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Decision making in the newsvendor problem: A cross-national laboratory study

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ABSTRACT

In this paper, we conduct a laboratory experiment using the classic newsvendor problem to examine cross-national differences in inventory ordering patterns between Chinese and American decision makers based on a theoretical examination of the role of the Doctrine of the Mean in Chinese decision making. Drawing on the theory of context-dependent preferences (specifically extremeness aversion), we also revisit the flat-maximum hypothesis of Bolton and Katok [12], i.e., "thinning the set of order options leads to newsvendor decisions that achieve a higher proportion of maximum expected profit." The results show that the "pull-to-center" effect is more prominent for Chinese than Americans, i.e., average order quantities of Chinese subjects are closer to the anchor of mean demand than those of American subjects. Furthermore, we find that thinning the set of order options such that the optimal order quantity is a middle option, not an extreme option in the choice set, leads to better performance in newsvendor decisions, which complements the flat-maximum hypothesis.

1. Introduction

Cross-national differences have been well documented in judgment and decision making, including differences in probability judgments [1–3] and risk preferences [4,5]. For example, Yates et al. [2] found that Chinese respondents showed greater overconfidence in the accuracy of their answers to general knowledge questions than Americans and Europeans, and they proposed that cross-cultural differences in education might account for such cross-national differences in overconfidence.

Despite the prevalence of cross-national studies in judgment and decision making, there is little research in operations management that investigates cross-national differences in operations decisions. Nowadays business operations are set in a global environment and firms need to deal with suppliers and customers in global supply chains. For example, according to the World Trade Organization's annual report (1998, p. 36, http://www.wto.org/english/res_e/booksp_e/anrep_e/anre98_e.pdf), the production of a particular "American" car takes place across a number of different countries. Thirty percent of the car's value comes from Korea for assembly, 17.5% from Japan for components and advanced technology, 7.5% from Germany for design, 4% from Taiwan and Singapore for minor parts, 2.5% from the United Kingdom for advertising and marketing services and 1.5% from Ireland and Barbados for data processing. Also, about 70% of the products sold on Wal-Mart's shelves are made in China [6]. At the national level, trade between the United States and China has been dramatically increasing since China joined the WTO in November, 2001. According to the US Census Bureau, China was the second largest trading partner for the US in 2007 (specifically, the US imported goods worth nearly 321.5 billion dollars from China in 2007).

These above examples indicate that operations decisions within a global supply chain may come from parties with different backgrounds. Since cross-national issues can affect procurement, production and distribution in global operations, purportedly optimal solutions predicted by theories in operations management are unlikely to apply across decision makers from different countries. In addition, ignorance or misperception of cross-national differences may lead to substantial operational inefficiencies in international businesses. Thus, it is important to study behavioral differences in decision makers from different countries and understand the effect of cross-national differences in global operations.

In this research, we aim to examine cross-national differences in the newsvendor setting. Recently there has been a growing interest in behavioral operations management (see reviews in [7–9]). In this stream of research, a number of papers have employed the classic newsvendor problem to study decision

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makers' behavior by using laboratory experiments and present inconsistencies between theoretical predictions and empirical observations in the newsvendor setting [10–18]. It has been widely observed that average order quantities systematically deviate from the optimal expected profit-maximizing quantity and actually fall between the mean demand (e.g., the center of the uniform demand interval) and the optimal order quantity, i.e., subjects order too few when they should order more and vice versa. This is called the "pull-to-center" effect in [15]. Several decision biases have been proposed to explain the "pull-to-center" effect in the newsvendor experiments. Specifically, Schweitzer and Cachon [10] proposed two decision biases in their study, i.e., a preference for minimizing ex-post inventory error, and the anchoring and insufficient adjustment bias. Su [17] proposed the boundedly rationality bias, in which a boundedly rational decision maker is prone to errors in the newsvendor experiments. Croson et al. [18] proposed the overconfidence bias, i.e., subjects tend to underestimate demand variation in the newsvendor decisions.

As discussed above, the "pull-to-center" effect has been replicated in various studies [10–18]. However, almost all of these studies used subjects from western countries (e.g., the United States) for their experiments. Prior literature suggests cross-cultural differences in decision making between Western and Eastern countries [5,19–22], for example, the United States and China are two representative countries with different cultures and decision makers from these two countries may behave differently in many aspects. Thus, in this study, we chose to examine possible differences in ordering patterns between Chinese and Americans in the newsvendor setting.

The main contribution of this paper is two fold. Firstly, to the best of our knowledge, our work is the first cross-national study in behavioral operations management using laboratory experiments. More specifically, from the perspective of cross-cultural differences between American and Chinese people, we conjecture that the "pull-to-center" effect is more prominent for Chinese than Americans, i.e., average order quantities of Chinese subjects are closer to the anchor of the mean demand than those of American subjects. The "pull-to-center" effect has been widely observed in the newsvendor experiments using American subjects. However, the ordering pattern is not known for Chinese decision makers in newsvendor decisions. Building on the theory of the Doctrine of the Mean, we hypothesize that Chinese tend to exhibit a more prominent "pull-to-center" effect than Americans in newsvendor decisions. This hypothesis is examined in Study 1.

Secondly, we identify conditions under which decision makers may perform better in newsvendor decisions. Previous experimental studies in the newsvendor problem suggest that decision makers nearly always incur inefficiencies by ordering a quantity different from the expected profit maximizing quantity. Bolton and Katok [12] propose that thinning the set of order options improves decision makers' performance in the newsvendor problem, which they called a *flat-maximum* hypothesis.[1] Through a laboratory experiment, they find that reducing the number of ordering options does not necessarily result in better performance for newsvendor decisions. On the basis of the theory of context-dependent preferences, we propose that extremeness aversion explains why the flat-maximum hypothesis was not supported. Specifically, we hypothesize that thinning the set of order options such that the optimal order quantity is a middle option, not an extreme option in the choice set, leads to better performance in newsvendor decisions. Study 2 is conducted to test this hypothesis.

