How Precious Are Scarce Products? An Experimental Study on a Turn-and-Earn Allocation Mechanism

Article *in* Decision Sciences · March 2019

DOI: 10.1111/deci.12358

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To appear at Decision Science.

How precious are scarce products? An experimental study on a turn-and-earn allocation mechanism

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Abstract: In this study, we conduct laboratory experiments to analyze a turn-and-earn allocation mechanism by which a single supplier allocates scarce products to two identical retailers. Under this mechanism, the supplier uses past sales to dynamically allocate scarce capacity among downstream retailers. The experimental data show that retailers strategically and systematically order more than predicted by standard theory. We find that the psychological scarcity effect is an important phenomena. Using cognitive hierarchy theory, we develop a behavioral model to consider the scarcity effect, which causes retailers to place additional value on the allocations in a supply-shortfall period. Using structural estimation, we show that retailers perceive scarce products as being more precious than the standard theory predicts, and exhibit an average of 2.7 reasoning steps during strategic interactions. Moreover, the retailers exhibit social rejoice preference. They are more likely to make myopic decisions when the degree of scarcity is relatively low. Comparing with the proportional allocation mechanisms by an additional experiment, we find that the turn-and-earn mechanism is more beneficial to the supplier but less to the retailers.

Keywords: supply chain; capacity allocation; scarcity effect; cognitive hierarchy; turn-and-earn mechanism.

1 Introduction

Competing for scarce resources is a common business activity for firms when their suppliers have inelastic capacity. In real-world industries, many supply chains face markets with fluctuating demand but have limited and inelastic supplies because of *ex ante* built manufacturing capabilities or some technical restrictions. For example, manufacturers cannot expand their capacities quickly in the semiconductor and automotive industries, the supply of precious stones for jewelry makers is limited (Eso et al. 2010), etc. It is common practice for multiple downstream retailers to be supplied by one upstream supplier with a fixed capacity. The appearance of a supply shortfall engages the retailers in capacity allocation games in which retailers compete for their desired allocations by placing orders.

It is affirmed that the type of competition between retailers depends on the allocation mechanism that the supplier uses. Existing theoretical studies provide extensive results describing retailers' order strategies for various allocation mechanisms, which are developed under a normative theory of

Nash Equilibrium. The seminal works of Cachon and Lariviere (1999a, 1999b, 1999c) on allocation games in operations management solve the equilibrium outcomes for several allocation rules, including proportional, linear, uniform, and lexicographic allocation rules. Their results suggest that the uniform allocation rule leads to truthful orders, whereas the proportional and linear allocation rules induce retailers to inflate their orders. Further, Hall and Liu (2010) investigate supply chain coordination under a proportional or linear allocation mechanism when retailers operate in independent markets. Cho and Tang (2011), Liu (2012), and Chen et al. (2013) investigate uniform and lexicographic rules, respectively, when retailers engage in demand competition. The above allocation rules serve as one-period mechanisms such that capacity assignments are influenced by decisions made in the current period. Another allocation mechanism, the so-called "turn-and-earn" mechanism, serves as a multi-period rule. This mechanism allocates the supplier's capacity according to retailers' sales in the previous period. Normative analyses reveal that this mechanism effectively benefits the supplier by inducing retailers to sell more products (Cachon and Lariviere 1999c) and mitigates demand variability in long-term operations (Lu and Lariviere 2012).

Theoretical analyses with deductive equilibrium methods provide insightful results. However, the equilibrium predictions are established based on presumptions that actual choices are perfectly rational and have achieved a steady state. However, many laboratory experiments show that the predictions of normative theory often fail to prescribe practical decision-making behavior. First, human decision-makers innately exhibit diversified behavioral characteristics when they solve operations management problems, and these behavioral characteristics have profound implications in specific environments. Second, human players usually make decision errors and develop inconsistent beliefs about other players' actions when they strategically interact with others. In case of complete information, Chen et al. (2012) experimentally examine a setting in which a supplier uses the proportional allocation mechanism to ration his capacity, and they suggest that human players make decision errors when choosing order quantities. Cui and Zhang (2017) also conduct experimental study of the proportional mechanism and show that human players in capacity allocation games have hierarchical cognitive levels of reasoning capabilities and overconfident beliefs in predicting their opponents' actions. Chen and Zhao (2015) show that, when a retailer has private information about her realized market demand, human retailers have different mental accounts regarding the incurred underage and overage costs, in addition to making decision errors. Zhao et al. (2016) apply a functional magnetic resonance imaging technique to compare brain activity across two elicitation methods (the strategy method and the direct-response method) and find no significant differences between subjects' ordering behavior under the two experimental methods in the context of capacity allocation games.

Recent laboratory studies on capacity allocation games have revealed some well-organized behavioral characteristics of human players, but these characteristics are established when the capacity is allocated according to the proportional mechanism, that is, the allocated quantities are proportional to retailers' order quantities. To the best of our knowledge, few laboratory studies have examined other types of allocation rules. In this study, we investigate the turn-and-earn mechanism, which serves as a dynamic mechanism to divide the upstream supplier's capacity based on downstream retailers' past sales. By employing laboratory experiments, we aim to examine how the turn-and-earn mechanism affects human retailers' ordering behavior and how human retailers play dynamic games.

The turn-and-earn mechanism has been widely applied in the automotive industry. It provides a method for matching supply and demand over a long horizon. Retailers earn higher allocations in the next period if they sell (i.e., turn) more units in the current period. Thus, if retailers are informed in advance that a supply shortfall will arise in the future, they can take action to earn greater guaranteed allocations in the future by inflating their current orders. Standard theory assumes that a retailer selects her best choice impartially by counting the incurred losses and gains in multiple periods, regardless of the contexts in which these losses and gains occur. However, some surveys show that managers sometimes make irrational decisions with specific biases depending on the contexts that they face. For example, in the case of higher pressure to achieve immediate performance targets, managers inflate immediate earnings by cutting expenditures on "discretionary" activities, such as marketing and R&D, to meet short-term goals, even though these cuts can have substantial negative effects on future performance (Mizik and Jacobson 2007). In our work, the turn-and-earn mechanism involves cases of both scarce and abundant capacity, through which we study the effects of these different cases on human retailers' ordering decisions.

The setting of this study involves a single supplier and two retailers playing a two-period capacity allocation game. A supply shortfall occurs only in the second period. The supplier employs the turn-and-earn mechanism to allocate limited capacity to satisfy orders from retailers. We adopt this simple structure to achieve the objectives of this study. This structure preserves the essence of long-term capacity competition induced by the turn-and-earn mechanism through which retailers receive higher future gains by selling more now. Using this setting to conduct an experiment, we aim to answer the following questions: How do retailers compete with each other when a supplier adopts the turn-and-earn mechanism to allocate its capacity? What are the behavioral preferences when retailers play dynamic two-period games in which each period is associated with a different situation? How effective is the turn-and-earn mechanism in comparison with other mechanisms?

We find that subjects playing the role of a retailer exhibit systematic bias in balancing the two periods' payoffs. The first observed bias is that the order quantities during the supply-abundant period are consistently larger than the standard predictions across treatments with various degrees of capacity scarcity. Our structural analyses suggest that the psychological scarcity effect can be a driving force behind this behavior. Subjects desire scarce commodities more strongly than they desire comparably available commodities. Similar behavioral preference has been reported to exist in other studies (e.g., Cachon et al. 2017). Another observed bias is the diverse order decisions, which indicate different levels of strategic-reasoning capabilities. This bias can be described by the cognitive hierarchy theory proposed by Camerer et al. (2004). Based on these observations, we develop a behavioral model. The structural estimates of parameters in the behavioral model reveal that, when capacity is scarce, human retailers psychologically place a higher value on the desired products than the standard theory predicts. Additionally, their decision behavior exhibits preference of social rejoice, and they perform an average of 2.7 reasoning steps in the cognitive hierarchy. We compare the turn-and-earn mechanism with the proportional allocation mechanism by an additional experiment, and find that the former results in higher sales volume for the supplier but in less profit for the retailers than the latter.

We organize the paper as follows. In Section 2, we formulate the capacity allocation model and present standard game-theoretic analyses. In Section 3, we present the laboratory experiments and report on the experimental results. In Section 4, we develop behavioral models incorporating the scarcity effect, cognitive hierarchy, and heterogeneous myopia or strategic forward looking. Section 5 illustrates structural estimation of the behavioral models using the experimental data. Section 6 provides additional discussion, and Section 7 concludes the study.

2 Problem Description

We consider a two-period game in a triadic supply chain that consists of one upstream supplier and two downstream retailers. The supplier has a fixed capacity of K units of a perfectly divisible commodity in each period and sells the commodity to the retailers at a wholesale price w. Because of restrictions from the internal or external environment, the supplier cannot expand its supply capacity if the total order quantity from the two retailers exceeds its capacity. To deal with the inelastic capacity and fluctuating demand, the supplier adopts a turn-and-earn mechanism to allocate its capacity according to historical sales, offering a higher assured allocation quantity to the retailer with higher past sales.

Our problem setting follows that of Cachon and Lariviere (1999c), who consider uncertain market demand with two possible sizes. In our study, we consider deterministic market demand, which simplifies the decision problem and makes the behavioral study more tractable. There are two identical retailers. Each retailer is assumed to be a local monopolist operating in an independent market; therefore, one retailer's sale quantity and price do not affect the other's market and profits. The retailer's focus is on winning its own desired quantity of allocation. The market size of each retailer in the two periods is deterministic and publicly known. The market price in each period is a linear decreasing function with respect to the sales quantity. We assume that the retailers do not carry inventory from period 1 to period 2, which is reasonable when the period is long and the inventory carrying cost is prohibitively expensive. For example, this assumption holds when Harley-Davidson allocates orders of motorcycles with model upgrades from year to year; hence, retailers do not carry inventory of the previous year's model (Cachon and Lariviere 1999c). The assumption of no inventory carryover allows us to focus on the behavioral factors and to highlight the qualitative results. The market in the first period is of size L, and the market in the second period is of size H. Specifically, the market price p with an output of q product units is given by $p_1 = L - q$ in the first period, and it is $p_2 = H - q$ in the second period.

