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ANALYSIS ON THE ORDER BEHAVIOR OF RETAILER WITH CONSIDERATION OF THE DECISION ENVIRONMENT AND THE DECISION MAKER'S GENDER

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Abstract. *Are women more risk averse than men and is the risk attitude of decision maker related to the decision environment in newsvendor decision? In this paper, with the computer experimental platform, we explore the relationship between the average order quantities determined by the human subjects and the decision-making environment, the relationship between the average order quantities and the gender difference of the subjects. The experimental data reveals a kind of trend that the ordering behavior in newsvendor problem is not perfectly rational. Under some circumstances, the average order quantity determined by the male is higher than that of the female, and the average order quantity determined under the condition of loss is higher than that under profitable condition. To explore and fully understand the principles of the ordering behavior in newsvendor decision will be potentially effective in improving the accuracy of decision making in practice.*

Keywords: Supply chain, Newsvendor decisions, Order behavior, Bounded rationality

1. **Introduction.** The newsvendor problem is one of the classic models in supply chain inventory management focusing on the purchase of perishable products. The model maximizes the expected profit by determining the 'optimal order' with the assumptions that the decision makers are homogeneous and perfectly rational. According to this theory, the optimal decision point may not be changed as long as the parameters, like the retail price, the purchase cost and the salvaged, that affect the optimal decision point maintain unchanged; it means that the optimal order quantity determined by the decision makers with different attributes, at different decision-making environment, should not be different. However, behavioral experimental researches have challenged the assumption that the decision makers are homogeneous and perfectly rational. So far, behavioral experimental researches in supply chain inventory management related to this article mainly include: individual differences and cognitive biases in decision making. Individual differences refer to the experimental observation that the gender, emotion, cognitive ability, age and other factors of decision makers have a systematic effect on their decision-making results [1-5]. Comparative analyses of empirical data and experimental data have confirmed the tendency that women are more risk averse than men in economic decision-making [6,7]. However, experimental researches in supply chain inventory management have also observed that gender has no significant effect on the ordering behavior of decision makers, and professional factors can significantly affect the ordering behavior [5].

Cognitive biases refer to the "cognitive limits" of human minds. Simon put forward the concept of bounded rationality, a theory about economic decision-making that individuals

do not seek to maximize their benefit from a particular course of action. Not only can not they get access to all the information required, but even if they could, their minds would be unable to process it properly. Based on the research of Simon, Tversky and Kahneman [4] put forward prospect theory, and according to the explanation from this theory, the risk attitude of decision maker is closely related to the decision environment. Behavioral experimental researches in supply chain inventory management also show that experienced procurement managers broadly exhibit the same kind of pull-to-center bias as students do, and the managers use information and task training no better than the students [8]. Researches also show that retail price and salvage have an "Anchoring" effect similar to purchase cost, and when the optimal order quantity is lower or higher, there is a gap between the subjects' actual mean order quantities and the optimal order quantities; the higher (the lower) the optimal order quantity is, the greater the difference between the two is [4].

The experimental observation that women are more risk averse than men, and the risk attitude of decision maker is closely related to the decision environment has been accepted extensively in economic decision-making. However, whether gender has significant effect on the ordering behavior, and whether the decision environment affects the ordering behavior in supply chain inventory management is still a controversial topic. In this paper, with the computer experimental platform and the students as the retailers, we carried out a series of newsvendor ordering experiments aiming at the three research hypotheses: the order quantity determined by the human subjects depends on the optimal order quantity only; the gender difference of retailers has no influence on their order quantity; the decision-making environment has no influence on their order quantity. The contrast analysis from the experimental data indicates that the ordering behavior of the human subjects is not perfectly rational, and the hypotheses have been rejected.

2. **Newsvendor Problem and the Hypotheses.**

2.1. **The descriptions of the models.**

In the newsvendor problem, the retailer chooses an order quantity q, which arrives before the start of a selling period. Let D be the stochastic demand during this period. Let $F(D)$ be the distribution function of demand and $f(D)$ the density function. For simplicity, assume $F(D)$ is continuous, differentiable and strictly increasing. The retailer purchases each unit for cost c and sells each unit at price $p > c$. When $q > D$, each unit remaining at the end of the period can be salvaged for $s < c$. Let $\pi(q, D)$ be realized profit; the newsvendor model finds the optimal order quantity q_n by maximizing the expected profit $E[\pi(q, D)]$. To compute the expected profit of a given order quantity q, the profit is divided into two cases.

