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Optimal Decisions of a Mass Customization Supply Chain under Customized Demand

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Abstract

We investigate a supply chain selling a mass customization (MC) product to the market. A decision model is built when the degree of customization, price and lead time of the MC product affect market demand. The optimal decisions of the MC supply chain are analyzed in non-cooperative decision-making and cooperative decision-making. Moreover, the sensitivity analysis of optimal customer order decoupling point (CODP) position is conducted. Our results show that compared with non-cooperative decision-making, the optimal CODP moves to a later position in cooperative decision-making. The relationships between the optimal CODP position and the price sensitivity coefficient are different in two different scenarios. The impact of the customization sensitivity coefficient on the optimal CODP position is opposite to the impact of the lead time sensitivity coefficient on the optimal CODP position. When the production cost coefficient or investment coefficient increases, the optimal CODP moves to an earlier position.

Keywords: Mass customization, MC supply chain, customer order decoupling point, customized demand.

1. Introduction

With the increasing diversity of customer demand, enterprises in different industries, such as fashion apparel, automobiles, and computer manufacturing carry out customized services to meet individualized requirements of customers. This makes the method of mass production gradually unable to adapt to customer demand. Enterprises are turning more to small batch production, or customized production. Mass Customization (MC) production has become a popular production method for enterprises in today's competitive market. For example, in automobiles, various brands such as Ford and BMW are implementing MC programs for customers to choose different colors as well as materials for interior design (see Choi et al. [2]).

In this study, we analytically explore the optimal decisions of an MC supply chain under customized demand. Thus, our research relates to studies on mass customization and CODP in supply chains.

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Pine and Davis [12] introduced the idea of mass customization (MC) that is the capability to provide customized products at a relatively low cost. Alford et al. [1] proposed that mass customization is a production mode that customizes any quantity of products for customers with the cost of mass production. MC is realized through the reorganization of product structure and manufacturing process, using modern information technology and flexible technology. Da Silveira et al. [3] and Hart [5] also suggested that mass customization is a production mode that customizes any quantity of products for customers based on the cost and speed of large-scale production, combined with the actual capabilities of enterprises.

With the advance of technologies, MC is a timely business practice (see Choi et al. [2], Heradio et al. [6] and Lai et al. [7]). The MC production mode is a combination of make-to-stock (MTS) and make-to-order (MTO). The boundary point for make-to-stock and make-to-order is called customer order decoupling point (CODP). In terms of the CODP, mass customization production can be divided into two kinds of production: mass production with a lower unit cost and customized production with a higher unit cost. The choice of CODP location is a key issue in mass customization production (see Liu et al. [11] and Zhou et al. [17]). Lee and Tang [8] analyzed the advantages and disadvantages of delaying the point of product differentiation. The CODP does not move the later the better. Garg and Tang [4] studied the problem of delays in multiple product differentiation points, and pointed out the conditions when one type of delayed differentiation is better than the other. Wang et al. [15] discussed the production scheduling system for multi-CODP in the context of mass customization.

Semini et al. [13] analyzed the ship design and construction industry from the perspective of the customer order decoupling point. They concluded that upstream CODP positions in the supply chain imply high levels of flexibility and customization, while downstream positions allow short lead times and lower prices. van Donk and van Doorne [14] explored the impact of the location of the CODP on supply chain integration. The results showed a clear relationship between supply chain integration and the location of the CODP. Zhou et al. [16] developed a two-stage tandem queuing network to derive the CODP position and base-stock level. Li et al. [9] explored the MC supply chain decisions with the consideration of the influences of return policy, product lead time and price on the demand. Liu et al. [10] introduced the concepts of mass customization and CODP into the field of logistics service to solve the problem of CODP.

The above studies have examined the influences of product price and lead time on market demand (see Li et al. [9] and Zhou et al. [17]). But they have not considered the impact of the degree of customization. This is the major difference between this paper and the existing studies. Market demand will be affected by factors including product price, lead time, and the degree of customization, which should be included in a supply chain decision model.

Therefore, this paper explores the optimal decisions of an MC supply chain when market demand is affected by the degree of product customization, price, and lead time. In non-cooperative decision-making, each company in a supply chain makes the optimal decision from its own perspective. In cooperative decision-making, companies in a supply

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chain make optimal decisions from an overall perspective. We compare the optimal decisions of non-cooperative decision-making and cooperative decision-making. In addition, the sensitivity analysis of the optimal CODP position is performed.

