Asia Pacific Management Review xxx (xxxx) xxx

HOSTED BY

Contents lists available at ScienceDirect

Asia Pacific Management Review

journal homepage: www.elsevier.com/locate/apmrv

The effect of information on supply chain coordination: A model of value discounting

Manh Ha Lam, Wei-Shiun Chang*

Institute of International Management, National Cheng Kung University, No. 1, DaxueRoad, East District, Tainan City, 701, Taiwan

ARTICLE INFO

Article history:
Received 8 July 2017
Received in revised form
6 May 2019
Accepted 19 June 2019
Available online xxx

Keywords:
Supply chain coordination
Buyback contract
Revenue sharing contract
Loss aversion
Feedback

ABSTRACT

Recent studies have found that decision makers do not perform as expected when they receive much, and frequent, information, that is, retailers order less than the optimal order quantity, assuming rationality, when they get frequent sale feedback. Loss aversion is one of the theories used to explain such behavioral phenomenon. However, the loss aversion model cannot explain why there is a gap between the ordering behaviors in retailing context with buyback and revenue sharing contracts. We propose an alternative model of value discounting to account for such a gap and explain why there is an information effect on the ordering behaviors. We test the theory with an experiment and find that the retailers' behaviors when facing two contracts and two information schemes match with the predictions of value discounting theory.

1. Introduction

Management information systems (MIS), which refers to the systematic use of technology to manage the flow of information, has several applications in retail business. In retail, MIS aggregates and disseminates information of a variety of activities, such as point-of-sale, logistics, inventory control, and internal communication to managers; this allows a business to operate more efficiently. The better use of MIS is built upon the rationality of the mangers to use the information properly. Prior research in finance finds that the professional traders, demonstrating irrationality, perform worse when they get information more frequently (Langer & Weber, 2008). The findings in this line of research call for more research on managers' behaviors—not just those related to MIS—to understand how information would affect managers' decision making. Very few studies have been done on the effect of information on retail business. However, this topic is of importance to academics, as well as those in the private sector, because we do not really know how retail managers process the information they receive from MIS. In this study, we focus on the information regarding the sales in two types of newsvendor retail contracts—buyback and revenue sharing contracts.

Previous theories suggest that buyback and revenue-sharing contracts, along with other contracts, can help in coordinating the channels effectively (Becker-Peth, Katok, & Thonemann, 2013; Cachon, 2003; Cachon & Lariviere, 2005; Zhang, Donohue, & Cui, 2015). Most prior theories assume that the channel members make decisions to maximize their profits. However, recent studies on behavioral aspects in contract setting have started to challenge this assumption. (Bolton & Katok, 2008; Ho, Lim, & Cui, 2010; Katok & Wu, 2009; Loch & Wu, 2008; Su, 2008; Zhang et al., 2015).

Loss aversion, which implies that the decision makers are more sensitive to losses than equivalent gains in wealth, is one of behavioral phenomena found to affect the order quantity in the context of channel coordination (Katok & Wu, 2009). However, the loss aversion model cannot explain why retailers behave differently in two contract mechanisms that are considered to be mathematically equivalent. Katok & Wu attribute the phenomenon to the framing effect, which states retailers might feel differently about the money they pay upfront. This theory could also explain another behavioral phenomenon related to the effect of sales information. Lurie and Swaminathan (2009) find that more frequent updates of feedback information are not necessarily beneficial. The decision makers are found to overweigh information about recent demand realization when ordering. The advent of advanced real-time information systems has made it possible for retailers to obtain

* Corresponding author.
E-mail addresses: halam9019@gmail.com (M.H. Lam), wschang@mail.ncku.edu.tw (W.-S. Chang).

Peer review under responsibility of College of Management, National Cheng Kung University.

https://doi.org/10.1016/j.apmrv.2019.06.003
1029-3132/

instant feedback about losses and gains on each decision they have made. An increase in feedback frequency has been found to be detrimental to managers' decision making in the newsvendor setting. In an investment study, Bellemare, Krause, Kröger, and Zhang (2003) observe the effect of feedback frequency on the amount of myopic loss aversion in investment behavior, and find that more frequent feedback systematically decreases the decision makers' willingness to take risk. These studies suggest that more frequent feedback about the loss and gain may make retailers behave differently.

This behavioral phenomenon is still far from being well understood. We, therefore, propose a discounting model to explain the effect of information feedback based on the widely used loss aversion models in the literature. We designed an ordering experiment that has features of buyback and revenue-sharing contracts.

Because not all retailers are equipped with a similar MIS in the real world, there exists a variation in the frequency at which information is provided to each retailer. This research, therefore, aims to bolster our current understanding about the impacts of feedback frequency, as well as its relationship with loss aversion and value discounting. Our contribution to the previous literature is two-fold. First, we conduct a series of laboratory experiments and validate that human agents' order decisions are subject to loss aversion and framing effect in the context of buyback and revenue sharing contracts. Second, we are the first to relate the effect of feedback information on loss aversion in the newsvendor setting.

2. Theoretical models

2.1. Standard economic predictions of supply chain coordination with contracting mechanisms

Most studies on supply chain contracting focus on the newsvendor setting or the newsvendor problem (Becker-Peth & Thonemann, 2016). The newsvendor problem is a single-period inventory problem, which comprises a supplier who produces seasonal products and a retailer who sells these products in the market. The retailer faces exogenous retail price and stochastic customer demand (Schweitzer & Cachon, 2000). As the production and distribution time is long, the retailer must make order decisions prior to the selling season; this leaves him vulnerable to the risk of inventory shortage if the order falls short of the realized demand and the risk of excess inventory if the realized demand is not as high as the quantity ordered earlier (Elahi, Lamba, & Ramaswamy, 2013).

In the newsvendor problem, the retailer faces an exogenous stochastic demand D during the selling period. $D > 0$ and D has the distribution function $F(x)$, density function $f(x)$, and an exogenous market selling price p. $F(x)$ is differentiable and strictly increasing. $F(0) = 0$. The retailer orders q units from the supplier, whose production cost is c per unit. We depart from Cachon (2003)'s models in assuming that there are no goodwill penalty costs if demand is not satisfied; further, unsold units have no salvage value in our models. These assumptions allow us to examine simpler loss aversion models.

Let $S(q)$ represent the expected sales in the selling season.

$$S(q) = \int_0^q xf(x)dx + q\int_q^\infty f(x)dx = q - \int_0^q F(x)dx$$

In an integrated supply chain, the profit maximizing manufacturer has its own retail channel and acts as a central planner for the supply chain. This centralized control setting provides us with a benchmark solution that maximizes total expected supply chain profit. At the beginning of the selling season, the integrated firm produces q units at a cost of c per unit, and sells these units at a price of p per unit.

