# The Wholesale Price Contract of Supply Chain Decision-making Behavior Research 

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#### Abstract

In recent years, the development of the concept of supply chain to be reckoned with, resulting in the problem that the supply chain is not coordination is increasingly attention. The wholesale price contract is a simple way to solve the supply chain coordination. It is by the supplier in the supply chain to determine a wholesale price. Then the supplier tells the wholesale price to retailers, retailers determine his order. This article elaborated on the basis of simple newsboy model, to establish a simple model of the wholesale price contract, and find out the optimal value of centralized decision-making and decentralized decision-making. Through the test, this article analyses the gap of the experimental data and the optimal value, and to find what factors in the wholesale price contract may affect the result of the experiment. It found there is not necessary link between the wholesale price and the retailer's order quantity.


## 1. Introduction

In previous management methods, the supply chain was in an uncoordinated state due to the uncertainty of production and multiple factors in the supply chain. Firstly, the supply chain is disordered because the information barriers and inconsistent goals among members of the supply chain. Furthermore, because the information between the internal and external parts of the supply chain and the information between the components of the supply chain is asymmetrical, the supply chain may cause exogenous risk because of the lack of external environmental information or the information from a member of the supply chain.

Finally, because each member of the supply chain system has their own subjective consciousness, the production target that they set profit maximization may differ greatly from the overall target of the supply chain (Robbins, S., 2016).
"Double marginal effect" refers to an enterprise only consider its own situation when making a decision, without considering the whole supply chain. It lead to the phenomenon that product price is higher than the marginal cost of production (Yong, Lin, Shihua, Ma, 2016).

The wholesale price contract can be used to alleviate the "double marginal effect". The article mainly considers the effect of fair concern on the supply and sale. Fairness concerns that when others are fairer to themselves, they will be more harmonious with each other, vice versa (Rabin, M., 1993). Fair concern exists because in the actual supply chain, people will always compare their income with each other.

## 2. Research status

After the supplier has produced the product, the product is delivered to the retailer under the contract. The retailer is responsible for selling the product. Suppliers are no longer responsible for these products. It is also said that once the product is delivered to the retailer, if the retailer cannot sell all the products, the retailer will form a certain inventory. The residual value of the product is very low or even has no use value. It can only be disposed of. All these losses must be borne by the retailers themselves.

Pasternack first introduced the concept of supply chain to people's vision (Pasternack, B. A., 1985). After that, scholars from different countries began a series of researches. More attention is paid to the study of various contracts in the supply chain. This paper tries to solve these problems: (1) what should the supply chain do when the supply chain cannot be coordinated as expected because force majeure causes disruption in supply chain demand? (2) How should it be coordinated due to the deviation of emergency factors? The conclusion is that in the case of only one supplier but with multiple retailers, the wholesale price contract can alleviate the problems on the supply chain and solve the supply chain problem when the supply chain is unexpected. The operation of wholesale price contract is explained experimentally. The difference between centralized decision making and decentralized decision making was studied (Xiaoyan, Fan, 2006). Based on a simple model of newspaper boy, the concept of simple game and investment portfolio was added, and the wholesale price contract was further studied (Xusong, Xu, Ming, Weng, 2008). When facing risks, newsboy shows concern for risks instead of ignoring them, which will affect the order quantity in wholesale price contracts. The conclusion shows that newsboy will avoid risks in the form of portfolio when facing the known risks.

The efficiency of decentralized and centralized coordination can be studied based on the newsboy model (Rong, Ma, Jun, Ma, Yatao, Wang, 2011). Ma concluded that the wholesale price of the supplier is only related to the cost and price elasticity of the commodity. By studying the influence of equity preference on the one-to-one simple model of newsboy, it is concluded that both supply and demand are willing to cooperate with altruistic preference, which can reduce the "double marginal effect" (Yanhong, Tan, 2017). By analysing the problem of simple wholesale price contract, scholars can discuss the wholesale model based on Nash negotiation model (Cengceng, Liu, Yongjie, Chu, Xianmin, Bu, 2013). There is a simple supply chain that consists of different retailers and suppliers, with strong suppliers and relatively weak retailers (Jixiang, Zhou, Yong, Wang, 2016). It is discussed how the wholesale price contract runs when the two parties cannot get the same information.