If no capacity restriction exists (i.e., a retailer's order is fully filled in each period), then each retailer maximizes total profit $q_L(L - q_L - w) + q_H(H - q_H - w)$, where q_L and q_H are the ordering decisions in the first and second periods, respectively. In this case, the optimal order in the first period is $q_L^* = \frac{L-w}{2}$, resulting in a profit of $\pi_L^* = \frac{(L-w)^2}{4}$, and the optimal order in the second period is $q_H^* = \frac{H-w}{2}$, with a corresponding profit of $\pi_H^* = \frac{(H-w)^2}{4}$. We refer to the quantity q_L^* (or q_H^*) as the *ideal allocation* and the profit π_L^* (or π_H^*) as the *ideal profit* for the retailer. Another trivial case is that in which the capacity is insufficient to cover the *ideal allocation*, resulting in the equal division of the capacity between the two retailers in each period. To examine the turn-and-earn mechanism, we consider an interesting case in which the supplier's capacity is sufficient to cover the total ideal allocation in the first period but is insufficient to do so in the second type period: that is, $2q_L^* < K < 2q_H^*$. This case is equivalent to $L - w < K < H - w$.

The adopted turn-and-earn mechanism makes allocations as follows. The supplier offers each retailer a *guaranteed allocation* in each period; each retailer is assured of receiving up to this amount if she places an order. In the first period, the two retailers equally share the capacity, and the initial *guaranteed allocation* is $\frac{K}{2}$ for everyone. In the second period, according to the sales difference Δ between the two retailers in the first period, the supplier reserves a current-period capacity equal to Δ for the sales leader and then divides the remaining capacity equally between the two retailers.

The guaranteed allocation of the sales leader is $\frac{K}{2}+\frac{\Delta}{2}$, and it is $\frac{K}{2}-\frac{\Delta}{2}$ for the sales laggard.

It is possible that a retailer can receive an allocated quantity that is larger than the guaranteed allocation. Formally, the mechanism is executed as follows. Each retailer $i \in \{1,\ 2\}$ makes two decisions: the order in the first period, $x_{i,1}$, and the order in the second period, $x_{i,2}$. The quantity allocated in the first period, $y_{i,1}$, given an order of $x_{i,1}$, is as follows:

$$y_{i,1} = \min\left\{x_{i,1},\ \max\left\{\frac{K}{2},\ K - x_{-i,1}\right\}\right\}. \tag{1}$$

Retailer i can access a capacity amount of $K - x_{-i,1}$ if her opponent's order of $x_{-i,1}$ is below the guaranteed allocation of $\frac{K}{2}$. Otherwise, retailer i can access only her guaranteed allocation of $\frac{K}{2}$. The resulting first-period payoff is

$$\pi_{i,1}(x_{i,1}, x_{-i,1}) = (L - y_{i,1} - w)y_{i,1}. \tag{2}$$

According to the sales $(y_{i,1},\ y_{-i,1})$ in the first period, the turn-and-earn mechanism implies that the guaranteed allocation of retailer i in the second period is $\frac{K+y_{i,1}-y_{-i,1}}{2}$. For an order $x_{i,2}$, the allocated quantity is

$$y_{i,2} = \min\left\{x_{i,2}, \max\left\{\frac{K + y_{i,1} - y_{-i,1}}{2}, K - x_{-i,2}\right\}\right\}. \tag{3}$$

The corresponding payoff function in period 2 is

$$\pi_{i,2}(x_{i,2}, x_{-i,2} | x_{i,1}, x_{-i,1}) = (H - y_{i,2} - w)y_{i,2}. \tag{4}$$

Myopic retailers focus only on the current period and do not optimize over two periods. Let $x_{M,1}$ and $x_{M,2}$ be the myopic equilibrium order quantities in period 1 and period 2, respectively. Due to symmetry and by Equation (2), the first-period equilibrium order quantity is

$$x_{M,1} = \arg\max_{x_{i,1}} \pi_{i,1}(x_{i,1}, x_{-i,1}) = q_L^*. \tag{5}$$

Consequently, the equilibrium allocated quantity is $y_{M,1} = q_L^*$. As a result, the second-period myopic order quantity follows from Equation (4)

$$x_{M,2} = \arg\max_{x_{i,2}} \pi_{i,2}(x_{i,2}, x_{-i,2} | x_{i,1} = x_{-i,1} = q_L^*) \geq \min\left\{\frac{K}{2},\ q_H^*\right\} = \frac{K}{2}. \tag{6}$$

The corresponding myopic allocated quantity is then $y_{M,2} = \frac{K}{2}$ for period 2.

Rather than focusing on a single period, strategic retailers optimize over all periods, choosing the strategy $\{x_{i,1},\ x_{i,2}\}$ to maximize the total payoffs of the two periods. As the supply is insufficient to meet the ideal allocation of q_H^* in the second period, a strategic retailer has an incentive to sell more products than the ideal quantity, q_L^*, in the first period to obtain a larger guaranteed allocation in the second period (Cachon and Lariviere, 1999c). An order quantity higher than q_L^* in the first period reduces the payoff in the current period but wins a higher *guaranteed allocation* in the second period.

To find the equilibrium ordering strategies of strategic retailers, we need to solve the two-period game with the payoff functions of (2) and (4). Their equilibrium ordering strategies can be solved by backward induction. As the second period is the last period, the optimal period 2 strategy maximizes the payoff (4) for given guaranteed allocations in period 2.

Lemma 1. *In period 2, if the guaranteed allocation* $\frac{K+y_{i,1}-y_{-i,1}}{2}$ *is greater than the ideal allocation* q_H^**, then the equilibrium strategy is* $x_{i,2}^* = q_H^*$*; otherwise,* $x_{i,2}^* \geq \frac{K+y_{i,1}-y_{-i,1}}{2}$.

This lemma specifies the rational ordering strategies of the retailers in period 2, in which the capacity is insufficient to meet the ideal allocations. These second-period strategies are affected by the first-period strategies through the guaranteed allocations. Hence, the strategic retailers choose their first-period ordering quantities to maximize the total payoff of the two periods as follows:

$$\Pi_i = \pi_{i,1}(x_{i,1}, x_{-i,1}) + \pi_{i,2}(x_{i,2}^*, x_{-i,2}^* | x_{i,1}, x_{-i,1}). \tag{7}$$

With Lemma 1, we obtain the following proposition specifying the retailers' equilibrium strategies for the two-period game.

Proposition 1. *Under the turn-and-earn mechanism, rational retailers have the equilibrium strategies as follows:*

(a) If $\frac{2(L-w)+H-w}{3} < K < H$*, the unique Nash Equilibrium is* $x_{1,1} = x_{2,1} = q^* = \frac{L-w}{2} + \frac{H-w-K}{4}$ *in the first period. In the second period, any quantity satisfying* $x_{i,2} \geq \frac{K}{2}$ *is a Nash Equilibrium for* $i \in \{1,\ 2\}$.

(b) If $K \leq \frac{2(L-w)+H-w}{3}$*, any quantity satisfying* $\frac{K}{2} \leq x_{i,1} \leq K$ *and* $\frac{K}{2} \leq x_{i,2} \leq K$ *is a Nash Equilibrium for* $i \in \{1,\ 2\}$.

The proof of this proposition is given in Appendix A along with all other propositions.

The order strategy in the first period depends on the capacity scarcity reflected by the capacity and the ideal allocations in the two periods. For a modest scarcity of $K > \frac{2(L-w)+H-w}{3}$ (which is equivalent to $3K > 4q_L^* + 2q_H^*$), Nash Equilibrium of the retailer's order quantity in the first period is unique at $\frac{L-w}{2} + \frac{H-w-K}{4}$ (which is equivalent to $q_L^* + \frac{1}{2}(q_H^* - \frac{K}{2})$), indicating moderate inflation of the desired order quantity above q_L^* but below $\frac{K}{2}$. Otherwise, when capacity is highly scarce, i.e., satisfying $K \leq \frac{2q_H^*+4q_L^*}{3}$, it is optimal to increase the order up to any quantity over the guaranteed allocation of $\frac{K}{2}$.

The above theoretical predictions are established on the assumption of rational decision-making. We conjecture that human players may have some behavioral biases when formulating their order strategies. For example, the two decision periods are associated with different situations that may have effects on the practical orders. We are motivated to develop a controlled laboratory experiment to observe decision behaviors in these situations.

3 Experiments and Results

To examine how human retailers respond to the turn-and-earn mechanism, we conduct laboratory experiments with capacity allocation game scenarios in which human subjects are recruited to play the roles of retailers and make the corresponding ordering decisions.

3.1 Experimental design and implementation

Three treatments are designed by varying the market size in the second period from a low level to a high level. A higher market size in the second period generates a higher degree of capacity scarcity, which drives the retailers to order more in the first period to win higher guaranteed allocations in the second period. The multiple treatments allow us to test the robustness of the results and compare the ordering behaviors of subjects with respect to different degrees of capacity scarcity in the second period. During the experiments, a computer plays the role of the supplier, which uses turn-and-earn mechanism to allocate its capacity. Each subject plays the role of one retailer and competes on capacity.

The parameters of the experimental treatments are set as follows. In all treatments, the supplier's capacity is fixed at $K = 200$ in each period. The market size in the first period is $L = 100$, and the market size in the second period, H, takes three values 240, 300 and 360. The low-scarcity treatment corresponds to $H = 240$, the intermediate-scarcity treatment to $H = 300$, and the high-scarcity treatment to $H = 360$. We set the wholesale price to zero to eliminate the effect of the loss from the purchasing cost, which helps us examine other prominent behavioral factors. Given these parameters, the ideal allocation, i.e., $q_H^*(= H/2)$, for each retailer in period 2 is 120, 150, and 180, respectively for the three treatments. Consequently, the relative supply shortage defined by $(2q_H^* - K)/K$ is 20%, 50%, and 80%, respectively. Furthermore, all three treatments satisfy the condition in Proposition 1 (a). Hence, the first period Nash Equilibrium order quantity q^* is 60, 75, and 90, respectively in three treatments. In the second period, Nash Equilibrium order is any quantity above 100 for all treatments. During the experiments, subjects are restricted to order an integer quantity no bigger than 200. We have not designed treatments for the condition in Proposition 1 (b) because Nash Equilibrium is not unique under this condition; hence, it is difficult to identify the behavioral factors.

We adopted a between-subjects design. A total of 90 subjects from a major university were recruited and randomly assigned to one of the three treatments. Each treatment had 30 subjects. In the experiments, every subject played the capacity allocation game for 50 rounds. A subject was randomly matched with another subject without learning the identity of the matched subject in every round. In the first period, a subject was required to place her order without knowing her opponent's choice; in the second period, the subject placed her order after being informed of her guaranteed allocation. To ensure that subjects understood the problem and the relative calculations, we provided instructions, exercises, profit tables, and profit curves to aid their decisions. The instructions are shown in Appendix B. All subjects were required to thoroughly understand the instructions and correctly finish the exercises before the experiments started. The experiments took about 70 minutes, and on average subjects earned roughly four times the local minimum hourly wage. We programmed the experiment software using the z-Tree system (Fischbacher 2007).

