Research on the Impact of Cloud Manufacturing Platform Pricing Strategies on the Profit of Single Channel Suppliers

Daohe Sun¹, Xin Yang¹* and Zixing Chen²

¹Zhonghuan Information College, Tianjin University of Technology, Tianjin, China
²School of Management, Tianjin University of Technology, Tianjin, China
Email: wing.lps@163.com

Abstract. Based on the Hotelling model, this paper compares the profit of single-channel transactions between the cloud supplier on the cloud manufacturing platform and the offline supplier with the manufacturer. It studies how the cloud manufacturing platform formulates the transaction charging coefficient so that the profit of the cloud supplier is greater than the profit of the offline supplier and guarantees its own profit, thereby attracting more suppliers to the cloud. And further consider the impact on supplier profit and cloud manufacturing platform revenue when the manufacturer's value perception coefficient changes, provide reasonable suggestions for cloud manufacturing platform pricing, and provide cloud suppliers with strategies to attract manufacturers.

Keywords. Hotelling model, Cloud manufacturing platform, Cloud supplier, Profit.

1. Introduction

In 2010, China has become the world's largest manufacturing country, but most manufacturing enterprises face problems such as overcapacity and idle resource capacity. Academia and industry in our country have proposed the concept of cloud manufacturing by drawing on cloud computing ideas. Cloud manufacturing achieves the goals of improving resource utilization, reducing manufacturing costs, and achieving a win-win situation for all parties through rational allocation and effective use of resources [1].

Li Bohu and his team proposed a new service-oriented networked manufacturing model, cloud manufacturing. The definition of cloud manufacturing is given [2]. Pan Xinyu analyzed the application cloud platform, the operation decision of supply chain enterprises after cloud manufacturing, and the supply chain coordination mechanism [3]. Peng Wei constructed a price game model among the participants. The Stackelberg price leadership model is used to analyze the price game equilibrium between the resource service provider and the agent [4]. Cao Y L [5] and others analyzed the situation when there are multiple candidate suppliers in the cloud manufacturing mode, so that achieve the optimal allocation of resources. Tang Menglan studied cloud market pricing and supplier quality incentive strategies under different market demand environments [6].

However, most of the research on cloud manufacturing today is about the realization of cloud manufacturing platforms. There is relatively little research on cloud manufacturing platform pricing decisions. In this case, some enterprises are in a wait-and-see attitude towards the cloud manufacturing platform. Therefore the cloud manufacturing platform's top priority is to attract more enterprises to go to the cloud. The platform's charging strategy is the core factor [7].

Based on the Hotelling model and Mathematica software technology, this article compares the profits of cloud manufacturing platform suppliers and offline suppliers' transactions with manufacturers. Study
how the cloud manufacturing platform can ensure the profit of the suppliers on the cloud while formulating the transaction charging coefficient to maximize the platform's revenue. And further consider the impact on the pricing and revenue of the cloud manufacturing platform when the manufacturer’s value perception coefficient changes.

2. Problem Description and Basic Assumptions

2.1. Problem Description

Fu Xingmei found that the position where an enterprise can ultimately maximize profits lies at both ends of the economic market. Therefore, suppose that there are cloud manufacturing platform supplier $s_1$ and offline supplier $s_2$ on the market. The products of the two suppliers are homogeneous and there is a competitive relationship between them. They are located at both ends of a linear city of length 1, and the manufacturer $m$ is evenly distributed on the linear city. Please see the following figure 1.

![Figure 1. Hotelling price competition model.](image)

The parameter settings in this model are shown in table 1. (i = 1, 2).

| Symbol | Symbol meaning |
|--------|----------------|
| $\lambda$ | Manufacturer's value perception coefficient |
| x | Manufacturer's location |
| t | Cost per unit distance paid by the manufacturer |
| $D_i$ | Supplier demand function |
| $P_i$ | Supplier $s_i$ price |
| $c_i$ | Cost of supplier $s_i$ |
| $W_i$ | Supplier $s_i$ profit |
| $\omega$ | Cloud manufacturing platform transaction charging coefficient (0 < $\omega$ < 1) |
| $\Pi$ | Cloud manufacturing platform revenue |

2.2. Basic Assumptions

In order to make the model more rigorous, the following assumptions are made:

Suppose 1. Assume the user's single-homing attribute.

