Information Sharing in Competing Supply Chain Under Demand Asymmetric

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Abstract: The competition model has developed from between enterprises to between supply chains, more and more companies lay emphasis on supply chain coordination. Besides, the development of information technology make coordination and management within supply chain possible. The paper consider information sharing in two competing supply chains, each consisting of one manufacturer and one retailer. Since the way of wholesale pricing could affect the result, we take linear wholesale price to conduct the investigation. It is concluded that the higher the possibility of market demand is high, the more likely retailers do not share information. When given the market demand is high, one supply chain do not share information, the optimal strategy the other supply chainis to share demand information.

Keywords: Competing supply chain, linear wholesale price, information sharing

1 Introduction

Intensifying market competition in the market shift competition from monomer competition between enterprises to group competition between supply chains, or even between the unions. Development of information technology has greatly enhanced the management and coordination capabilities among upstream and downstream enterprises. The relation of enterprises change from opposite competition to co-competition and a "win-win" relation. However, it is unrealistic to achieve "integration" in supply chain, thus, transmission of information between supply chains does not reach the ideal state, which resulted in incomplete information. There are many ways to convey information in supply chains, the most common one is information sharing, of course, information sharing is conditional. Since the way of wholesale pricing could affect the result, we take linear wholesale price to conduct the investigation.

Retailers often have direct contact with ultimate consumers to know the market demand conditions, while the manufacturers had no direct knowledge of the relevant information in this regard, which is the very information manufacturers need when make production decisions. Accurate information enables manufacturers to produce on demand, reduce inventory, cut down the resources occupation and waste, decrease risks. Therefore, manufacturers hope that the retailers to share demand information to optimally arrange production. Whether the retailers decided to participate in information sharing depends on the value of sharing information.

There are a mount of paper working on information sharing. According to information content, it could be divided to two parts, one is sharing demand information under demand asymmetric, Xiaohang Yue, John Liu(2006) assessed the benefits of sharing demand forecast information in a manufacturer-retailer supply chain, consisting of a traditional retail channel and a direct channel. It is indicated that the direct channel has a negative impact on the retailer’s performance, and, under some conditions, the manufacturer and the whole supply chain are better off. U.W. Thonemann(2002) analyzed how sharing advance demand information (ADI) can improve supply-chain performance. It study how the values of A-ADI and D-ADI depend on the characteristics of the supply chain and on the quality of the shared information, and we identify conditions under which sharing A-ADI and D-ADI can significantly reduce cost. Jian-Cai Wang, Hon-Shiang Lau, Amy Hing Ling Lau(2009) considered a dominated manufacturer (Manu) supplying a dominant retailer(Reta), Manu knows the product’s unit manufacturing cost deterministically, whereas Reta knows it only in the form of an--a priori subjective
distribution \( m \), then figure out that when should a manufacturer share truthful manufacturing cost information with a dominant retailer. Albert Y. Ha and Shilu Tong (2008) discussed contracting and information sharing in two competing supply chains, each consisting of one manufacturer and one retailer, and conclude the result under different contracts.

Our research is inspired by the analysis of Albert Y. Ha and Shilu Tong (2008). This paper first discuss information sharing in two competing supply chain, it considered contracting and how contract type (contract menus and linear price contract) affected the value of information sharing in supply chains under horizontal competition and asymmetric information. The two supply chains are identical, except they may have different investment costs for information sharing. Manufacturers can only provide homogeneous product to the retailers. The retailer could directly observe demand information, while the manufacturer can not acquire the demand information. Assume that demand could be high or low, under either circumstances, the reserve profit of retailer is zero, the two retailers use the same type of contract (either contract menus or linear price contract) and the contract type is common knowledge for both the manufacturers and the retailers, but the terms of the contract is unobservable for the other supply chain. Based on the assumption, the problem is discussed in two stage, in the first stage, the manufacturers decide whether to invest in information sharing. In the second stage, given the information structure created in the first stage, the manufacturers offer contracts to their retailers and the retailers engage in Cournot competition. When the manufacturers use contract menus, the dominant strategy of each supply chain is to invest in information sharing when the investment costs are low. For the case of linear price contracts, the value of information sharing to a supply chain becomes negative, and the dominant strategy of each supply chain is not to invest in information sharing regardless of investment costs. This paper comprehensively describe information sharing decision equilibrium under different investment cost for information sharing. It is concluded that information sharing could become a source of competitive advantage.