The expected profit of the integrated firm is:

$$E(\pi_c) = \int_0^q pxf(x)dx + \int_q^\infty pqf(x)dx - cq$$

The optimal production quantity of a centralized supply chain is q^*, where

$$q^* = F^{-1}\left(\frac{p-c}{p}\right) \quad (1)$$

$\frac{p-c}{p}$ is also known as the channel optimal critical ratio. The retailer ordering this quantity optimizes the system's total profits. Any contract that can give the retailer an incentive to do so is said to coordinate the system.

Cachon (2003) shows that the revenue sharing contract can coordinate the supply chain. Under a revenue sharing contract, the retailer pays w_r per unit ordered at the beginning of the selling season and shares with the manufacturer an additional r per unit sold at the end of the selling season (Cachon & Lariviere, 2005; Katok & Wu, 2009).

Under the revenue sharing contract, the expected profit of the retailer is:

$$E(\pi_r) = \int_0^q (p-r)xf(x)dx + \int_q^\infty (p-r)qf(x)dx \; - w_r q$$

and the optimal order quantity of the profit maximizing retailer is

$$q_r^* = F^{-1}\left(\frac{p-w_r-r}{p-r}\right) \quad (2)$$

Let $\varnothing$ be the retailer's share of the total profit. The revenue sharing contract can coordinate the supply chain if its parameters are set as follows (Cachon, 2003; Cachon & Lariviere, 2005):

$$w_r = \varnothing c, \; r = (1-\varnothing)p. \quad (3)$$

Another contract that can achieve channel coordination is the buyback contract. Under this type of contract, the retailer is charged a wholesale price w_b per unit at the time of placing the orders and receives a buyback price of b per unit for units that are unsold after the selling period.

Under the buyback contract, the expected profit of the retailer is:

$$E(\pi_b) = \int_0^q (px + b(q-x))f(x)dx + \int_q^\infty pqf(x)dx \; - w_b q$$

and the optimal order quantity of the profit maximizing retailer is:

$$q_b^* = F^{-1}\left(\frac{p-w_b}{p-b}\right). \quad (4)$$

The buyback contract coordinates the supply chain if its parameters satisfy:

$$b = (1-\varnothing)p, \; w_b = b + \varnothing c \quad (5)$$

The standard theories suggest that the retailers will order the optimal quantity based on the critical ratios $\frac{p-w_r-r}{p-r}$ and $\frac{p-w_b}{p-b}$ under the buyback contract and revenue sharing contract, respectively. Various combinations of (w_r, r) would lead to the same order quantity if they result in the same $\frac{p-w_r-r}{p-r}$ under revenue sharing contract; similarly, different combinations of (w_b, b) would lead to the same order quantity if they result in the same $\frac{p-w_b}{p-b}$ under buyback contract (Becker-Peth et al., 2013; Becker-Peth & Thonemann, 2016). If a set of (w_r, r) makes $\frac{p-w_r-r}{p-r}$ equal to $\frac{p-w_b}{p-b}$ from a set of (w_b, b), the retailer is expected to order the same quantity from buyback and revenue-sharing contracts.

2.2. Studies on behavioral aspects in supply chain contracting

Recent studies have challenged the assumption that the decision makers in supply chain contracting are rational profit maximizers. In the literature, several behavioral effects that influence the retailer's order decisions have been documented. The "pull-to-center" phenomenon was first found in a supply chain setting by Schweitzer and Cachon (2000). Pull-to-center refers to the fact that relative to the optimal solution, subjects tend to order too many items in low critical ratio scenarios and too few in high critical ratio scenarios (Benzion, Cohen, Peled, & Shavit, 2008). Pull-to-center is also present in the newsvendor problem in several studies (Bostian, Holt, & Smith, 2008; Elahi et al., 2013; Katok & Wu, 2009; Zhao & Zhao, 2016). The anchoring on mean demand, which suggests that the order quantities adjust from the mean demand towards the optimal order over time can explain the pull-to-center bias (Bostian et al., 2008). Another explanation for it is demand chasing. Bolton and Katok (2008) suggested that demand chasing, in which individuals have a tendency to adjust their inventory decisions based on the previous demand, leads to the pull-to-center effect (Bolton & Katok, 2008). Several other studies found similar effects of anchoring on mean and demand chasing in a supply chain contracting setting (Kalkanci, Chen, & Erhun, 2011; Wu & Chen, 2014). Similarly, Ho et al. (2010) incorporate reference-dependent attributes into the standard newsvendor model to explain the pull-to-center effect. They assume that there is different psychological aversion toward leftover cost and stock-out cost, with the psychological costs of the former being greater than those of the latter.

While studies on behavioral newsvendor models primarily focus on the wholesale price contract, a few studies examine other types of contracts. Focusing on the revenue sharing and buyback mechanism, Katok and Wu (2009) conduct a laboratory experiment to study the retailer's order-placing decisions and the supplier's contract parameters-setting behaviors. In their study, any differences from the theoretical predictions are attributed to individual's biases, such as loss aversion and pull-to-center effect (Katok & Wu, 2009). Evidences of loss aversion are also found in other studies. Ho and Zhang (2008) use a laboratory setting to study how the utilization of fixed fee impacts the retailer's orders under quantity discount contracts. They find that two-part tariffs and quantity discount contracts, despite being equivalent, do not perform equally in the laboratory. Loss aversion is considered a plausible driver for the observed phenomenon. Davis (2015) applies different behavior models to explain order decisions of the retailers under supply chain pull contracts and concludes that loss aversion and reference dependence can explain the data well (Davis, 2015). However, loss aversion may not be able to completely explain why retailers behave differently in buyback and revenue sharing contract, as found in Katok and Wu (2009).

Studying inventory ordering decisions, Lurie and Swaminathan (2009) found that providing frequent feedback has negative impact on the supply chain performance; this is because the human decision makers have the tendency to anchor on recent data and are biased by this information. Feedback is also found to be related to the investor's myopic loss aversion in investing, which discourages the investors from taking risks (Bellemare et al., 2003). In this study, we investigate if other factors, besides loss aversion, may play a role in shaping ordering behavior in the buyback and revenue sharing contracts, and how feedback exerts an impact on the retailers' decisions when pull-to-center is eliminated.

2.3. Loss aversion in supply chain coordination with buyback and revenue sharing contracts

We start our analysis of behavioral ordering with a simple loss aversion model. A simple "kinked" piecewise-linear loss-aversion utility function is usually adopted to incorporate loss aversion into the single-period newsvendor model. Without loss of generality, the retailer's initial wealth W_0 is assumed to be 0 at the beginning of the selling season. The following loss-aversion utility function is widely used in the literature

$$\mu(\pi_r) = \begin{cases} W - W_0 \text{ if } W \geq W_0 \\ \lambda(W - W_0) \text{ if } W < W_0 \end{cases},$$

where λ is the retailer's loss aversion coefficient (a value > 1 means that people are more sensitive to losses than gains of the same value) and W is the retailer's final wealth after the selling season.