(a) For demand D lower than the order quantity q, where

$$E[\pi(q, D)] = \int_0^q [px - cq + s(q - x)]f(x)dx \tag{1}$$

(b) For demand D exceeding the order quantity q, where

$$E[\pi(q, D)] = \int_q^\infty (pq - cq)f(x)dx \tag{2}$$

Then

$$E[\pi(q, D)] = \int_0^q [px - cq + s(q - x)]f(x)dx + \int_q^\infty (pq - cq)f(x)dx \tag{3}$$

Let $q_n = \arg\max E[\pi(q, D)]$, and

$$\frac{dE[\pi(q, D)]}{dq} = (p - c) - (p - s) \int_0^q f(x)dx = 0 \tag{4}$$

Then, the order quantity that maximizes the expected profit is

$$q_n = F^{-1}\left(\frac{p - c}{p - s}\right) \tag{5}$$

2.2. **Hypotheses.** By balancing the costs of ordering too little against the costs of ordering too much, the mathematical model can provide the well-known 'optimal order'. However, is the optimal order quantity determined by the human subjects in actual situation really like this? To explore and measure the gap between the theoretical model and the experimental observations, we first investigate the conclusion denied by the previous scholars through the experiments "the order quantity of retailers depends on q_n only".

Hypothesis 1: The order quantity of retailer is q_n.

Then we extend the previous behavioral experimental researches from the relationship between the order quantities of human subjects and demand scale, retail price and salvage, to the relationship between the order quantity determined by the human subjects and the gender difference of the subjects; especially we explore the impact of the gender difference on the order quantity determined by the human subjects in different purchase cost, retail price, and demand scale.

Hypothesis 2: The gender difference of retailers has no influence on their order quantity.

Finally, we compare the order quantity determined by the human subject when he or she is in a state of profit or loss. According to the explanation of prospect theory, when the decision maker is in a profitable environment, he or she will be more sensitive of excess ordering, and then he or she will tend to reduce the order quantity. When the decision maker is in a loss environment, he or she will be more sensitive of stock out, and then he or she will exhibit risk chasing, and tend to increase the order quantity.

Hypothesis 3: The decision-making environment has no influence on the order quantity of retailers.

3. The Experiments and the Results Analysis.

3.1. **The experiments.** The experiments included 80 college students from two universities in Yantai, China, 20 males and 6 females, majoring in logistics management. They have studied some basic courses in economics, management, statistics supply chain and logistics management, and have been familiar with newsvendor problem, but they do not grasp the optimization knowledge to the problem. We carried out the experiments in the computer laboratory of the college approximately 4 hours each time. The experiment was programmed using Visual Basic and Excel. Each subject was free to fulfill the experimental task at his or her own pace independently of the other participants. The experiment can provide feedback of the previous actual demand (randomly generated by the software) and the previous and accumulated profit.

Before the experiments, we spent 2 hours in explaining and demonstrating the experimental procedure and the use of the software, answering their questions to help the subjects to fully understand the experiment, especially to understand the actual significance of the related parameters, in order to deepen their philosophy that the right amount of order may bring profit, and too much or too little of the order quantity may cause a loss. After the explanations, two exercises were given to check up whether the subjects could understand the experiment, and we declared that we should only accept the data from the subjects who had presented the correct solutions to the two exercises. In order to obtain high quality experimental data, we announced two disciplines, one is the strict