The rest of the paper is organized as follows. Section 2 presents Study 1 to examine cross-national differences in ordering patterns between Americans and Chinese from a cross-cultural perspective. Section 3 describes Study 2, which revisits and complements the flat-maximum hypothesis in newsvendor decisions. We discuss some managerial implications and limitations of the study, and conclude the paper in Section 4.

2. Study 1

2.1. The Doctrine of the Mean

The Doctrine of the Mean (*Zhong Yong* or *Chung Yung*), attributed to Confucius and deeply embedded in the Chinese culture, has an extensive impact on Chinese people's thoughts and behavior [23–25]. In Confucian philosophy, the Doctrine of the Mean implies that it was "as bad to go beyond one's target as it was to come up short" [23]. It is also captured by two Chinese adages, one is "going too far is as bad as not going far enough" and the other one is "anything which is carried to the extreme will inevitably bring about just the opposite effect" [23,26]. Thus, according to Confucius, the "Mean" is "without inclination to either side," which can be rendered as "Equilibrium" and further identified as "Harmony." The Doctrine of the Mean also suggests that "if the goal is to attain prolongation and propagation of life, one must neither be excessive nor be insufficient, but always try to hold the Golden Mean as the best policy" [23,26].

Bian and Keller [27] applied the Doctrine of the Mean to explain why Chinese decision makers are risk averse in risky health and safety decisions and tend to avoid the options with extreme outcomes, whereas it is not the case for their American counterparts in these decision settings. Briley et al. [28] proposed that culture influences individuals' decisions when they are required to explain their choices. For example, due to principles such as the Doctrine of the Mean, Hong Kong decision makers' preference for compromises will increase when they need to provide reasons for their choices. Cui and Zhang [29] found that the Doctrine of the Mean guides Chinese Designers in their design inspirations. Lowe and Corkindale [30] showed that the Chinese are less willing to try a new product or adopt an innovative service than the Australians. They argued that Chinese may regard adopting or using this new/innovative product or service as an extreme behavior and a violation of the Doctrine of the Mean. Sui [31] suggested that the Doctrine of the Mean and the principle of harmony affect marketing practices of firms in mainland China, compared to those in the United Kingdom and Hong Kong. When investigating the differences in conflict management styles between Chinese and Western managers, Tang and Kirkbride [32] considered "Chung Yung" as one aspect of cultural values that lead the Chinese executives to favor the less assertive "compromising" behaviors as their dominant styles.

Based on the above discussion, we conjecture that the Doctrine of the Mean plays an important role in ordering decisions for Chinese decision makers, i.e., in the newsvendor problem, people of the Chinese culture tend to avoid extreme choices and lean toward middle options when faced with decisions under uncertainty. More specifically, when explaining the "pull-to-center" effect in the newsvendor problem observed in experimental data from American subjects, Schweitzer and Cachon [10] proposed the "anchoring and insufficient adjustment" bias, i.e., decision makers tend to anchor on the mean demand and

[1] Flat-maximum refers to the flatness of the newsvendor's expected profit function around the neighborhood of the maximum, which may impede learning. Bolton and Katok [12] hypothesized that "thinning the set of order options will both sharpen expected payoff differences between neighboring order quantities, and make comparison of draws for neighboring order quantities more reliable," thus leading to better performance.

insufficiently adjust toward the optimal quantity. So, following the Doctrine of the Mean, Chinese decision makers have a greater tendency to think that it is safer to choose ordering quantities around the mean demand, thus "anchoring" on this mean demand. This is consistent with one fundamental action principle of Chinese people in the sense that they are more careful not to make big mistakes, but are less concerned with accomplishing something. It also echoes with the finding in [33] that Chinese executives tend to choose face-saving options. Therefore, it seems plausible to hypothesize that Chinese decision makers are more likely to anchor on the mean demand and insufficiently adjust toward the optimal quantity compared to their American counterparts, i.e., the "pull-to-center" effect is more prominent for Chinese than Americans in newsvendor decisions.

2.2. Experimental design

To test the above proposition, we conduct a study using a $2 \times 2 \times 2$ between-subjects experiment design (i.e., Chinese vs. US, 100 vs. 3 order quantities, high-safety-stock vs. low-safety-stock conditions). Specifically, we replicated the experiment studied in Bolton and Katok [12] for the 100-option and 3-option treatments, under both high-safety-stock and low-safety-stock conditions. That is, in the high-safety-stock condition, $p=12$, $c=3$, $R=200$, $D \sim U(0, 100)$, with $Q^*=75$, the 100 options were the integers between 1 and 100 and the 3 options included 35, 50, and 75 (see [12] for an explanation on how the three values were chosen for the 3-option treatment).[2] In contrast, in the low-safety-stock condition, $p=12$, $c=9$, $R=50$, $D \sim U(50, 150)$, with $Q^*=75$, the 100 options were the integers between 51 and 150 and the 3 options included 75, 100, and 115. Table 1 summarizes the sets of options in different treatments.