3.2 Experimental results

We collected 1,500 records of data for each treatment, with 30 subjects playing the game for 50 rounds. We aggregate data of each subject as an independent sample to conduct statistical analysis. Table 1 reports the summary statistics of the data for the first period. Subjects exhibit a systematic bias such that the orders in the first period substantially exceed the standard predictions of Nash Equilibrium. The statistical t-test suggests that this difference is significant at the level of $p < 0.001$ in each treatment. In the high-scarcity case, the observed orders in the first period are 116.91 on average, whereas Nash Equilibrium order quantity is 90. In the intermediate-scarcity and low-scarcity cases, the observed average orders in the first period are 88.90 and 65.23, respectively, which are significantly larger than the respective Nash theoretical predictions of 75 and 60.

By comparing the experimental data with the standard Nash Equilibrium, we can make several observations as follows.

1. The standard Nash Equilibrium does not explain the experimental data well. Figure 1 shows the distributions of subjects' orders in the first period. The order quantities of subjects are distributed over the entire interval [0, 200], whereas the standard theory predicts a deterministic order quantity. The shapes of the data distributions are skewed to the right of the

Table 1: Summary statistics of orders in the first period

	High-scarcity	Intermediate-scarcity	Low-scarcity
Orders by Subject	116.91 (17.49)	88.90 (10.45)	65.23 (7.42)
Nash Equilibrium	90	75	60
t-value	8.43	7.29	3.86
Significance Level	< 0.001	< 0.001	< 0.001

Note: Values in parentheses are standard deviations.

standard Nash Equilibrium. Specifically, over 90% (1401 units) of the data are distributed on the right side of Nash Equilibrium in the high-scarcity treatment condition. Over 85% (1323 units) of the data are on the right side of Nash Equilibrium in the intermediate-scarcity condition. In the low-scarcity condition, over 60% (917 units) of the data are larger than Nash Equilibrium.

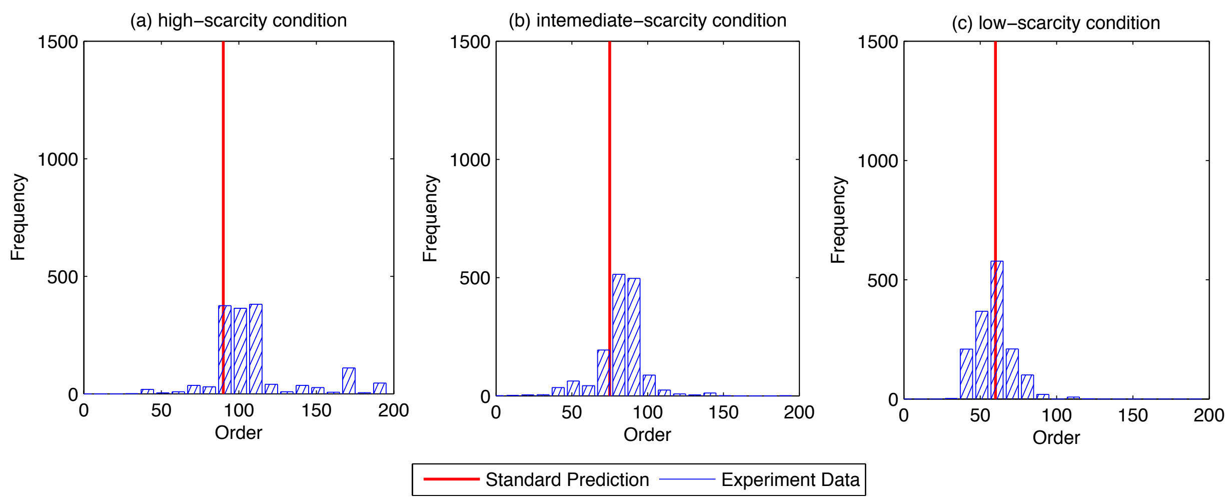

Figure 1: Experimental orders in the first period

2. In the high-scarcity condition, a large portion of the data (about 70%) is larger than the guaranteed allocation of $\frac{K}{2}$. As displayed by the histograms on the left side of Figure 1, the data are not uniformly distributed between the guaranteed quantity of 100 and the upper bound of 200, but they are mostly concentrated in the interval [100, 120]. One conjecture about these choices is that the subjects believe that their opponents may order less than the guaranteed quantity, giving them a chance to obtain more than the guaranteed quantity of 100.

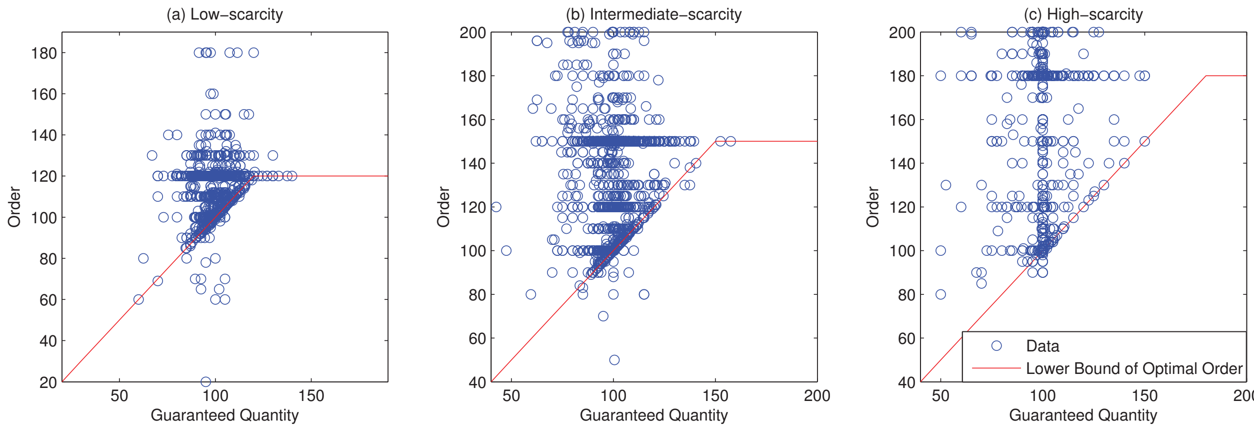

Figure 2: Experimental orders in the second period

3. A certain portion of the data coincides with the myopic choice of $q_L^* = 50$, especially in the low-scarcity condition. In the distributions shown in Figure 1, the myopic prediction of $q_L^* = 50$ is one of the peaks, but its percentage decreases with capacity scarcity. In the low-scarcity treatment, 198 data points (13.2%) belong to a myopic decision. In the other treatments, in which capacity is rather tight, the percentages of myopic decisions are quite low. Only 1.5% (22 data points) of the data belong to such a decision in the intermediate-scarcity condition, and only 1.3% (13 data points) of the data belong to such a decision in the high-scarcity condition.

4. In the second period, unlike in the first period, subjects are almost perfectly rational. As shown in Figure 2, over 99% of the data follow the strategies in Lemma 1. When the *guaranteed quantity* is larger than the *ideal allocation*, the optimal orders are exactly equal to the *ideal allocation*, which corresponds to the flat line in the figures; when the *guaranteed quantity* is smaller than the *ideal allocation*, the optimal orders are above the *guaranteed quantity*.

5. The experimental data show a very weak time trend, implying that learning or mimicking has no significant impact on our qualitative results. Hence, rematching is not an issue. We rematch the subjects across the whole group in our experiment. Doing so might have led to certain behavioral patterns ("cultural norms") due to mimicking within the group. This problem can be avoided by using small cohorts in the experiment. However, splitting the entire group into smaller cohorts may induce other unrelated behavioral factors because, in this setting, when each cohort has too few subjects, the matching is close to fixed matching.

4 A Behavioral Model

To explain the observations of the retailers' ordering decision in the first period, we explore the most likely behavioral factors and use them to develop behavioral models.

4.1 Scarcity effect

Retailers are essentially making tradeoffs between payoffs in the two periods. The ideal best payoff in the first period is π_L^*, and the corresponding order quantity is q_L^*. Strategic retailers maximize the total payoffs in the two periods by considering the second period when making a decision in the first period. Thus, retailers may order more than q_L^* in the first period to win a favorable guaranteed allocation in the second period. When the retailer treats the allocated products equally in two periods, the optimal order quantity is Nash Equilibrium as shown in Proposition 1. However, our experimental data show a systematic deviation, as subjects order higher quantities than standard theory predicts. One way to explain this deviation is to assume that subjects receive extra positive utility from the second period allocation, which drives them to order more than the optimal value in the first period to obtain a higher allocation in the second period.

One psychological theory that can explain our experimental findings is the psychological effect of scarcity (Brock 1968), by which "any commodity will be valued to the extent that it is unavailable" (p. 246). People more frequently choose a product when it is scarce than when it is abundant, and scarcity can serve as an attractive mechanism that increases the subjective value of the good (Mittone and Savadori 2009). Using empirical data from the automotive industry, Balachander et al. (2009) show that the scarcity of a car can increase consumers' preferences for the product. In a field study of lightning deals on Amazon.com, Cui et al. (2016) also find that the scarcity of inventory prompts consumers to make immediate purchases, implying that the valuation associated with purchasing a product can be increased by its scarcity. In the supply chain setting, Sterman and Dogan (2015) analyze the experiment data of retailers' order quantities in a supply chain game of beer distribution, and show that scarcity causes retailer to hoard inventory, that is, to order more irrationally. They state that this scarcity effect has psychiatry and neuroscience support. Cachon et al. (2017) find that a decrease of inventory can increase sales, that is, scarcity in inventory increases the psychological product value to the buyer.

In our capacity allocation game, the presence of supply scarcity may enhance the psychological valuation of the products in the second period, which causes our experimental subjects to treat the desired allocation in the supply-shortfall period as more precious. This behavioral preference further drives retailers to aggressively order more in the first period. We propose a utility function in which subjects receive extra utility $\lambda \geq 0$ from the allocated products in the second period, as follow:

$$u_\lambda(x_{i,1}, x_{i,2};\ x_{-i,1}, x_{-i,2}) = \pi_{i,1}(x_{i,1}, x_{-i,1}) + \pi_{i,2}(x_{i,2}, x_{-i,2}|x_{i,1}, x_{-i,1}) + \lambda y_{i,2}. \tag{8}$$

When there is a scarcity effect, the retailers compete for the scarce capacity and aim to maximize utility in Equation (8). The retailer's Nash Equilibrium order strategy is characterized by the following proposition.