2.3.1. Revenue sharing contract with loss aversion

Following (Chen, Hao, & Li, 2014; Wang & Webster, 2007, 2009), we formulate loss aversion in revenue sharing contract as follows.

Let k_r be the realized demand at which the retailer breaks even—that is, the retailer makes a loss if the realized demand $D < k_r$—and k_r is a function of the retailer's order and given by

$$k_r = \frac{w_r}{p - r} q.$$

The retailer's expected utility when loss aversion is incorporated is given as:

$$E(\mu(\pi_r)) = \lambda \int_0^{k_r(q)} ((p-r)x - w_r q) f(x) dx + \int_{k_r(q)}^{q} ((p-r)x - w_r q) f(x) dx + \int_q^{\infty} ((p-r)q - w_r q) f(x) dx ,$$

where $\int_0^{k_r(q)} ((p-r)x - w_r q) f(x) dx$ is the retailer's expected loss, and $\int_{k_r(q)}^{q} ((p-r)x - w_r q) f(x) dx + \int_q^{\infty} ((p-r)q - w_r q) f(x) dx$ is the retailer's expected gain.

We can rewrite the above equation as

$$E(\mu(\pi_r)) = E(\pi_r) + (\lambda - 1) \int_0^{k_r(q)} ((p-r)x - w_r q) f(x) dx,$$

where $E(\pi_r)$ is the expected profit of the profit maximizing retailer.

The problem a loss averse retailer now faces is to maximize $E(\mu(\pi_r))$, which contains a loss aversion coefficient. The following two propositions can be obtained from the loss aversion model with revenue sharing contract.

Proposition 1. $E(\mu(\pi_r))$ is concave in q and there is a unique optimal order quantity ($q_r^{\lambda*}$) that maximizes the loss-averse retailer's expected utility and satisfies the F.O.C.:

$$[p - r - w_r - (p - r)\,F(q_r^{\lambda*})] - (\lambda - 1)w_r\,F(k_r(q_r^{\lambda*})) = 0 \tag{6}$$

Proposition 2. A loss-averse retailer will order less than the profit maximizing retailer, that is, $q_r^{\lambda*} < q_r^*$

2.3.2. Buyback contract with loss aversion

Similarly, let k_b be the realized demand at which the retailer breaks even in the market with buyback contract, and k_b is a function of the retailer's order given by

$$k_b(q) = \frac{w_b - b}{p - b} \cdot q$$

The retailer's expected utility when loss aversion is incorporated is given by:

$$E(\mu(\pi_b)) = \lambda \int_0^{k_b(q)} (px + b(q - x) - w_b q) f(x)dx + \int_{k_b(q)}^{q} (px + b(q - x) - w_b q) f(x)dx + \int_q^{\infty} (pq - w_b q) f(x)dx\,,$$

where $\int_0^{k_b(q)} (px + b(q - x) - w_b q) f(x)dx$ is the retailer's expected loss, and $\int_{k_b(q)}^{q} (px + b(q - x) - w_b q) f(x)dx + \int_q^{\infty} (pq - w_b q) f(x)dx$ is the retailer's expected gain.

We can rewrite the equation above as

$$E(\mu(\pi_b)) = E(\pi_b) + (\lambda - 1) \int_0^{k_b(q)} (px + b(q - x) - w_b q) f(x)dx,$$

where $E(\pi_b)$ is the expected profit of the profit maximizing retailer.

The problem that a loss-averse retailer now faces is to maximize $E(\mu(\pi_b))$, which contains a loss aversion coefficient. The following two propositions can be obtained from the loss aversion model with revenue sharing contract.

Proposition 3. $E(\mu(\pi_b))$ is concave in q and there is a unique optimal order quantity ($q_b^{\lambda*}$) that maximizes the loss-averse retailer's expected utility and satisfies the following F.O.C:

$$[p - w_b - (p - b)\,F(q_b^{\lambda*})] - (\lambda - 1)(w_b - b)\,F(k_b(q_b^{\lambda*})) = 0 \tag{7}$$

Proposition 4. A loss-averse retailer will order less than the profit maximizing retailer, that is, $q_b^{\lambda*} < q_b^*$

2.4. A discounting model and the framing effect

Even though (6) and (7) predict no difference between the revenue sharing and buyback contracts, different framings under buyback and revenue sharing contract can lead to a difference in the salience of the psychological losses incurred in these two types of contract. Katok and Wu (2009) argue that in the relatively low demand situation (demand can be as low as 0), the effect of loss aversion on the retailers' order decisions is more severe under the buyback contract than that under the revenue sharing one. In the low demand situation, the retailer is not guaranteed any revenue, so the potential losses caused by paying the upfront wholesale price loom large, whereas the potential gains from a rebate for unsold quantities in the buyback contract and the potential losses from a revenue share in the revenue sharing contract become less salient. The retailer must pay a higher wholesale price under a buyback contract than under a revenue sharing one and, thus, a buyback mechanism induces lower order quantities (Katok & Wu, 2009). The loss aversion model alone cannot explain the findings in Katok and Wu (2009).

In our paper, we develop a discounting model to account for the framing effect found in Katok and Wu (2009). We argue that the reason for a lower order quantity in a buyback contract than that in the revenue sharing contract could be that people discount the money received later on.

We assume that individuals discount the money received at the later period (m_1 at time one) with a discounting factor $\alpha > 0$ for its perceived current value m_0, that is, $m_0 = \frac{1}{1+\alpha} m_1$. Note that we do not treat discounting factor as an interest rate, that is, the real value of money received at time zero is the same as time one; however, individuals feel that the value at time one is discounted to that at time zero.

The retailer's expected utility in a revenue sharing contract when loss aversion and discounting is incorporated can be given by:

$$E(\mu(\pi_r)) = \lambda \int_0^{k_r(q)} \left(\frac{1}{1+\alpha}(p - r)x - w_r q\right) f(x)dx + \int_{k_r(q)}^{q} \left(\frac{1}{1+\alpha}(p - r)x - w_r q\right) f(x)dx + \int_q^{\infty} \left(\frac{1}{1+\alpha}(p - r)q - w_r q\right) f(x)dx$$

Then F.O.C. for the optimal order quantity in a revenue sharing contract with loss aversion and discounted value can be given by

$$F(q_r^{\lambda,\alpha*}) = \frac{p - r - w_r - (\lambda - 1)w_r\,F(k_r(q_r^{\lambda,\alpha*}))}{(p - r)} - \frac{(\lambda - 1)\left(\frac{1}{1+\alpha} - 1\right)[w_r F(k_r(q_r^{\lambda,\alpha*})) + w_r q_r^{\lambda,\alpha*} f(k_r(q_r^{\lambda,\alpha*}))] + \left(\frac{1}{1+\alpha} - 1\right)w_r}{\frac{1}{1+\alpha}(p - r)}. \tag{8}$$