In Study 1, we recruited 76 undergraduate students at Fudan University in Shanghai, China for the 100-option and 3-option treatments. The data from American subjects were obtained via private communication from authors of [12] for the 100-option and 3-option treatments.[3] The laboratory protocol in our experiment was similar to that in [12], including the materials for the experiment (i.e., the instructions, experiment descriptions, game screens, etc.), experimental procedure and subject payments (i.e., average earnings were about 14 RMB in our experiment). In particular, to make the results of Chinese subjects comparable to those of Americans, we followed the method known as back-translation with decentering (Brislin [34]) to translate the materials for the experiment used in [12].[4]

Also similar to [12], we conducted the experiment in a computer laboratory at the School of Management of Fudan University. Before the study, each subject was presented with a self-starting computerized experiment which was programmed using Visual Basic and Excel.[5] Then we gave a brief instruction presentation and question and answer session to subjects on what the experiment was mainly about and how they would operate the software. After they were clear about the instructions, each of them practiced the experiment for ten rounds before they started the session. Then subjects made 100 consecutive inventory purchasing decisions in each session of the experiment. More specifically, in each round, subjects were presented with a newsvendor problem and were required to determine an order quantity before demand was realized. At the end of each round, an outcome summary report was provided to subjects, including the realized market demand, the order quantity, the sales quantity, the overage and shortage quantities, the realized profit and the total accumulated profit up to that round.

Table 1
The six treatments in the two studies.

	High-safety-stock condition	Low-safety-stock condition
100 options	Treatment 1: Integers between 1 and 100	Treatment 2: Integers between 51 and 150
3 options	Treatment 3: 35, 50, 75	Treatment 4: 75, 100, 115
4 options	Treatment 5: 35, 50, 75, 90	Treatment 6: 60, 75, 100, 115

Further, in each session, subjects received the same sequence of demand draws, which was randomly identified before the experiment. Specifically, the average of 100 demand draws in the high-safety-stock and low-safety-stock condition was 50.3 and 100 with the standard deviation of 28.9 and 29.1, respectively. Note that the sequence of demand draws in our experiment was different from that in the experiment of [12]. However, there was no significant difference between the 100-round demand draws in our experiment and those in their experiment under both the high-safety-stock and low-safety-stock conditions (Mann–Whitney, two-tailed $p=0.97$ and 0.99, respectively).[6]

2.3. Results

Fig. 1 illustrates the average order quantities by Chinese and American subjects in every 10 rounds for the 100-option treatments under both high-safety-stock and low-safety-stock conditions. We can see that the "pull-to-center" effect also appeared for Chinese subjects, as repeatedly observed from American subjects in the previous literature. That is, under both conditions, Chinese subjects' average order quantities fell between the optimal order quantity of 75 and the mean demand (centered at 50 or 100 in the two conditions), and they were significantly different from 75 (Wilcoxon, two-tailed $p < 0.001$). More interestingly, as we expected, the "pull-to-center" effect was more prominent for Chinese subjects than American subjects. In particular, compared to the American counterparts, on average Chinese subjects ordered less in the high-safety-stock condition, but ordered more in the low-safety-stock condition. Further, the difference in the order quantities of each round between Chinese subjects and American subjects was

[2] As described in Bolton and Katok [12], in the newsvendor problem, p is the unit market price, c is the unit product cost, R is the fixed rent incurred for the newsvendor during the selling season, and D is the market demand. See more details in Section 2.1 of Bolton and Katok [12].

[3] Note that in [12], they recruited executive MBA students for the 100-option high-safety-stock treatment and undergraduate students for other treatments. Recall that through a laboratory study, Bolton et al. [13] did not find any significant differences in newsvendor decisions between freshmen business students, graduate business students and experienced procurement managers. Thus we believe that professional working experience should not be a concern in the comparison of the performance between Chinese subjects and American subjects.

[4] In a preliminary study, we ran the experiment in English to the Chinese participants, and found that the results were similar to those reported in the main body of the paper with the experiment that was in Chinese.

[5] Note that Bolton and Katok [12] used the z-Tree software to run their experiment. Although the two experiments were run using different software, our subjects were presented with the same instructions, experiment descriptions and game screens during the experiment as in their study. Thus, the impact of the software difference on the results of comparisons can be considered to be negligible, if there is any.

[6] Recall that in Bolton and Katok's [12] experiment, participants were also presented with the same sequence of 100-round demand draws, except that in the 100-option high-safety-stock treatment, each of the executive M.B.A. students faced a different sequence of random demand draws.

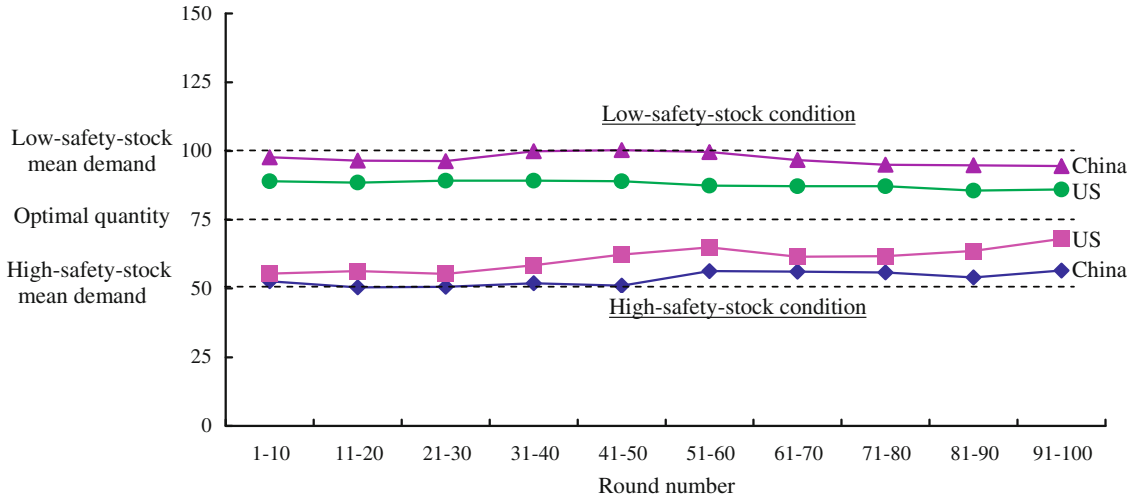


Fig. 1. Order quantities in every 10 rounds in the 100-option treatments (Chinese subjects vs. American subjects).

significant for both high-safety-stock and low-safety-stock conditions (Wilcoxon, one-tailed $p < 0.001$ in both conditions).