Suppose 2. Assuming that the supplier is a rational manager, then $0 < c_1 < P_i$.

Suppose 3. Because cloud suppliers lack the rent compared to offline suppliers, then $c_1 < c_2$.

Suppose 4. Assuming that $\lambda$ is the value perception coefficient of the manufacturer and $\omega$ is the transaction charging coefficient of the cloud manufacturing platform, then $0 < \lambda < 1$ and $0 < \omega < 1$.

Suppose 5. Assuming $0 < t < c_1 < c_2$, $t$ is the unit distance cost that the manufacturer needs to pay.
3. Model Building and Analysis

3.1. Basic Assumptions
Based on the above model and model assumptions, it is now assumed that there is a \( x \) in a linear city. There is no difference when the manufacturer \( m \) buys the products of cloud supplier \( s_1 \) and offline supplier \( s_2 \) at \( x \). And manufacturers on the left side of \( x \) all buy at supplier \( s_1 \), and manufacturers on the right side of \( x \) buy at supplier \( s_2 \). Then the supplier's demand function is:

\[
D_1 = \frac{1}{1-x} \\
D_2 = 1-x
\]  

(1)  
(2)

then \( x \) satisfies:

\[
\lambda P_1 + t \frac{x^2}{2t} = \lambda P_2 + t(1-x)^2
\]  

(3)

We get \( x = \frac{t+\lambda(P_2-P_1)}{2t} \), and bring it into (1) and (2), we will get:

\[
D_1 = \frac{t+\lambda(P_2-P_1)}{2t} \\
D_2 = \frac{\lambda(P_2-P_1)}{2t}
\]  

(4)  
(5)

The supplier's profit is:

\[
W_1 = \omega(P_1-c_1) \times D_1 = \omega(P_1-c_1) \times \frac{t+\lambda(P_2-P_1)}{2t} \\
W_2 = (P_2-c_2) \times D_2 = \frac{P_2-c_2}{2t} \times \frac{\lambda(P_2-P_1)}{2t}
\]  

(6)  
(7)

The benefits of the cloud manufacturing platform are:

\[
\Pi = \omega(P_1-c_1) \times D_1 = \frac{\omega(P_1-c_1)(t+\lambda(P_2-P_1))}{2t}
\]  

(8)

3.2. Model Analysis
At \( x \), there is no difference in the products purchased by manufacturers at \( s_1 \) and \( s_2 \), that is to say, the value perception coefficient of the manufacturer is 1. It shows that at this time \( \lambda = 1 \), we can get:

\[
x = \frac{t+P_2-P_1}{2t}
\]  

(9)

1. At this \( x \), both suppliers set their own product prices for the purpose of maximizing their own profits. By \( \frac{\partial^2 W_1}{\partial P_1^2} = \frac{\omega-1}{t} \leq 0 \) (\( 0 < \omega < 1 \)) and \( \frac{\partial^2 W_2}{\partial P_2^2} = \frac{1}{t} > 0 \) can get the maximum profit of the supplier. And the first-order condition of maximization is:

\[
\begin{align*}
\frac{\partial W_1}{\partial P_1} &= \frac{(1-\omega)(t+P_2-2P_1+c_2)}{2t} = 0 \\
\frac{\partial W_2}{\partial P_2} &= \frac{t-2P_2+P_1+c_2}{2t} = 0
\end{align*}
\]  

(10)

In this way, we can get the pricing of our products when two suppliers want to maximize their profits:

\[
P_1 = \frac{3t+2P_1+c_2}{3} \\
P_2 = \frac{3t+c_1+2c_2}{3} \\
P_2 - P_1 = \frac{c_2-c_1}{3}
\]  

(11)  
(12)  
(13)

From \( c_1 < c_2 \), we can get \( P_2 - P_1 > 0 \), which means that the pricing of cloud suppliers is lower than that of offline suppliers.

2. Bring (11) and (12) into (9), we can get:

\[
D_1 = \frac{3t-c_1+c_2}{6t}
\]  

(14)

\( x > 0 \) can be obtained from \( c_1 < c_2 \), then we can know that when the price of the cloud supplier is lower than that of the offline supplier, there will always be a manufacturer with a high price sensitivity coefficient that will buy the product of the cloud supplier.
\[ D_2 = 1 - \frac{3t + c_1 - c_2}{6t} \]  \quad (15)

Because this article mainly considers the situation when \( D_2 > 0 \), then \( t > \frac{c_2 - c_1}{3} \).

