Ordering decisions in the presence of product sales promotional information

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Abstract

Based on extant literature in behavioral operations management, we investigate the effects of retail promotions in a multi-period inventory ordering setting under two different transit times. Our laboratory experiment finds the awareness of upcoming promotions assists in optimizing ordering decisions and reducing supply chain costs. We also find that additional detail related to the price discount of the promotion is not as effective in reducing supply chain costs. Our experiment provide evidence on supply line underweighting where longer transit times exacerbate supply chain costs. Additionally, we find that those unaware of a promotion tend to accumulate inventory after a promotion.

Keywords: Behavioral operations management, Ordering decisions, Laboratory experiments

Introduction

Since the seminal work of Schweitzer & Cachon (2000), the field of behavioral operations management has seen a growth in the literature of inventory ordering decisions. Numerous aspects of ordering decisions, such as the newsvendor problem, stationary and nonstationary demand and the beer distribution game have come under scrutiny during this period (Croson & Donohue, 2006; Tokar et al., 2014). Majority of these works focus on single-period inventory models (newsvendor problem) where the product becomes obsolete after a single ordering period. Emphasis on multi-period inventory ordering decisions has been scarce despite their importance in the real-world (Bloomfield & Kulp, 2013).

Retail promotions such as price discounts and multi buys (selling additional stock keeping units at a reduced price) lead to volatility in demand (Tokar et al., 2014). Normative literature has modeled the effect of promotions on operations activities such as inventory management (Cheng & Sethi, 1999) and production decisions (Sogomonian & Tang, 1993). A behavioral operations management study explores whether awareness of the magnitude and the time of a retail promotion leads to cost savings in the supply chain (Tokar et al., 2011). Although Tokar et al. (2014) investigate the effect of demand shocks on ordering decisions, they do not exclusively focus on retail promotions. Both these works (Tokar et al., 2011; Tokar et al., 2014) are also limited to a product that becomes obsolete after a single-period ordering period. This leaves a cavity in our understand of how ordering decisions are influenced by promotional information.

Transit time or lead time refers to the time it takes to receive an order from the time it is placed. Extant literature shows that transit time has a moderating effect on ordering decisions. Research shows that longer transit times complicates the decision-making process leading to inefficiencies (Bloomfield & Kulp, 2013). This is partly because misperception of feedback is exacerbated by longer transit times (Sterman, 1989). Ultimately, this results in over or under ordering that affects the rest of the supply chain (Sterman, 1989; Croson et al., 2014).

This paper investigates the effect of promotional information on ordering decisions for multi-period inventory items (durable products). We also examine the moderating effect of transit times in this context. We report on the results of a controlled laboratory experiment that tests three hypotheses made through a systematic literature review. The next section of the paper reviews the extant literature and presents the hypotheses that drive this research. This is followed by a description of the methodology employed in this study. We analyze the data collected from the experiment in the penultimate section before discussing the conclusions in a closing section.

Background

We began with a systematic review of the literature relating to ordering and inventory decisions, which helps us identify research gaps and present the hypotheses that forms that foundation of this research.

Effect of promotional information on ordering decisions

Retail promotions are commonly employed in the retail industry to boost sales and revenue. Promotions assert pressure on the rest of the supply chain to conform in ensuring the timely availability of products in the right quantities (Cheng & Sethi, 1999; Craig et al., 2016). While promotions can be a source of boosting revenue, gearing the supply chain to cater the demand uplift and notify the customers is costly (Urbanski, 2003). Improving promotional execution and avoiding overordering or underordering would benefit the entire supply chain by reducing costs (Ailawadi et al., 2009).

Literature has especially investigated how promotions influence the forecasters to intervene with system-generated forecasts (Trapero et al., 2013; Trapero et al., 2015). However, the effect of promotions on inventory ordering decisions hasn't been explored extensively. Tokar et al. (2014) investigate the effect of demand shocks on ordering decisions, not exclusively focusing on promotions for a single-period product. They find that the uncertainty of a demand shock leads the decision makers to brace for a loss. The results show that this leads to suboptimal, biased decisions. The effects of the uncertainty results in overstocking by ordering too much, too early. This provides evidence that uncertainty in the magnitude and the timing of the demand shock confounds the decision maker. The general trend in such circumstances is to overorder when the demand increases (Sterman, 1989).