2. Problem and Assumptions

A mass customization (MC) product is produced in a supply chain and sold to the market. The MC supply chain includes a supplier and a manufacturer. The supplier provides standard components to the manufacturer with a Make-to-Stock (MTS) production mode. The manufacturer assembles components into an MC product to meet the requirements of customers. After receiving the customer's order, the manufacturer uses a Make-To-Order (MTO) production mode. The MC supply chain combines two production modes of mass production with a lower unit production cost and customized production with a higher unit production cost. The CODP is the point that separates from mass production and customized production in the MC supply chain. The CODP is located between the supplier and the manufacturer in our model, which is represented by the triangle in Figure 1.

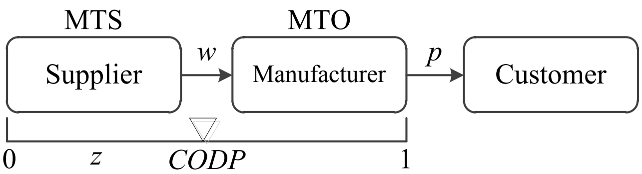

Figure 1: MC Supply Chain Model.

The main variables are listed in Table 1.

The CODP position is represented by $0 \leq z \leq 1$. It means that the procedure from 0 to z is the mass process. The customized process begins from z. A larger z indicates that the supply chain has a longer mass process. The supplier offers components to the manufacturer at the price of w. The manufacturer assembles the components into a finished product (MC product) and sells it at price p. After a customer places an order, the product is received after time t.

The degree of product customization is represented by $1 - z$. A larger z means a lower degree of customization. $z = 1$ indicates that the product is fully processed in an MTS mode. $z = 0$ means that the product is completely processed in an MTO mode. Assume that the product lead time t is linearly and negatively correlated with CODP position z. $t = t_0(1 - z)$, where $t_0 > 0$ is the base lead time of the MC product.

The production cost for the components at the supplier is c_s. Assume that $c_s = \eta_1 z$, where $\eta_1 > 0$ is the production cost coefficient for the components. In order to improve the mass process, the supplier invests F_s in research and development (R&D). $F_s = \eta_2 z^2/2 + \eta_0$, where η_0 is the base investment and η_2 is the investment coefficient for the mass process. As the mass process becomes longer, both the production cost and investment of the supplier increase.

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Table 1: List of main variables.

Variable	Description
z	The CODP position.
w	The price of the components per unit MC product.
p	The selling price of the MC product.
D	The market demand for the MC product.
a	The market capacity of the MC product.
t	The lead time of the MC product.
t_0	The base lead time of the MC product.
k	price sensitivity coefficient of demand.
θ	lead time sensitivity coefficient of demand.
b	customization sensitivity coefficient of demand.
F_s	The investment for the mass process.
η_1	The production cost coefficient for the components.
η_0	The base investment for the mass process.
η_2	The investment coefficient for the mass process.
c_s	The production cost for the components per unit MC product.
c_M	The customization cost per unit MC product.
c_0	The base customization cost of the MC product.

The customization cost for the MC product at the manufacturer is c_M. Assume that $c_M = c_0(1 - z)$, where $c_0 > 0$ is the base customization cost. When the degree of customization is reduced, the customization cost c_M decreases. Assume $c_0 > \eta_1$, which means that the customization cost of one unit product is higher than its cost of mass production.

The market demand for the MC product is D. $D = a - kp - \theta t + b(1 - z)$, where a, k, θ, $b > 0$. a is the market capacity of the MC product, mainly affected by factors such as product quality and brand image. k is the price sensitivity coefficient of demand. θ is the lead time sensitivity coefficient of demand. b is the customization sensitivity coefficient of demand. The market demand for the MC product will increase, if the degree of customization of the product increases. The market demand will also increase, if the selling price or the lead time decreases.

Assume $a - kc_0 - \theta t_0 + b > 0$, which indicates that the market demand for the MC product is greater than 0 when the product is fully customized. Assume $a - k\eta_1 > 0$, which indicates that the demand for the MC product is also greater than 0 when the product is completely mass produced, or processed in an MTS mode.

The profit of the supplier π_S is given as follows:

$$\pi_S = D(w - c_s) - F_s, \tag{2.1}$$

where Dw, Dc_s and F_s are the supplier's income, production cost and investment, respectively.

