increase and the product ratios of customization decrease, uncertainty costs increase.

Additionally, if the product ratios of standardized goods are higher, it is rational to standardize orders with easier predictability, lower inventory risks and lower demand prediction costs. For example, if steady receipt of orders from customers with similar preferences is expected, the strategy of preparing inventories by manufacturing standardized goods is more likely to be used (Rabinovich and Evers 2003).

In this way, if things start off with a 100% product ratio of customization and the product ratios of standardized goods are subsequently raised, the next step is to move on to orders with difficult predictability. This means that, as the product ratios of customization decrease, uncertainty costs rise increasingly. Therefore, uncertainty costs will depict a decreasing concave-up curve.

**5.2.3 Total Cost**

Supposing these above-mentioned conditions are in place with respect to production costs and uncertainty costs, then two cost curves can be depicted and concave-up cost curves can also be obtained with regard to the shape of cost curves based on the total of these two costs, as illustrated in Figure 1.

The lowest point *E* of the total cost curves shows the postponement level *X* that can be the most cost-saving, and setting the product ratios of customization at that level is likely to be the most efficient and competitive. That is, if a company's product ratios of customization are higher or lower than this optimization level, they will be shouldered with higher costs, which will affect their competitiveness. As a result, the company will adjust its operation to the optimized level.

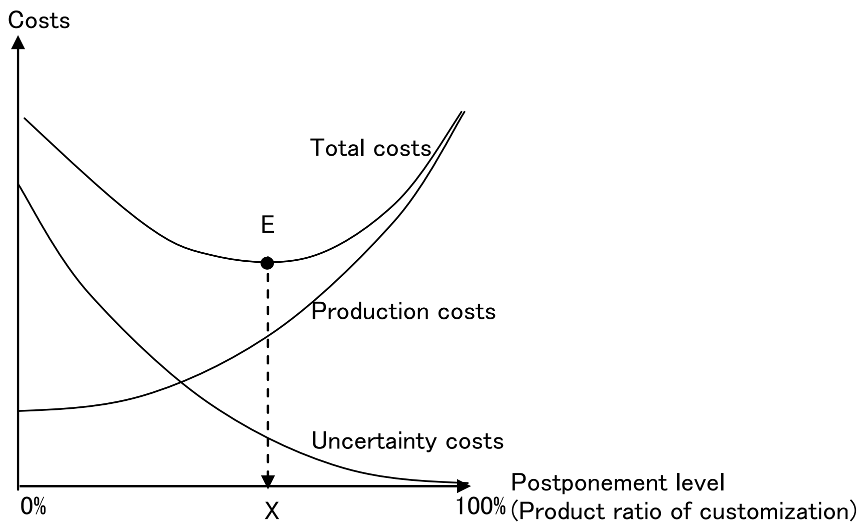


Figure 1. Optimal postponement level of customization

As noted above, the total cost curve concerning the product ratios of customization has a concave-up shape. However, if the change in either product costs or uncertainty costs greatly affects the change in the total cost, the total cost curve may show as either increasing or decreasing. This means that the product ratio of customization can be 0% (100% standardized products) or 100% (100% customized products), though this is less likely to occur in the postponement-speculation of inventories.

In fact, there are industries whose products are all standardized or customized. In the case of industries whose products are all standardized, the production costs for customization increase more and the effect of reductions in uncertainty costs through customization is smaller (Figure 2). Conversely, with regard to industries whose products are all customized, uncertainty cost increases matter even more than do production cost reductions through standardization.