Proposition 2. *Under the turn-and-earn mechanism, retailers who value scarcity have the equilibrium strategies as follows:*

(a) If $\frac{2(L-w)+H-w+\lambda}{3} < K < H$*, the unique Nash Equilibrium is* $x_{1,1} = x_{2,1} = q^* = \frac{L-w}{2} + \frac{H-w-K+\lambda}{4}$*; In the second period, any quantity satisfying* $x_{i,2} \geq \frac{K}{2}$ *is a Nash Equilibrium for* $i \in \{1,\ 2\}$.

(b) If $K \leq \frac{2(L-w)+H-w+\lambda}{3}$*, any quantity satisfying* $\frac{K}{2} \leq x_{i,1} \leq K$ *is a Nash Equilibrium for* $i \in \{1,\ 2\}$*. In the second period, any quantity satisfying* $\frac{K}{2} \leq x_{i,2} \leq K$ *is a Nash Equilibrium for* $i \in \{1,\ 2\}$.

The second period equilibrium strategy in Proposition 2 is not affected by scarcity factor and remains the same as the one in Proposition 1. This is because retailers are rational decision makers in the second period, as shown by the experimental data in Figure 2. However, equilibrium order quantities in the first period increase with the scarcity parameter λ due to the scarcity effect.

The behavioral model of Equation (8) captures the scarcity effect, which partly explains the decisions of retailers in the first period. However, this scarcity model is insufficient because it does not explain the diversity in the first period decisions, as shown in Figure 1. Hence, we consider cognitive hierarchy model to capture the diverse sophistication levels of the retailers.

4.2 Cognitive hierarchy

The cognitive hierarchy (CH) model, proposed by Camerer et al. (2004), assumes that the players have different levels of strategic reasoning capability and form their own beliefs about others' reasoning levels. The CH model is established based on the "level-k" thinking introduced by Stahl and Wilson (1994, 1995) and Nagel (1995). It has strong experimental support in many classic economic settings, such as guessing games (Costa-Gomes and Crawford 2006), private-value auctions (Crawford and Iriberri 2007), centipede games (Ho and Su 2013), and action commitment games (Carvalho and Santos-Pinto 2014). In a capacity allocation game under the proportional mechanism, Cui and Zhang (2017) show that human retailers have such hierarchical cognitive levels when competing with other retailers. CH model relaxes players' beliefs on their opponents' actions by allowing the subjects to have different levels of strategic reasoning; thus, it may help explain the diversity of the observed decisions. In the CH model, there are two assumptions. First, the players in the population have different sophistication levels of strategic reasoning. Second, players are overconfident in believing that they are more sophisticated and can think through more steps than their opponents do.

The CH model consists of an iterative process of reasoning for players performing k steps of reasoning as well as a frequency distribution $f(k)$ of step k players. The distribution of reasoning step k follows a Poisson distribution given by

$$f(k) = \frac{e^{-\tau}\tau^k}{k!}, \tag{9}$$

where the parameter τ captures a player's sophistication level. Its value reflects the mean reasoning steps of all players. A larger value of τ indicates that the players reason through more steps and their strategies are closer to Nash Equilibrium. When the value of τ goes to ∞, the players have infinite reasoning capability, and their strategies converge to Nash Equilibrium. Therefore, the bigger is the τ, the closer is the strategy predicted by CH to Nash Equilibrium.

The iterative process begins with "step 0" type players, who choose a random strategy by assigning an equal probability to each possible alternative. In our capacity allocation game, we assume that "step 0" type subjects simply choose a random strategy by placing orders following a uniform distribution between 0 and 200. "Step k" players believe that all other players reason in strictly fewer than k steps. The other players' reasoning steps h are distributed according to a truncated Poisson distribution as follows:

$$g_k(h) = \frac{f(h)}{\Sigma_{l=0}^{k-1} f(l)}, \text{ for } 0 \leq h \leq k-1. \tag{10}$$

In our experiments, step 1 players best respond to step 0 players who apply a random order strategy. Step 2 subjects believe that the other subjects are a combination of step 0 and step 1 players. Consequently, step 2 subjects best respond to a combination of step 0 and step 1 players. As the number of reasoning steps k increases, players' beliefs about their opponents $g_k(h)$ approach the actual distribution $f(h)$. Thus, players are more sophisticated at higher reasoning steps, which illustrates that a larger parameter τ indicates a higher sophistication level.

The order strategy q_k of step k players maximizes their utilities, given their own beliefs that the reasoning steps of their opponents are distributed from step 0 to step $k-1$ according to a truncated

Poisson distribution $g_k(\cdot)$. Based on Equation (8), a step k player's strategy q_k is then given by

$$q_k = \arg\max_{x_{i,1}} E_{B^k}[u_\lambda(x_{i,1}, x^*_{i,2}(x_{i,1}, B^k);\ B^k, x^*_{-i,2}(x_{i,1}, B^k))], \tag{11}$$

where B^k is the step k player's belief on the other player's order quantity such that $Prob(B^k = x) = \sum_{0\le l<k}[g_k(l)Prob(q_l = x)]$. If there are multiple optimizers in Equation (11), the players randomize across these optimizers with equal probabilty. Therefore, the order strategy q_l for all $k \geq l \geq 0$ can be a random variable.

To account for variance of the order decisions as shown in Figure 1, we assume a normally distributed zero-mean error ϵ accompanied by the data. That is, the observed order quantities of step k subjects are $\widetilde{q_k} = q_k + \epsilon$, where $\epsilon \sim N(0,\ \sigma^2)$. Since the order quantities of subjects are restricted to integers over the interval $[0,\ 200]$, the error ϵ for step k subjects is a truncated distribution over the interval $[-q_k,\ 200 - q_k]$. Let $\varphi^k(x)$ denote the probability that step k subjects order quantity x.

The frequency of k-step reasoning among the population follows Poisson distribution $f(\cdot)$. Thus, the CH model predicts that the probability of order quantity x in the first period follows

$$\psi(x) = \sum_k \varphi^k(x) f(k).$$

Figure 3 illustrates some numerical examples on the predictions of our experimental data under the CH model, where we present the results of $\tau \in \{1,\ 2,\ 8\}$, $\lambda = 1.5$ and $\sigma = 12$. The figure shows that the CH model has the flexibility to fit the experiment data as shown in Figure 1. The order distribution can be shifted by manipulating the different sophistication levels τ.

4.3 Heterogeneous myopia or strategic forward looking

With the observation of substantial data indicating myopic strategies, we assume that the population of subjects is heterogeneous in the sense that the strategies of both myopic and strategic players may be chosen. Let θ denote the fraction of myopia, and the remaining $1 - \theta$ fraction of choices are strategic forward looking accompanied by a scarcity effect and cognitive hierarchy. When subjects choose a myopic strategy, they correctly choose the quantity $q^*_L = \frac{L}{2}$ in the first period. The optimal decision of the myopic problem in the first period follows the same optimal rule as the second-period problem. We have observed that subjects perform perfectly in the second period, so it is reasonable to assume that myopic subjects also perform perfectly in the first period. When subjects choose an imperfect forward-looking strategy with a scarcity effect and cognitive hierarchy, we assume that they correctly know that their opponents are heterogeneous and may

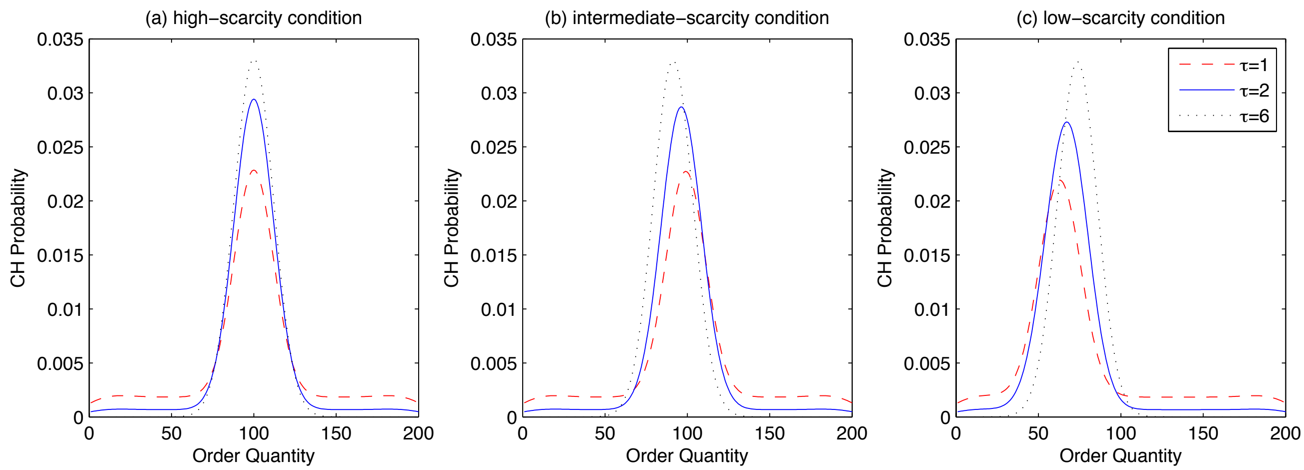

Figure 3: Predictions of the standard CH model with $\lambda = 60$ and $\sigma = 12$

be myopic or strategic forward looking. That is, "strategic" subjects believe that their opponents choose a myopic quantity q_L^* with probability θ and choose a hierarchical cognitive strategy with a scarcity effect with probability $1 - \theta$.

After adding this pattern of heterogeneity, the probability of observing order quantity x in the data is predicted by

$$\theta \cdot M(x) + (1 - \theta)\psi(x), \tag{12}$$

where $M(x)$ is the myopic strategy and $\psi(x)$ is the forward-looking strategy. The value of $M(x)$ is one if the observed quantity x is a myopic quantity and zero otherwise. When subjects formulate a forward-looking strategy, they believe that their opponents may be myopic with probability θ and may be strategic according to $\psi(x)$ with probability $1-\theta$. To compute $\psi(x)$ in (12), the distribution of B^k in Equation (11) is replaced by $Prob(B^k = x) = (1 - \theta) \sum_{0 \leq l < k} [g_k(l) Prob(q_l = x)]$ if $x \neq q_L^*$; $Prob(B^k = q_L^*) = \theta + (1 - \theta) \sum_{0 \leq l < k} [g_k(l) Prob(q_l = q_L^*)]$. The parameter θ presents the extent of myopia (or the forward-looking strategy). If θ is one, subjects are purely myopic, and the order quantity is $q_L^* = \frac{L}{2}$. If θ is zero, subjects are purely strategic, optimizing over the two periods. When θ is between zero and one, subjects may choose both strategies. A larger value of θ indicates a higher fraction of myopic choices or a lower fraction of strategic choices.