It is seen that most scholars have discussed the use of wholesale price contracts under different factors. But there is little concern about the role of fairness concerns in wholesale price contracts which is a field we are studying deeply.

## 3. Modeling and analysis

### 3.1 Create the Model

For the convenience of research, the article chooses one to one simple model in which only suppliers and retailers. The supplier decides the wholesale price. The retailer decides the quantity demanded. Both suppliers and retail are risk-neutral. No matter how many products the retailer needs, the supplier will always meet his requirements. It is assumed that both suppliers and retailers can make the decision to maximize the benefits under the existing information, assuming that the market demand is random and obeys a certain parameter distribution. It is assumed that the supply of goods can be delivered right away. Do not consider the loss caused by not selling products.

Supplier's wholesale price - W
Supplier cost - C
Supplier's profit - Ls
Retailer's profit - Lr
The price of goods - P
Order quantity - Q
Market demand - D
Distribution function of market demand -- $\mathrm{F}(\mathrm{x})$
The density function of market demand -- $f(x)$

### 3.1.1 Profit

Supplier's profit:

$$
\begin{equation*}
\mathrm{Ls}=(\mathrm{W}-\mathrm{C}) * \mathrm{Q} \tag{1}
\end{equation*}
$$

Retailer's profit:

$$
\begin{equation*}
\mathrm{Lr}=\mathrm{P} * \operatorname{MIN}(\mathrm{Q}, \mathrm{D})-\mathrm{W}^{*} \mathrm{Q} \tag{2}
\end{equation*}
$$

The market demand obeys the uniform distribution.

### 3.1.2 The optimal model

The optimal model of decentralized decision making:

$$
\begin{gather*}
\operatorname{Lr}(\mathrm{Q}, \mathrm{~W})=\mathrm{P} * \mathrm{E} \min (\mathrm{Q}, \mathrm{D})-\mathrm{W} * \mathrm{Q}  \tag{3}\\
\mathrm{Q}^{*}(\mathrm{~W})=\mathrm{b}-(\mathrm{W} / \mathrm{P}) *(\mathrm{~b}-\mathrm{a}) \quad(\mathrm{W}<\mathrm{P})  \tag{4}\\
\mathrm{Q}^{*}(\mathrm{~W})=0 \quad(\mathrm{~W} \geq \mathrm{P})  \tag{5}\\
\mathrm{Ls}\left[\mathrm{Q}^{*}(\mathrm{~W}), \mathrm{W}\right]=(\mathrm{W}-\mathrm{C}) * \mathrm{Q}^{*}(\mathrm{~W})  \tag{6}\\
\mathrm{W}^{*}=\operatorname{Min}\{\mathrm{P}, \mathrm{C} / 2+(\mathrm{P} / 2) * \mathrm{~b} /(\mathrm{b}-\mathrm{a})\} \tag{7}
\end{gather*}
$$

The optimal model of centralized decision making:

$$
\begin{gather*}
\mathrm{L}(\mathrm{Q})=\mathrm{P} * \mathrm{E} \min (\mathrm{Q}, \mathrm{D})-\mathrm{C} * \mathrm{Q}  \tag{8}\\
\mathrm{Q}=\mathrm{b}-(\mathrm{b}-\mathrm{a}) *(\mathrm{C} / \mathrm{P}) \tag{9}
\end{gather*}
$$

### 3.2Decentralized Decision System

Under the decentralized decision-making system, suppliers and retailers only consider their own positions. The optimal order quantity $\mathrm{Q}^{*}$ of the decentralized system is determined by the retailer's profit function Lr. Using the function LS, the optimal wholesale price $\mathrm{W}^{*}$ of the decentralized system can be obtained.