We also found a similar pattern in the 3-option treatments, illustrated in Fig. 2. For the 3-option treatments, Chinese subjects' order quantities were significantly lower than their American counterparts in the high-safety-stock condition (Wilcoxon, one-tailed $p < 0.001$), and significantly higher than American subjects in the low-safety-stock condition (Wilcoxon, one-tailed $p < 0.001$).

We also examined differences in order dynamics between Chinese and American subjects using the models of the demand-chasing heuristic and the mean anchor heuristic proposed in Bostian et al. [14] (see Section 3 of [14] for details of these two models). Table 2 presents parameter estimates for the model of the demand-chasing heuristic for both Chinese and American subjects. For the static model, in the high-safety-stock condition, β is 0.1549 for Chinese and 0.0904 for their American counterparts (β is the degree of adjustment towards the most recent demand observation relative to the last choice, i.e., the higher the value of β, the more demand chasing). In the low-safety-stock condition, β is 0.0973 and 0.0899, respectively, for Chinese and American participants. The estimates are significantly different ($p < 0.01$) between the two groups in both conditions. We found similar results for the dynamic model of the demand-chasing heuristic. Therefore, we may conclude that Chinese tend to chase demand more than their American counterparts. This is consistent with the Doctrine of the Mean, which suggests that Chinese people are very careful not to make big mistakes, and tend to choose face-saving options. Consequently, Chinese tend to match their order quantities with the most recent demand observations, thus showing a more prevalent demand-chasing behavior pattern.

Parameter estimates for the models of the mean anchor heuristic are provided in Table 3. Similarly, we found that for both the static and dynamic models, Chinese have a lower tendency to deviate from the mean demand and adjust toward the optimal order quantity than their American counterparts. For example, for the static model, in the high-safety-stock condition, α is 0.1411 for Chinese and 0.4302 for their American counterparts (α represents the extent to which subjects adjust away from the mean demand anchor toward the optimal order quantity, i.e., a smaller value of α implies a lower tendency to move away from the mean demand). In the low-safety-stock condition, α is 0.1152 and 0.4876, respectively, for Chinese and American participants. The estimates are significantly different ($p < 0.01$) between the two groups in both conditions. This is also consistent with the Doctrine of the Mean, which implies Chinese people tend to choose middle options when they are faced with uncertain decisions.

In summary, we found significant differences in newsvendor decisions between Chinese and Americans. More specifically, compared to American decision makers, Chinese ordered significantly less in the high-safety-stock condition and significantly more in the low-safety-stock condition. This implies that Chinese decision makers tend to show a more pronounced "pull-to-center" effect in newsvendor decisions relative to their American counterparts. As a result, it is found that cultural principles that provide guidance for decision-making appear to affect individuals' behavior in the operations field as well. Similar to the findings in [28] that American consumers prefer intermediate alternatives less than their East Asian counterparts, in the newsvendor problem Chinese decision makers prefer the intermediate alternatives more. Due to the Doctrine of the Mean, the Chinese decision makers tend to reason that ordering too much is similar to ordering too little and neither is good. Therefore, their order decisions center on the mean demand more significantly than the American decision makers.

3. Study 2

3.1. Context-dependent preferences

Bolton and Katok [12] proposed a flat-maximum hypothesis that decreasing the number of order options leads to better newsvendor performance. By comparing subjects' performance in the 3-option and 9-option treatments to that in the 100-option treatment under both high-safety-stock and low-safety-stock conditions, they found that their flat-maximum hypothesis was not supported, i.e., thinning the set of order options did not significantly improve decision makers' performance.[7] They also pointed out that in their 3-option and 9-option treatments, the optimal profit-maximizing quantity of 75 was an extreme choice, but it was not the case in the 100-option treatment. In this study,

[7] Recall that in [12], for the high-safety-stock condition, the 100 options were the integers between 1 and 100, the 9 options were 35, 40, 45, 50, 55, 60, 65, 70, and 75, and the 3 options were 35, 50, and 75. For the low-safety-stock condition, the 100 options were the integers between 51 and 150, the 9 options were 75, 80, 85, 90, 95, 100, 105, 110, and 115, and the 3 options were 75, 100, and 115.

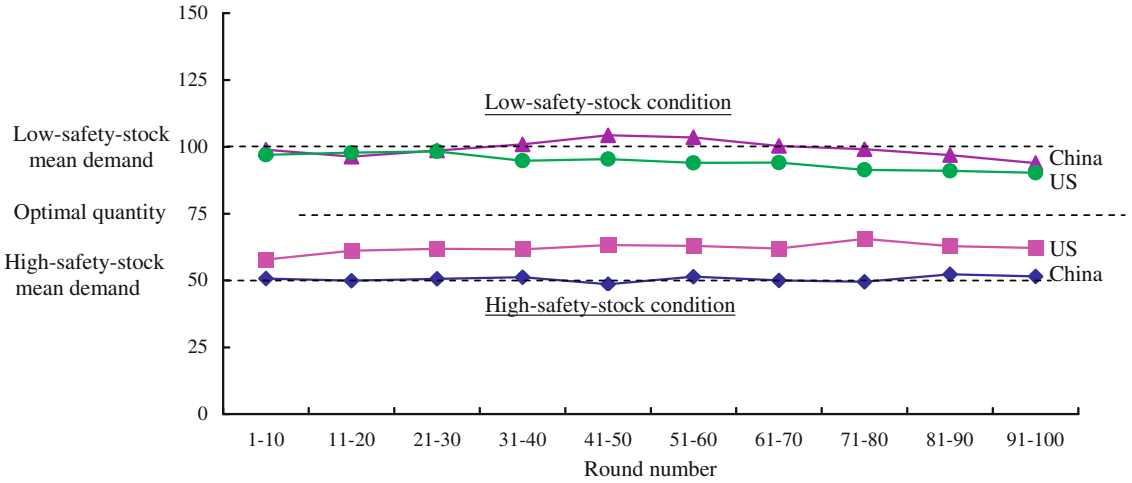


Fig. 2. Order quantities in every 10 rounds in the 3-option treatments (Chinese subjects vs. American subjects).

we propose that based on the theory of context-dependent preferences [35,36], extremeness aversion may explain why the flat-maximum hypothesis was not supported in their study.