Similarly, the retailer's expected utility in a buyback contract when loss aversion and discounting is incorporated can be given by:

Please cite this article as: Lam, M. H., & Chang, W.-S., The effect of information on supply chain coordination: A model of value discounting, Asia Pacific Management Review, https://doi.org/10.1016/j.apmrv.2019.06.003

$$E(\mu(\pi_b)) = \lambda \int_0^{k_b(q)} \left(\frac{1}{1+\alpha} px + \frac{1}{1+\alpha} b(q-x) - w_b q\right) f(x)dx + \int_{k_b(q)}^{q} \left(\frac{1}{1+\alpha} px + \frac{1}{1+\alpha} b(q-x) - w_b q\right) f(x)dx + \int_q^{\infty} \left(\frac{1}{1+\alpha} pq - w_b q\right) f(x)dx$$

The F.O.C. for optimal order quantity in buyback contract with loss aversion and discounted value can be given by

$$F\left(q_b^{\lambda,\alpha*}\right) = \frac{(\lambda-1)(w_b-b)F\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right)}{(p-b)} - \frac{(\lambda-1)\left(\frac{1}{1+\alpha}-1\right)\left[w_b F\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right) + w_b q_b^{\lambda,\alpha*} f\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right)\right] + \left(\frac{1}{1+\alpha}-1\right) w_b}{\frac{1}{1+\alpha}(p-b)}. \quad (9)$$

Comparing two contracts' order quantities with both loss aversion and discounted value, we obtain the following proposition.

Proposition 5. $q_b^{\lambda,\alpha*} < q_r^{\lambda,\alpha*} < q^*$

Studying the effect of feedbacks on the retailers' order decision, Lurie and Swaminathan (2009) find that more frequent feedbacks lead to a deterioration in profits in the newsvendor context. Bolton and Katok (2008) also observe the negative impact of feedback on decision making. They find that the decision makers tend to anchor on average demand and fail to adjust their orders toward profit-maximizing quantities (Bolton & Katok, 2008). While these studies attribute subjects' lower performance to demand chasing in the newsvendor context, we by applying Proposition 5, conjecture that the absence of feedback (information about gains and losses after each round) reduces the framing effect regarding the retailers' discounting on money received and leads to a higher order quantity.

We attempt to relate the effect of information to the discounting model we propose. It seems reasonable to believe that the framing effect of discounting is salient when retailers receive frequent updates on sale information. If this is true, then we should use a model with loss aversion and discounting to examine the retailer's ordering behavior. In other words, one may observe the retailer orders according to the optimal order quantities based on equation (8) for those in a revenue-sharing contract and on equation (9) for those in a buyback contract.

When retailers do not observe the feedback information, they may be immune to the effect of framing. Therefore, one should use a model with only loss aversion to examine the retailers' ordering behavior. The retailers' ordering is then expected to accord with equation (6) for those in a revenue-sharing contract and with equation (7) for those in a buyback contract. It should be noted that discounting effects persist even when there is no feedback information; however, the effect becomes weaker in the absence of information on gains/losses. Using equations (6) and (7) (in which discounting effect is eliminated) helps to illustrate our proposition better.

One may observe the effect of the availability of information by comparing the optimal order quantities based on equations (6) and (8) for the revenue-sharing contract and equations (7) and (9) for the buyback contract; we obtain the following proposition.

Proposition 6. Order quantities are lower in "with feedback" treatments than in "without feedback" treatments $q_b^{\lambda,\alpha*} < q_b^{\lambda*}$ **and** $q_r^{\lambda,\alpha} < q_r^{\lambda*}$

3. Newsvendor experiments

3.1. Experimental design

To test the discounting theory, we have a 2×2 between-subject design with contract (buyback/revenue-sharing) and feedback (with/without) features to detect the framing effect and information effect. In "with feedback" treatments, subjects are given feedback on gains/losses after each round. In "without feedback" treatments, however, participants can view their accumulated earnings only after they complete the experiment. Our experiment contains 50 periods with 50 parameter sets that yield the same optimal ordering quantities for all treatments. Table 1 shows the setup for the parameters. Detailed contract parameters are presented in the Appendices.

We recruited 94 subjects from a public research university (we will be happy to reveal the identity of the university once our study is accepted) and the experiment yielded 4,700 decisions for our analysis. The experiment was programmed in z-Tree (Fischbacher, 2007).

Subjects were assigned the role of a retailer and asked to choose the order quantities for a hypothetical product in 55 rounds (50 official rounds; there were 5 trial rounds to familiarize participants with the procedure of the experiment). After the instructions were read out, subjects were required to answer six questions designed to test their understanding of the tasks. Subjects were not allowed to communicate with each other during the experiment. To incentivize the subjects, the experimenter offered cash payments based on the total profits obtained in the 50 official rounds. The average earnings of each subject were around 300 denominated in local currency (equivalent to 2.2 times of minimum wage) in an approximately 1.5-h experiment.

4. Results

The average orders placed by subjects during the rounds are shown in Fig. 1. The graph shows that in most periods, subjects ordered, on average, lower than 50 units. We also observe the differences in order quantities between treatments, specifically between buyback and revenue-sharing contracts, and between the "with feedback" and "without feedback" treatments.

In the analysis, we examine three behavioral effects. First, we test whether subjects demonstrate loss aversion in their ordering decisions when facing the newsvendor problem. Second, we test if there is a framing effect wherein subjects perceive different losses when facing two forms of mathematically equivalent wholesale contracts. Third, we test if the availability of transaction information also affects subjects' ordering quantity.

In the behavioral model assuming loss aversion, the order

Table 1
Summary of treatment parameters.

	Treatments 1 & 2	Treatments 3 & 4
	Buyback Contract	Revenue-sharing Contract
Demand	D ~ U (0,100)	
Supplier's Production Cost, c	c = 500	
Selling Price, p	p = 1000	
Share Rate, $\varnothing$	from 0.02 to 1 with a step of 0.02	
Transfer	50 values of b and $b = (1-\varnothing)p$	50 values of r and $r = (1-\varnothing)p$
Wholesale Price	50 values of w_b and $w_b = b + \varnothing c$	50 values of w_r and $w_r = \varnothing c$
Optimal Quantity	$\mathbf{q_b^*} = 50$	$\mathbf{q_r^*} = 50$

