Supply Chain Capacity Competition and Optimization Based on Online Transaction Advantage of Backwardness

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Abstract: This paper is concerned with supply chain competition and capacity optimization under the assumptions that consumer demands in both online and offline markets are relative to each other. It focuses on “leader-follower” game model under supply chain framework of “one strong traditional manufacturer and one traditional retailer whose status is weakest, one online manufacturer is an up-rising star, and the strong traditional manufacturer competes with the online manufacturer in online markets”. After that the paper analyzes supply chain partners' optimal capacity decision and distribution by numerical analysis. Some conclusions could be found out as follows: Firstly, the appropriate offline market capacity can realize the strong traditional manufacturer's production cost minimize; Secondly, the retailer can avoid two manufacturers' capacity allocation excessive tilt to online market, however, this restriction capacity is limited, the retailer's competitive advantage has a upper limit; Thirdly, Industry capacity allocation proportion reaches the maximum somewhere, which suggests that the competitiveness of the up-rising online manufacturer gradually strengthen, and the increase of offline market capacity will go against the strong traditional manufacturer's maintain dominance of supply chain. Fourthly, the increasing of offline market capacity can improve consumer welfare, and the increasing of industry e-commerce development level will intensify three supply chain's competition; Finally, the excess capacity can be solved. The online manufacturer need pay much higher than the strong traditional manufacturer's online promotion effort to realize its revenue's significant improvement.

Introduction

At present, compared with Chinese offline entity economy's globalization dividend away, the demographic dividend decreasing, and the default payment for goods of some manufacturing enterprises, etc. Online markets are boom since 2012, which have been basically merged together with offline real economy. The digital consumption trend of the domestic consumer is fast-growing, buying fruit, snacks, shoes on Yihaodian, Taobao, going to Jingdong store to buy digital products, home appliances and buy books on Dangdang, etc., all of these consumption habits have been formed, online shopping has become a normal consumption. The report of China Internet Network Information Center in 2015 showed that, whether in personal computer port or mobile devices port, Chinese online shopping user attributes has already been close to entirely netizens. By the end of 2014, Chinese netizens' online shopping habits have already been formed. The prosperity of online markets have forced an implementation of online manufacturers, such as Tmall's many costume sellers, such as Liebo, Qigege, etc. Offline stores living space is greatly compressed, facing the fate of the transformation or reshuffle.

Kinds of traditional manufacturers try to intensify online marketing by channel and brand promotion ways, with some upstart online manufacturers compete for market share. Redistribution of industry production capacity is an emerging questions. About the conflict and coordination of online market
research, there are a large number of domestic and foreign literature foundation. Such as, Cattani Lee H (2002), Kevin Zhu (2004), K (2006), etc. Peiqin Li (2013) has discussed in detail.

Model Description and Analysis

It supposes that the manufacturer $j(j=1,2)$ sells homogeneous product $i(i=1,2)$, both of them compete on the internet at the same time. Being a weaker partner, the online manufacturer $M_2$ can have more rights in competition on the Internet through improving its promotion levels. Simultaneously, the strongest manufacturer $M_1$ still has a traditional retailer $R$ whose status is weakest, it has to provide better services such as more comfortable shopping environments, closer places, etc. to keep its market share. The demands functions are decided not only by two manufacturers’ pricing mechanisms, but also by their promotion effort levels, which are divided by two dimensions: channel promotion effort level $e_d$ and brand promotion effort level $e_b$. Channel promotion competition happens on the Internet between manufacturer $M_1$ leader and the online manufacturer $M_2$, which are indicated by $e_{d1}$ and $e_{d2}$ respectively, and their brand sale effort $e_{b1}$ and $e_{b2}$ respectively. To simplify the analysis, we assume that two kind coefficients of sale effort are same $\kappa(\kappa>0)$, and their promotion costs are $g(e_d) = \kappa e_d (e_d \geq 0)$, $g(e_b) = \kappa e_b (e_b \geq 0)$ (i=1,2). On the other hand, the traditional retailer $R$ provides additional service $e_r (e_r > 0)$, and its service cost is $\eta e_r^2/2$, $\eta$ is the coefficient of service cost. Respectively, the parameter $\mu$ is the marginal demand of retailer $R$’s additional service. Besides, the retailer $R$ has to pay $F(F>0)$ for its store rents, facility wages, etc. It comes out three partners’ demand functions as follows: $D_1=\left[ a_r-mp_1+np_2+\theta(p_r-p_1)+\gamma e_{d1}-\lambda e_{d2} - \varphi(e_r-e_{d1}) \right]e_{b1}$;

$D_2=\left[ a_r-mp_1+np_2+\theta(p_r-p_1)+\gamma e_{d1} - \lambda e_{d2} - \varphi(e_r-e_{d1}) \right]e_{b2}$; $D_3=\left[ a_r-mp_2+\theta(p_r-p_2)+\theta(p_2-p_1)+\gamma e_r+\varphi(e_r-e_{d1})+\varphi(e_r-e_{d2}) \right]$.