The market demand D obeys the uniform distribution between a and $\mathrm{b}, \mathrm{E}$ min $(\mathrm{Q}, \mathrm{D})$ are the expected values of demand. The optimal order quantity of the model is obtained by the function formula. Then the second derivative of the profit function is obtained.

Because the two derivative of function is less than 0 , it is easy to know that the derivative should be a decreasing function.

Let L' $=0$.

$$
\begin{equation*}
\mathrm{Q}^{*}(\mathrm{~W})=\mathrm{b}-\mathrm{W} *[(\mathrm{~b}-\mathrm{a}) / \mathrm{P}] \tag{10}
\end{equation*}
$$

It is easy to know that when the optimal order is equal to $\mathrm{b}-\mathrm{W}$ * [(b-a)/P], the retailer's profit is the largest. The optimal order quantity is the function of the wholesale price.

When $\mathrm{W}<\mathrm{P}$, the retailer makes a profit and the order quantity falls between a and b . When $\mathrm{W} \geq$ P , the retailer will not make a profit or loss and the retailer will not make an order because the profit is 0 , because the retailer has a profit of 0 .

Next, the best wholesale price can be obtained.

$$
\begin{equation*}
\mathrm{Ls}=(\mathrm{W}-\mathrm{C}) *\{\mathrm{~b}-[\mathrm{W} *(\mathrm{~b}-\mathrm{a})] / \mathrm{P}\} \tag{11}
\end{equation*}
$$

Obviously, the second derivative function of Ls is less than zero which means that the first derivative function is monotonically decreasing. $\mathrm{Ls}^{\prime}=0$.

$$
\begin{equation*}
\mathrm{W} 1=\mathrm{C} / 2+(\mathrm{P} / 2) *[\mathrm{~b} /(\mathrm{b}-\mathrm{a})] \tag{12}
\end{equation*}
$$

So the best wholesale price of the supplier is available.

$$
\begin{gather*}
\mathrm{W}^{*}=\min \{\mathrm{P}, \mathrm{C} / 2+(\mathrm{P} / 2) *[\mathrm{~b} /(\mathrm{b}-\mathrm{a})]\}  \tag{13}\\
\mathrm{Q}^{*}\left(\mathrm{~W}^{*}\right)=\mathrm{b} / 2-\mathrm{C} *[(\mathrm{~b}-\mathrm{a}) /(2 * \mathrm{P})] \tag{14}
\end{gather*}
$$

It is worth noting that this conclusion is based on the risk neutrality of both parties.

### 3.3 Centralized Decision System

Under the centralized decision-making system, the article assumes that the total profit of the supply chain is $\mathrm{L}(\mathrm{Q})$, the optimal order quantity obtained under this condition is Q ' and Q ' is the maximum order quantity for $\mathrm{L}(\mathrm{Q})$.

$$
\begin{equation*}
\mathrm{L}(\mathrm{Q})=\mathrm{P} * \mathrm{E} \min (\mathrm{Q}, \mathrm{D})-\mathrm{C} * \mathrm{Q} \tag{15}
\end{equation*}
$$

It can be seen that the total profit of the supply chain is only related to the order quantity which has nothing to do with the wholesale price.

Obviously, the second derivative function of Ls is less than zero which means that the first derivative function is monotonically decreasing. $\mathrm{L}^{\prime}(\mathrm{Q})=0$.

$$
\begin{equation*}
\mathrm{Q}^{\prime}=\mathrm{b}-\mathrm{C} *[(\mathrm{~b}-\mathrm{a}) / \mathrm{P}] \tag{16}
\end{equation*}
$$

When $0 \leq \mathrm{Q}^{\prime}<\mathrm{Q}^{\prime}, \mathrm{L}(\mathrm{Q})$ is a decreasing function.
When $\mathrm{Q}>\mathrm{Q}^{\prime}, \mathrm{L}(\mathrm{Q})$ is increasing function.
When $\mathrm{Q}=\mathrm{Q}^{\prime}, \mathrm{L}(\mathrm{Q})$ gets the maximum value.
Under the centralized decision making condition, the optimal order quantity of the total profit of the supply chain is Q'.