Table 1. The experimental contents and parameters

Relationship between mean order quantities and retail price			*Relationship between mean order quantities and demand scale*			*Relationship between mean order quantities and purchasecost*		
Exp. No.	*Exp. No.*	*Retail price*	*Exp. No.*	*Exp. No.*	*Demand scale*	*Exp. No.*	*Exp. No.*	*Purchase cost*
105-3	*106-3*	$P = 70$	*107-2*	*108-2*	*(0,80)*	*109-2*	*110-2*	$C = 40$
105-6	*106-6*	$P = 130$	*107-5*	*108-5*	*(0,120)*	*109-5*	*110-5*	$C = 80$
Uniform demand (0,100) *Purchase cost* $C = 60$ *Salvaged* $S = 0$ $N = 30$			*Retail price* $P = 100$ *Purchase cost* $C = 60$ *Salvaged* $S = 0$ $N = 30$			*Uniform demand (0,100)* *Retail price* $P = 100$ *Salvaged* $S = 0$ $N = 30$		

emphasizing that the participants should not talk to each other, and peep at others' experimental data. The other is the combination incentive method of cash and the course scores. The cash and the course scores are calculated according to the quality of their experimental results.

In the experiments, each subject was informed of a series of newsvendor order problems, and the demand distribution was uniform throughout the experiment. In order to explore whether the order quantities depend on the decision environment (where the decision-maker was in a state of profit or loss), the subject was informed that the previous 30 rounds of purchase decision had been made out; he or she could see from the software that he or she was in a profitable state or a loss state, and then was asked to finish the remaining 30 rounds of the decision. It was emphasizing that the previous accumulated profit or loss would be added to their experimental result of the remaining 30 rounds.

The details of the experimental parameters are shown in Table 1. In order to compare the difference between the corresponding cases, 12 experiments were included in this research. Experiments 105, 107, 109 were referred to as the case where the decision-maker was in a state of profit, and experiments 106, 108, 110 were the corresponding case where the decision-maker was in a loss state. The experiments consist of three categories: the relationship between the mean order quantities and the retail price; the relationship between the mean order quantities and the demand scale; and the relationship between the mean order quantities and the purchase cost. In each of the three categories, the variable is retail price, demand scale, and purchase cost respectively. Each of the three categories consists of two variable options: low and high. For each variable and variable value, there are two decision environments: profit or loss. The suffix number m in the experimental item means the experimental results from the subjects of male, and f means the results from female. So that item105-3m, 107-2m, 107-5m, 108-2m, 109-2m, 110-5m, mean the experimental results from the subjects of male, and 105-3f, 107-2f, 107-5f, 108-2f, 108-5f, 109-2f, 110-5f mean the experimental results from female. In the figures, the suffix number qn means the optimal order quantity.

3.2. **The results and analysis.** 12 experiments were included in this research. Before the experimental data statistics, we exclude the flawed data submitted not in accordance with the requirements. The flawed data mainly include: (1) Some subjects forgot to answer the two questions left before the experiments or did not give the right answers; (2) More flawed data were submitted by the subjects who had only completed parts of the required experimental projects that we could not accept them for the lack of its corresponding data for the trend analysis and contrast analysis; (3) Some subjects did not complete enough rounds of decisions. After excluding the flawed data, there are only

18 reports results from males; in order to match the 18 results from males, we had to randomly selected 18 reports results from the females.

T-test assesses whether the average values of two groups are statistically and significantly different from each other. By running it, we can find whether the difference between two groups of average order quantities determined by the human subjects is significantly different from each other, which will allow us to gauge whether the two groups of subjects are statistically and significantly different from each other, and the discrete degree of the answers from the human subjects and their standard error. From the contrast analysis of the experimental data, 7 groups of the contrast data were significantly different by T-test, and the rest of the data were not significantly different. Figure 1 to Figure 7 demonstrate the actual mean order quantities between the corresponding experiments and the optimal order quantities. Table 2 demonstrates the T-test values between the corresponding experiments.