The parameter $\theta(\theta>0)$ represents price demand pervasion level between dual markets, and the parameter $\varphi(\varphi>0)$ represents sale effort demand pervasion level between dual markets. The parameter $c_j(j=1,2)$ is manufacturer $j$’s product cost, $p_j(j=1,2)$ is its Internet sale price, which has that $p_j>c_j(j=1,2)$. The parameter $p_r$ is the retailer $r$’s sale price, and $w$ is its wholesale price. The relationships $p_1>p>r>c_1$ must come into existence. The parameter $a_e$ indicates product $i(i=1,2)$’s “comprehensive market demand base”. Similarly, $a_r$ represents customer demand in traditional market. Besides, $m$ is the product demand’s reaction level to itself, $n$ represents products’ differentiation effects. $m>n>0$. $\gamma$ is the product’s sale effort demand reaction level to itself, $\lambda$ represents products’ sale effort differentiation effects, $\gamma>\lambda>0$. The timing of decisions is captured in a two-period framework. Firstly manufacturer $M_1$ and online manufacturer $M_2$ play a leader-follower game to decide optimal variables. Secondly, being a weakest supply chain partner, the traditional retailer joins dual market competition. By backward induction, all of the optimal variables and revenues can be calculated in Table 1. Accordingly, it can conclude some theorems and corollaries as follows:

Theorems 1 Under dual market competition, the condition that the traditional retailer $r$ could exist is $H<0$, that is, $2\eta(m+2d)>(\gamma+2\varphi)^2$.

Corollary 1 When Manufacturer $M_2$ is in second-rate predominance status, the higher the offline retailer's channel promotion level, the bigger its optimal revenues.
Corollary 2 When Manufacturer $M_2$ is in second-rate predominance status, the greater the offline retailer's purchase and sale price difference, the bigger its optimal revenues.

Corollary 3 When Manufacturer $M_2$ is in second-rate predominance status, the greater the sales promotion effort level's difference between online and offline markets, the lower the offline retailer's optimal revenues.

Theorems 2 Under dual market competition, the condition that online manufacturer 2 could get optimally maximal revenues is $p_2^* > c_2$.

Corollary 4 When Manufacturer $M_2$ is in second-rate predominance status, if $\frac{\partial \pi_2}{\partial \varepsilon_{e_2}} > 0$, the revenue of online manufacturer $M_2$ is positive correlation of channel promotion effort level, on the contrary it is negative correlation; If $\frac{\partial \pi_2}{\partial \varepsilon_{e_2}} > 0$, the revenue of online manufacturer $M_2$ is positive correlation of brand promotion effort level, on the contrary it is negative correlation.

Corollary 5 When Manufacturer $M_4$ is in second-rate predominance status, if $N \geq 0$, the price $p_2^*$ is positive correlation of the price $p_1^*$, on the contrary it is negative correlation; If $P \geq 0$, the price $p_2^*$ is positive correlation of the price $w$, on the contrary it is negative correlation.

Corollary 6 When Manufacturer $M_2$ is in second-rate predominance status, the brand promotion effort level of online manufacturer $M_2$ is irrelevant with all of optimal decision variables, except its optimal revenue $\pi_2^*$.

Theorems 3 Under dual markets competition, the condition that manufacturer 1 could get optimally maximal revenues is,

$$\begin{cases} 
\bar{Q} < 0 \\
4\bar{Q}R_s - (\bar{S}_e + \bar{T}) > 0
\end{cases}$$

Corollary 7 When $w > c$, the strongest leader manufacturer $M_1$ would like to join in the dual market competition.

Theorems 4 if $\left[ \frac{-m + \theta + n}{2(m + \theta)} \right]^* < 0$, $\left[ \frac{-m + \theta + \delta}{2(m + \theta)} \right]^* < 0$, and $p_r^* = p_{1, r}, \pi'_r, e_r = e_{1, r}, p'_1 = p_{1, 1}$, the supply chain coordination exists.