Context-dependent preferences suggested that the choices that decision makers make are influenced by the decision context (i.e., the set of alternatives under consideration), which is counter to the principle of value maximization [36,37]. To describe the effect of context on choice, Simonson and Tversky [35] further proposed two principles, tradeoff contrast and extremeness aversion, which assumes that preferences among a set of choice alternatives under consideration depend on the relational properties of alternatives.

Extremeness aversion occurs when "the attractiveness of an option is enhanced if it is an intermediate option in the choice set and is diminished if it is an extreme option," which violates the independence of irrelevant alternatives principle and the betweenness inequality principle [35]. For the purpose of illustration, consider a set of three two-dimensional options $\{x, y, z\}$, where, e.g., x is the point (x_1, x_2) displayed in Fig. 3. By construction, y is between x and z, and $x_1 < y_1 < z_1$ and $x_2 > y_2 > z_2$ (i.e., the middle option y has a small advantage and a small disadvantage relative to both extreme options x and z, whereas each extreme option has a large advantage and a large disadvantage with respect to the other extreme option).

Extremeness aversion has been used to explain the compromise effect [38,39] and polarization [35]. More specifically, when extremeness aversion is symmetric on both attributes, the compromise effect occurs, i.e., the addition of an extreme option increases the attractiveness of the middle option with respect to the other option. This implies that adding z to $\{x, y\}$ increases the attractiveness of y relative to x and adding x to $\{y, z\}$ increases the attractiveness of y relative to z. But, when extremeness aversion is asymmetric and only applies to one attribute, polarization occurs. For example, in a choice set of products involving tradeoffs between quality and price, adding a middle product in the choice set could make the high quality, high price product more attractive with respect to the low quality, low price product, if polarization favors quality. In this case, extremeness aversion only applies to quality but not to price.

Thus, we conjecture that extremeness aversion may serve as an explanation on why the flat-maximum hypothesis was not supported in Bolton and Katok [12]. Specifically, consider the 3-option treatment which consists of three ordering quantities $\{x, y, z\}$. Without the loss of generality, we assume that x is the smallest and z is the largest quantity. In addition, each option varies on two dimensions, chance of overage (attribute 1) and chance of underage (attribute 2). It is clear that the order quantity x has the lowest chance of overage and the highest chance of underage, while the order quantity z has the highest chance of overage and the lowest chance of underage, i.e., $x_1 < y_1 < z_1$ and $x_2 > y_2 > z_2$. Therefore, in this context, y is the middle option with attribute values between the values of the other two more extreme options, x and z. Consequently, in the 3-option treatment in which the optimal order quantity of 75 is an extreme option, subjects are less likely to choose 75 in comparison with the middle order quantity since the middle option becomes the compromise choice and is more attractive. This leads to the result that the performance in the 3-option treatment was not significantly better than that in the 100-option treatment, i.e., the flat-maximum hypothesis was not supported (the same logic also holds for the 9-option treatment).

Accordingly, we conjecture that the compromise effect also occurs with the optimal order quantity of 75 if an adjacent order quantity is appropriately added to the 3-option treatment such that 75 becomes a middle option rather than an extreme option. Since the compromise effect suggests that the addition of an extreme option increases the attractiveness/share of the middle option, the optimal quantity of 75 will be more preferred in the new 4-option treatment (in which 75 is a middle option) than in the 3-option treatment (in which 75 is an extreme option). Therefore, based on the flat-maximum hypothesis in Bolton and Katok [12], we hypothesize that thinning the set of order options such that the optimal order quantity is a middle option, not an extreme option in the choice set, leads to better performance in newsvendor decisions.

3.2. Experimental design

To test the above hypothesis, we conducted the second study using a 3×2 between-subjects experiment design (i.e., three sets of ordering options with 100, 3 and 4 quantities, and two conditions with high-safety-stock and low-safety-stock cases). In particular, the 100-option and 3-option treatments under both high-safety-stock and low-safety-stock conditions are the same as in Study 1. In the 4-option treatment under both high-safety-stock and low-safety-stock conditions, the 4 options were 35, 50, 75 and 90 in the high-safety-stock condition, and 60, 75, 100, and

Table 2
Parameter estimates for demand-chasing heuristic.