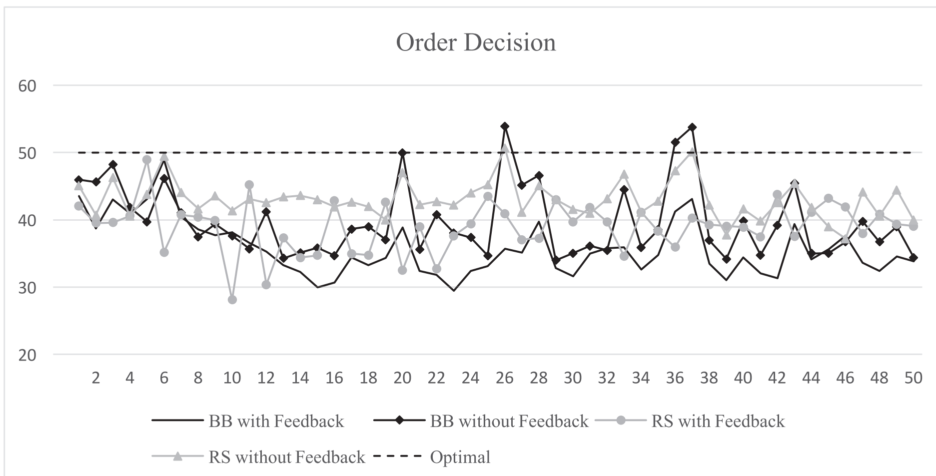

Fig. 1. Orders placed by subjects during the various rounds.

Table 2
Order quantity by treatments.

		Information		$H_0: q^*_w = q^*_{w/o}$
		With Feedback	Without Feedback	z-value
Buyback	Order Quantity	35.76(15.28)[35]***	39.76 (19.10)[40]***	−5.20 ***
	# of Subj/Obs	17/850	21/950	
Revenue- Sharing	Order Quantity	38.92(13.69)[40]***	43.04 (19.01)[41.5]***	−5.88***
	# of Subj/Obs	26/1300	30/1500	
	z-value	−5.75***	−3.72***	

Note: Standard deviations are reported in parentheses and median orders in square brackets. Significance levels: $p < 0.05$ (*); $p < 0.01$ (**); $p < 0.005$ (***).

quantity is expected to fall below the optimal quantity of 50 units in our parameter setting. We performed a Wilcoxon signed-rank test for all the four treatments and the results are reported in the cells of the order quantity in Table 2. The test results show that subjects ordered significantly less than 50 in all the treatments ($p < 0.005$). The observed under-ordering is consistent with loss aversion. To verify the framing effects, we performed a Mann-Whitney *U* test for a two-sample comparison between the two contracts (see last row in Table 2) and between information manipulations (see last column in Table 2). If the order decisions are indeed subject to value discounting, we would observe a larger order quantity in the revenue sharing contract than the buyback contract. Statistical testing shows that subjects in both the “with feedback” and “without feedback” groups order significantly more under the revenue sharing contract than under the buyback contract ($p < 0.005$). Further, we find that there is an effect of feedback on order quantity under both the buyback and revenue sharing contracts. Order quantities are significantly smaller when feedback is provided than when it is not, for both revenue sharing and buyback contracts ($p < 0.005$).

Previous studies found that the decision makers adjust their decisions according to contract parameters (Becker-Peth et al., 2013; Becker-Peth & Thonemann, 2016), recent demand realization, and anchor on previous decision (Wu & Chen, 2014). We, therefore, take these effects into consideration, run multiple random-effect regression models on order quantity, and report the results in Table 3.

To compare the revenue sharing and buyback contracts, we fit the following model for each feedback condition separately:

$$q_{i,t} = \gamma_0 + \gamma_{q-1} \cdot q_{i,t-1} + \gamma_{d-1}\left(d_{t-1} - q_{i,t-1}\right) + \gamma_R R + \eta_i + \varepsilon_{i,t}. \quad (11)$$

To compare different feedback conditions, we fit the following model for each contract type separately

Please cite this article as: Lam, M. H., & Chang, W.-S., The effect of information on supply chain coordination: A model of value discounting, Asia Pacific Management Review, https://doi.org/10.1016/j.apmrv.2019.06.003

Table 3
GLS regression on order quantity.

	Comparison between contracts, with feedback	Comparison between contracts, without feedback	Comparison between feedback conditions, Buyback Contract	Comparison between feedback conditions, Revenue Sharing Contract
	(1)	(2)	(3)	(4)
R	**2.294** (***)	**2.636** (***)		
F			**2.620** (***)	**3.397** (***)
$q_{i,t-1}$	0.311 (***)	0.2 (***)	0.332 (***)	0.175 (***)
$d_{t-1} - q_{i,t-1}$	0.0017	−0.024	−0.016	−0.001
C			0.010 (***)	−0.001
Constant	24.446 (***)	31.827 (***)	18.820 (***)	32.312
	0	0	0	0
	12.280	16.925	14.297	15.190
Observation	2107	2499	1862	2744

Column 1 and Column 2 use the model in equation (11) for "with feedback" and "without feedback," respectively. Column 3 and Column 4 use the model in equation (12) for buyback contract and revenue sharing contract, respectively.
$p < 0.10$ (*), $p < 0.05$ (**), $p < 0.005$ (***).

$$q_{i,t} = \gamma_0 + \gamma_c C + \gamma_{q-1} q_{i,t-1} + \gamma_{d-1} \left(d_{t-1} - q_{i,t-1}\right) + \gamma_F F + \eta_i + \varepsilon_{i,t}. \quad (12)$$

In these models, the dependent variable $q_{i,t}$ is the subject i's order quantity in period t. The variable $q_{i,t-1}$ is subject i's order quantity in period t - 1. The variable $d_{t-1} - q_{i,t-1}$ reflects the difference between the demand that subject i observed in period t-1 and his or her order in that period; the variable C is the contract parameter (b in buyback contract and r in revenue sharing contract); and η_i and $\varepsilon_{i,t}$ are the two error components in the models.

Dummy variable R is equal to 1 if revenue-sharing contract (0 otherwise). Dummy variable F is equal to 1 if feedback is not provided (0 otherwise). The variable R and F are the focus of the analysis.

Because the effect of value discounting is less salient in the revenue sharing contract, our prediction is that R coefficients should be significantly positive in column 1 and 2. From Table 3, we do observe that the coefficients on R in both column 1 and 2 are significantly positive ($p < 0.005$). We also posit that the discounting effect would become salient when subjects are provided with feedback of gains and losses in each round; this should translate into significantly positive coefficients on F in column 3 and 4. Again, looking at Table 3, we find results that are consistent with our prediction. Further, from regression models, we observe that subjects adjusted their orders based on the decision taken in the previous round ($p < 0.005$ in all 4 columns). While subjects adjusted their orders based on the value of b in buyback contracts ($p < 0.005$), we do not find any significant effect of the value of r on subjects' orders in revenue sharing contracts. In no model do we observe the effect of recent demand information on subjects' orders.