By the way, all of the optimal variables are listed below in Table 1. Some conclusions can be found out from Table 1. Firstly, brand promotion level does not influence every optimal variables except manufacturer $M_1$ and $M_2$'s optimal revenues. Secondly, being a judgement condition, the $F$ is only relevant with manufacturer $M_1$'s promotion effort level. Finally, due to the offline retailer did not consider the problem such as store rent, which causes offline retailers will do the business at lower prices, in fact if taking into account the rent problem, the retailer's living space is little. If you need to support and encourage retailers to maintain the offline market, strong manufacturer $M_1$ should take corresponding measures such as subsidies, supply chain coordination problem can also be further analyzed. The model of supply chain coordination does not exist.
Table 1. Optimal variables of the model.

| \( a_i \) | \( a_i(e_i)^2 - f(e_i) \) |
| \( a_i \) | \( a_i(e_i)^2 - f(e_i) \) |

**Numerical Simulation Analysis**

With the improvement of industry e-commerce development level, the online market capacity change. New competitors to enter and product innovation breakthrough, all of which could also lead to offline market capacity change. How "Online market capacity rate \( g \) " and "offline market capacity \( a_r \) " influence to decide the production capacity of the supply chain optimization decision? Basic parameter assumptions are as follows, \( c_1 = 0.0002(K - 250)^4 + 4 \), \( c_2 = 0.7c_1 \), \( m = 19, n = 10 \), \( e_{b1} = h_1e_{d1} \), \( F = 100, \theta = 3, \eta = 2, \kappa = 1, \gamma = 0.5, \lambda = 0.3, \phi = 0.2 \); \( a_r = ga_r (g > 0) \); \( e_{b2} = h_2e_{d1} \); \( e_{d2} = h_1e_{d1} \).

When industry e-commerce development level is certain, offline market capacity \( a_r \)'s change will affect some variables, here several kinds of states are mainly analyzed:

Firstly, online market capacity rate \( g \) is low at \( g = 0.7 \) in Chart 1. As offline market capacity \( a_r \) increasing, many variable curves are concave and have minimal point. Such as, the manufacturer \( M_1 \)'s capacity allocation curve \( \frac{D_1}{D_r} \) has minimal point (649.25, 0.82725), the curve \( \frac{D_1 + D_2}{D_r} \)'s minimal point is (648.5, 2.092); the manufacturer \( M_1 \)'s online pricing curve has minimal point (364.7, 14.3218), the manufacturer \( M_2 \)'s online pricing curve has minimal point (363.2, 12.7159), the manufacturer \( M_1 \)'s wholesale pricing curve \( w \) has minimal point (371, 12.899), and its production cost curve \( c_1 \) has minimal point (568.2, 4). On the contrary, the industry capacity allocation curve \( \frac{D_1 + D_r}{D_r} \) is convex, which has maximal point (648.07, 1.445). Besides, the curve \( D_r \) and the curve \( (p_r - p_i) \) is increasing as offline market capacity \( a_r \) becomes bigger, and the growth slowed significantly. All of these critical points suggest many characters, for example, at \( g = 0.7 \), some offline market capacity \( a \) \( a_r \) can realize the manufacturer \( M_1 \) production cost minimize \( c_1 = 4 \), if offline market capacity \( a_r \) has any change, the manufacturer \( M_2 \)'s optimal production cost can't be reached. In the other hand, some conclusions can be made from the curve \( D_r \). The offline retailer's competitive ability is weakest, at the beginning the demand could become bigger as offline market capacity \( a_r \) increasing, and the retailer restricts two manufacturers' capacity allocation is excessive tilt to online market, however, this restriction capacity is limited, in place of \( a_r \approx 649 \), the retailer's competitive advantage reaches
maximal point, then gradually weakened. Industry capacity allocation proportion curve $\frac{D_1 + D_2}{D_2}$ also reached the maximum in place of $a_r \approx 649$. It suggests that the competitiveness of the manufacturer $M_2$ gradually strengthen, since its total production has transcended the manufacturer $M_1$’s production, the increase of offline market capacity $a_r$ will go against manufacturer $M_1$’s maintain dominance of supply chain. Besides, the pricing curve $p_1, p_2$’s minimal point come out earlier as offline market capacity $a_r$ increasing, which means that the increasing of $a_r$ can improve consumer welfare when offline market capacity $a_r$ is low.