3. Bring (11), (12), (14), (15) into (6), (7) and (8), the profit of the suppliers and the profit of the cloud manufacturing platform are:

\[ W_2 = \frac{(1-\omega)(3t-2c_1)(1-\omega)}{18t} \quad (16) \]
\[ \Pi = \frac{\omega(3t-c_1+c_2)^2}{18t} \quad (17) \]
\[ W_1 \quad \text{Let} \quad W_1 - W_2 = \frac{(1-\omega)(3t-c_1+c_2)^2 - (3t+c_1-c_2)^2}{18t} \geq 0, \text{ and } 0 < \omega < 1 \]

we can get:

\[ 0 < \omega < 1 - \frac{(3t+c_1-c_2)^2}{(3t-c_1+c_2)^2} \quad (19) \]

It can be seen that when \( 0 < \omega < 1 - \frac{(3t+c_1-c_2)^2}{(3t-c_1+c_2)^2} \), the profit of suppliers on the cloud is higher than that of offline suppliers. And the value of \( \omega \) is related to the cost \( c_1, c_2 \) of the two suppliers and the unit distance cost \( t \) that the manufacturer needs to pay. When \( c_2 \) and \( t \) are unchanged, the larger \( c_1 \) is, the smaller \( \omega \) is.

When \( \lambda \neq 1 \), when we consider the manufacturer’s value perception coefficient, it can also be said that the manufacturer’s comprehensive consideration of the supplier’s service quality and price, then:

\[ x = \frac{t + \lambda(P_2 - P_1)}{2t} \quad (20) \]

1. Both suppliers still set their own product prices for the purpose of maximizing their own profits. The first-order conditions for maximizing the suppliers’ profits are:

\[ P_1 = \frac{3t + 2\lambda c_1 + \lambda c_2}{3\lambda} \quad (21) \]
\[ P_2 = \frac{3t + \lambda c_1 + 2\lambda c_2}{3\lambda} \quad (22) \]
\[ P_2 - P_1 = \frac{\lambda(c_2 - c_1)}{3} \quad (23) \]

From \( c_1 < c_2 \), we can get \( P_2 - P_1 > 0 \), which means that the pricing of cloud suppliers is lower than that of offline suppliers. And this relationship is not related to \( \lambda \).

2. From the relationship between \( P_2 \) and \( P_1 \), we can get:

\[ D_1 = \frac{3t + \lambda(c_2 - c_1)}{6t} \quad (24) \]
\[ D_2 = 1 - \frac{3t + \lambda(c_2 - c_1)}{6t} \quad (25) \]

This article mainly considers the situation when \( D_2 > 0 \), at this time \( t > \frac{\lambda(c_2 - c_1)}{3} \). And when \( c_1, c_2 \) and \( t \) are unchanged, the larger \( \lambda \), the larger \( D_1 \). It means that the demand of cloud manufacturing platform suppliers is higher.

3. Bring (21), (22), (24), (25) into (6) and (7), we can get:

\[ W_1 = \frac{(1-\omega)(3t-2\lambda c_1 + \lambda c_2)^2}{18\lambda t} \quad (26) \]
\[ W_2 = \frac{(3t + \lambda(c_1 - c_2))^2}{18\lambda t} \quad (27) \]

Let \( W_1 - W_2 = \frac{(1-\omega)(3t-\lambda c_1 + \lambda c_2)^2 - (3t+\lambda c_1 - \lambda c_2)^2}{18\lambda t} \geq 0 \), and \( 0 < \omega < 1 \), we can get:

\[ 0 < \omega < 1 - \frac{(3t+\lambda c_1 - \lambda c_2)^2}{(3t-\lambda c_1 + \lambda c_2)^2} \quad (28) \]

when \( 0 < \omega < 1 - \frac{(3t+c_1-c_2)^2}{(3t-c_1+c_2)^2} \), the profit of the cloud supplier is higher than the profit of the offline supplier. And the value of \( \omega \) is related to the cost \( c_1, c_2 \) of the two suppliers, the unit distance cost \( t \) that the manufacturer needs to pay, and the value perception coefficient \( \lambda \) of the manufacturer. When \( c_1, c_2, \) and \( t \) are unchanged, the higher the \( \lambda \), which means the manufacturer is more satisfied with the price
and service quality of the supplier on the cloud, the size of $\omega$ can be made larger.