It is noteworthy that computing order in the article is reversed, after obtaining retailers’ contingent action rules, it is suppose to solve the Stackelberg Model in one supply chain, instead of solving the Cournot Model in the consume market. According to converse solving rule, the optimal sales volume of the retailers should be figured out first, then the retailers determine the optimal order quantity based on the optimal sales volume, at last, the manufacturers make a decision on the wholesale price on the basic of optimal order quantity.

This paper solves the model in a correct process; discuss the impact of information sharing to the profit of the supply chains. The higher the possibility of market demand is high, the more likely retailers do not share information. When given the market demand is high, one supply chain do not share information, the optimal strategy the other supply chains is to share demand information.

2 Problem description and symbol assumption

Considering two homogenous competing supply chain, each is composed of one manufacturer and one retailer, the manufacturer provide homogeneous products to retailer in the same supply chain. It is assumed that the reserve profit of retailers is zero, and the sales volume is equal to order quantity. The two retailers could observe demand of the consumers, while the manufacturers could not. Give the information structure, this problem would be solved in three steps, firstly, figure out the contingent action rules to the manufacturer’s wholesale price, by solve a Cournot model, secondly, optimize the manufacturers’ profit and the optimal wholesale price can be obtained, thirdly, the optimal order quantity could be gotten on the basis of wholesale price.

The manufacturers, retailers and supply chains are represent by \( i, j \) respectively, the retailers compete with each other in the market under a linear demand function, in particular, the demand function is \( p = A - q_i - q_j \), where \( p \) is the market-clearing price, \( q_i \) and \( q_j \) is the sales volume of retailer \( i \) and
respectively. \( A \) is the capacity of the market, which vary according to demand state. Assume that the demand could be high or low, \( A \) is given by

\[
A = \frac{A_H}{A_L} \beta \left(1 - \beta\right) \quad (1)
\]

\( A_H \) and \( A_L \) indicate the high and low demand condition respectively, and \( A_H > A_L > 0 \), \( \beta \) is the probability of high demand.

On the ground of the information sharing decision, the information structure could be described as SS (the two supply chain share demand information), NN (neither supply chain share information) and NS (only one of the supply chains share demand information, since either supply chain do not share information would conduct the same result, we assume supply chain \( i \) do not share demand information).

3 Analyses under different information structure

3.1 Information Sharing in both Supply Chain (SS)

Under this circumstance, all the companies know the real demand state \( d \). \( w_d \) is the wholesale price.

The order of the solving process is, the two retailers could figure out controversial action rules in the Cournot market, the manufacturers know that the retailers will determine the order quantity in accordance with the rules, and the manufacturers will decide the wholesale price accordingly.

\[
\max_{q_i} \left( A_d - q_d - q_d - w_d q_d \right) \quad (2-1)
\]

\[
\max_{w_i} \left( A_d - q_d - w_d q_d \right) \quad (2-2)
\]

\[
\max_{w_j} w_j \quad (2-3)
\]

\[
\max_{q_j} \left( A_d - q_d - q_d - w_d q_d \right) \quad (2-4)
\]

Compute the partial derivative of (2-1) and (2-2), the first-order conditions are

\[
q_d = \frac{A_d - q_d - w_d}{2} \quad (3)
\]

\[
q_d = \frac{A_d - q_d - w_d}{2} \quad (4)
\]

Simultaneous (3) and (4), the contingent action rules are

\[
q_d = \frac{A_d + w_d - 2w_d}{3} \quad (5)\]

\[
q_d = \frac{A_d + w_d - 2w_d}{3} \quad (6)
\]

(5) to (2-3) (2-4), optimize the profit of the two manufactures

\[
\max \pi_i = w_d \frac{A_d + w_d - 2w_d}{3} \quad (7)
\]

\[
\max \pi_j = w_d \frac{A_d + w_d - 2w_d}{3} \quad (8)
\]

(8) Compute the partial derivative of (7) and (8), the first-order conditions of maximize the profit of the manufacturers are

\[
w_d = \frac{A_d + w_d}{4} \quad (9)
\]