5. Conclusions

In this paper, we study how the retailers behave in a market having two types of contracts—revenue sharing and buyback. Our focus is on the impact of information (feedback arising from the transaction) on the ordering quantities. While new information technology presents opportunities for decision makers to respond to varying conditions and make instant changes, we found that retailers' biased behaviors mean that frequent feedback is not necessarily beneficial to the whole supply chain. More specifically, retailers order less than the optimal ordering quantities in a market with more frequent feedback. Further, the downward deviation is more salient in a market with a buyback contract than in one with a revenue sharing contract. We offer an alternate explanation to Lurie and Swaminathan (2009)'s observation of the harmful effect of feedback in the newsvendor setting. We believe the lower order quantities, a deviation from the rational order quantities, are because of the fact that retailers discount the money they would receive in the future. We analyze the ordering decisions with an analytical model involving loss aversion and discounted value; further, we conduct a series of experiments to validate the widely claimed loss aversion effect in a newsvendor setting.

We find that retailers order less in both contracts, and a lower quantity in the buyback contract than that in the revenue sharing contract. The loss aversion model can explain why retailers order less than the rational optimal order quantities; however, it cannot explain why there is a gap between two contracts that are supposed to yield the same order for loss-averse retailers. Inspired by the outcome in Katok & Wu (2009), we show that the framing effect of the money that the retailers receive upfront, between two contracts, could lead to such results. With another set of treatments—with feedback—we demonstrate that providing information on gains/losses after each round makes the perception of gains and losses more salient in the context of supply chain coordination; thus, subjects who are provided with feedback after each round could feel that the money they have paid upfront becomes salient (too costly). In other words, they discount the money they receive later on. The findings of this research are also consistent with those in Langer and Weber (2008) and Bellemare et al. (2003), who find that providing investors with more frequent feedback made them more reluctant to take risks; thus, investors receiving the most frequent feedback delivered the lowest performance.

There are certainly some interesting directions on this topic. First of all, the effect of discounting on different contracts is still yet well understood. One may study the complex contracts such as hybrid of the buyback and revenue sharing contracts, or other quantity discount contract. Second, further research on the effect of loss aversion and feedback on decision making in these contexts is worth of studying because of its broad applications. Such knowledge would lend valuable insights into how supply chain efficiency can be improved. Since it is detrimental to the efficiency of the supply chain, understanding what may mitigate the negative effect of feedback on the retailer's ordering is of great importance to practitioners. Finally, one could examine the learning effect on the effect of feedback as we do not know yet whether the framing effect and discounting effect is persistent or not.

Acknowledgments

This work is supported by grant MOST 104-2410-H-006-001-

MY2 from the Ministry of Science and Technology, Taiwan.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apmrv.2019.06.003.

References

Becker-Peth, M., Katok, E., & Thonemann, U. W. (2013). Designing buyback contracts for irrational but predictable newsvendors. *Management Science, 59*(8), 1800–1816.

Becker-Peth, M., & Thonemann, U. W. (2016). Reference points in revenue sharing contracts—how to design optimal supply chain contracts. *European Journal of Operational Research, 249*(3), 1033–1049.

Bellemare, C., Krause, M., Kröger, S., & Zhang, C. (2003). *Myopic loss aversion, information dissemination, and the equity premium puzzle* (Working paper).

Benzion, U., Cohen, Y., Peled, R., & Shavit, T. (2008). Decision-making and the newsvendor problem: An experimental study. *Journal of the Operational Research Society, 59*(9), 1281–1287.

Bolton, G. E., & Katok, E. (2008). Learning by doing in the newsvendor problem: A laboratory investigation of the role of experience and feedback. *Manufacturing & Service Operations Management, 10*(3), 519–538.

Bostian, A. A., Holt, C. A., & Smith, A. M. (2008). Newsvendor "pull-to-center" effect: Adaptive learning in a laboratory experiment. *Manufacturing & Service Operations Management, 10*(4), 590–608.

Cachon, G. P. (2003). Supply chain coordination with contracts. *Handbooks in Operations Research and Management Science, 11*, 227-339.

Cachon, G. P., & Lariviere, M. A. (2005). Supply chain coordination with revenue-sharing contracts: Strengths and limitations. *Management Science, 51*(1), 30–44.

Chen, X., Hao, G., & Li, L. (2014). Channel coordination with a loss-averse retailer and option contracts. *International Journal of Production Economics, 150*(0), 52–57.

Davis, A. M. (2015). An experimental investigation of pull contracts in supply chains. *Production and Operations Management, 24*(2), 325–340.

Elahi, E., Lamba, N., & Ramaswamy, C. (2013). How can we improve the performance of supply chain contracts? An experimental study. *International Journal of Production Economics, 142*(1), 146–157.

Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics, 10*(2), 171–178.

Ho, T.-H., Lim, N., & Cui, T. H. (2010). Reference dependence in multilocation newsvendor models: A structural analysis. *Management Science, 56*(11), 1891–1910.

Ho, T.-H., & Zhang, J. (2008). Designing pricing contracts for boundedly rational customers: Does the framing of the fixed fee matter? *Management Science, 54*(4), 686–700.

Kalkanci, B., Chen, K.-Y., & Erhun, F. (2011). Contract complexity and performance under asymmetric demand information: An experimental evaluation. *Management Science, 57*(4), 689–704.

Katok, E., & Wu, D. Y. (2009). Contracting in supply chains: A laboratory investigation. *Management Science, 55*(12), 1953–1968.

Langer, T., & Weber, M. (2008). Does commitment or feedback influence myopic loss aversion? An experimental analysis. *Journal of Economic Behavior & Organization, 67*(3), 810–819.

Loch, C. H., & Wu, Y. (2008). Social preferences and supply chain performance: An experimental study. *Management Science, 54*(11), 1835–1849.

Lurie, N. H., & Swaminathan, J. M. (2009). Is timely information always better? The effect of feedback frequency on decision making. *Organizational Behavior and Human Decision Processes, 108*(2), 315–329.

Schweitzer, M. E., & Cachon, G. P. (2000). Decision bias in the newsvendor problem with a known demand distribution: Experimental evidence. *Management Science, 46*(3), 404–420.

Su, X. (2008). Bounded rationality in newsvendor models. *Manufacturing & Service Operations Management, 10*(4), 566–589.

Wang, C. X., & Webster, S. (2007). Channel coordination for a supply chain with a risk-neutral manufacturer and a loss-averse retailer. *Decision Sciences, 38*(3), 361–389.

Wang, C. X., & Webster, S. (2009). The loss-averse newsvendor problem. *Omega, 37*(1), 93–105.

Wu, D. Y., & Chen, K. Y. (2014). Supply chain contract design: Impact of bounded rationality and individual heterogeneity. *Production and Operations Management, 23*(2), 253–268.

Zhang, Y., Donohue, K., & Cui, T. H. (2015). Contract preferences and performance for the loss-averse supplier: Buyback vs. Revenue sharing. *Management Science, 62*(6), 1734–1754.