Extra information and decision support leads to better and more effective decision-making (Tokar et al., 2011; Becker-Peth & Thonemann, 2018). There is evidence of supply chain costs being reduced when there is information to better inform ordering decisions (Spiliotopoulou et al., 2016). In this context, supply chain cost refers to the summation of inventory holding cost and lost sales cost during the experiment. A recent newsvendor experiment reports that subject who are aware of the demand distribution anchor their ordering decisions on the available information while those without this information anchor on the historic demand (D'Urso et al., 2017). This phenomenon of anchoring on the most recent demand observations in the absence of additional information has been reported in some of the previous research (Lawrence & O'Connor, 1992; Bostian et al., 2008). Research have shown that information sharing could lead to benefits from retail promotions to all stakeholders (Iyer & Ye, 2000; Tokar et al., 2011). Yet, there's no evidence explaining whether the availability of retail promotion information may impact ordering decisions for durable products.

Motivated by this literature, we first investigate whether the provision of promotional information aids the decision maker to reach more accurate ordering decisions. Our industry observations have revealed that the supply managers who oversee the ordering operations may not always have access to promotional information. Despite this, they respond to forecasts which have already captured impending promotions without being informed of the full details of the demand spikes. Thus, we hypothesize:

- H_1: Access to retail promotional information improves the accuracy of ordering decisions.

On the contrary, there is also evidence that frequent information could be counterproductive. This poses the risk of the decision maker anchoring his/her decisions on the most recent information available (Lurie & Swaminathan, 2009). When faced with a difficult decision, humans have shown to give more weight on the information than seems most salient to the decision (Fischer et al., 1987; Kahneman & Frederick, 2002). Humans have also shown a tendency to find it difficult to make accurate decisions when too much information is available. This phenomenon is termed as information overload (Becker et al., 2007; Tokar et al., 2012). Based on this literature, we hypothesize that:

- H_2: Awareness of the price discount of a retail promotion does not significantly improve the accuracy of ordering decisions compared to being merely aware of the presence of a promotion.

Effect of transit times on ordering decisions in the presence of promotions

As outlined in the introduction, transit time has proven to complicate ordering decisions. Evidence shows that decision makers struggle to order optimally when there are orders in transit (Sterman, 1989; Tokar et al., 2012; Croson et al., 2014). This is because the decision makers give prominence to the inventory level rather than the inventory position when making ordering decisions (Tokar et al., 2012). This phenomenon has been termed as supply line underweighting in the literature (Sterman, 1989; Croson et al., 2014).

Majority of the literature in inventory ordering decisions deal with a static transit time across all their experiments. One study compares the results from the immediate replenishment with a three-period lag to find out whether transit time exacerbates supply chain costs (Bloomfield & Kulp, 2013). They find that the effects of longer transit times are more pronounced in multi-period ordering decisions in comparison to single-period ordering decisions. This could be explained by the cognitive load faced by the decision maker who needs to consider both the inventory level and the transit time when placing orders. This results in a misperception of feedback that would not manifest itself in a single-period inventory setting (Sterman, 1989).

Construal level theory (CLT) refers to the perception an individual has about an object/concept. Humans tend to better understand objects/concepts which can be easily construed (Liberman & Trope, 1998). This theory applies in the presence of transit lags as the decision maker may not form a concrete opinion of the products in transit when placing an order. This is because the products are not physically available to the decision maker in their inventory.

The effect of transit times on ordering decisions in the presence of promotions has not been explored in the literature. Given the uncertainty in demand and costs associated with retail promotions, understanding this relationship would better inform the research community and the industry on how to be more cost-effective. Based on this literature and research gap, we hypothesize:

- H_3: Longer transit times significantly increase supply chain costs from ordering decisions.

Methodology

We chose to implement a controlled laboratory experiment to find answers to the three hypotheses. Laboratory experiment is a rigorous and robust methodology used in behavioral operations management to test and build theory (Bachrach & Bendoly, 2011; Siemsen, 2011; Deck & Smith, 2013; Katok, 2018). Carefully designed laboratory experiments help establish causal connections with behavioural factors (Croson & Donohue, 2002; Tokar, 2010). This can produce useful insights that predict how humans behave in the real-world (Deck & Smith, 2013; Katok, 2018). To effectively prove the hypotheses, researchers create several treatment groups by manipulating the focal variables. The outcomes of those groups are then compared with those of a control group (placebo) (Bendoly et al., 2010).