The model considering all the behavioral factors above is a full model, which includes the behavioral parameters λ, τ, and θ. To test the significance of each behavioral factor, we consider three nested models. The first model is the standard cognitive hierarchy model, which is called the *CH model*. The *CH model* assumes that subjects equally consider the payoff in the first period and the favorable allocation in the second period and that subjects follow a cognitive hierarchy game model during strategic interactions. As this model captures the variation in the subjects' ordering strategies, we use it as the base model. The second model restricts the parameter λ to zero and reduces the full model to consider strategic cognitive hierarchy and the myopic strategy. We call this model the *myopic CH model*. The third model restricts the parameter θ to zero and considers both the scarcity effect and the cognitive hierarchy. We call this model the *scarcity-effect-CH model*. The significance of the scarcity effect can be tested by comparing the *CH model* with the *scarcity-effect-CH model*, and the significance of heterogeneous myopia or strategic forward looking can then be tested by comparing the *scarcity-effect-CH model* with the full model.

5 Structural Estimation

With the proposed behavioral models, we structurally estimate the parameters using the experimental data. The likelihood function is as follows:

$$\prod_{n=1}^{N}[\theta \cdot M(x_n) + (1-\theta)\psi(x_n)],$$

where $N = 1500$ is the total number of data points. As these data are collected through the random matching method, in which each retailer faces a new competitor in each round, these data are considered more independent than those in other alternative method such as fixed matching.

Table 2 reports the parameter estimates based on the experimental data for the three treatments. Each behavioral assumption included in the full model is statistically tested using log-likelihood ratio tests, resulting in a significance level of $p = 0.001$. In other words, the full model fits the data best for all treatments. Taking the high-scarcity treatment as an example, the log-likelihood scores of the four behavioral models are -6655.5, -6682, -6973.2, and -6989.9. The log-likelihood ratio test suggests that $\chi^2 = 668.8$, with a significance level of $p < 0.001$, when the full model is compared with the standard CH model; $\chi^2 = 635.4$, with a significance level of $p < 0.001$, when the full model is compared with the myopic-CH model; and $\chi^2 = 53$, with a significance level of $p < 0.001$, when the full model is compared with the scarcity-effect-CH model. Similarly, for the other two treatments, the full model sufficiently improves the likelihood, and statistical tests suggest that the full model is the best, as the other three nested models are rejected at a significance level of $p < 0.001$.

First, we look at the estimation of the scarcity effect. The results show that subjects place extra valuation on the allocated products in the second period. The estimated parameter of λ is significantly larger than zero in all three treatments. In the intermediate-scarcity and low-scarcity conditions, the estimate of λ is 34.58 and 35.47, respectively. In the high-scarcity condition, the

Table 2: Structural estimation results

	CH Model	*Myopic CH model*	*Scarcity-effect-CH model*	*Full model*
No. of parameters	2	3	3	4
		High-Scarcity Condition		
λ	-	-	131.01	130.93
τ	1.01	1.02	1.34	1.39
σ	12.47	12.52	9.37	9.41
θ	-	0.01	-	0.01
Log-likelihood	-6989.9	-6973.2	-6682.0	-6655.5
χ^2 against full model	668.8	635.4	53	
Significance level	< 0.001	< 0.001	< 0.001	
		Intermediate-Scarcity Condition		
λ	-	-	32.84	34.58
τ	1.57	1.46	1.93	2.09
σ	12.06	11.37	7.59	7.86
θ	-	0.01	-	0.01
Log-likelihood	-6365.0	-6341.8	-6099.8	-6053.6
χ^2 against full model	622.8	576.4	92.4	-
Significance level	< 0.001	< 0.001	< 0.001	
		Low-Scarcity Condition		
λ	-	-	25.01	35.47
τ	6.42	7.99	4.93	4.60
σ	11.49	11.67	10.21	9.02
θ	-	0.09		0.13
Log-likelihood	-5852.6	-5674.6	-5685.3	-5360.9
χ^2 against full model	983.4	627.4	648.8	-
Significance level	< 0.001	< 0.001	< 0.001	

estimate of λ is 130.93. By comparing the likelihood, the scarcity effect contributes more to explaining the data than myopia does in the high-scarcity and intermediate-scarcity conditions.

Second, we examine the estimation of cognitive hierarchy parameters. Subjects have limited reasoning steps, especially in the high-scarcity and intermediate-scarcity cases, in which subjects make two reasoning steps on average. From the estimates, parameter τ decreases with the degree of capacity scarcity. In the high-scarcity condition, the estimated number of reasoning steps is 1.39, which is significantly smaller than that in intermediate-scarcity condition of 2.09 and that in the low-scarcity condition of 4.6. This is because the higher the scarcity is, the more intense competition the retailers face; hence, their order quantities are farther away from Nash Equilibrium, as shown in Table 1. Consequently, the reasoning sophistication level is less in high scarcity case than in low scarcity case. Our structural estimates show that subjects take 2.7 reasoning steps on average, which is quite close to the result of 2.6 thinking steps on average estimated by Cui and Zhang (2017) for the capacity allocation game under the proportional allocation mechanism.

Finally, we discuss the heterogeneous strategies of retailers. The fraction of myopia is substantially larger in the low-scarcity condition than the other two scarcity conditions. The estimated value of θ is 0.13 in the low-scarcity condition, which indicates that 13% of the data is myopic and the remaining 87% of the data is strategically forward looking following the behavioral rules captured by the scarcity-effect-CH model. In the other two conditions, the fraction of myopia is quite low, at only 1%.

From the estimations, we know that subjects are more likely to choose myopic strategies in the situation with less supply scarcity. In the low-scarcity condition, the improvement of the log-likelihood score by adding the myopic behavior is larger than that of the scarcity effect. When the market size in the second period is relatively small, subjects can achieve respectable remaining quantities even in the worst case, in which their opponents take away their ideal allocations. For example, in the low-scarcity condition, a subject can obtain 80 units in the second period even if her opponent takes away the ideal quantity of 120, so the subject's profit in the second period is still 88.9% of the ideal profit (12,800/14,400). However, in the other two conditions, in which the market size of the second period is relatively large, the worst case of choosing a myopic strategy results in only 55.6% and 21.0% of the ideal profits, respectively, for the intermediate-scarcity and high-scarcity conditions. Thus, the potential cost of choosing a myopic strategy is rather high when the market is large in the second period. In this case, retailers are more likely to maximize the total payoffs of the two periods in the first period rather than concentrating only on the current period. Our estimates show that subjects in the low-scarcity condition choose myopic strategies with a probability of 0.13, whereas they do so with a probability of 0.01 in the other two treatments.

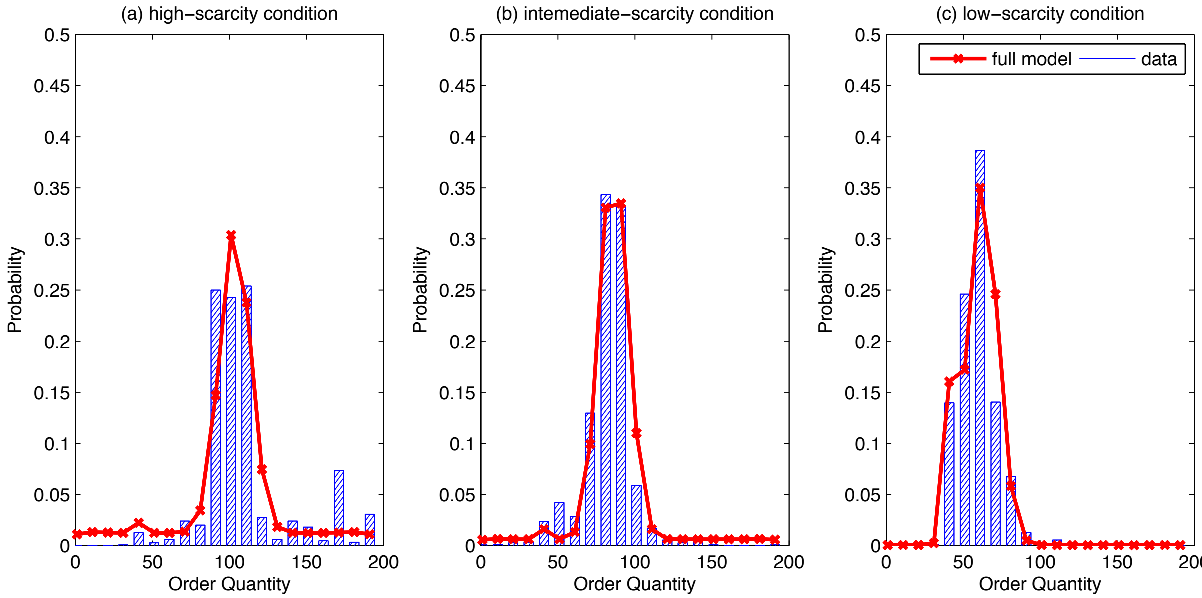

Figure 4: Comparisons of orders between the data and the full model

The full model provides more nuanced descriptions of the behavioral decisions and accommodates the experimental observations well. Figure 4 plots a comparison of the order quantities predicted by the full model against the experimental data, and shows that the full model predictions are close to the ordering decisions of subjects. Thus, the behavioral factors incorporated in the model can calibrate the classic theory to better conform to practice. Our structural estimation also provides several systematic regularities on the behavioral parameters that help us understand human decision-making behavior in other similar situations.

To test the robustness of each behavioral factor in the models, we perform a cross-validation using the data from the first 30 rounds to train the models, and we test the significance level of each behavioral factor using the data from the last 20 rounds. The results show that the full model best fits the data in the low-scarcity case, and this result is significant. The scarcity-effect-CH model best fits the data in both the high-scarcity and intermediate-scarcity cases. These results indicate that the scarcity effect is robust for each case, and myopia only appears when the scarcity level is low.

6 Extended Discussion

Our experimental study on capacity competition under the turn-and-earn mechanism reveals some behavioral characteristics that may appear frequently in practical management. This section explores the practical implications of the decision biases for the allocation of scarce products and compares the performance of this mechanism with alternative allocation mechanisms.