	High-safety-stock condition						Low-safety-stock condition					
	China		US		Difference		China		US		Difference	
	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic
β	0.1549		0.0904		***		0.0973		0.0899		***	
	(4.557e−4)		(4.596e−4)				(4.815e−4)		(4.545e−4)			
β_1		0.1006		0.1218		***		0.1087		0.1022		***
		(6.888e−4)		(0.001)				(0.001)		(8.292e−4)		
Δ_β		0.0084		−0.0063		***		−0.0025		−0.0032		***
		(0.1014)		(0.0002)				(0.0002)		(1.749e−4)		
σ_ε	19.7622	19.7147	16.5154	16.5049			15.0909	15.0895	14.9418	14.9389		
β_{100}		0.1179		0.1093				0.1037		0.0962		
ll	−5763.4	−5761.0	−5027.2	−5026.6			−5496.4	−5496.4	−5486.6	−5486.4		

Note:
1. The values in the brackets are the standard deviations of parameter estimates.
2. In Bostian et al. [14], a dynamic partial-adjustment model for the demand-chasing heuristic is given by $x_t = x_{t-1} + \beta_t(d_{t-1} - x_{t-1}) + \varepsilon_t$, where x_t and x_{t-1} are the actual order quantities in time period t and $t-1$, d_{t-1} is the observed demand in period $t-1$, ε_t is an i.i.d. normal error term, $\beta_t = (1+\Delta_\beta)\beta_{t-1}, t > 1$, β_t is the degree of adjustment towards the observed demand in period $t-1$, Δ_β is the percentage increase or decrease in the demand-chasing heuristic from round to round. Note that β_t=1 implies full demand chasing. In addition, the dynamic model reduces to be a static model when Δ_β=0 (i.e., $\beta_t = \beta_{t-1} = \cdots = \beta_1 = \beta$).
***: $p < 0.01$.

Table 3
Parameter estimates for mean anchor heuristic.

	High-safety-stock condition						Low-safety-stock condition					
	China		US		Difference		China		US		Difference	
	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic
α	0.1411		0.4302		***		0.1152		0.4876		***	
	(6.325e−4)		(6.667e−4)				(6.325e−4)		(6.325e−4)			
α_1		0.0519		0.2323		***		0.0387		0.413		***
		(5.999e−4)		(0.001)				(6.787e−4)		(0.0013)		
Δ_α		0.018		0.0115		***		0.0188		0.0032		***
		(1.505e−4)		(0.0001)				(2.320e−4)		(0.0000)		
σ_ε	19.2012	19.1126	18.4628	18.1099			15.889	15.8391	17.0166	16.9795		
α_{100}		0.0728		0.2821				0.055		0.4392		
ll	−5792.9	−5788.2	−5178.3	−5160.9			−5603.5	−5600.4	−5672.1	−5669.9		

Note:
1. The values in the brackets are the standard deviations of parameter estimates.
2. In Bostian et al. [14], a dynamic model for the mean anchor heuristic is given by $x_t = \overline{d} + \alpha_t(x^* - \overline{d}) + \varepsilon_t$, where x_t is the actual order quantity in time period t, $\overline{d}$ is the mean demand, x^* is the optimal order quantity, ε_t is an i.i.d. normal error term, $\alpha_t = (1+\Delta_\alpha)\alpha_{t-1}, t > 1$ is interpreted as the extent to which subjects adjust away from the mean demand anchor toward the optimal order quantity in period t, Δ_α is the percentage increase or decrease in the insufficient adjustment bias from round to round. Note that α_t=1 would be full adjustment to the optimal order quantity. In addition, the dynamic model reduces to be a static model when Δ_α=0 (i.e., $\alpha_t = \alpha_{t-1} = \cdots = \alpha_1 = \alpha$).
***: $p < 0.01$.

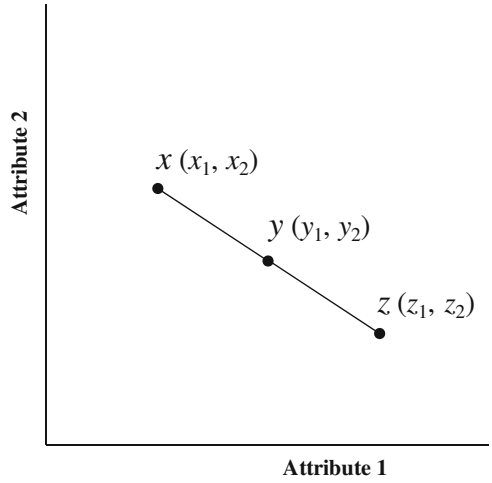


Fig. 3. An illustration of extremeness aversion.

115 in the low-safety-stock condition. Note that compared to the 3-option treatments, different and more extreme ordering quantities (i.e., 90 in the high-safety-stock condition and 60 in the low-safety-stock condition) were added to the sets of ordering options. In other words, the optimal quantity of 75 units was no longer the extreme option, but a middle option in our 4-option treatments. Moreover, we chose to add 90 in the 4-option high-safety-stock condition because it still yields a positive expected profit and has a distance of 15 relative to 75 which is symmetric to the distance between 35 and 50. Similarly, 60 was chosen for the 4-option low-safety-stock treatment. Moreover, for the 4-option treatments, we recruited 37 undergraduate students from Fudan University (note that the data for the 100-option and 3-option treatments were obtained from Study 1). The same experimental procedure was followed to complete the 4-option treatments in a computer laboratory at the School of Management of Fudan University as in Study 1.

3.3. Results

For comparisons across the treatments, we use the evaluation criterion adopted in [12], which was referred to as *proportion of maximum expected profit achieved*. For a given order quantity, this metric is computed by calculating the expected profit associated with this quantity divided by the expected profit associated with the optimal order quantity.

Fig. 4 shows the aggregate results on the percentage of choices with the optimal quantity in the 100-option, 3-option, and 4-option treatments. It is not surprising to see that the optimal quantity (of 75) was chosen much more frequently in the 4-option and 3-option treatments relative to the 100-option treatment. Specifically, in the 100-option treatment, 75 only accounted for approximately 1% and 2% of the total ordering times in the low-safety-stock and high-safety-stock conditions, respectively.[8] More interestingly, we find that compared to the 3-option treatment, 75 was chosen significantly more often in the 4-option treatment (Wilcoxon, one-tailed $p<0.001$ for both conditions, respectively). For example, in the 3-option treatments, subjects selected 75 in nearly 20% of the total times in both conditions. In contrast, 75 was chosen in about 41% and 32% of the total times in the 4-option treatment for the low-safety-stock and high-safety-stock conditions.