Zhao, Y., & Zhao, X. (2016). How a competing environment influences newsvendor ordering decisions. *International Journal of Production Research, 54*(1), 204–214.

Please cite this article as: Lam, M. H., & Chang, W.-S., The effect of information on supply chain coordination: A model of value discounting, Asia Pacific Management Review, https://doi.org/10.1016/j.apmrv.2019.06.003

APPENDICES

A. Proofs of Propositions

Proof of Proposition 1

To show the expected utility function is concave, we show its second derivative is negative, then the F.O.C. is shown as,

$$\frac{dE(\mu(\pi_r))}{dq} = (p-r)\int_q^{\infty} f(x)dx) - w_r + (\lambda-1)(-w_r)\int_0^{k_r(q)} f(x)dx)$$

$$= (p - r)(1 - F(q)) - w_r + (\lambda-1)(-w_r)F(k_r(q))$$

$$= [p - r - w_r - (p-r)F(q)] - (\lambda-1)w_r F(k_r(q))$$

We further attain the second partial derivative as,

$$\frac{d^2E(\mu(\pi_r))}{dq^2} = -(p\text{-}r)f(q) - (\lambda-1)(w_r)\frac{dF(k_r(q))}{d(k_r(q))}\frac{d(k_r(q))}{d(q)} = -(p\text{-}r)f(q) - \frac{(w_r)^2(\lambda-1)}{p-r} f(k_r(q))$$

$$= -\left[(p-r)f(q) + \frac{(w_r)^2(\lambda-1)}{p-r} f(k_r(q))\right]$$

Since $p > r$ and $\lambda > 1$, the second partial derivative is always negative. ■

From above, the loss-averse retailer's expected utility is concave in q and to find the optimal order quantity we let $\frac{dE(\mu(\pi_r))}{dq} = 0$, then we attain an optimal order quantity $(q_r^{\lambda*})$ that satisfies:

$$[p - r - w_r - (p-r)F(q_r^{\lambda*})] - (\lambda-1)w_r F(k_r(q_r^{\lambda*})) = 0$$

Proof of Proposition 2

To compare the optimal order quantity under the standard rational model and the loss aversion model, we compare two equations from their F.O.C. of respective objective functions. We first rewrite the equation that satisfies the F.O.C. of the objective function with loss aversion as

$$\Rightarrow \quad F(q_r^{\lambda*}) = \frac{p-r-w_r}{p-r} - \frac{(\lambda-1)w_r F(k_r(q_r^{\lambda*}))}{p-r}$$

Since $\frac{p-r-w_r}{p-r} = F(q_r^*)$

⇨ $F(q_r^{\lambda *}) = F(q_r^*) - \frac{(\lambda-1)w_r F(k_r(q_r^{\lambda *}))}{p-r}$

Because $\frac{(\lambda-1)w_r F(k_r(q_r^{\lambda *}))}{p-r} > 0$

⇨ $F(q_r^{\lambda *}) < F(q_r^*)$

⇨ $q_r^{\lambda *} < q_r^*$ ■

Proof of Proposition 3

Similar to the proof of Proposition 1, we find second partial derivative is always negative.

First, the first derivative is

$$\frac{dE(\mu(\pi_b))}{dq} = p\int_q^{\infty} f(x)dx + b\int_0^q f(x)dx - w_b + (\lambda-1)(b-w_b)\int_0^{k_b(q)} f(x)dx)$$

$$= p(1-F(q)) + b\,F(q) - w_b + (\lambda-1)(b-w_b)F(k_b(q))$$

$$= p - w_b - (p-b)F(q) - (\lambda-1)(w_b-b)F(k_b(q))$$

Then, the second derivative of expected utility function is

$$\frac{d^2E(\mu(\pi_r))}{dq^2} = -(p-b)f(q) - (\lambda-1)(w_b-b)\frac{dF(k_b(q))}{d(k_b(q))}\frac{d(k_b(q))}{d(q)}$$

$$= -(p-b)f(q) - \frac{(w_b-b)^2(\lambda-1)}{p-b} f(k_b(q))$$

$$= -\left[(p-b)f(q) + \frac{(w_b-b)^2(\lambda-1)}{p-b} f(k_b(q))\right]$$

Because $p > w_b > b$ and $\lambda > 1$, the second partial derivative above is strictly negative. ■

From above, the loss-averse retailer's expected utility is concave in q and let $\frac{dE(\mu(\pi_{rb}))}{dq}$ = 0, we get the optimal order quantity $(q_b^{\lambda *})$ that satisfies:

$$p - w_b - (p-b)F(q_b^{\lambda *}) - (\lambda - 1)(w_b - b)F(k_b(q_b^{\lambda *})) = 0$$

<u>The Proof of Proposition 4</u>

Similar to the proof of proposition 3, we rewrite the equation that satisfies the F.O.C of objective function on the argument q as

$$\Rightarrow \quad F(q_b^{\lambda *}) = \frac{p-w_b}{p-b} - \frac{(\lambda-1)(w_b-b)F(k_b(q_b^{\lambda}))}{p-b}$$

$$\text{Since } \frac{p-w_b}{p-b} = F(q_b^{*})$$

$$\Rightarrow \quad F(q_b^{*}) - \frac{(\lambda-1)(w_b-b)F(k_b(q_b^{\lambda *}))}{p-b}$$

Because $\frac{(\lambda-1)(w_b-b)F(k_b(q_b^{\lambda *}))}{p-b} > 0$

$$\Rightarrow \quad F(q_b^{\lambda *}) < F(q_b^{*})$$

$$\Rightarrow \quad q_b^{\lambda *} < q_b^{*}$$

■

<u>The Proof of Proposition 5</u>

The F.O.C for the model with loss aversion and value discounting to attain the optimal quantity in revenue sharing contract is

$$\frac{1}{1+\alpha}\left[p - r - w_r - (p-r)\,F(q_r^{\lambda,\alpha})\right] - \frac{1}{1+\alpha}(\lambda - 1)w_r\,F\left(k_r\left(q_r^{\lambda,\alpha}\right)\right) + (\lambda - 1)\left(\frac{1}{1+\alpha} - 1\right)\left[w_r F\left(k_r\left(q_r^{\lambda,\alpha}\right)\right) + w_r q_r^{\lambda,\alpha} f\left(k_r\left(q_r^{\lambda,\alpha}\right)\right)\right] + \left(\frac{1}{1+\alpha} - 1\right)w_r = 0$$

We rewrite this as

$$F\left(q_r^{\lambda,\alpha *}\right) = \frac{p - r - w_r - (\lambda-1)w_r\,F\left(k_r\left(q_r^{\lambda,\alpha *}\right)\right)}{(p-r)} - \frac{(\lambda-1)\left(\frac{1}{1+\alpha}-1\right)\left[w_r F\left(k_r\left(q_r^{\lambda,\alpha *}\right)\right) + w_r q_r^{\lambda,\alpha *} f\left(k_r\left(q_r^{\lambda,\alpha *}\right)\right)\right] + \left(\frac{1}{1+\alpha}-1\right)w_r}{\frac{1}{1+\alpha}(p-r)} \quad (1)$$