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The profit of the manufacturer π_M is given as follows:

$$\pi_M = D(p - w - c_M), \tag{2.2}$$

where D_p, D_w and Dc_M are the manufacturer's income, purchase cost and customization cost, respectively.

Based on the above assumptions, equation (2.1) and equation (2.2) can be expressed as:

$$\pi_S = [a - kp - \theta t_0(1-z) + b(1-z)](w - c_s) - (\eta_2 z^2/2 + \eta_0), \tag{2.3}$$
$$\pi_M = [a - kp - \theta t_0(1-z) + b(1-z)](p - w - c_0(1-z)). \tag{2.4}$$

3. Optimal Decisions of MC Supply Chain in Non-cooperative Decision-making

In non-cooperative decision-making, each company in the MC supply chain makes the optimal decisions from the perspective of maximizing its own profit. Assume that the supplier acts as the Stackelberg leader in our model. The supplier determines the CODP position (z) and the price of components (w). The manufacturer acts as a follower, which decides the selling price (p) of the MC product.

The supplier's optimal decision is shown as below:

$$\max : \pi_S(z,w) = [a - kp - \theta t_0(1-z) + b(1-z)](w - c_s) - (\eta_2 z^2/2 + \eta_0), \tag{3.1}$$
$$\text{s.t. } 0 \le z \le 1,\ w > 0.$$

The manufacturer's optimal decision is shown as below:

$$\max : \pi_M(p) = [a - kp - \theta t_0(1-z) + b(1-z)](p - w - c_0(1-z)), \tag{3.2}$$
$$\text{s.t. } p > 0.$$

An inverse reasoning method is used to solve the Stackelberg game model. First, the optimal selling price p^* is solved for a given price of components w and CODP position z. Then, the optimal CODP position z^* and the price of components w^* are solved based on the optimal selling price p^*.

From equation (3.2) we can get $\dfrac{\partial^2 \pi_M(p)}{\partial p^2} = -2k < 0$. Therefore, $\pi_M(p)$ is a concave function with respect to p, and has a maximum value.

Solving $\dfrac{\partial \pi_M(p)}{\partial p} = 0$, we can get the optimal selling price:

$$p^*_{NC} = [kw + (\theta t_0 - kc_0 - b)z + a - \theta t_0 + kc_0 + b]/(2k). \tag{3.3}$$

Theorem 1. *When $4k\eta_2 > (\theta t_0 + kc_0 - k\eta_1 - b)^2$, the supplier's profit function $\pi_S(z,w)$ is a concave function with respect to z and w, which has a maximum value.*

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Proof. The Hessian matrix of the supplier's profit function $H(\pi_s)$ is the following:

$$H(\pi_s)=\begin{bmatrix}\dfrac{\partial^2\pi_s}{\partial w^2} & \dfrac{\partial^2\pi_s}{\partial w\partial z}\\ \dfrac{\partial^2\pi_s}{\partial z\partial w} & \dfrac{\partial^2\pi_s}{\partial z^2}\end{bmatrix}=\begin{bmatrix}-k & (\theta t_0+kc_0+k\eta_1-b)/2\\ (\theta t_0+kc_0+k\eta_1-b)/2 & -\eta_1(\theta t_0+kc_0-b)-\eta_2\end{bmatrix}. \quad (3.4)$$

The determinant of $H(\pi_s)$ is

$$|H(\pi_s)|=k\eta_2-\frac{1}{4}(\theta t_0-b+kc_0-k\eta_1)^2. \quad (3.5)$$

When $4k\eta_2>(\theta t_0+kc_0-k\eta_1-b)^2$, $|H(\pi_s)|>0$. As $-k<0$ and $|H(\pi_s)|>0$, the Hessian matrix is negative. Therefore, the supplier's profit function $\pi_S(z,w)$ is a concave function with respect to z and w, and has a maximum value. Theorem 1 holds.