6.1 Understanding human managerial behavior

The retailers should treat supply shortfalls more calmly, especially when the turn-and-earn mechanism is employed. The experimental data show that people over-aggressively strive for the ideal allocation when a supply shortfall occurs. We remind managers that they may be attached to the psychological scarcity effect, which likely causes them to purchase the desired products at substantially high costs, even if doing so may result in unprofitable business. In contrast, retailers should realize that their competitors probably experience the psychological scarcity effect and may apply aggressive strategies to compete for scarce products. Thus, when a retailer forms her responsive strategies, she should account for the psychological scarcity effect on the beliefs of her competitor's actions. We also remind retailers to make better tradeoffs between losses or gains in multiple periods in dynamic decisions. In practice, the decisions of multiple periods usually involve different situations that may trigger some contingent psychological biases, shift retailers' decisions, and reduce operational performance. In practice, retailers should be aware of these inherent behavioral trends and employ some decision tools to overcome them.

When a firm formulates an operational strategy over a long time horizon, it may perform myopically. Our laboratory experiments apply the simplest possible setting to create the cleanest environment. Nevertheless, as much as 13 percent of the data conforms to the myopic strategy, which maximizes the profit in the current period but ignores future periods. It is notable that this tendency to perform myopically arises only in the low-scarcity treatment, in which the cost of being myopic is relatively low. Undoubtedly, practical businesses are much more complex than our experimental setting, which exposes management myopia more easily. In practice, managers are more likely to focus on short-term rather than long-term performance. To remedy this behavioral tendency, powerful institutional incentive mechanisms may be designed to induce managers focusing more on long-term operations.

Competition is a common management activity. In combination with behavioral game theory, our study provides laboratory evidence for the cognitive hierarchy theory that human players usually have limited reasoning ability and tend to form overconfident beliefs about the actions of competitors. Thus, retailers in a competitive environment should be aware of the fact that their competitors generally do not have infinite reasoning ability and they may not apply the strategy of perfect competition. In some situations, competitors may apply a collaborative strategy, which offers an opportunity to end competition and open a win-win trigger. Retailers with such knowledge can try to cooperate rather than compete to achieve long-term success. Our results on capacity competition again provide an example indicating that competition harms the competitors.

6.2 Understanding the turn-and-earn mechanism behaviorally

The turn-and-earn mechanism is a commonly used allocation method to assign capacity in the automotive industry when manufacturers cannot keep up with demand. The allocation is based on previous sales, with high-selling retailers receiving more capacity in the next period. We provide empirical evidence that the turn-and-earn mechanism is an effective way to distribute products (Cachon and Lariviere 1999c, Lu and Lariviere 2012). Our laboratory observations affirm this advantage that subjects order more than they need in the first period, and we find that this mechanism is even more effective in promoting sales than the standard theory predicts. Lu and Lariviere (2012) suggest that the turn-and-earn mechanism can smooth order fluctuations and reduce the bullwhip effect over a long time horizon. Our experimental data verify this virtue. Subjects exaggerated their desired quantities of products when the market size was relatively low, resulting in less variability in the supply chain. Such behavior helps to overcome the demand variability, especially in a highly variable market. In addition to order smoothing, the supplier also earns more profit in practice than the theory predicts by benefiting from the psychological scarcity effect possessed by downstream retailers. This result provides empirical evidence for the favoring of the turn-and-earn mechanism in the automotive industry. For example, Dodge runs strictly on a turn-and-earn scheme to allocate trucks to dealers, thus, can dominate the market (Cachon and Lariviere, 1999c).

6.3 Discussion of other possible behavioral preferences

Other behavioral preferences aside from the scarcity effect may also help explain the experimental results of this study. In the social preference dimension, social rejoice newsvendors, who enjoy outperforming their peers, order higher than the rational optimal quantity when their demands are independent, according to theoretical analysis by Avci et al. (2014). To understand if the social rejoice is one of the drivers for the retailer's ordering behavior in our setting, we include it in our behavioral models. Let $\delta \geq 0$ be the parameter of social rejoice and social regret, we then follow Avci et al. (2014) to add social rejoice term in Equation (8), leading to the utility of player i as follows:

$$
\begin{aligned}
u_\delta(x_{i,1}, x_{i,2};\ x_{-i,1}, x_{-i,2}) =& \pi_{i,1}(x_{i,1}, x_{-i,1}) + \pi_{i,2}(x_{i,2}, x_{-i,2}|x_{i,1}, x_{-i,1}) + \lambda y_{i,2} \\
&+ \delta[\pi_{i,1}(x_{i,1}, x_{-i,1}) + \pi_{i,2}(x_{i,2}, x_{-i,2}|x_{i,1}, x_{-i,1}) \\
&- \pi_{-i,1}(x_{i,1}, x_{-i,1}) - \pi_{-i,2}(x_{i,2}, x_{-i,2}|x_{i,1}, x_{-i,1})]. \qquad (13)
\end{aligned}
$$

Equation (13) instead of Equation (8) produces a full model consisting of five behavioral parameters. Using the experimental data, we make structural estimates of the full model and various sub-models of either scarcity or rejoice, as shown in Table 3. We observe that the log-likelihood values of scarcity models are a little bit higher than those of social rejoice models. Hence, the scarcity models fit the data slightly better than the rejoice models. However, the significant levels of the scarcity-CH-myopic model and the rejoice-CH-myopic model indicate that both scarcity effect and social rejoice play significant roles for explaining the retailers' ordering behavior in turn-and-earn mechanism. Therefore, the social rejoice does help explain the retailers' behavior.

Table 3: Structural estimation comparison between scarcity and social rejoice models

	Scarcity-CH	*Rejoice-CH*	*Scarcity-CH-myopic*	*Rejoice-CH-myopic*	*Full*
No. of Para.	3	3	4	4	5
δ	-	1.51	-	1.55	0.82
λ	35.96	-	42.51	-	39.86
θ	-	-	0.04	0.04	0.05
τ	2.14	2.79	2.30	3.21	2.87
σ	10.58	10.38	10.25	10.49	9.85
Log-likelihood	-18972	-19000	-18703	-18746	-18629
χ^2 test	686	742	148	234	-
Sign. level	< 0.001	< 0.001	< 0.001	< 0.001	-

In the temporal dimension, another possible behavior is time discounting, which means that subjects may care less about future consequences (Frederick et al. 2002). In this problem, subjects may diminish the payoff outcomes in the second period when they make choices in the first period. We assume that a subject's discount rate is $\rho > 0$ and that the weight attached to the second period is $\frac{1}{1+\rho}$, where $\rho > 0$. The subject's utility function with respect to x_i becomes $u_\rho(x_{i,1}, x_{i,2};\ x_{-i,1}, x_{-i,2}) = \pi_{i,1} + \frac{1}{1+\rho}\pi_{i,2}$. When ρ goes to infinity, the retailers order myopic quantities. Hence, the myopia preference is consistent with this extreme time discounting case, which exists only in the low-scarcity case. However, for both high and intermediate scarcity cases, the order quantity in the first period considering time discounting is lower than the standard results, which contradicts the experimental observations that the first period quantity is higher, as shown in Table 1. Thus, time discounting is not a prominent behavioral preference in all three cases.

In the cognitive dimension, one possible behavioral preference is mental account. Our behavioral model of Equation (8) considering the scarcity effect is consistent with the general framework of the mental account theory proposed by Thaler (1985). Retailers might have different psychological accounts for the two periods when evaluating their economic outcomes. The scarcity effect causes them to place extra valuation on the desirability of a favorable allocation in a supply-shortfall period; therefore, the mental valuation of the allocated products is more precious in subjects' minds than the standard theory predicts. Another possible cognitive factor is bounded rationality in the quantal response equilibrium (QRE) model. If we use QRE to model the retailers decision, the retailers' equilibrium order quantities would have a uniform distribution between 100 and 200 because these oder quantities result in the same allocation of 100 in both periods, hence, the same payoff. However, this uniform order quantity contradicts the experiment data because about 50% of our data in the high-scarcity condition is distributed between 100 and 120, as shown in Figure 1. Therefore, QRE is not a proper behavioral model for the setting in this study. Loss-aversion preference is also a typical behavior in cognitive dimension. As our focus is on scarcity effect, we control loss-aversion preference by designing the experiment such that retailers incur 0 costs. Hence, loss-aversion is not considered in our behavioral model.

6.4 Performance comparison with the proportional mechanism

The turn-and-earn mechanism is one mechanism that is used for the allocation of scarce product quantities in practice. The existing literature theoretically compares the strengths and weaknesses of many mechanisms for profit-maximizing supply chain partners (Cachon and Lariviere 1999b, 1999c; Lu et al. 2012). However, the behavioral preferences are experimentally studied only for a few mechanisms, such as the proportional allocation mechanism by Chen et al. (2012). Hence, a reasonable comparison considering decision biases can be made between the turn-and-earn mechanism and the proportional allocation mechanism.

We conduct an experiment of the proportional allocation mechanism using the same treatment parameters as those in Subsection 3.1 and similar procedures in Appendix B for the turn-and-earn mechanism. The performance comparison is shown for the experimental results of both mechanisms in Table 4.

We observe that the supplier sells significantly more products in the turn-and-earn mechanism than in proportional allocation mechanism: 32% higher in High-scarcity, 21% higher in

Table 4: Performance comparison of mechanisms: Turn-and-earn versus proportional allocation

	High-scarcity	Intermediate-scarcity	Low-scarcity
Supplier quantity in turn-and-earn	397.74 (11.34)	375.92 (31.39)	329.77(22.13)
Supplier quantity in proportion	300.68 (4.47)	300.53 (2.00)	301.61 (11.65)
Retailer profit in turn-and-earn	25972.74(21.15)	20722.77 (29.80)	16062.90(15.23)
Retailer profit in proportion	28435.58 (319.91)	22445.20 (12.00)	16295.19 (382.41)

Note: Values are averaged for one round of two periods. Retailer values are averaged for each subject. Values in parentheses are standard deviations.

Intermediate-scarcity, and 10% in Low-scarcity. In contrast, the retailer makes about 10% higher profit in each treatment. The reason for the performance difference is revealed by the retailers' ordering quantities in the two periods, as shown in Table 5. For the supplier, the first period makes a big difference as the supplier has sufficient capacity. In the first period, the retailer orders significantly more in the turn-and-earn mechanism than in the proportional allocation mechanism. This causes the supplier to sell more in the turn-and-earn mechanism than in the proportional allocation mechanism. In the second period, the retailers' order exceeds the supplier's capacity, the supplier's sales volume equals the capacity in both mechanisms. Therefore, the turn-and-earn mechanism provides higher benefit to the supplier but less benefit to the retailer than the proportional allocation mechanism.