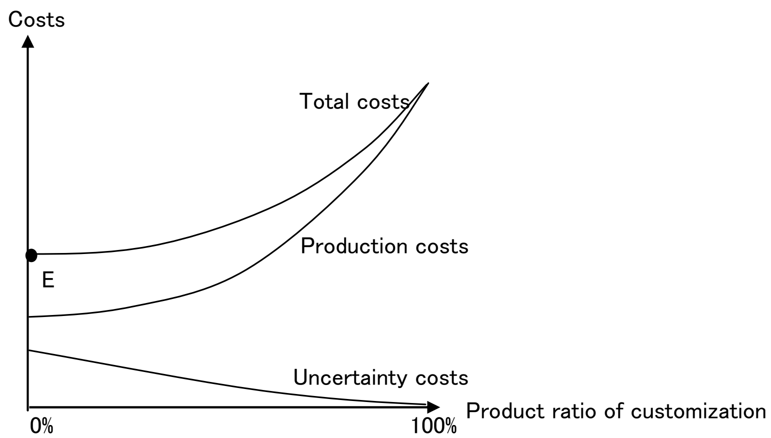


Figure 2. An example of 100% standardized products

5.3. Cost Curves Concerning the Process Ratios of Customization

### 5.3.1 Production Cost

Product ratios have been focused on so far, but this section looks at customization as form postponement from the perspective of process ratios. Just as in the case of product ratios, production costs and uncertainty costs can also be used for the examination of process ratios.

The cost of production increases as process ratios become higher, that is, as the percentage of customization increases. The main reason for this is that the manufacturing of customized products is more complex and planned mass production is therefore more difficult.

In addition, if the process ratio of customization is raised, the operation usually starts with processes in which customized production and procurement are technically easier. At the same time, the higher the process ratios of customization are (as production processes *after* receipt of customer orders increase), the greater the time pressures are , when customers are less tolerant of delays.

Therefore, since the rate of increase of production costs gradually becomes higher, the production cost curve is likely to show an increasing and concave-up shape in terms of process ratios.

### 5.3.2 Uncertainty Cost

The uncertainty cost increases as customized process ratios become lower because inventory risks and demand prediction costs increase when a make-to-forecast approach is adopted before customer orders have been received. Additionally, standardized production and procurement is likely to be undertaken when the risks associated with potential prediction failure are smaller. For instance, standardization is likely to be appropriate where production and procurement in advance can be transferred to other products or where work-in-process inventory costs are smaller. Therefore, the uncertainty cost curve is likely to show a decreasing concave-up shape in terms of process ratios.

### 5.3.3 Total Cost

In general, the two curves concerning production and uncertainty costs in relation to process ratios depict a similar shape to those seen in relation to product ratios, and obtaining the total cost curve leads to the process ratio at which the total production costs and uncertainty costs are lowest.

This suggests that it is possible to determine the degree to which the production process should be customized in terms of process ratios, with the intent of creating the most efficient system on the basis of conditions concerning production technology and customer demand.

Furthermore, all materials are seldom customized and 100% customization in terms of process ratios is relatively rare. However, products that are 100% standardized; that is, products with 0% customization, just like popular commodity goods, are relatively common. In the case of completely standardized products, uncertainty cost reductions through customization become smaller. As a result, the total cost curve is concave-up and increasing, which means that the total cost is lowest in the case of customization with a 0% process ratio.

## 6. Customization Based on Information Technology

In essence, the Bucklin-type postponement-speculation model is intended to show the competitive equilibrium point. However, the modified model set out in this paper explains the creation of competitive advantage based on process innovation. More specifically, it means that, by making changes to production costs through process innovation in a certain industry, total costs can be reduced and, at the same time, the point at which these total costs are lowest will move in relation to the degree of postponement. Through this reduction, particular companies can enjoy competitive advantage over other companies using existing systems, until competitors reach their level.

For example, one of the factors that affects the introduction of customization in various industries is the use of information technology in production systems. This phenomenon is explained by the Bucklin-type postponement-speculation model in the following section.

The development of information technology facilitates the sending of orders processed by computer to an automated production line, which assembles parts according to the information contained in the order. In addition, this technology can also be used to process information about the procurement of parts. It facilitates a quick and efficient make-to-order system, with minimum inventories of parts, through the sharing of information concerning production and inventories with suppliers. This information-technology-based innovation in production systems boosts operational capability on the production line of both manufacturers and parts suppliers, which in turn controls the rising slope of the production cost curve. For example, if the production costs of customization are lowered by a certain ratio, the reduction effect of computer-aided information processing increases as the product and process ratios of customization increase. Additionally, economies of scale work well for information systems and, as the product and process ratios of customization increase, greater cost reduction is likely, compared with conventional methods.

As Figure 3 illustrates, the optimal postponement level transfers to postponement along with the change in the production cost curve, through the introduction of computer-aided production systems. By this line of reasoning, the ratio of customized products is raised in terms of product ratios; and the ratios of production and procurement in response to customer orders increase in terms of process ratios, leading to more customized product specifications.