Secondly, compared with $g = 0.7$, some optimal variable s' change rules are different in Chart 2 with $g = 0.9$, which are showed as follows: The curve $(p_r - p_1)$ becomes from concave to monotone increasing, and $419.377 \leq a_r \leq 872.409$, which means the retailer’s competitive advantage is worst at the minimal point of the curve $(p_r - p_1)$; the critical points have changed. The concave curve $D_1 + D_2$’s critical points move to top left, in other words, from point(649.25, 0.827), (648.5, 2.092) to (571.2, 1.059), (571, 2.636). This trend moving to top left indicates that, the increasing of industry e-commerce development level will intensify three supply chain's competition. Especially, the minimal point of curve $D_1 + D_2$’s change highlights the manufacturer $M_2$’s second-rate predominance status has increased. The convex curve $D_1 + D_2$’s maximal point moves to bottom left, from (648.07, 1.445) to (571, 1.307), which indicated that, at $a_r \approx 571$ the manufacturer $M_1$ total capacity's speed increase begins to decline, the manufacturer $M_2$’s second-rate predominance status becomes more prominent. Both offline market capacity $a_r$’s increasing and the retailer's weakness further threaten the manufacturer $M_1$’s supply chain leading role.

All of pricing curves' minimal points disappears, that is, as offline market capacity $a_r$ increasing, the advantage of the retailer's "retailer price increases, wholesale price descends" is gone.

Chart 1. Optimal variables’ curve at $g = 0.7$. 

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Risk Prevention of Excess Capacity, Lack of Capacity and Optimization

Based on Table 2’s benchmark, it can conclude that the manufacturer $M_1$’s optimal capacity is excess, which is shown in the first column of table 2. Assume that manufacturer $M_1$’s capacity is temporary excess, and the production cost $c_2 = 2.844$, let's dig supply chain competition's laws deeply.

Firstly, by improving online promotion effort level of the manufacturer $M_1$ and $M_2$, the excess capacity can be solved, shown in the second column of Table 2. When the manufacturer $M_1$’s optimal capacity $K^* = 232.277$ increases to 250, the production cost $c_1$ descends from 4.063 to 4, which realize short-term production cost's optimization. At the same time, the manufacturer $M_1$’s wholesale price upraises, online price decreases slightly and online demand increase, and the total revenue increases too. On the other hand, by the manufacturer $M_2$’s wholesale price upraising, online price decreases slightly and online demand increase, and the total revenue increases too. At the same time, if the manufacturer $M_1$ and $M_2$ compete online, keeping the manufacturer $M_1$’s optimal capacity 250, increase channel promotion level $e_{d1}$ from 0.574 to 0.577, then all of the price variables $p_r, p_1, w$ will descend down, especially the manufacturer $M_2$’s online promotion scale increase from $h_1 = 1.5$ to $h_1 = 15$ very quickly, which means the manufacturer $M_2$ need pay out much more efforts than the manufacturer $M_1$. 

Chart 2. Optimal variables' curve at $g = 0.9$. 

Secondly, based on excess capacity situation, the manufacturer $M_1$ need improve revenue to enlarge its capacity, and to make optimal capacity decision from excess capacity to optimal capacity ,even to lack of capacity situation, seen in the third column of Table 2, which belongs to capacity optimization in the manufacturer $M_1$ short-term excess capacity situation. As the manufacturer $M_1$’s optimal capacity increases from 240 to 250, and the capacity decision reaches to the best, meanwhile, the product cost $c_i$ descends from 4.063 to 4, which reaches to the best status too.

Thirdly, long-term capacity optimization is in short-term overcapacity situation. The variables are $K^*$ and $e_{d1}$ other parameters assignment is changeless, shown in the fourth column of Table 2.

The short-term production cost curve is $c_i=0.0002(K-350)^2+4$ . Compared with the curve $c_i=0.0002(K-250)^2+4$ when the optimal output reaches 350, the manufacturer $M_1$’s production cost decrease obviously, and all the optimal pricing decision significantly decrease, the retailer's optimal service level declines too;

Both manufacturer $M_1$ and $M_2$’s online market demand descend at the same time. The manufacturer $M_1$’s revenue increases, however, the manufacturer $M_2$’s revenue decreases. Overall comparatively speaking, when the manufacturer $M_1$ adopts long-term capacity optimization strategy, and the short-

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Table 2. Capacity optimization’s numerical simulation analysis.