From Figure 1 and Table 2, we can see that at low "retail price", whether male or female subjects, the average order quantities determined by the human subjects are far higher than the optimal order quantity, and the average order quantities determined by the male are higher than that of the female. From Figure 2, Figure 3 and Table 2, we can see that at low "demand scale", whether male or female subjects, the average order

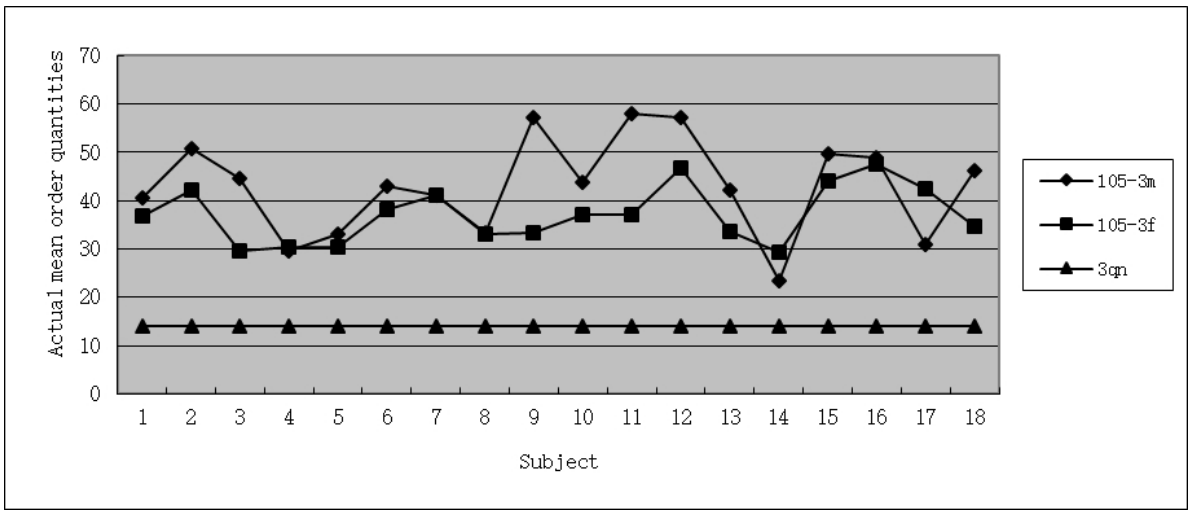

FIGURE 1. Mean order quantity under low price

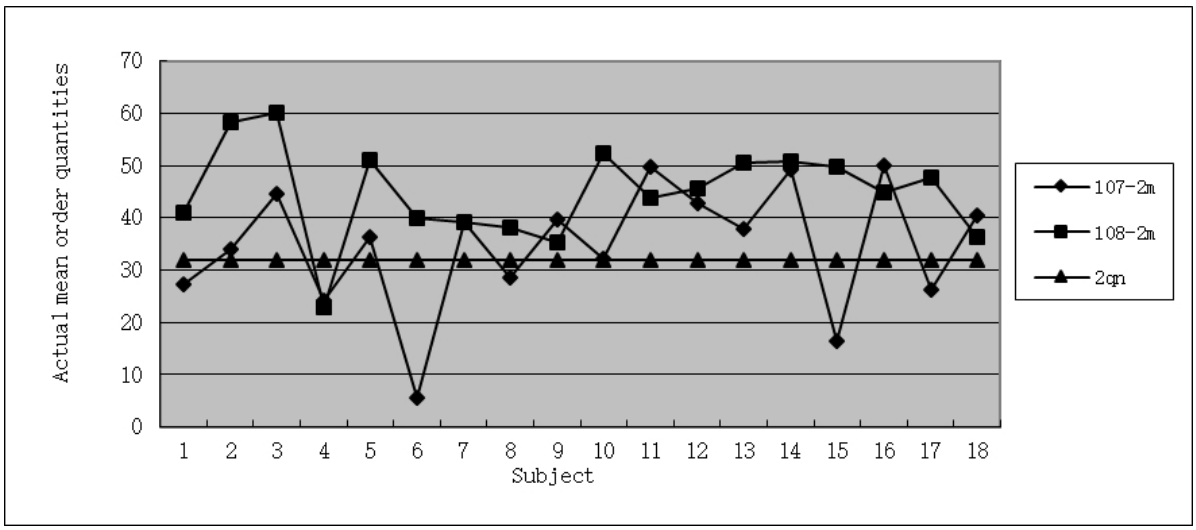

FIGURE 2. Mean order quantity by male under low demand scale

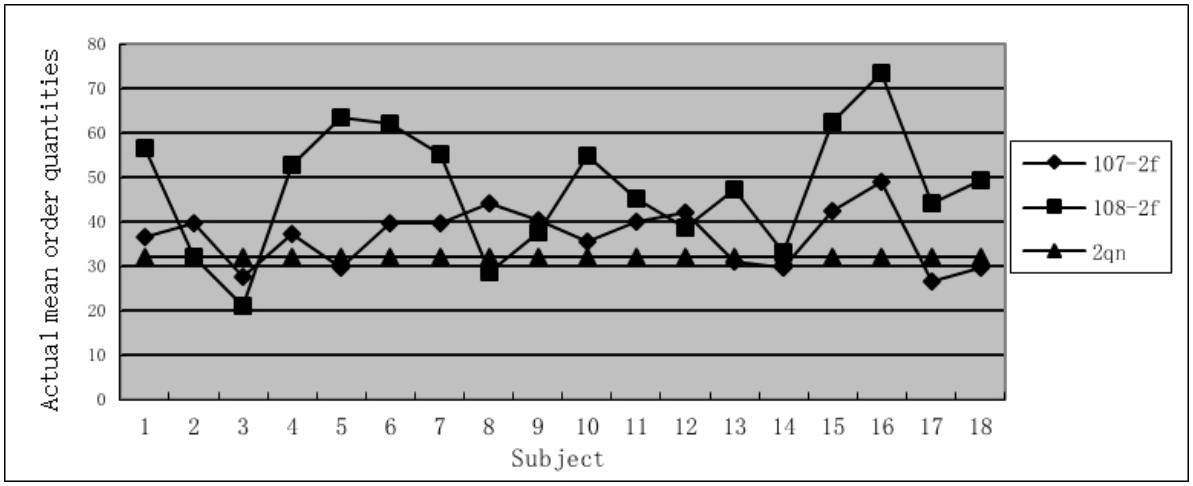

FIGURE 3. Mean order quantity by female under low demand scale

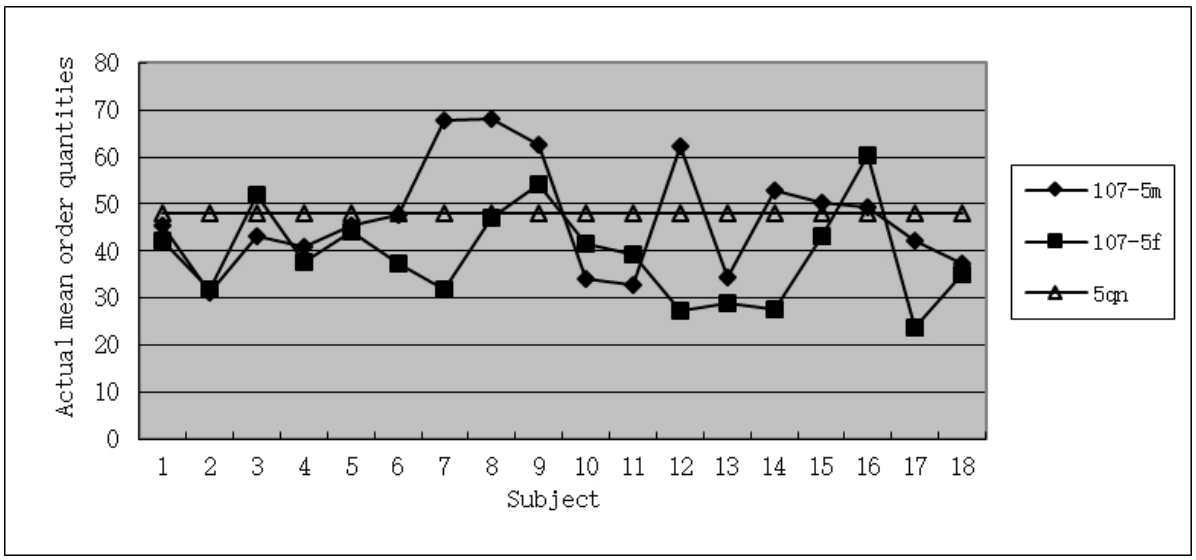