### 4. Example Analysis

Mathematica is the most powerful system among the universal computing systems in the world. Since its release in 1988, it has had a profound influence on how to use computers in technology and other fields. As a scientific computing software, it combines numerical and symbolic computing engines, graphics systems, programming languages, text systems, and advanced connections with other applications. In order to verify the correctness of the model and analysis in this article, the following uses Mathematica software and the assignment method to analyze examples. Let $c_1 = 80$, $c_2 = 100$, $t = 10$, and the effect of $\lambda$ on the transaction charging coefficient $\omega$ of the cloud manufacturing platform is shown in figure 2. It can be seen from figure 2. that as $\lambda$ increases, $\omega$ increases.

![Figure 2](image)

**Figure 2.** The influence of $\lambda$ on the transaction charging coefficient $\omega$ of the cloud manufacturing platform.

Let $\omega = 0.15$, Mathematica can get the profits of the two suppliers and the profit graph of the cloud manufacturing platform, as shown in figure 3. It can be seen from figure 3 that the profits of suppliers on the cloud are higher than those of offline suppliers. However, with the increase of $\lambda$, the profit of the cloud manufacturing platform and the profits of the two suppliers decrease.

![Figure 3](image)

**Figure 3.** The effect of $\lambda$ on the revenue of the cloud manufacturing platform and the profits two suppliers.

### 5. Conclusion and Inspiration

This article compares the profits of suppliers on the cloud and offline suppliers by establishing a Hotelling price competition model and performing pricing analysis. By reasonably formulating the transaction charging coefficient of the cloud manufacturing platform. Thereby incentivizing more suppliers to go to the cloud. Through the research results, it is found that the cloud-based channel can save manufacturers time and purchase costs compared to offline channels. And when the manufacturer value perception coefficient is not considered, the size of the cloud manufacturing platform transaction charging coefficient is related to the cost $c_1$, $c_2$ of the two suppliers and the unit distance cost $t$ that the manufacturer needs to pay. When we consider the manufacturer's value perception coefficient, as $\lambda$ increases, the profit of the cloud manufacturing platform and the profits of the two suppliers decrease.
In reality, the important factor that determines whether a supplier will go to the cloud is the transaction cost. Whether the charging factor is reasonable has a direct impact on the survival of the cloud manufacturing platform. Cloud suppliers already have a competitive advantage in price. If they want to further develop the market, they need to increase their own advantages in product quality and service. In the future, we will further study the impact of information security factors on the profits of cloud suppliers and offline suppliers.

Acknowledgments
This paper is supported by Tianjin Enterprise Science and Technology Commissioner Project (Project No: 19JCTPJC59800).

References
[1] Han M 2011 E-bayes reliability analysis of liquid rocket engine based on non-failure data Acta Aeronautica ET Astronautica Sinica 132 (12) 2213-2219 (in Chinese)
[2] Vlokp J, Wnek M and Zygmunt M 2004 Utilising statistical residual life estimates of bearings to quantify the influence of preventive maintenance actions Mechanical System and Signal Processing 18 (4) 833-847
[3] Wang W 2002 A model to predict the residual life of rolling element bearings given monitored condition information to date IMA Journal of Management Mathematics 13 (1) 3-16
[4] Gebraeel N Z, Lawly M A and Li R 2005 Residual-life distributions from component degradation signals: A Bayesian approach IIE Trans. 37 (6) 543-557
[5] Baruah P and Chinnam R B 2003 HMMs for diagnostics and prognostics in machining process International Journal of Production Research 43 (6) 1275-1293
[6] Li Y G and Nikitsaranont P 2009 Gas turbine performance prognostic for condition-based maintenance Applied Energy 86 (10) 2152-2161
[7] Gebraeel N Z and Lawly M A 2008 A neural network degradation model for computing and updating residual life distributions IEEE Transactions on Automation Science and Engineering 5 (1) 387-401