Table 5: Retailer order quantity comparison: Turn-and-earn versus proportional allocation

	High-scarcity	Intermediate-scarcity	Low-scarcity
Period 1 in turn-and-earn	116.91 (17.49)	88.72 (10.41)	65.06 (7.50)
Period 1 in proportion	50.68 (3.24)	50.36 (1.05)	51.08 (1.31)
Period 2 in turn-and-earn	149.40 (29.01)	133.57 (19.53)	114.47 (6.82)
Period 2 in proportion	197.87 (5.54)	198.67 (2.05)	189.07 (19.04)

Note: Values are averaged for each period in one round for each subject. Values in parentheses are standard deviations.

7 Conclusion

Dynamic decision-making is commonly involved in the long-term operations of real-world business. Many studies have addressed various dynamic operational problems in supply chain management, but most take a theoretical perspective, and few take an experimental perspective. In this study, we experimentally examine two-period competition between two retailers. We use the capacity competition under the turn-and-earn mechanism to create a two-period decision environment for retailers who consider the future when making current choices. By conducting laboratory experiments, we find that subjects systematically sell more products in a supply-abundant period than predicted by the standard theory. Structural analyses suggest that the psychological scarcity effect can be the behavioral drive behind this phenomenon. Subjects may place a higher valuation on the desired products in a supply-shortfall period than the standard theory predicts. We further develop a behavioral model to accommodate subjects' decision-making behavior.

The behavioral model formulates subjects' utility functions such that they place additional valuation on the allocation in a supply-shortfall period. To describe the imperfect strategic interactions between two competitors, we incorporate the scarcity effect model into a cognitive hierarchy framework to account for limited reasoning capability and overconfident beliefs. The structural estimates reveal that subjects take an average of 2.7 reasoning steps in the problem setting. Additionally, subjects' decisions are heterogeneous and may be myopic, and the myopic behavior varies across different situations. When the capacity scarcity is relatively low, a substantial portion of the data, as much as 13%, coincide with myopic choices; when the capacity scarcity becomes intermediate or high, the myopia fades, affecting only 1% of decisions. In additional, structural estimates show that the retailers also exhibit social rejoice preference. Our study highlights four behavioral characteristics: the scarcity effect, social rejoice, cognitive hierarchy, and heterogeneous myopia and forward looking. The behavioral model including these behaviors provides a compelling explanation of the experimental observations and fits the data well.

Our research contributes to the behavioral operations management literature in three ways. First, we identify the strategic competition behavior when a supplier uses turn-and-earn mechanism to manage capacity and find that human retailers' decisions are influenced by the psychological scarcity effect when they are engaged in supply-shortfall situations. The scarcity effect is commonly associated with human decision-makers (e.g., Shah et al. 2012), but it is not discovered in a competitive supply chain setting. Our experimental study indicates that operational strategies should take account of the scarcity effect as it profoundly affects system performance. Second, our experimental data verify the behavioral assumptions in the cognitive hierarchy model. Although some existing empirical evidence has shown that decision-makers have different sophistication levels in strategic reasoning (Goldfarb and Yang 2009, Goldfarb and Xiao 2011), the cognitive hierarchy model has not been widely used in supply chain settings to explain the equilibrium behavior (Cui and Zhang 2017). We provide experimental evidence that the cognitive hierarchy model is useful to explain equilibrium behavior in the field of supply chain management. Third, we compare the turn-and-earn mechanism with the proportional mechanism by an experiment, and find that the former leads to higher sales volume for the supplier but to less profit for the retailer than the latter.

Acknowledgement

The authors thank the department editor, the senior editor, and two anonymous reviewers for their constructive comments of improving the paper. This research is supported by NSF of China under grants 71501004, 71761137004, and 71371105.

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Appendix A: Proofs of Propositions

Proposition 1

We solve Nash Equilibrium by backward induction.

In the second period: if the sales of two retailers in the first period are $y_{i,1}$ and $y_{-i,1}$, the guaranteed allocation in the second period will be $\frac{K}{2} + \frac{y_{i,1}-y_{-i,1}}{2}$ and $\frac{K}{2} + \frac{y_{-i,1}-y_{i,1}}{2}$, respectively, for the two retailers. The optimal order strategy in the second period follows

$$\begin{cases} x^*_{i,2} = \dfrac{H-w}{2} & \text{if} \quad \dfrac{K}{2} + \dfrac{y_{i,1}-y_{-i,1}}{2} \geq \dfrac{H-w}{2} \\ x^*_{i,2} \in \{x | x \geq \max\{\dfrac{K}{2} + \dfrac{y_{i,1}-y_{-i,1}}{2},\ K - \dfrac{H-w}{2}\}\} & \text{if} \quad \dfrac{K}{2} + \dfrac{y_{i,1}-y_{-i,1}}{2} < \dfrac{H-w}{2}. \end{cases}$$

As a consequence, the optimal sales in the second period follows

$$y^*_{i,2} = \begin{cases} \dfrac{H-w}{2} & \text{if} \quad \dfrac{K}{2} + \dfrac{y_{i,1}-y_{-i,1}}{2} \geq \dfrac{H-w}{2} \\ \max\{\dfrac{K}{2} + \dfrac{y_{i,1}-y_{-i,1}}{2},\ K - \dfrac{H-w}{2}\} & \text{if} \quad \dfrac{K}{2} + \dfrac{y_{i,1}-y_{-i,1}}{2} < \dfrac{H-w}{2} \end{cases}$$

In the first period:

Given opponent's order strategy $x_{-i,1}$, the sales of the retailer i with order strategy $x_{i,1}$ is

$$y_{i,1}(x_{i,1},\ x_{-i,1}) = \begin{cases} \dfrac{L-w}{2} & \text{if} \quad x_{i,1} \leq \max\{\dfrac{K}{2},\ K - x_{-i,1}\} \\ \max\{\dfrac{K}{2},\ K - x_{-i,1}\} & \text{if} \quad x_{i,1} > \max\{\dfrac{K}{2},\ K - x_{-i,1}\} \end{cases}$$

The payoff of the first period is $\pi_{i,1}(x_{i,1},\ x_{-i,1}) = \frac{(L-w)^2}{4} - (y_{i,1} - \frac{L-w}{2})^2$.

The payoff of the second period with order strategy $(x_{i,1},\ x^*_{i,2})$ is

$$\pi_{i,2}(x^*_{i,2},\ x^*_{-i,2}|x_{i,1}, x_{-i,1}) = \frac{(H-w)^2}{4} - (\min\{\frac{H-w}{2},\ \max\{\frac{K}{2} + \frac{y_{i,1}-y_{-i,1}}{2},\ K - \frac{H-w}{2}\}\} - \frac{H-w}{2})^2,$$

where $y_{i,1} = \min\{x_{i,1},\ \max\{K - x_{-i,1},\ \frac{K}{2}\}\}$ and $y_{-i,1} = \min\{x_{-i,1},\ \max\{K - x_{i,1},\ \frac{K}{2}\}\}$.

Nash Equilibrium order strategy $(x^*_{i,1},\ x^*_{i,2})$ maximizes the total profit of the two periods: $\pi_{i,1}(x_{i,1},\ x_{-i,1}) + \pi_{i,2}(x^*_{i,2},\ x^*_{-i,2}|x_{i,1}, x_{-i,1})$.

Because the retailer's profit depends on her allocation, we first analyze the retailer's optimal allocation with a given strategy of her opponent, then solve retailer i's best order strategy with respect to her opponent's order strategy $x_{-i,1}$.

Denote $\prod_i(y_{i,1},\ x_{-i,1}) = \pi_{i,1}(x_{i,1},\ x_{-i,1}) + \pi_{i,2}(x^*_{i,2},\ x^*_{-i,2}|x_{i,1}, x_{-i,1})$, the optimal allocation $y^*_{i,1}$ satisfies $\frac{\partial \prod_i(y_{i,1},\ x_{-i,1})}{\partial y_{i,1}} = 0$.

It involves three cases: (1) $y_{-i,1} = x_{-i,1}$; (2) $y_{-i,1} = K - y^*_{i,1}$; and (3) $y_{-i,1} = \frac{K}{2}$.

In case (1), the retailer i's optimal strategy makes opponent $-i$'s allocation of $y_{-i,1}$ equal to her order quantity of $x_{-i,1}$, thus the opponent $-i$'s order quantity $x_{-i,1}$ satisfies $x_{-i,1} \leq K - y^*_{i,1}$, where $y^*_{i,1}$satisfies $\frac{\partial \prod_i (y_{i,1},\, x_{-i,1})}{\partial y_{i,1}} = -\frac{5}{2} y^*_{i,1} + (L-w) + \frac{H-w-K+x_{-i,1}}{2} = 0$.

In case (2), the retailer i's optimal strategy makes opponent $-i$'s allocation of $y_{-i,1}$ equal to the remaining quantity $K - y^*_{i,1}$. $x_{-i,1}$ satisfies $x_{-i,1} > K - y^*_{i,1}$ and $\frac{K}{2} \leq K - \frac{2(L-w)+(H-w)}{6}$, where $y^*_{i,1}$ satisfies $\frac{\partial \prod_i (y_{i,1},\, x_{-i,1})}{\partial y_{i,1}} = -3 y^*_{i,1} + (L-w) + \frac{H-w}{2} = 0$.

In case (3), the retailer i's optimal strategy makes opponent $-i$'s allocation of $y_{-i,1}$ equal to the guranteed quantity $0.5K$. $x_{-i,1}$ satisfies $x_{-i,1} > K - y^*_{i,1}$ and $\frac{K}{2} > K - \frac{2(L-w)+(H-w)}{6}$, where $y_{i,1}*$ satisfies $\frac{\partial \prod_i (y_{i,1},\, x_{-i,1})}{\partial y_{i,1}} = -\frac{5}{2} y^*_{i,1} + (L-w) + \frac{H-w-0.5K}{2} = 0$.