### 3.4 Analysis of Model

The double marginal effect is caused by the difference between decentralized decision making and centralized decision making in the supply chain. Centralized decision-making helps to improve this coordination problem. The model shows that in a distributed system to consider the optimal order quantity and the optimal wholesale price, centralized system only need to consider the optimal order quantity. As far as the optimal order quantity under centralized and decentralized decision is concerned, the supplier's cost cannot be higher than the wholesale price, so $\mathrm{C}<\mathrm{W}^{*}$.
$\mathrm{Q}^{*}<\mathrm{Q}^{\prime}$, it is easy to know that the optimal order quantity of decentralized is smaller than the centralized optimal order quantity. Then the total profit of the supply chain increases as Q increases between Q1 and Q2. Therefore, centralized decision-making can promote market transactions.

## 4. Experimental process

Using Z-tree software, six volunteers were invited to help complete the experiment. In the experiment, one person represented the supplier and the other represented the retailer. In this simulated two-stage supply chain, the wholesale price is allowed to be equal to the sale price of the commodity which is to produce a zero order quantity. The market demand is uniform distribution of a certain parameter. Using the Z-tree to simulate the market demand by generating random numbers distributed uniformly during each round of experiments. In reality, the order quantity is a discrete distribution, but in the experiment it is simplified into a simple continuous distribution. The experiment is based on the reality of the domestic brand mobile phone market. The supplier corresponds to the manufacturer, and the retailer corresponds to the regional distribution and the retail channel, the three kinds of virtual smart phone products as the trading objects. To simplify the study, it is assumed that the residual value of the three products that are not sold at the end of the current period is 0 . Different experiments are carried out in turn based on three kinds of products.

### 4.1 Experiment

### 4.1.1 Decentralized Experiment of $A$ and $B$

Decentralized supply chain experiments for A and B products with no information disclosure: The experimental rules are introduced to the subjects, indicating that the retailer is faced with a newsboy decision problem in the decentralized supply chain. The optimal order quantity is affected by the sales price and the wholesale price. The supplier determines the wholesale price by observing the optimal order quantity equation. Both of them aim to maximize their own profit. A is the product with high total profit and $B$ is the product with low total profit.

Experiment of group A: Firstly, a decentralized decision-making experiment was conducted on product A. Software randomly divided two volunteers into one group. The software automatically assigns the roles to each group. Through the software interface, both parties are informed that the market share of both products is middle level which means the equal game status between the supplier and the retailer. Suppliers obtain product cost, retail price and market demand distribution through software interface. Retailers obtain retail prices and distribution of market demand through software interface. The cost of the product is supplier's private information. The supplier determines the wholesale price based on cost, retail price and market demand. After knowing the wholesale price, retailers determine the quantity ordered based on the distribution of wholesale prices and market demand. After at, the software produces the current demand random number and calculates the profit of the supplier and the seller. The wholesale price, the order quantity and the supplier's profit are displayed to the supplier through the software interface. The wholesale price, the demand, the order quantity and the retailer's profit are displayed to the retailer. Profit is private information of both parties. The demand is private information of the retailers. So the 20 round is circulated and 60 sets of data are obtained.

Experiment of group B: Next, the same experiment was performed on product B and 60 sets of data were obtained.

### 4.1.2 Decentralized Experiment of $\mathbf{C}$

A decentralized decision experiment for C products with equal information between suppliers and retailers: The role of each group is unchanged. Through the software interface, the market share of both suppliers and retailers that the product is medium level. The cost, the sale price and the distribution of the market demand are told by the software interface to all the participants. Repeat the experiment. Suppliers and retailers independently decide the wholesale price and order quantity without communicating. At the end of each period, order quantity, current market demand and profits of both sides is displayed on the software screen of two members in each group. So the 20 round is circulated and 60 sets of data are obtained.