Substitute p^*_{NC} into equation (3.1). Solving $\dfrac{\partial\pi_s(z,w)}{\partial z}=0$ and $\dfrac{\partial\pi_s(z,w)}{\partial w}=0$, we can get the optimal CODP position and optimal price of components:

$$z^*_{NC}=(a+b-\theta t_0-kc_0)(\theta t_0+kc_0-k\eta_1-b)/[4k\eta_2-(\theta t_0+kc_0-k\eta_1-b)^2], \quad (3.6)$$

$$w^*_{NC}=(a+b-\theta t_0-kc_0)[2\eta_2+\eta_1(\theta t_0+kc_0-k\eta_1-b)]/[4k\eta_2-(\theta t_0+kc_0-k\eta_1-b)^2]. \quad (3.7)$$

4. Optimal Decisions of MC Supply Chain in Cooperative Decision-making

In cooperative decision-making, supply chain companies form a virtual enterprise, and optimal decisions are made to maximize the overall profit of the virtual enterprise. The overall profit of the MC supply chain is expressed by π, and $\pi=\pi_S+\pi_M$.

The optimal decisions of the MC supply chain are shown as below:

$$\max:\ \pi(z,p)=[a-kp-\theta t_0(1-z)+b(1-z)](p-\eta_1 x-c_0(1-z))-(\eta_2 z^2/2+\eta_0), \quad (4.1)$$
$$\text{s.t. } 0\le z\le 1,\ p>0.$$

Theorem 2. *When $2k\eta_2>(\theta t_0+kc_0-k\eta_1-b)^2$, The overall profit function of the MC supply chain $\pi(z,p)$ is a concave function with respect to z and p, which has a maximum value.*

Proof. The Hessian matrix of the overall profit function $H(\pi)$ is the following:

$$H(\pi)=\begin{bmatrix}\dfrac{\partial^2\pi}{\partial p^2} & \dfrac{\partial^2\pi}{\partial p\partial z}\\ \dfrac{\partial^2\pi}{\partial z\partial p} & \dfrac{\partial^2\pi}{\partial z^2}\end{bmatrix}=\begin{bmatrix}-2k & \theta t_0-b-k(c_0-\eta_1)\\ \theta t_0-b-k(c_0-\eta_1) & 2(\theta t_0-b)(c_0-\eta_1)-\eta_2\end{bmatrix}. \quad (4.2)$$

The determinant of $H(\pi)$ is

$$|H(\pi)|=2k\eta_2-(\theta t_0+kc_0-k\eta_1-b)^2. \quad (4.3)$$

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When $2k\eta_2 > (\theta t_0 + kc_0 - k\eta_1 - b)^2$, $|H(\pi)| > 0$. As $-2k < 0$ and $|H(\pi)| > 0$, the Hessian matrix is negative. Therefore, the profit function of the supply chain is a concave function with respect to z and p, which has a maximum value. Theorem 2 holds.

Solving $\dfrac{\partial \pi(z,p)}{\partial z} = 0$ and $\dfrac{\partial \pi(z,p)}{\partial p} = 0$, we can get the optimal CODP position and optimal selling price:

$$z_c^* = \frac{(a+b-\theta t_0 - kc_0)(\theta t_0 + kc_0 - k\eta_1 - b)}{2k\eta_2 - (\theta t_0 + kc_0 - k\eta_1 - b)^2}, \tag{4.4}$$

$$p_c^* = \frac{\eta_2(a+b-\theta t_0 - kc_0) - ((a+b)(c_0 - \eta_1) + \theta t_0 \eta_1)(\theta t_0 + kc_0 - k\eta_1 - b)}{2k\eta_2 - (\theta t_0 + kc_0 - k\eta_1 - b)^2}. \tag{4.5}$$

Corollary 1. *The optimal CODP of the MC supply chain in cooperative decision-making moves to a later position than that in non-cooperative decision-making.*

Proof. It can be inferred from equations (3.6) and (4.4) that $z_c^* > z_{NC}^*$. In cooperative decision-making, the CODP will be moved to a later position than that in non-cooperative decision-making. Thus, corollary 1 holds. Corollary 1 indicates that the mass process will increase, or the degree of product customization will be reduced in cooperative decision-making.

5. Sensitivity Analysis of the Optimal CODP Position

Equation (3.6) and Equation (4.4) show that the expressions of the optimal CODP positions are similar for non-cooperative decision-making and cooperative decision-making. Thus, the sensitivity analyses of the two positions are similar. The following is a sensitivity analysis of the optimal CODP position for the non-cooperative decision-making. In the numerical analysis, the parameters are set as follows: $a = 200$, $k = 0.3$, $\theta = 60$, $t_0 = 2$, $b = 20$, $c_0 = 2$, $\eta_1 = 60$, $\eta_0 = 1000$, $\eta_2 = 50000$. Some of the parameters use the data from Li et al. [9], which meet the assumptions in this study.