By solving the above formulas, we obtain the optimal allocation in the first period $y^*_{i,1}$ with respect to the opponent's order strategy $x_{-i,1}$. Denote $Z = \max\{\frac{K}{2},\ K - \frac{2(L-w)+(H-w)}{6}\}$, it follows

$$y^*_{i,1}(x_{-i,1}) = \begin{cases} \dfrac{2(L-w) + x_{-i,1} + (H-w-K)}{5} & \text{if} \quad x_{-i,1} \leq Z \\ \dfrac{2(L-w)+(H-w)}{6} & \text{if} \quad x_{-i,1} > Z \quad \text{and} \quad \dfrac{K}{2} \leq K - \dfrac{2(L-w)+(H-w)}{6} \\ \dfrac{2(L-w)+H-w-0.5K}{5} & \text{if} \quad x_{-i,1} > Z \quad \text{and} \quad \dfrac{K}{2} > K - \dfrac{2(L-w)+(H-w)}{6} \end{cases}$$

To obtain $y^*_{i,1}(x_{-i,1})$, the optimal order quantity $x^*_{i,1}(x_{-i,1})$ is

$$\begin{cases} x^*_{i,1}(x_{-i,1}) = y^*_{i,1}(x_{-i,1}) & \text{if} \quad y^*_{i,1}(x_{-i,1}) \leq \max\{\dfrac{K}{2},\ K - x_{-i,1}\} \\ x^*_{i,1}(x_{-i,1}) \in \{x | x \geq \max\{\dfrac{K}{2},\ K - x_{-i,1}\}\} & \text{if} \quad y^*_{i,1}(x_{-i,1}) > \max\{\dfrac{K}{2},\ K - x_{-i,1}\} \end{cases}$$

Nash Equilibrium $(x_{1,1},\ x_{2,1})$ satisfies two equations: (1) $x_{1,1} = x^*_{1,1}(x_{2,1})$; (2) $x_{2,1} = x^*_{2,1}(x_{1,1})$.

By solving the above equations, we obtain Nash Equilibrium $x_{1,1} = x_{2,1}$ following:

$$\begin{cases} x_{1,1} = x_{2,1} = \dfrac{L-w}{2} + \dfrac{H-w-K}{4} & \text{if} \quad 2L + H - 3w < 3K \\ \begin{cases} x_{1,1} \in \{x | x \geq \dfrac{K}{2}\} & \text{if} \quad 2L + H - 3w \geq 3K \\ x_{2,1} \in \{x | x \geq \dfrac{K}{2}\} & \text{if} \quad 2L + H - 3w \geq 3K \end{cases} \end{cases}$$

□

Proposition 2

By equation (8), the objective function of retailer i is $u_\lambda(x_i, x_{-i}) = \frac{(L-w)^2}{4} + \frac{(H-w)^2}{4} - (y_{i,1} - \frac{L-w}{2})^2 - \lambda * (y_{i,2} - \frac{H-w}{2})^2$.

Following the same method as the proof of Proposition 1, the optimal allocation in the first period $y^*_{i,1}$ with respect to the opponent's order strategy $x_{i,1}$ follows

$$
y_i^{1*}(x_{-i,1}) = \begin{cases} \dfrac{2(L-w)+\lambda x_{-i,1}+\lambda(H-w-K)}{4+\lambda} & \text{if} \quad x_{-i,1} \leq Z \\ \dfrac{(L-w)+0.5\lambda(H-w)}{2+0.5\lambda} & \text{if} \quad x_{-i,1} > Z \quad \text{and} \quad \dfrac{K}{2} \leq K - \dfrac{(L-w)+0.5\lambda(H-w)}{2+0.5\lambda} \\ \dfrac{(L-w)+0.5\lambda(H-w-0.5K)}{2+0.5\lambda} & \text{if} \quad x_{-i,1} > Z \quad \text{and} \quad \dfrac{K}{2} > K - \dfrac{(L-w)+0.5\lambda(H-w)}{2+0.5\lambda} \end{cases}
$$

The corresponding order quantity $x_i^{1*}(x_{-i,1})$ is

$$
\begin{cases} x_i^{1*}(x_{-i,1}) = y_i^{1*}(x_{-i,1}) & \text{if} \quad y_i^{1*}(x_{-i,1}) \leq \max\{\dfrac{K}{2},\ K - x_{-i,1}\} \\ x_i^{1*}(x_{-i,1}) \in \{x | x \geq \max\{\dfrac{K}{2},\ K - x_{-i,1}\}\} & \text{if} \quad y_i^{1*}(x_{-i,1}) > \max\{\dfrac{K}{2},\ K - x_{-i,1}\} \end{cases}
$$

Nash Equilibrium $(x_{1,1},\ x_2^1)$ satisfies two equations: (1) $x_{1,1} = x_1^{1*}(x_{2,1})$; (2) $x_{2,1} = x_2^{1*}(x_{1,1})$.

By solving the above equations, we obtain Nash Equilibrium $x_{1,1} = x_{2,1}$ in the following:

$$
\begin{cases} x_{1,1} = x_{2,1} = \dfrac{L-w}{2} + \lambda\dfrac{H-w-K}{4} & \text{if} \quad 2(L-w)+\lambda(H-w) < (2+\lambda)K \\ \begin{cases} x_{1,1} \in \{x | x \geq \dfrac{K}{2}\} & \text{if} \quad 2(L-w)+\lambda(H-w) \geq (2+\lambda)K \\ x_{2,1} \in \{x | x \geq \dfrac{K}{2}\} & \text{if} \quad 2(L-w)+\lambda(H-w) \geq (2+\lambda)K \end{cases} \end{cases}
$$

Consequently, we have the results in proposition 2 that

$$
\begin{cases} x_{1,1} = x_{2,1} = \dfrac{L-w}{2} + \lambda\dfrac{H-w-K}{4} & \text{if} \quad \lambda < \dfrac{2(K-L+w)}{H-w-K} \\ \begin{cases} x_{1,1} \in \{x | x \geq \dfrac{K}{2}\} & \text{if} \quad \lambda \geq \dfrac{2(K-L+w)}{H-w-K} \\ x_{2,1} \in \{x | x \geq \dfrac{K}{2}\} & \text{if} \quad \lambda \geq \dfrac{2(K-L+w)}{H-w-K} \end{cases} \end{cases}
$$

□

Appendix B: Instructions of the Experiment

General description

Thank you for participating in this decision-making experiment. The instructions are simple; if you follow them carefully and make good decisions, you could earn a considerable amount of money, which will be paid to you in cash before you leave today. Different subjects may earn different amounts of cash. What you earn today depends partly on your decisions, partly on the decisions of others, and partly on chance.

The experiment will consist of 50 decision rounds. In each round, you will be randomly matched with another player in this room. Each player will take on the role of a retailer in a supply chain.

Retailers order products from the same manufacturer but sell them in different markets. There are two periods. The second period has a better market than the first period. Given the same output, the market price of the second period is higher than that of the first period.

In each decision round, you will make two decisions: how much to order in the first period (OrderA), and how much to order in the second period (OrderB), specifying how many units you want to order for each market condition. The quantity of stock you receive may differ from your order, and will depend on the quantity ordered by you as well as the other player whom you are matched with. In the second period, the stock you receive also depends on the received stocks in the first period. You can receive Δ more stock than the other player in the second period if you get Δ more stock than the other player in the first period.

You will sell all the stock you received to your market in each period. The market price linearly decreases with the output. If you output more, the market price will be lower. Thus, you can achieve the maximal profit in each period as long as the quantity you receive is exactly the best output. Your objective is to maximize the total profits of the two periods.

It is important that you do not look at others' decisions, and that you do not talk, laugh, or exclaim aloud during the experiment. You will be warned if you violate this rule the first time. If you violate the rule a second time, you will be asked to leave and you will not be paid.

Experimental procedures

The following four steps will be repeated for every decision round that you participate in.

Step 1: Players submit OrderA

Each player chooses an integer number for OrderA between 0 and 200. OrderA is the number of units you would like to order in the first period. You will decide on your OrderA without seeing the decisions made by the other player.

Step 2: Players receive stock and earn profit for the first period

In total, 200 units of stock are available. The following procedure describes how these units will be divided between you and the player you are matched with.

The computer calculates TOTAL ORDERS, which is the sum of your OrderA and that of the player you are matched with.

If TOTAL ORDERS is less than or equal to 200, the STOCK you receive is equal to your OrderA.

If TOTAL ORDERS is greater than 200, the STOCK you receive depends on the order of the player you are matched with.

(1) If the order of your matched player (OrderA2) is smaller than or equal to 100, your STOCK is 200 - OrderA2.

(2) If the order of your matched player (OrderA2) is larger than 100, your STOCK is the minimum value between 100 and OrderA.

Let us consider the following examples.

1. Suppose that your Order A is 40 and TOTAL ORDERS is revealed to be 110. Then, you will receive a STOCK of 40.

2. Suppose that your Order A is 110 and TOTAL ORDERS is revealed to be 160. Then, you will receive a STOCK of 110.

3. Suppose that your Order A is 140 and TOTAL ORDERS is revealed to be 220. Then, you will receive a STOCK of 100.

You market price is 100-STOCK, and your profit earned in this period is STOCK*(100-STOCK).

Step 3: Players submit Order B

Each player chooses an integer number for Order B between 0 and 200. Order B is the number of units you would like to order for the second period. You will decide on your Order B without seeing the decisions made by the other player.

Step 4: Players receive stock and earn profit for the second period

In total, 200 units of stock are available. If you get Δ more STOCK than the other player in the first period, you have Δ more guaranteed stock, GSTOCK, in the second period. GSTOCK=100+0.5*Δ. In contrast, your guaranteed stock is GSTOCK=100-0.5*Δ if you get Δ less STOCK than the other player in the first period.

The computer calculates TOTAL ORDERS, which is the sum of your Order B and that of the player you are matched with.

If TOTAL ORDERS is less than 200, the STOCK you receive is equal to your Order B.

If TOTAL ORDERS is greater than 200, the STOCK you receive depends on GSTOCK and the order of the player you are matched with.

(1) If the order of your matched player (OrderB2) is smaller than or equal to her guaranteed stock (equal to 200 - GSTOCK), your STOCK is 200 - OrderB2.

(2) If the order of your matched player (OrderB2) is larger than her guaranteed stock (equal to 200 - GSTOCK), your STOCK is the minimum value between GSTOCK and Order A.

Let us consider following examples.

1. Suppose that you receive 40 and the other player receives 100 in the first period, in the second period, your guaranteed stock is 70 and the other player's guaranteed stock is 130. In the second

period, suppose that you order 90 and the other player orders 160; then, you receive a STOCK of 70.

2. Suppose that you receive 90 and the other player receives 50 in the first period; in the second period, your guaranteed stock is 120 and the other player's guaranteed stock is 80. In the second period, suppose that you order 150 and the other player orders 160; then, you receive a STOCK of 120.

You market price is 360 - STOCK, and your profit earned in this period is STOCK*(360 - STOCK).

Final payoff

Your earnings for the experiment will be determined as follows. First, we will add up your total earning points from all 50 rounds. Then we will multiply your total points by 1/15,000, that is,15,000 earning points worth 1 unit of money. The resulted number of units is the amount you will be paid when you leave the experiment. Note that, the more profits you earn, the more money you will receive.