Simultaneous (9) and (10), the optimal wholesale prices are

\[
w_d = w_d = \frac{A_d}{3} \quad (11)
\]

Substitute (11) to (5) and (6), optimal order quantity is

\[
q_d = q_d = \frac{2A_d}{9} \quad (12)
\]

Substitute (11) and (12) to (2), the profit of each firm in the supply chain could be obtained, to unify with the other two situations and simplify the comparison, we list all the results under different demand states.
\[ \pi_{ij}^R = \pi_{ij}^M = \frac{4A_{ij}^2}{81} \]  
(13) \[ \pi_{Li}^R = \pi_{Li}^M = \frac{4A_{Li}^2}{81} \]  
(14) 
\[ \pi_{Hi}^R = \pi_{Hi}^M = \frac{2A_{Hi}^2}{27} \]  
(15) \[ \pi_{ij}^R = \pi_{ij}^M = \frac{2A_{ij}^2}{27} \]  
(16) 

3.2 No Information Sharing (NN)
Neither the supply chains share demand information. Besides, we assume that the manufacturer would offer the same wholesale price if he do not know the demand information, this assumption would be also used in the following research. The model could be solve in the same way of SS, 
\[ \max_{q_i} (A_d - q_{di} - q_{dj} - w_{di})q_{di} \]  
(17-1) \[ \max_{q_j} (A_d - q_{di} - q_{dj} - w_{dj})q_{dj} \]  
(17-2) 
\[ \max_{w_i} [\beta q_{ij}^H + (1 - \beta)q_{ij}^L] \]  
(17-3) \[ \max_{w_j} [\beta q_{ij}^H + (1 - \beta)q_{ij}^L] \]  
(17-4) 
Compute the partial derivative of (17-1)and (17-2), the first-order conditions of maximize the retailers’ profit are 
\[ \hat{q}_{di} = \frac{A_d - q_{di} - w_{di}}{2} \]  
(18) \[ \hat{q}_{dj} = \frac{A_d - q_{dj} - w_{dj}}{2} \]  
(19) 
Simultaneous (19)and(20), the contingent action rules are 
\[ q_{di}^* = \frac{A_d + w_j - 2w_j}{3} \]  
(20) \[ q_{dj}^* = \frac{A_d + w_i - 2w_i}{3} \]  
(21) Substitute (20)and (21) to (17-3) and (17-4), 
\[ \max_{w_i} w_i \left[ \beta A_{di} + w_j - 2w_j \right] \]  
(22) \[ \max_{w_j} w_j \left[ \beta A_{dj} + w_i - 2w_i \right] \]  
(23) 
Compute the partial derivative of (22)and (23), the first-order conditions of optimize the profit of the manufacturers are 
\[ w_i = \frac{\beta A_{di} + (1 - \beta)A_d + w_j}{4} \]  
(24) \[ w_j = \frac{\beta A_{dj} + (1 - \beta)A_d + w_i}{4} \]  
(25) 
Simultaneous (24)and(25), the optimal wholesale prices are 
\[ w_i = w_j = \frac{\beta A_{di} + (1 - \beta)A_d}{4} \]  
(26) Substitute (26) to (20) and (21), optimal order quantity is 
\[ q_{di}^* = \frac{(3 - \beta)A_{di} + (1 - \beta)A_d}{9} \]  
(27) \[ q_{dj}^* = \frac{(2 - \beta)A_{dj} + \beta A_{di}}{9} \]  
(28) 
Substitute (26), (27) and (28) to (17), the profit of each firm in the supply chain could be conducted 
\[ \pi_{Li}^M = \pi_{ij}^M = \pi_{ij}^L = \frac{2(\beta A_{di} + (1 - \beta)A_d)^2}{27} \]  
(29) \[ \pi_{Li}^R = \pi_{ij}^R = \frac{[3 - \beta - (1 - \beta)A_d]^2}{81} \]  
(30) \[ \pi_{Li}^M = \pi_{ij}^M = \pi_{ij}^L = \frac{\beta A_{di} + (1 + \beta)A_d}{81} \]  
(31) 