Fig. 5 plots the aggregate proportions of maximum expected profit achieved in the 100-option, 3-option, and 4-option treatments. First, we observe that compared to the 100-option treatment, Chinese participants performed better in the 3-option treatment for the high-safety-stock condition, but not for the low-safety-stock condition. Also, both differences were not significant (Mann–Whitney, one-tailed $p=0.457$ and 0.063, respectively). This is consistent with the finding in [12], which implies that a thinner set of options did not significantly improve newsvendor decisions if the optimal quantity was an extreme option in the choice set.

More importantly, we find that the 4-option treatment outperformed the 100-option and 3-option treatments for both low-safety-stock and high-safety-stock conditions. In particular, subjects performed significantly better in the 4-option treatment than in the 100-option treatment (Mann–Whitney, one-tailed $p<0.001$ for both conditions). This is also true for the difference in the performance between the 4-option treatment and the 3-option treatment (Mann–Whitney, one-tailed $p<0.001$ for both conditions).

Fig. 6 displays the proportions of maximum expected profit achieved for Chinese subjects as time evolves in the 100-option, 3-option, and 4-option treatments (i.e., each data point corresponds to the average proportion of maximum expected profit achieved per 10 rounds). Pairwise comparisons also reveal that subjects performed significantly better in the 4-option treatment relative to either the 100-option treatment or the 3-option treatment for both conditions (Wilcoxon, one-tailed $p<0.001$ in both conditions for the two between treatment comparisons: 4-option vs. 100-option, 4-option vs. 3-option). This is consistent with the aggregate results over all rounds discussed above.

Thus, our findings indicate that thinning the set of order options such that the optimal order quantity is a middle option rather than an extreme option leads decision makers to perform better in their ordering decisions. This is consistent with the hypothesis. In addition, Study 2 was conducted only using Chinese subjects. Comparison between Chinese and American subjects' performance in this 4-option treatment can be explored in further research.

4. Discussion and conclusion

In this paper, we conduct a laboratory experiment using the classic newsvendor problem to examine cross-national differences in ordering patterns between Chinese and American decision makers based on a theoretical examination of the role of the Doctrine of the Mean in Chinese decision making. Drawing on the theory of context-dependent preferences (specifically extremeness aversion), we revisit the flat-maximum hypothesis of [12]. The results show that the "pull-to-center" effect is more prominent for Chinese than Americans, i.e., average order quantities of Chinese subjects are closer to the anchor of mean demand than those of American subjects. Furthermore, we find that thinning the set of order options such that the optimal order quantity is a middle option, not an extreme option, in the choice set, leads to better performance in newsvendor decisions, which complements the flat-maximum hypothesis.

Our study sheds some light on global operations in the sense that firms may need to understand differences in procurement patterns to successfully manage various functions in global supply chains. Our experimental findings are limited to the newsvendor setting and more research is needed to help advance our understanding of

[8] In the 100-option treatment, about 17.5% and 13.5% of the order quantities were near optimal (between 70 and 80) in the low-safety-stock and high-safety-stock conditions, respectively.

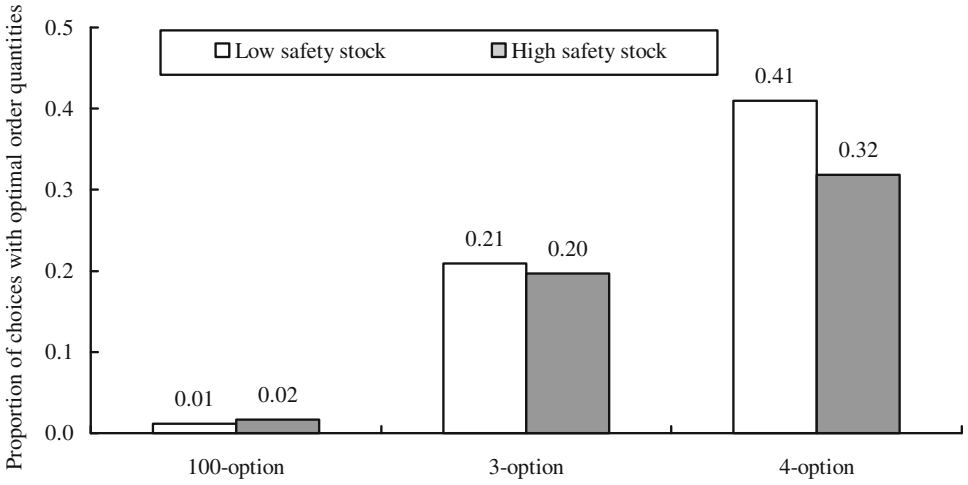
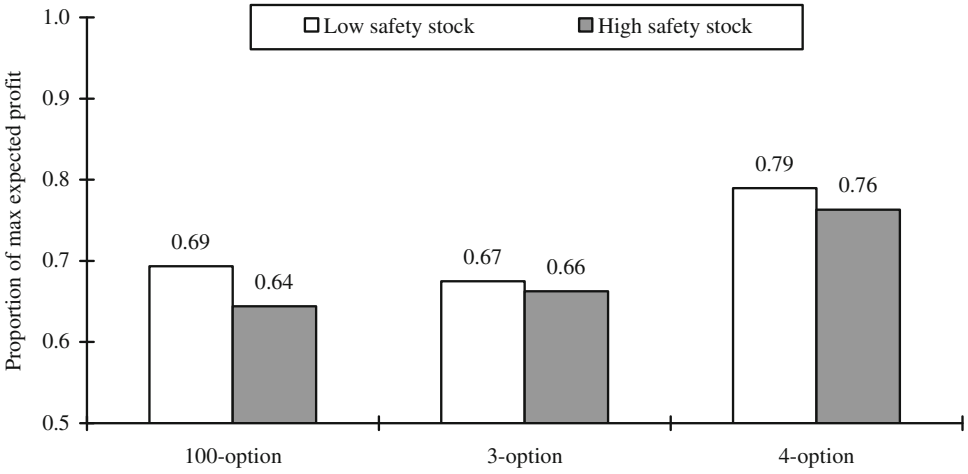


Fig. 4. Proportion of choices with optimal order quantities (75) in 100-option, 3-option and 4-option treatments.