Experimental design & implementation

Our laboratory experiment was designed using z-Tree (Fischbacher, 2007). The experiment contains a control group and two treatment groups to reflect the level of promotional information provided to the subjects (Table 1). Subjects in the control group have no access to specific information regarding an upcoming promotion. Subjects in the first treatment group are informed of the presence of an upcoming promotion (I_1). Those in the second treatment group are informed of the price discount of an upcoming promotion (I_2). The design of the experiment utilizes the forecasting, sales and supply management data of a Fast-Moving Consumer Goods (FMCG) company in Australia to make sure a real-life situation is replicated.

Table 1 – Characteristics of the laboratory experiment

Treatment	Level of promotional information	No. of participants	No. of periods for each transit time
Control group	-	44	9
Treatment 1	I_1	45	9
Treatment 2	I_2	51	9

The subjects are adequately informed about the experiment and their objectives with a task description before they begin. Prior to the experiment, we present a questionnaire that captures subjects' demographic information and their relevant experience. The experiment contains two ordering tasks containing nine ordering periods each. The ordering tasks are identical in nature, except for the transit time. The transit time in one of the ordering tasks is one ordering period, and two ordering periods in the other task. A retail promotion occurs once in each ordering task. The promotional period occurs in the sixth ordering period when transit time is one ordering period and the seventh ordering period when the transit time is two ordering periods. These periods are selected to allow subjects to familiarize with the experiment prior to the promotion.

Each ordering task is preceded by a practice round to familiarize the subjects with the task. The sequence of the ordering tasks is split into two to mitigate the order effect. The subjects are expected to make orders after considering sales forecasts, inventory levels, transit time and promotional information that may or may not be provided to them. The experiment provides the subjects with information on their previous ordering decisions and actual sales to aid their decisions. The experiment concludes by asking the subjects to rate the considerations driving their ordering decisions.

The induced value theory posits that the subjects require an induced value to control economically relevant characteristics and motivate the subjects to perform better (Smith, 1976). Therefore, the subjects were guaranteed a \$5 show up fee. Depending on how well they minimized the overall costs incurred during the experiment, the subjects could earn a maximum incentive of \$15. Based on literature, we assign the per unit loss of sales as \$2 and per unit inventory cost as \$1 per period (Sterman, 1989; Croson & Donohue, 2006; Tokar et al., 2014). This cost asymmetry is corroborated by the industry (Goodwin, 1996). Equation 1 illustrates how the overall cost is calculated. Here, c^i is the total cost incurred by subject i where c_h is inventory holding cost and c_l is lost sales cost. Additionally, d_t is the actual demand and x_t is the net inventory at the start of period t where $t \epsilon [1,9]$.

$$c^i = \sum_{t=1}^{n} [c_h(x_t - d_t)^+ + c_l(d_t - x_t)^+] \quad (1)$$

The participating subjects are postgraduate students studying operations and supply chain management courses. This selection ensures that the subjects have good understanding of the key concepts relevant to the scope of the experiment. The experiments were conducted at two institutions: The University of Sydney, Australia; and University of Moratuwa, Sri Lanka. Overall, 140 subjects took part in the experiments, earning \$9.98 on average. Based on the responses to the demographic questions, we find that 46.8% of the subjects are between 26 and 35 years old, and 46.7% are between 18 and 25. We also note that we have a good gender equality in our experiment where 51.8% of all subjects are male. We observe that 67 subjects possess industry experience in supply chain management, and 44 of them held managerial positions (middle or top) at the time of the experiment. It is interesting to note that our subject pool has gained educational and/or employment experience in 39 countries covering all six inhabited continents.

Data analysis and discussion

We run a general linear model (GLM) on the supply chain costs accumulated by each subject. GLMs provide a rich framework to analyze the treatment effects of laboratory experiments (Morris, 2011). The effect from both the treatment and the transit time were considered in this analysis. The GLM passes the lack-of-fit test, validating the model and our data ($p > 0.100$). Equation 2 showcases the general linear model that was derived from our experimental results. The relationship between the supply chain cost (Cost) with the treatment groups (Control_Group, Treatment_1, Treatment_2) and the transit time (Transit Time_1 = one ordering period, Transit Time_2 = two ordering periods) is shown therein.

$$\text{Cost} = 32414 + 6000 * \text{Control\_Group} - 4047 * \text{Treatment\_1} - 1954 * \text{Treatment\_2} - 6431 * \text{Transit Time\_1} + 6431 * \text{Transit Time\_2} \quad (2)$$

Our findings show a significant effect between treatments ($p = 0.014$). This indicates that the availability of promotional information has a significant effect on supply chain costs, proving H_1. The results show that the subjects in treatments 1 and 2, perform significantly better in controlling supply chain costs. The GLM shows that treatment 1 generates $10047 less in supply chain costs than the control group on average. Based on this, we could argue there is merit in sharing retail promotion information with decision makers who work to ensure timely availability of products to satisfy promotional demands.