3.3 Information Sharing in one Supply Chain
Since the supply chains are identical, either supply chain do not share information would have the same impact on the supply chain, that is to say, the result wil be symmetrical, let supply chain \( i \) do not share demand information. Under such situation, the model could be written as follows
\[
\max q_{Hj}^\prime (A_H - q_{Hj}^\prime - q_{Hj}^0 - w_j) \quad (32- \text{R}_1 -1) \max q_{Li}^\prime (A_L - q_{Li}^\prime - q_{Li}^0 - w_i) \quad (32- \text{R}_1 -2)
\]
\[
\max q_{Hj}^\prime (A_H - q_{Hj}^\prime - q_{Hj}^0 - w_j) \quad (33- \text{R}_1 -1) \max q_{Li}^\prime (A_L - q_{Li}^\prime - q_{Li}^0 - w_j) \quad (33- \text{R}_1 -2)
\]
\[
\max w_i [\beta q_{Hi} + (1 - \beta) q_{Li}] \quad (34- M_i)
\]
\[
\max w_i q_{Hj} \quad (35- M_j -1) \max w_j q_{Li} \quad (35-)
\]

\( M_j \) -2) Solve Cournot game of (32) and (33), the contingent action rules are
\[
q_{ln}^* = \frac{A_H + w_{Hj} - 2w_j}{3} \quad (36-1) \quad q_{ln}^* = \frac{A_L + w_{Li} - 2w_i}{3} \quad (36-2)
\]
\[
q_{ln}^* = \frac{A_H + w_{Hj} - 2w_{Hj}}{3} \quad (37-1) \quad q_{ln}^* = \frac{A_L + w_{Li} - 2w_{Li}}{3} \quad (37-2)
\]
Substitute (36) and (37) to (34)and (35),
\[
\max m_q = \max w_i \frac{A_L - w_i - 2w_{Li}}{3} \quad (38) \max m_{\pi_{Hj}} = \max w_{Hj} \frac{A_H + w_j - 2w_{Hj}}{3} \quad (39-1)
\]
\[
\max m_{\pi_{Li}} = \max w_{Li} \frac{A_L + w_i - 2w_{Li}}{3} \quad (39-2) \quad \text{Compute the partial derivative of (36)and (37), the optimized response functions of the wholesale price are}
\]
\[
w_j = \frac{(A_H + w_{Hj}) + (1 - \beta)(A_L + w_{Li})}{4} \quad (40) \quad w_{Hj} = \frac{A_H + w_j}{4} \quad (41-1)
\]
\[
w_{Lj} = \frac{A_L + w_i - 2w_{Li}}{3} \quad (41-2) \quad \text{Simultaneous (40)and(41), the optimal wholesale prices are}
\]
\[
w_j = \frac{\beta A_H + (1 - \beta) A_L}{4} \quad (42) \quad w_{Hj} = \frac{(3 + \beta) A_H + (1 - \beta) A_L}{12} \quad (43-1)
\]
\[
w_{Lj} = \frac{\beta A_H + (2 - \beta) A_L}{12} \quad (43-2) \quad \text{Substitute (42) and (43) to (36) and (37), the optimal order quantity is}
\]
\[
q_{Hj}^* = \frac{7A_H + \beta A_{Hj} - 7A_L + 7\beta A_L}{36} \quad (44-1) \quad q_{Li}^* = \frac{6A_L - 7\beta A_H + 7\beta A_L}{36} \quad (44-2)
\]
\[
q_{Hj}^* = \frac{3A_H + \beta A_{Hj} + (1 - \beta) A_L}{18} \quad (45-1) \quad q_{Li}^* = \frac{6A_L + \beta A_{Hj} - \beta A_L}{18} \quad (45-2)
\]