Mann-Whitney tests (one-tailed, sample size = number of subjects)

	Comparisons (all rounds)	*p*-value
Low safety stock	H_0: 4-option ≤ 100-option	< 0.001
	H_0: 4-option ≤ 3-option	< 0.001
	H_0: 3-option ≤ 100-option	0.063
High safety stock	H_0: 4-option ≤ 100-option	< 0.001
	H_0: 4-option ≤ 3-option	< 0.001
	H_0: 3-option ≤ 100-option	0.457

Fig. 5. Proportion of maximum expected profit achieved in 100-option, 3-option and 4-option treatments.

cross-national differences in global operations. Nonetheless, our general approach suggests that cultural differences are likely to arise. For example, suppose a US retailer opens a chain store in China and implements vendor managed inventory (VMI) with a Chinese supplier to manage one of the high-profit products. The retailer's business decisions, e.g., shelf arrangement and promotions, depend on her understanding of the inventory policies being used. The retailer may assume that the Chinese supplier manages the inventory in a way similarly to how she does. However, our findings suggest that the Chinese supplier is likely to fulfill the inventory differently than what the US retailer has expected. For example, the US retailer may arrange too much shelf space for this product, or assign too large of a sales force/advertising budget to manage this product based on her own projections of inventory replenishment and associated costs and profits.

In this research, we base our findings on the theory of the Doctrine of the Mean. One potential limitation of this study is that there might be some other factors which could play a role in cross-national ordering differences. For example, differences in the demographic information between Chinese and American

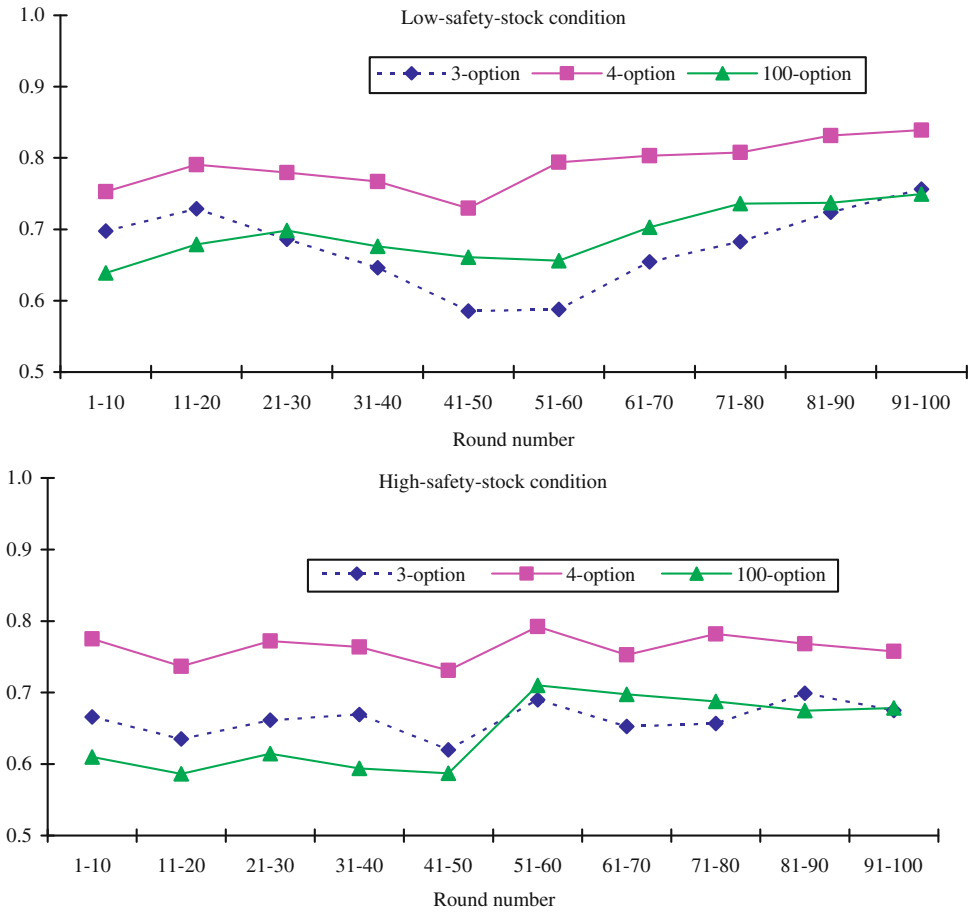


Fig. 6. Proportion of maximum expected profit achieved as time evolves in 100-option, 3-option and 4-option treatments.

respondents might also have an impact on their ordering difference. As mentioned before, professional working experience has been shown not to be a critical factor in behavioral newsvendor decisions in [13]. However, this might not be true for other demographic indicators, such as gender, race and age.

Finally, as mentioned before, we are, to our knowledge, the first to conduct a cross-national study in behavioral operations management using laboratory experiments. According to the major findings on newsvendor decisions in our paper, we believe that there may also be significant cross-national differences in decision making in other emerging areas of behavioral operations management, such as behavioral issues in supply chain contracting, sourcing and auctions. Related studies on these topics, perhaps using a verbal protocol approach to examine operational decisions as in Gavirneni and Xia [40], would be interesting and merit further research.

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