Equation 2 indicates that the subjects in treatment 2, where price discount information is available, performed worse than those in treatment 1. As per Equation 2, the difference between the average supply chain costs for treatment 1 and treatment 2 is $2093. This is despite them performing significantly better than those in the control group. This substantiates the literature on information overload as the subjects seem to have overreacted to the promotion compared to the other treatments. Results from the exit questionnaire provide evidence to back this up. Running a Kruskal-Wallis test, we find that the importance given on the promotional information is significantly higher ($p = 0.002$).

The analysis provides evidence that transit time also has a significant effect on the supply chain costs. The results show that subjects accumulated higher supply chain costs under longer transit times, disproving H_3 ($p < 0.000$). The results conform with the construal level theory and previous observations of supply line underweighting. Thus, the subjects seem to struggle to control supply chain costs when all other factors are identical except for the transit time.

Analyzing the inventory level over the course of the experiment, reveals that subjects in treatment 2 tend to accumulate more inventory for the promotional period (Figure 1 and Figure 2). It is likely that the information on the magnitude of the price discount prompts the subjects to be overoptimistic about a promotion. We also observe that the subjects who are cognizant of an impending promotion tend to accumulate inventory in lead up to the promotional period. This effect is most profound for the longer transit time. The results also indicate that the subjects in the treatment group show a tendency to increase their inventory level after the conclusion of the promotional period. This is interesting given that our experiment does not allow backordering where lost sales could be served at a cost. Thus, it seems that the subjects increase their inventory levels either in anticipation of future demand uplifts or compulsively to compensate for lost sales.

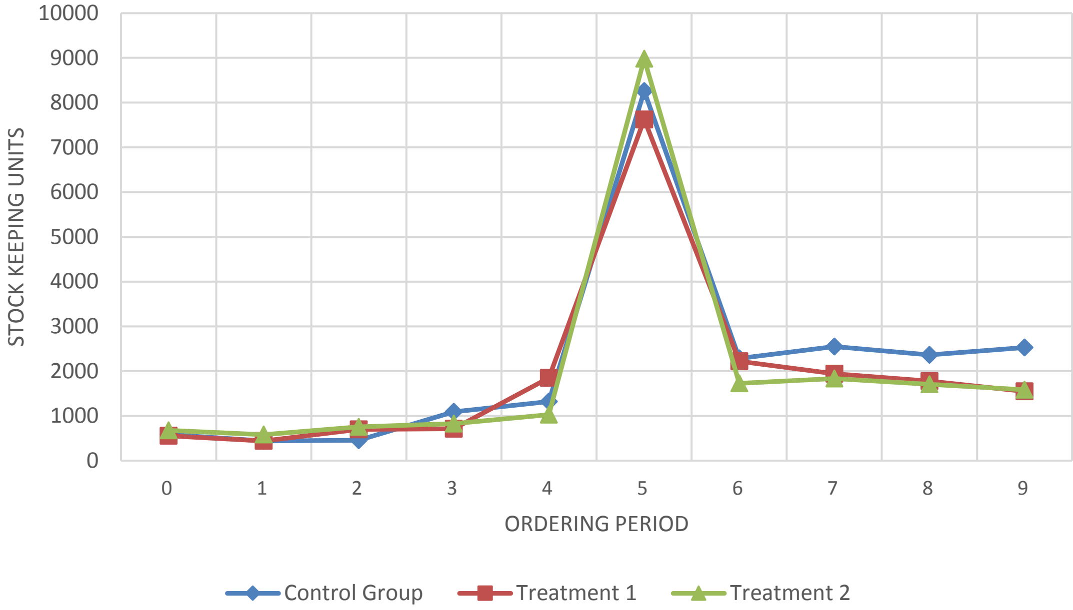


Figure 1 – Average inventory level per period for a transit time of one ordering period