5.1. Impact of price sensitivity coefficient

Corollary 2. *Scenario* 1. *When*

$$4\eta_2(k^2c_0(c_0 - \eta_1) + (a+b-\theta t_0)(\theta t_0 - b)) \geq (\theta t_0 + kc_0 - k\eta_1 - b)^2(ac_0 - \eta_1(a+b-\theta t_0)),$$

the optimal CODP position becomes smaller with the increase of the price sensitivity coefficient.

Scenario 2. *When*

$$4\eta_2(k^2c_0(c_0 - \eta_1) + (a+b-\theta t_0)(\theta t_0 - b)) < (\theta t_0 + kc_0 - k\eta_1 - b)^2(ac_0 - \eta_1(a+b-\theta t_0)),$$

the optimal CODP position becomes larger with the increase of the price sensitivity coefficient.

Proof. From equation (3.6), we can get

$$\frac{\partial z^*}{\partial k}=\frac{4\eta_2(k^2c_0(c_0-\eta_1)+(a+b-\theta t_0)(\theta t_0-b))-(\theta t_0+kc_0-k\eta_1-b)^2(ac_0-\eta_1(a+b-\theta t_0))}{-[4k\eta_2-(\theta t_0+kc_0-k\eta_1-b)^2]^2}, \tag{5.1}$$

The relationship between the optimal CODP position z^* and the price sensitivity coefficient k depends on which of $4\eta_2(k^2c_0(c_0-\eta_1)+(a+b-\theta t_0)(\theta t_0-b))$ and $(\theta t_0+kc_0-k\eta_1-b)^2(ac_0-\eta_1(a+b-\theta t_0))$ is larger. According to equation (5.1), Corollary 2 holds.

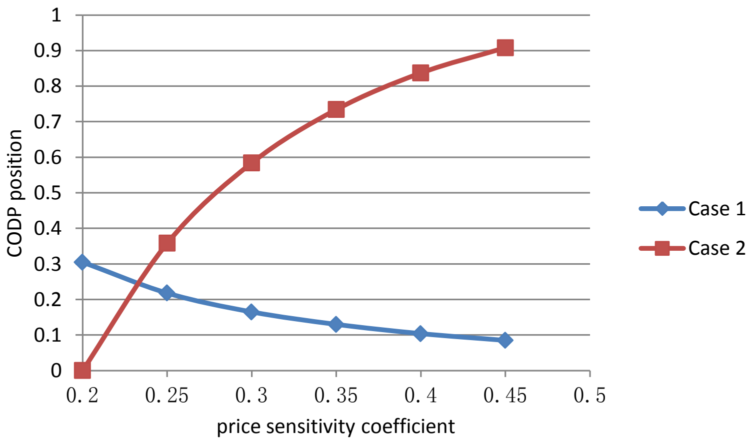

Figure 2: Impact of price sensitivity coefficient on CODP position.

Figure 2 shows the influence of the price sensitivity coefficient on the optimal CODP position in scenario 1 and scenario 2. In scenario 1, z^* decreases if the price sensitivity coefficient increases. It means the degree of customization of the MC product will increase. In scenario 2, the degree of customization of the MC product will be reduced if the price sensitivity coefficient increases.

5.2. Impact of lead time sensitivity coefficient

Corollary 3. *Case I. When* $(\theta t_0+kc_0-k\eta_1-b)^2(a-k\eta_1)\geq 4k\eta_2(2\theta t_0+2kc_0-a-2b-k\eta_1)$, *the optimal CODP position becomes larger with the increase of the lead time sensitivity coefficient.*

Case II. When $(\theta t_0+kc_0-k\eta_1-b)^2(a-k\eta_1)<4k\eta_2(2\theta t_0+2kc_0-a-2b-k\eta_1)$, *the optimal CODP position becomes smaller with the increase of the lead time sensitivity coefficient.*

Proof. From equation (3.6), we can get

$$\frac{\partial z^*}{\partial \theta}=\frac{(\theta t_0+kc_0-k\eta_1-b)^2(a-k\eta_1)+4k\eta_2(a+2b+k\eta_1-2\theta t_0-2kc_0)}{[4k\eta_2-(\theta t_0+kc_0-k\eta_1-b)^2]^2}t_0, \tag{5.2}$$

The relationship between the optimal CODP position z^* and θ in the MC supply chain depends on which of $(\theta t_0+kc_0-k\eta_1-b)^2(a-k\eta_1)$ and $4k\eta_2(2\theta t_0+2kc_0-a-2b-k\eta_1)$ is larger. According to equation (5.2), Corollary 3 holds.