In addition, the introduction of computer-aided production systems facilitates the lowering of costs in relation to the optimal degree of postponement, as well as facilitating the postponement of customization itself. These process innovations are expected to take place in many industries. However, a great variety of know-how is necessary for the introduction and efficient operation of an innovative system and companies that are first to launch these new systems are likely to enjoy the benefits of efficient customization compared with their competitors (Lee 1998; van Hoek, Vos and Commandeur 1999; Yang and Burns 2003). Large-scale customization based on cost advantage constitutes the core essence of mass-customization.

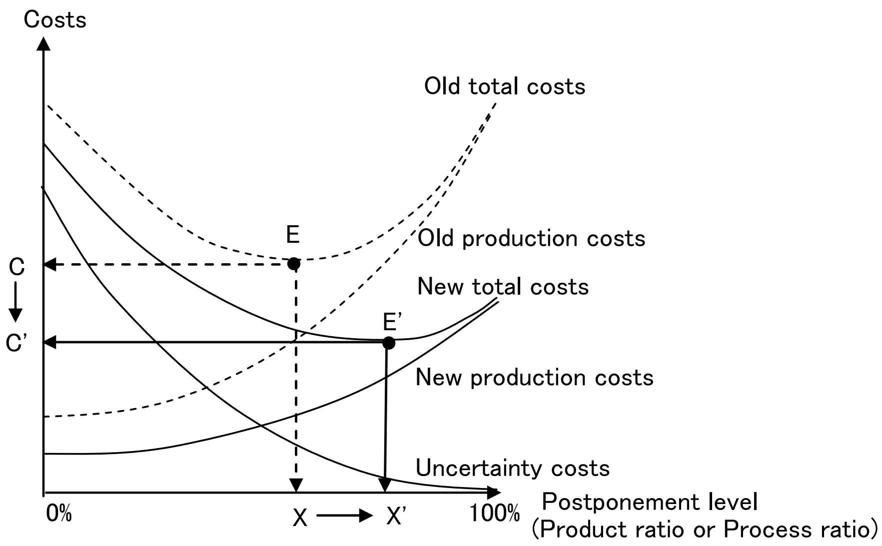


Figure 3. Impact of information technology on form postponement

Moreover, in a situation where customer demands in a certain market segment are becoming diversified, the uncertainty cost concerning these customers is different from that of other customers and a greater degree of postponement is likely to be the ideal. The customization strategy of targeting these customers will be effective.

In this way, the postponement-speculation model explains how particular companies can gain competitive advantage through customization in an industry in which the conventional pattern of make-to-forecast was predominant.

## 7. Conclusion

The preceding studies about postponement-speculation sought to explain the qualitative diversity of all forms of postponement, including physical distribution, by typological models. Several patterns of postponement strategies have been presented on the basis of those models.

However, a notable point about postponement strategy concerns not only the type of postponement, but also the degree of postponement that should be pursued under any given set of circumstances; that is, what the optimal degree of postponement is. To examine the latter subject, it is necessary to set a theoretical framework to consider the optimal degree of postponement in relation to individual forms of postponement, such as physical distribution, make-to-order of standardized products and customization.

Based on this critical thinking, this study focuses attention strongly on customization, regarding it as a postponement level and has examined the optimal level from the perspective of the Bucklin-type postponement-speculation model. This model is based on the assumption that the total cost to achieve a certain postponement level, measured by the scales of product ratios and process ratios, is the sum of all production costs and uncertainty costs. The paper has drawn a framework in which the optimal degree of postponement can be judged on the basis of those two costs.

This model shows how a company can achieve postponement and cost advantage by making changes to production costs through computer-aided innovations in the production system. In addition, the model is helpful in considering the targeting of postponement strategy, with a focus on different variables affecting uncertainty costs according to the customer segment in question. The model can also explain the differences in the diffusion of postponement strategy by industry, on the basis of two different cost conditions.

This study focuses on customization as form postponement, but the optimal level of "customization-free make-to-order" can also be explained by a similar model, when the interpretation of production and uncertainty costs is slightly modified. That is, it is possible to speculate on where the optimal level of product and process ratios of make-to-order is, on the basis of production and uncertainty costs. This subject of manufacturing standard products in response to customer orders is significant, especially when considering the issues of JIT (just-in-time) and QR (quick response) in the supply chain.

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