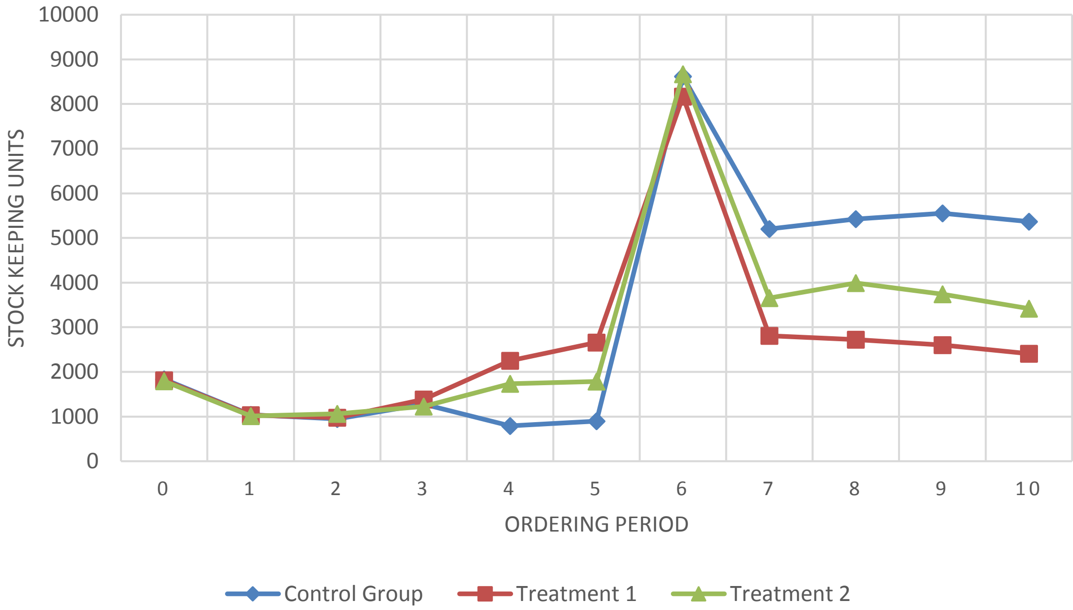
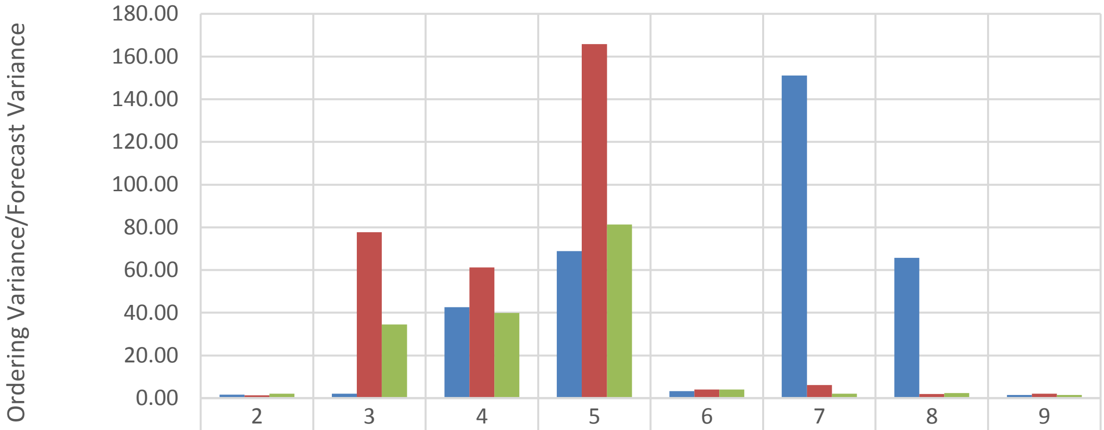


Figure 2 – Average inventory level per period for a transit time of two ordering periods