FIGURE 4. Mean order quantity under high demand scale

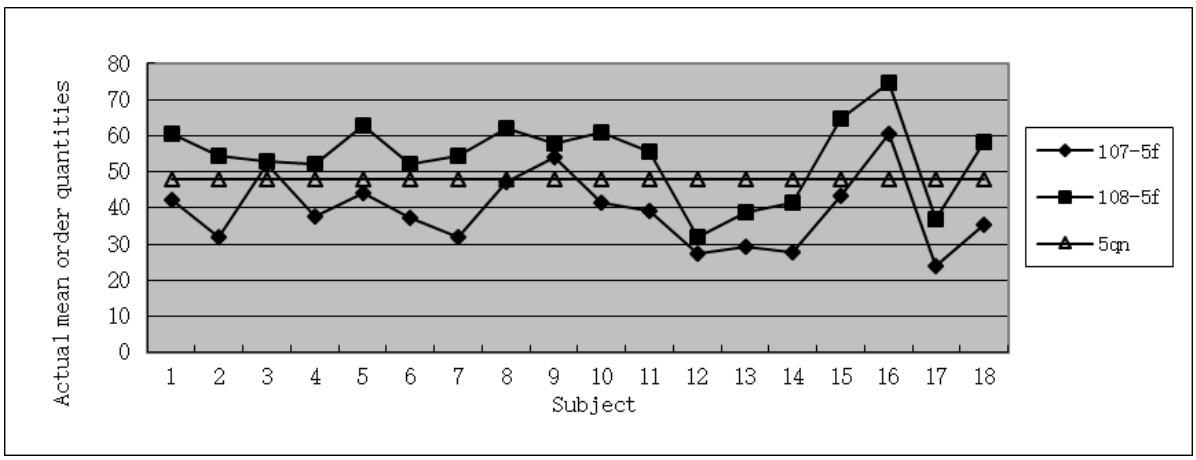

FIGURE 5. Mean order quantity by female under high demand scale

quantities by the human subjects are far higher than the optimal order quantity, and whether male or female subjects, the average order quantities determined by the human subjects in the state of loss are much higher than that in the state of profit.