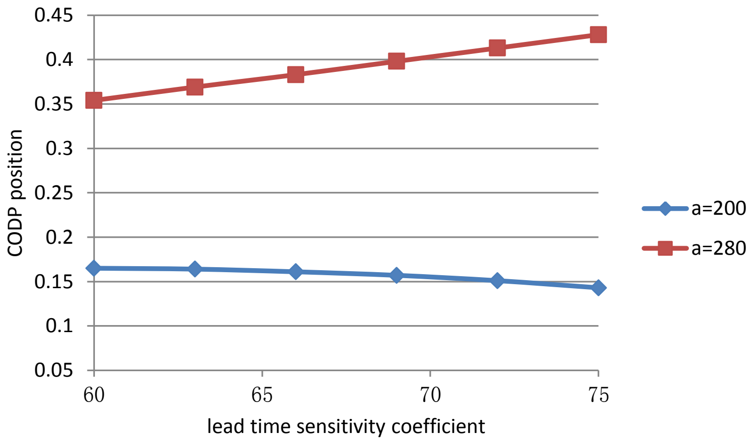

Figure 3: Impact of lead time sensitivity coefficient on CODP position.

Figure 3 shows the influence of the lead time sensitivity coefficient on the optimal CODP position when $a = 280$ and $a = 200$. When the market capacity a is large and Case I is satisfied, z^* becomes larger if the lead time sensitivity coefficient θ increases. It means that the supply chain will shorten the lead time of the MC product to increase the sales. When the market capacity a is small and Case II is satisfied, z^* becomes smaller if θ increases. It means that the supply chain will increase the lead time of the MC product.

5.3. Impact of customization sensitivity coefficient

Corollary 4. *Case I. When* $(\theta t_0 + kc_0 - k\eta_1 - b)^2(a - k\eta_1) \geq 4k\eta_2(2\theta t_0 + 2kc_0 - a - 2b - k\eta_1)$*, the optimal CODP position becomes smaller with the increase of the customization sensitivity coefficient.*

Case II. When $(\theta t_0 + kc_0 - k\eta_1 - b)^2(a - k\eta_1) < 4k\eta_2(2\theta t_0 + 2kc_0 - a - 2b - k\eta_1)$*, the optimal CODP position becomes larger with the increase of the customization sensitivity coefficient.*

Proof. From equation (3.6), we can get

$$\frac{\partial z^*}{\partial b} = -\frac{(\theta t_0 + kc_0 - k\eta_1 - b)^2(a - k\eta_1) + 4k\eta_2(a + 2b + k\eta_1 - 2\theta t_0 - 2kc_0)}{[4k\eta_2 - (\theta t_0 + kc_0 - k\eta_1 - b)^2]^2}. \tag{5.3}$$

Based on equation (5.3), Corollary 4 holds. It can be inferred from equations (5.2) and (5.3) that $\frac{\partial z^*}{\partial b} = -\frac{\partial z^*}{\partial \theta}\Big/ t_0$. This indicates that the impact of the customization sensitivity coefficient on the optimal CODP position is opposite to the impact of the lead time sensitivity coefficient on the optimal CODP position.

5.4. Impact of production cost coefficient and investment coefficient

Corollary 5. *As the production cost coefficient η_1 or investment coefficient η_2 increases, the optimal CODP position z^* becomes smaller.*

Proof. From equation (3.6), we can get

$$\frac{\partial z^*}{\partial \eta_1} = \frac{-k(a+b-\theta t_0 - kc_0)(4k\eta_2 + (\theta t_0 + kc_0 - k\eta_1 - b)^2)}{[4k\eta_2 - (\theta t_0 + kc_0 - k\eta_1 - b)^2]^2}. \tag{5.4}$$

In equation (5.4), $k > 0$ and $a + b - \theta t_0 - kc_0 > 0$, so $\frac{\partial z^*}{\partial \eta_1} < 0$. It indicates that z^* decreases when the cost factor η_1 increases.

The numerator and denominator of formula (3.6) are both greater than 0. When η_2 increases, the denominator of equation (3.6) becomes larger. Therefore, z^* decreases in η_2. Corollary 5 holds.