<table>
<thead>
<tr>
<th></th>
<th>$a_0$</th>
<th>$a_1$</th>
<th>$a_2$</th>
<th>$a_3$</th>
<th>$b_0$</th>
<th>$b_1$</th>
<th>$b_2$</th>
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<th>$c_2$</th>
<th>$c_3$</th>
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<th>$p_3$</th>
<th>$w$</th>
<th>$\gamma$</th>
<th>$\delta$</th>
</tr>
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<tbody>
<tr>
<td><strong>Benchmark</strong></td>
<td>0.2</td>
<td>1.3</td>
<td>2.0</td>
<td>2.5</td>
<td>0.32</td>
<td>0.25</td>
<td>0.21</td>
<td>2.0</td>
<td>1.5</td>
<td>1.0</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.05</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Excess</strong></td>
<td>0.777</td>
<td>0.8</td>
<td>2.0</td>
<td>1.5</td>
<td>0.32</td>
<td>0.25</td>
<td>0.21</td>
<td>2.0</td>
<td>1.5</td>
<td>1.0</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.05</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>0.773</td>
<td>0.8</td>
<td>2.0</td>
<td>1.5</td>
<td>0.32</td>
<td>0.25</td>
<td>0.21</td>
<td>2.0</td>
<td>1.5</td>
<td>1.0</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.05</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Lack</strong></td>
<td>0.772</td>
<td>0.8</td>
<td>2.0</td>
<td>1.5</td>
<td>0.32</td>
<td>0.25</td>
<td>0.21</td>
<td>2.0</td>
<td>1.5</td>
<td>1.0</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.05</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
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<tr>
<td><strong>Capacity</strong></td>
<td>0.665</td>
<td>0.8</td>
<td>2.0</td>
<td>1.5</td>
<td>0.32</td>
<td>0.25</td>
<td>0.21</td>
<td>2.0</td>
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<td>1.0</td>
<td>0.5</td>
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<td>0.1</td>
<td>0.05</td>
<td>0.04</td>
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<tr>
<td><strong>Optimization</strong></td>
<td>0.611</td>
<td>0.8</td>
<td>2.0</td>
<td>1.5</td>
<td>0.32</td>
<td>0.25</td>
<td>0.21</td>
<td>2.0</td>
<td>1.5</td>
<td>1.0</td>
<td>0.5</td>
<td>0.3</td>
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<td>0.05</td>
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term production cost curve \( c_i = 0.0002(K - 250)^2 + 4 \) moves to the right and becomes \( c_i = 0.0002(K - 350)^2 + 4 \), online market's fierce competition declines, consumer welfare increase obviously, and the retailer gets the maximum benefit.

The shadow area \( SATC4 \) is benchmark quantity, which shows that the point \((K^*, \beta)\) is in short-term overcapacity location, the manufacturer \( M_1 \) should improve promotion level to enlarge market demand to optimize short-term capacity to the point \((\bar{K}_0, \beta)\); if the manufacturer \( M_1 \) improves capacity to the \((K^*, \beta)\), from the third column of Table 2 we can conclude that, as the manufacturer \( M_1 \)'s capacity increases, the speed of increasing revenues decreases progressively, until its revenue turns to decrease. However, the manufacturer \( M_2 \)'s revenue increases rapidly, until to exceed the manufacturer \( M_1 \)'s revenue, which is not reasonable. The manufacturer \( M_1 \) should enlarge fixed asset size such as plant, equipment, etc. to push \( SATC4 \) forward to \( SATC5 \), here, the curve \( LATC \) is the manufacturer \( M_1 \)'s long-term production cost curve. We have discussed before that every short-term production cost curve's gradient \( \alpha \) is invariant, but \( \beta \) and \( K_0 \) will change on the curve \( LATC \).

![Chart 3. The manufacturer \( M_1 \)'s long-term production cost curve analysis.](image)

**Conclusion**

All kinds of numerical simulation analysis result shows that supply chain coordination does not exist. The root of the disorder of the supply chain still is because of strong traditional manufacturer's dual role. Due to the second-mover advantages of online manufacturers, the manufacturer \( M_1 \) and \( M_2 \) become main rivals of the supply chain competition, the competitive position of the retailer has been further weakened, supply chain "chain-to-chain" competition is stronger than the competition within the chain competition. Disorder of supply chain has not changed the nature of supply chain, however, we need to design by contract, such as signing with retailers the revenue sharing contract, etc. to achieve supply chain coordination, which is the future direction of the research of this paper.

**References**