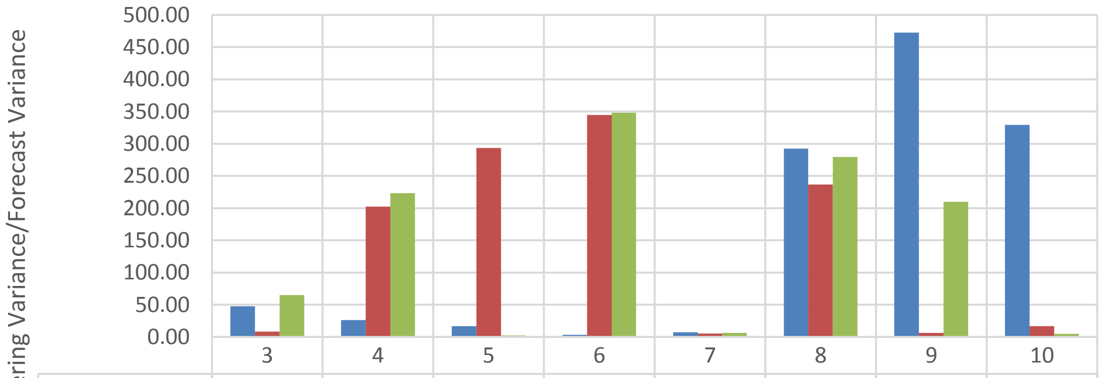
Inspired by Croson & Donohue (2006), we analyzed the ratio between the mean order variance and the mean forecast variance for each ordering period. This was done for all treatment groups and transit times and the results are presented in Figure 3 and 4. We use variance as it captures the volatility in ordering decisions. Our findings are reinforced further by the ratio between the order quantity and the forecasts. We removed the last ordering period from the analysis to avoid end game behavior (Tokar et al., 2011). Figures 3 and 4 highlight higher order variances than the forecast variance for the control group after the promotional period. This backs our previous finding that the control group orders more than what is required after the promotion occurs.

Figure 3 and 4 also show that the subjects in the treatment groups accumulate inventory in the lead up to the promotional period. Figure 1 and 2 which show the inventory level backs this result. This finding is in line with findings of Tokar et al, (2014) who report that the decision makers brace for demand shocks. It is interesting to note that the variance of orders coinciding with the promotional period is low when compared with other ordering periods. This suggests that retail promotions can potentially lead to sporadic ordering decisions before and after a promotion.



	2	3	4	5	6	7	8	9
Control Group	1.68	2.06	42.59	68.80	3.35	151.18	65.76	1.41
Treatment 1	1.31	77.71	61.17	165.82	4.05	6.18	1.94	2.14
Treatment 2	2.04	34.57	39.83	81.34	4.05	2.01	2.35	1.51

Figure 3 – Mean order variance/mean forecast variance for a transit time of one ordering period. The sixth period coincides with the retail promotion.



	3	4	5	6	7	8	9	10
Control Group	47.51	26.05	16.56	3.49	7.28	292.31	472.37	329.16
Treatment 1	8.16	202.22	293.57	344.85	5.37	236.59	6.33	16.69
Treatment 2	65.05	223.38	2.51	347.93	6.05	279.64	209.62	4.75

Figure 4 – Mean order variance/mean forecast variance for a transit time of two ordering periods. The seventh period coincides with the retail promotion.

Conclusion

This research investigates the effect of two levels of retail promotional information on ordering decisions. We also examine the moderating effect from transit times in this context. Using real-world data from an Australian fast-moving consumer goods company, we design and conduct a laboratory experiment using postgraduate students in operations and supply chain management as the subjects. The experiment contains a controlled group and two treatment groups to test the effects from retail promotional information and transit times..

Our findings show that sharing retail promotion information improves ordering decisions. This is despite the subject in the control group receiving forecasts adjusted for promotions despite being blindsided on the reason for the demand spike. Our experiment also finds that awareness of the price discount of a promotion is not as effective as merely being aware of the promotion. Comparing the experimental data between the two tested transit times indicate that the subjects underweight the supply line. This results in exacerbated supply chain costs under longer transit times. Our results also indicate sporadic ordering behavior in the absence of promotional information. This is most pronounced before and after the promotion occurs while ordering for the promotional period shows less volatility. The control group demonstrates the demand chasing heuristic where they accumulate inventory in the aftermath of a retail promotion, possibly bracing for another demand shock.

This paper is one of the first experimental contributions on multi-period ordering decisions. It also gives new insights on the effect of retail promotions on ordering decisions and how information provision may lead to reducing supply chain cost. We encourage future research to explore multi-period ordering decisions further as it lags the experimental work that has been published on single-period ordering decisions. Future works connecting retail promotions and ordering decisions that extend the scope of this study would also advance our understanding of this important topic.

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