Figure 4 and Figure 5 show the influences of the production cost coefficient and investment coefficient on the optimal CODP position. When η_1 or η_2 increases, the supply chain will reduce the mass process. Thus, the customized process will increase.

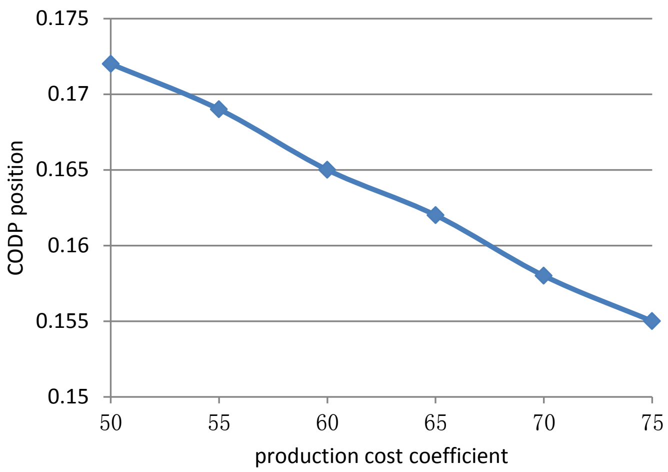

Figure 4: Impact of production cost coefficient on CODP position.

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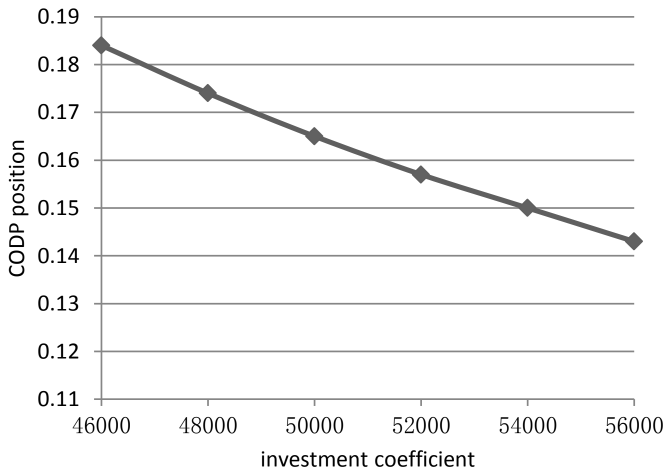

Figure 5: Impact of investment coefficient on CODP position.

6. Conclusions and Management Insights

6.1. Conclusions

This paper studies the optimal decisions of an MC supply chain under personalized demand. A supply chain optimization model is constructed that considers the influences of the degree of customization, price, and lead time of an MC product on market demand. The optimal CODP position and pricing decisions of the MC supply chain are obtained in non-cooperative decision-making and cooperative decision-making. In addition, the sensitivity analysis of the optimal CODP position is conducted.

Our results show that the optimal CODP of the MC supply chain in cooperative decision-making moves to a later position than that in non-cooperative decision-making. The sensitivity analysis shows that the CODP moves to an earlier position as the price sensitivity coefficient increases in scenario 1. The CODP moves to a later position with the increase of the price sensitivity coefficient in scenario 2. When the market capacity is large, the CODP moves later with the increase of the lead time sensitivity coefficient. When the market capacity is small, the CODP moves earlier as the lead time sensitivity coefficient increases. The impact of the customization sensitivity coefficient on the optimal CODP position is opposite to the impact of the lead time sensitivity coefficient on the optimal CODP position. When the production cost coefficient or investment coefficient increases, the optimal CODP moves earlier.

6.2. Management insights

From a practical management point of view, the conclusions in this paper can be used to improve the MC supply chain profitability. First, product price, lead time, the degree of customization and the production cost influence the CODP. These critical factors should be taken into account when deciding the optimal CODP. Second, our model can

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be used to calculate the optimal CODP. As the level of cooperation among supply chain companies increases, the optimal CODP moves to a later position. Third, the relevant conclusions can be used to adjust the CODP. For example, if a supplier finds that its production cost increases, it should move the CODP to an earlier position. When the market capacity is large, the optimal CODP should be moved to a later position if the lead time sensitivity coefficient increases.

In this study, it is assumed that the lead time, the production cost for the components, and the customization cost for the MC product are all linearly related to the CODP position. In further research, the optimal decisions can be considered when the lead time and related cost are nonlinearly related to the CODP position so that the guidance significance for practice could be increased.

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