### 4.1.3 Centralized Experiment of $A$ and $B$

Centralized decision experiment of product A and B: It is shown to the subjects that both suppliers and retailers in the centralized supply chain are faced with a newsboy decision problem. The total profit of the supply chain is the common goal. They will distribute profits according to the proportion acceptable to both sides, but how to allocate specifically is not considered in the experiment. The centralized supply chain requires the suppliers and retailers to agree on the optimal order quantity. The optimal order quantity is influenced by selling price, wholesale price and production cost. The centralized decision-making experiment of product A is carried out. The role of each group is unchanged. Costs, sales prices and market demand distributions are exposed through the software interface. According to the distribution of cost, sales price and market demand, the two parties jointly agree on the maximum amount of order to make both sides profit. After that, the current demand random number and the total profit of the supply chain are generated by the software. The quantity, demand and total profit of the current period are displayed to the supplier and retailer through the software interface. So the 20 round is circulated and 60 sets of data are obtained. Next, we conduct the same experiments on B products and get 60 sets of data.

### 4.2Setting Experimental Parameters

$\operatorname{Cost}(\mathrm{C})$, sales price $(\mathrm{P})$, a and b are fixed value. The wholesale price and quantity is set by the participants, market demand (D) randomly generated by the software. In the experimental, the products A, B and C are the three models of mobile phones. The phone model of product A is vivoP which unit cost is expressed in Ca and retail price is expressed in Pa . The phone model of product B is vivo X which unit cost is expressed in Cb and retail price is expressed in Pb . The phone model of product C is vivoY which unit cost is expressed in Cc and retail price is expressed in Pc. A is a highly profitable product. Its cost is 2,000 yuan and the sales price is 4,600 yuan. Demand for A is uniformly distributed from 4,000 to 24,000 . B is a product with low profits. Its cost is 1,600 yuan
and the sales price is 2,800 yuan. Demand for B is uniformly distributed from 40,000 to 280,000 . C is a medium-profit product. Its cost is 800 yuan and the sales price is 1,500 yuan. Demand for C is uniformly distributed from 20,000 to 220,000.

### 4.3Theoretical Value of Experiment

According to the experiment, the theoretical value as shown in table 1.
Table 1: These are theoretical values of the experiment.

|  | Decentralized |  |  |  | Centralized |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Q* | W | Ls | L | Q' $^{\prime}$ | L |
| A | 0.77 | 3760 | 1346.78 | 1836.1 | 1.53 | 2509.57 |
| B | 7.14 | 2433 | 5952.38 | 7995.2 | 14.3 | 10971.4 |
| C | 5.67 | 1225 | 2408.33 | 3462.5 | 11.3 | 4666.67 |

The units of $\mathrm{Q}^{*}$, Ls and L are all ten thousand.
It is assumed that the quantity of orders determined by the retailer is related to the wholesale price established by the supplier, the higher the wholesale price, the less the order quantity and the less wholesale price, the more order quantity.

It is assumed that in the case of information transparency, there is a fair concern between the two experimenters, and the profit distribution gap between the two roles will be reduced.

Affected by the actual demand, the quantity of orders in the short term will deviate from the optimal solution in the direction of actual demand.

### 4.4Characteristic Analysis of Data

According to the experimental data of A and B , the results are shown in table 2.
Table 2: There are the experimental results of asymmetric information.

|  |  | Q* | D | Ls | Lr | L |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| A | Optimum | 0.77 | 1.4 | 1346.78 | 489.39 | 1836.17 |
|  | Average | 0.98 | 1.42 | 1660.17 | 390.18 | 2025 |
|  | Variance | 0.11 |  | 400797 | 762152 | 874836 |
| B | Optimum | 7.14 | 16 | 5952.38 | 2042.86 | 7995.24 |
|  | Average | 12.8 | 20.6 | 9094.81 | 5083.73 | 14178.55 |
|  | Variance | 14.35 |  | 14311794 | 16311057 | 20681358 |

Digital units are all ten thousand.

### 4.4.1 Information Asymmetry

Analysis results under information asymmetry: For vivoP: The average wholesale price of the experiment is 3695.55 and the theoretical optimal value is 3760 . The wholesale price fluctuates along the optimal price, but most of them are below the optimal value. For vivoX, the average value of the wholesale price of the experiment is 2295.52 and the theoretical optimal value is 2433.33 . It shows that the experimental value and the optimal value are also close.