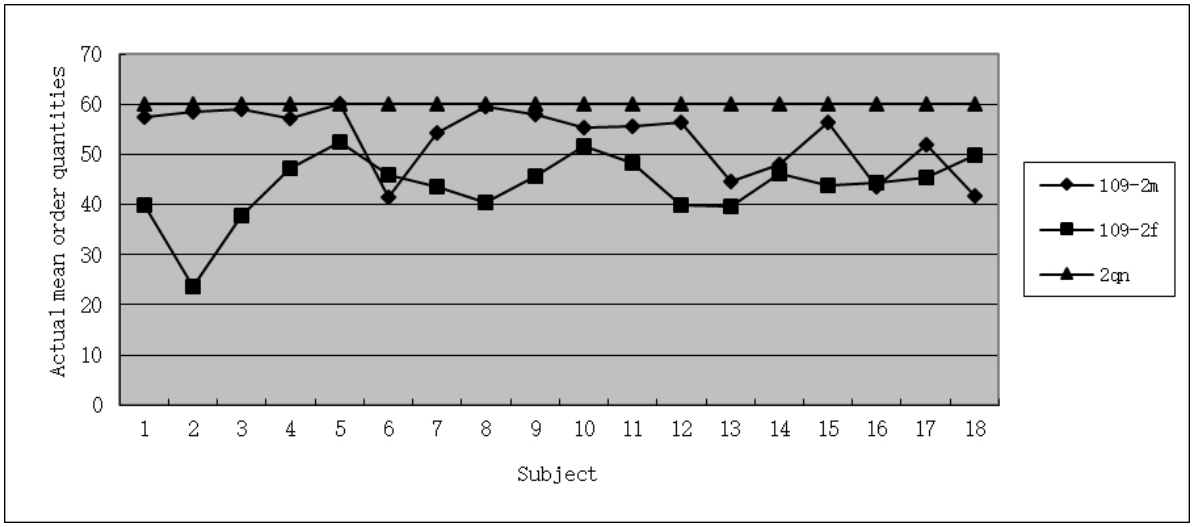

FIGURE 6. Mean order quantity under low cost

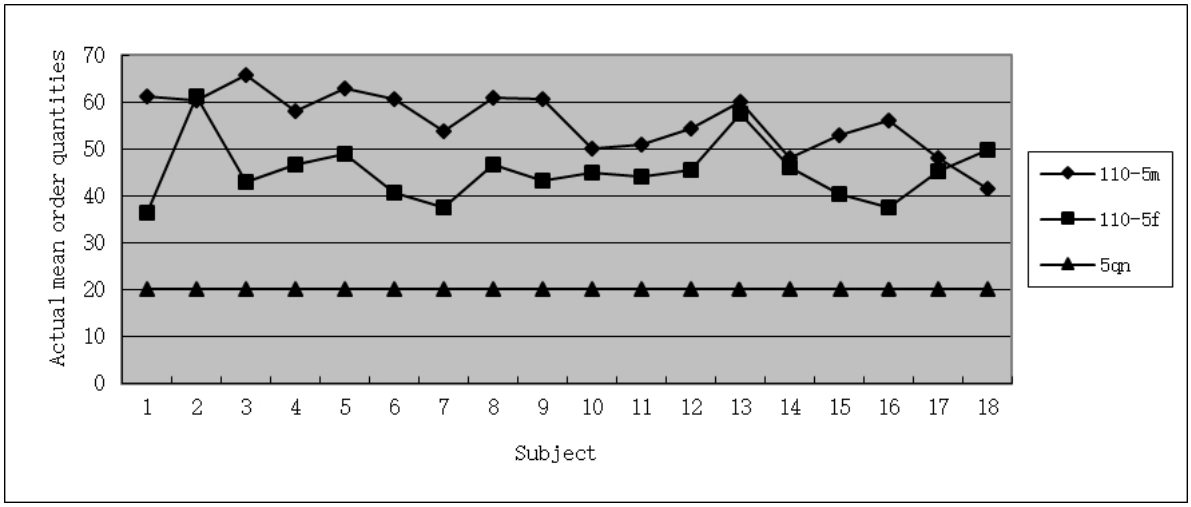

FIGURE 7. Mean order quantity under high cost and loss state

TABLE 2. T-test analysis between the corresponding results

Actual mean order quantities between the corresponding experiments and their optimum order quantities					*T-test analysis results*	
Actual mean order quantities between the corresponding experiments				*Optimum order quantities*	*Two-tailed test value*	*t Stat*
105-3m	*43.00*	*105-3f*	*37.09*	*14*	*2.03224*	*2.1684*
107-2m	*34.67*	*108-2m*	*44.87*	*32*	*2.03224*	*−2.9090*
107-2f	*36.72*	*108-2f*	*47.67*	*32*	*2.03224*	*−3.0354*
107-5m	*47.15*	*107-5f*	*39.21*	*48*	*2.03224*	*2.1841*
107-5f	*39.21*	*108-5f*	*54.03*	*48*	*2.03224*	*−4.2534*
109-2m	*53.26*	*109-2f*	*43.66*	*60*	*2.03224*	*4.4511*
110-5m	*55.90*	*110-5f*	*45.28*	*20*	*2.03224*	*4.9864*

$P < 0.05$

Figure 4 and Figure 5 illustrate the "high demand scale" situation. From Figure 4 and Table 2, we can see that, whether male or female subjects, the average order quantities determined by the human subjects are lower than the optimal order quantity, especially that of the female, and the average order quantities determined by the male are higher

than that of the female. From Figure 5 and Table 2, we can see that the average order quantities determined in the state of loss are much higher than that determined in a profit state.

From Figure 6 and Table 2, we can see that at low "purchase cost" and a profit state, whether male or female subjects, the average order quantities determined by the human subjects are far lower than the optimal order quantity, especially that of the female, and the average order quantities determined by the male are higher than that of the female. From Figure 7 and Table 2, we can see that at high "purchase cost" and a loss state, whether male or female subjects, the average order quantity are far higher than the optimal order quantity, especially that of the male, and the average order quantities determined by the male are much higher than that of the female.