Substitute (42)-(45) to (32)-(35), the profit of each company could come out
\[
\pi_{Hi}^H = \left[ (5 - 9\beta) A_H - 7(1 - \beta) A_L \right]^2 \quad (46-1) \quad \pi_{Li}^L = \left[ -7\beta A_H + (8 + 7\beta) A_L \right]^2 \quad (46-2)
\]
\[
\pi_{Hj}^H = \left[ 3(1 + \beta) A_H + (1 - \beta) A_L \right]^2 \quad (47-1) \quad \pi_{Li}^L = \left[ \beta A_H + (4 - \beta) A_L \right]^2 \quad (47-2)
\]
\[
\pi_{Li}^H = \left[ \beta A_H + (1 - \beta) A_L \right] \left[ (\beta - 4\beta) A_H + 4(1 - \beta) A_L \right] \quad (48) \quad \pi_{Li}^L = \left[ (3 - \beta) A_H + (1 - \beta) A_L \right] \left[ 3(1 + \beta) A_H + (1 - \beta) A_L \right] \quad (49-1)
\]
\[
\pi_{Hj}^H = \left[ \beta A_H + (4 - \beta) A_L \right]^2 \quad (49-2)
\]

4 Conclusion
We compare the overall benefit of supply chain under different information structures, based on the benefit of each member of supply chain in different information structures introduced in previous
sections. To make the results easy be observed and compared, we set $\beta = 0.8$ to compare the benefits in different conditions (see Figure 1 and Figure 2). And set $A_H = 100$ and $A_L = 60$. Its results showed in Figure 3 and Figure 4. These hypotheses have no influence on the general trend of profits. Figure 1 and Figure 2, respectively show the overall profits cooperation of different supply chains in high and low market demand. $PiCNISS$ shows the overall profit of any supply chain when two supply chains share demand information. $PiCNN$ indicates the overall profit of any supply chain when two supply chains don’t share demand information. When only one supply chain share demand information, $PiC1NS$ show the overall profit of the supply chain which don’t share demand information and $PiC2NS$ show the overall profit of the supply chain which share demand information.

From Figure 1, we could find, when the market demand information is high, $A_L$ will be closer to $A_H$, then the benefit of supply chain in different conditions will be greater. Furthermore, $\pi_{C1}^{NN} > \pi_{C1}^{NS} > \pi_{C1}^{SS}$, that is the profit of supply chain which share demand information of NS is the greatest and the profit of supply chain which don’t share demand information is the least. To some extent, the profits of two supply chains which don’t share information is greater than it of two supply chains which share information. From Figure 2, we could find, when the market demand information is low, with $A_L$ closer to $A_H$, $\pi_{C1}^{NS}$ is diminishing. On the contrary, $\pi_{C1}^{NN}$, $\pi_{C1}^{SS}$, $\pi_{C2}^{NS}$ are gradually increasing. To some extent, $\pi_{C1}^{NS} > \pi_{C1}^{NN} > \pi_{C1}^{SS}$, under NS condition, the profit of supply chain which don’t share information is much higher than that of supply chain which share information.

From Figure 3, we could find, when the figure of $A_H$ and $A_L$ were set and the market demand is high, with $\beta$ increasing, that is the possibility of market demand be high will increase, $\pi_{C1}^{NS}$ will gradually decrease and $\pi_{C1}^{NN}$, $\pi_{C1}^{SS}$, $\pi_{C2}^{NS}$ will gradually increase. When $\beta$ is greater than a certain figure, $\pi_{C2}^{NS} > \pi_{C2}^{SS} > \pi_{C2}^{NN} > \pi_{C1}^{NS}$. The possibility of market demand be high is greater, under NS condition, the profit of one supply chain sharing demand information is the greatest, and the profit of one supply chain which don’t share demand information is the least. From Figure 4, we could find, when the market demand information is low, with $\beta$ increasing, that is the possibility of market demand be high will increase, the overall profit of supply chain in different conditions will gradually increase, that is $\pi_{C1}^{NN} > \pi_{C2}^{NS} > \pi_{C1}^{SS} > \pi_{C1}^{NS}$. The overall profit under NN condition is the greatest, though it is the least under NS condition.

![Figure 1](image.png)
In conclusion, $\pi_C^{CS}$ is in average level in all cases. When the market demand is high, $\pi_C^{NS}$ is greater. $\pi_C^{NN}$ is the greatest when the figure of $A_H$ and $A_L$ were set and the actual market demand is low. $\pi_C^{NS}$ is greater when the figure of $\beta$ was set and the actual market demand is low, though the profit in other cases is far less than that of supply chain in other information structure. The higher the possibility of market demand, the more likely retailers do not share information. When given the market demand is high and one supply chain do not share information, the optimal strategy of the other supply chain is to share information.
References