For vivoP: The average order quantity is 0.98 and the theoretical optimal value is 0.76522 . The optimal value of the order quantity is less than the average of the actual order quantity. The optimal value of actual demand in the market is1.4, the average value of the actual demand is 1.42 . When the retailer predicts the market demand, it will always determine the quantity of the order according to the real demand of the market which makes the average value of the order quantity deviate from the optimal value and draws close to the optimal value of the actual demand of the market. This is most likely to lead to retailers ordering more than the optimal value. For vivoX, the average value of the retailer's order is 12.7983 , the optimal order quantity in theory is 16 and the average market demand is 20.558 . It can be seen that the experimental data deviate from the optimal value direction which is consistent with the actual market value.

The article assumes that the higher the wholesale price, the lower the actual order quantity,
otherwise the order will be increased. For vivoP: by calculating the average quantity and average wholesale price, it is concluded that the absolute value of the correlation coefficient is less than 0.3. It is easy to know that the relationship between the wholesale price and the order quantity is very weak. The correlation coefficient is negative means that the higher wholesale price, the lower order quantity. The fluctuation diagram of them is shown in figure 1.


Figure 1: Wholesale price and order quantity fluctuation situation of VivoP.
Similarly, for vivoX, the value of $\rho$ is 0.315 , the linear relationship is relatively weak, but the correlation coefficient is positive at that time. In other words, as the wholesale price rises, so does the volume of orders. The fluctuation of the wholesale price and order quantity of vivoX is shown in figure 2.


Figure 2: Wholesale price and order quantity fluctuation situation of VivoX.
Through the first group of experiments, it is easy to see that the fluctuation of the order quantity, the wholesale price and the real demand of the market are not regular. It can be seen from figure 3 and figure 4.


Figure 3: The first group of Q/W/D fluctuations in A products.


Figure 4: The first group of Q/W/D fluctuations in B products.

### 4.4.2 Information Symmetry

Analysis results under information symmetry: The result shows that when information is not
open, the profit of vivoP retailer is $33 \%$ of the supplier's profit. For vivoX, the profit of the retailer is $73 \%$ of the profit of the supplier and the profit of the retailer is $24 \%$ of the profit of the supplier after the information is given to both sides. The decrease of profit percentage is just the opposite of the hypothesis. The experiment assumes that both sides know others' profits because of the disclosure of both parties' information which will make both sides be affected by fair concern and make both sides try to make their profits fair. But the result of the experiment shows that after the symmetry of information, the profit gap between the supplier and the retailer widened. There are three explanations for this phenomenon:

Because the market demand adopts the method of generating random numbers, the change is relatively large, while the real market demand changes are very small. That makes greater profit gap between the supplier and the retailer when they take measures because of major changes in market demand.

In the experiment of information symmetry and information asymmetry, the cost price of the product we designed is different and lacks the contrast.

Fairness concerns do not affect the sale and purchase between supplier and retailer on the supply chain.

It can be seen that the total profit of the centralized supply chain is greater than that of distributed supply chain, but it can be seen that there is a certain gap between the average value and the optimal value.

## 5. Conclusions

On the basis of the newsboy model and the derivation of the mathematical formula, the experiment is designed to deal with the wholesale price contract between the supplier and the retailer on the two-stage supply chain. After analysing the relationship between wholesale price and order quantity, the article finds that there is no linear correlation between them. It does not confirm the hypothesis: when the wholesale price falls, the order quantity will increase and when the wholesale price increases, the quantity of goods ordered decreases. Furthermore, the size of the order determined by the retailer is far from the optimal solution derived from our model. This is due to the actual market demand. The actual order quantity always deviates from the actual market demand and the mean of the market demand is not consistent with the optimal solution, so the deviation caused by the market demand is not consistent with the optimal solution. Finally, it did not draw the conclusion that fairness concern would affect both sides' actions.

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