As the above analysis shown in Figure 1 to Figure 7 and Table 2, we can see that, whether male or female subjects, no matter the decision makers were in a state of loss or profit, no matter the decision variables were at high "value" or low "value", the average order quantities determined by the human subjects are far from the optimal order quantity. Therefore, we reject Hypothesis 1. From Figure 1 to Figure 7 and Table 2, four of the six groups of experimental items show that, whether the decision variables were at high "value" or low "value", no matter whether the decision environments was profit or loss, the average order quantities determined by the male are higher than that of the female. Therefore, we reject Hypothesis 2. From Figure 1 to Figure 7 and Table 2, three of the six groups of experimental items show that, whether the decision variables were at high "value" or low "value", the average order quantities determined by the human subjects in the state of loss are higher than that determined in the state of profit. Therefore, we reject Hypothesis 3.

4. **Conclusions.** The experimental observation that woman is more risk averse than men, and the risk attitude of decision maker is closely related to the decision environment, has been accepted extensively in economic decision-making. However, in the ordering behavior of newsvendor problem, it is still a controversial topic. In this paper, we explore this controversial issue through experimental research.

The main contributions of this paper are as follows. First, the conclusion of this research further proves that in newsvendor model, "the order quantity of retailers depends on q_n only" is not always correct. Second, it is found that the decision environment, profit or loss, has an effect on the actual mean order quantities determined by the human subjects. Under some circumstances the actual mean order quantities determined by the human subjects in the state of loss are higher than that in the state of profit. Finally, it is found that the gender difference of the subjects can also influence their actual mean order quantities. Under some circumstances the actual mean order quantities determined by the male are higher than that of the female. It should be explained that, only 7 groups of the contrast data obtained from the 12 experimental projects are significantly different by T-test, and the rest of the contrast data show that the difference is not significant.

Although we could not give an absolute strict variable relationship in the ordering behavior of newsvendor problem from the 7 groups of the contrast data, the above-mentioned conclusions do reveal a kind of trend in the decision-making made by human subjects in actual situation. It indicates that the ordering behavior of newsvendor decision is not perfectly rational, and the decision-makers might respond irrationally to the decision environment. The conclusions of this experimental observation could inspire the scholars to make further ordering behavior research on the supply chain contract design in different decision-making environment, to explore the influence of the gender difference on the supply chain policy determined by human subjects. The significance of the experimental findings is to apply the conclusions of the experimental research to the practical decision-making of supply chain management. To explore and fully understand the principles in

the ordering behavior of newsvendor decision, introducing the conclusion of experimental findings into the traditional newsvendor model, it will be potentially effective in improving the accuracy of decision-making in practice.

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REFERENCES

[1] M. E. Schweitzer and G. P. Cachon, Decision bias in the newsvendor problem with a known demand distribution: Experimental evidence, *Management Science*, vol.46, no.3, pp.404-420, 2000.

[2] M. Becker-Peth, E. Katok and U. W. Thonemann, Designing buyback contracts for irrational but predictable newsvendors, *Management Science*, vol.59, no.8, pp.1800-1816, 2013.

[3] U. Benzion, Y. Cohen, R. Peled and T. Shavit, Decision-making and the newsvendor problem: An experimental study, *Journal of the Operational Research Society*, vol.59, no.9, pp.1281-1287, 2008.

[4] K. Fu, D. Geng, D. Gao and Y. Yang, Analysis on the order behavior of retailer with consideration of bounded rationality, *ICIC Express Letters*, vol.10, no.7, pp.1779-1786, 2016.

[5] B. Jiang, *Influence of Individual Differences and Cognitive Bias on Newsvendor Ordering Decision*, Master Thesis, Central South University, 2011.

[6] S. Frederick, Cognitive reflection and decision making, *Journal of Economic Perspectives*, vol.19, no.4, pp.25-42, 2005.

[7] C. C. Eckel and J. G. Philip, Rebate versus matching: Does how we subsidize charitable contributions matter? *Journal of Public Economics*, vol.87, nos.3-4, pp.681-701, 2003.

[8] G. E. Bolton, A. Ockenfels and U. W. Thonemann, Managers and students as newsvendors, *Management Science*, vol.58, no.12, pp.2225-2233, 2012.