Similarly, from the F.O.C for the model with loss aversion and value discounting to attain the optimal order quantity of buyback is

$$\frac{1}{1+\alpha}\left[p - w_b - (p-b)\,F(q_b^{\lambda})\right] - \frac{1}{1+\alpha}(\lambda-1)(w_b-b)F\left(k_b\left(q_b^{\lambda}\right)\right) + (\lambda - 1)\left(\frac{1}{1+\alpha}-1\right)[w_bF\left(k_b\left(q_b^{\lambda,\alpha}\right)\right) + w_bq_b^{\lambda,\alpha}f\left(k_b\left(q_b^{\lambda,\alpha}\right)\right)] + \left(\frac{1}{1+\alpha}-1\right)w_b = 0$$

We rewrite above equation as

$$F\left(q_b^{\lambda,\alpha*}\right) = \frac{(\lambda-1)(w_b-b)F\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right)}{(p-b)} - \frac{(\lambda-1)\left(\frac{1}{1+\alpha}-1\right)[w_bF\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right)+w_bq_b^{\lambda,\alpha*}f\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right)]+\left(\frac{1}{1+\alpha}-1\right)w_b}{\frac{1}{1+\alpha}(p-b)} \quad (2)$$

We know that b=r and w_b=$w_r + r$

We can rewrite equation (1) as

$$F(q_r^{\lambda,\alpha*})=\frac{\frac{1}{1+\alpha}(p-r)-w_r+(\lambda-1)[(\frac{1}{1+\alpha}-1)w_rq_r^{\lambda,\alpha*}f\left(k_r(q_r^{\lambda,\alpha*})\right)-w_rF\left(k_r(q_r^{\lambda,\alpha*})\right)]}{\frac{1}{1+\alpha}(p-r)} \quad (3)$$

and rewrite equation (2) as

$$F(q_b^{\lambda,\alpha*}) = \frac{\frac{1}{1+\alpha}p-w_b+(\lambda-1)[(\frac{1}{1+\alpha}-1)w_bq_b^{\lambda,\alpha*}f\left(k_b(q_b^{\lambda,\alpha*})\right)+(\frac{1}{1+\alpha}b-w_b)F\left(k_b(q_b^{\lambda,\alpha*})\right)]}{\frac{1}{1+\alpha}(p-r)} \quad (4)$$

Using equation (4)-(3), we attain

$$F\left(q_b^{\lambda,\alpha*}\right) - F\left(q_r^{\lambda,\alpha*}\right)$$

$$= \frac{\frac{1}{1+\alpha}r + w_r - w_b + (\lambda-1)[(\frac{1}{1+\alpha}-1)(w_bq_b^{\lambda,\alpha*}f\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right) - w_rq_r^{\lambda,\alpha}f\left(k_r\left(q_r^{\lambda,\alpha*}\right)\right)] + (\lambda-1)[(\frac{1}{1+\alpha}b + w_r)F\left(k_r(q_r^{\lambda,\alpha*})\right) - w_bF\left(k_b(q_b^{\lambda,\alpha*})\right)]}{\frac{1}{1+\alpha}(p-r)}$$

Using proof by contradiction, let $q_b^{\lambda,\alpha*}= q_r^{\lambda,\alpha*}$, then we see the value in the right hand side of the equation above is negative, while it is 0 in the left hand side, contradicted. Let $q_b^{\lambda,\alpha*} > q_r^{\lambda,\alpha*}$, the value in the left hand side is positive, while the value in the right hand side is negative, Contradicted. ■

Proof of Proposition 6:

To show $\mathbf{q_b^{\lambda,\alpha}} < \mathbf{q_b^{\lambda}}$, we compare the first derivative of objective function from two models—with loss aversion and with loss aversion and value discounting. We compute the difference between $F\left(q_b^{\lambda,\alpha*}\right)$ and $F(q_b^{\lambda*})$ from above propositions and we have

$$F\left(q_b^{\lambda,\alpha*}\right) - F\left(q_b^{\lambda*}\right)$$

$$= \frac{\frac{1}{1+\alpha}p - w_b + (\lambda - 1)[(\frac{1}{1+\alpha} - 1)w_b q_b^{\lambda,\alpha*} f\left(k_b(q_b^{\lambda,\alpha*})\right) + (\frac{1}{1+\alpha}b - w_b)F\left(k_b(q_b^{\lambda,\alpha*})\right)]}{\frac{1}{1+\alpha}(p-b)}$$

$$- \frac{p - w_b - (\lambda - 1)(w_b - b)F(k_b(q_b^{\lambda*}))}{p-b}$$

We can rewrite above equation as

$$F\left(q_b^{\lambda,\alpha*}\right) - F\left(q_b^{\lambda*}\right)$$

$$= \frac{(\frac{1}{1+\alpha} - 1)w_b + (\lambda - 1)(\frac{1}{1+\alpha} - 1)w_b q_b^{\lambda,\alpha*} f\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right) + (\lambda - 1)\frac{1}{1+\alpha}(w_b - b)\left(F\left(k_b(q_b^{\lambda*})\right) - F\left(k_b\left(q_b^{\lambda,\alpha*}\right)\right)\right) - (\lambda - 1)\frac{\alpha}{1+\alpha} w_b F\left(k_b(q_b^{\lambda*})\right)}{\frac{1}{1+\alpha}(p-b)}$$

Using proof by contradiction, let $q_b^{\lambda*} = q_b^{\lambda,\alpha*} \geq 0$. Then left hand side of the equation is 0 and right hand side is negative, which contradicts the assumption. Also let $0 \leq q_b^{\lambda*} < q_b^{\lambda,\alpha*}$. The left hand side is positive and right hand side is negative. ■

Similarly, we compute the difference between $F\left(q_r^{\lambda,\alpha*}\right)$ and $F(q_r^{\lambda*})$ to prove $q_r^{\lambda,\alpha*} < q_r^{\lambda*}$, then we attain

$$F\left(q_r^{\lambda,\alpha*}\right) - F\left(q_r^{\lambda*}\right) = \frac{\frac{1}{1+\alpha}(p - r) - w_r + (\lambda - 1)[(\frac{1}{1+\alpha} - 1)w_r q_r^{\lambda,\alpha*} f\left(k_r(q_r^{\lambda,\alpha*})\right) - w_r F\left(k_r(q_r^{\lambda,\alpha*})\right)]}{\frac{1}{1+\alpha}(p-r)} -$$

$$\frac{p - r - w_r - (\lambda - 1)w_r F(k_r(q_r^{\lambda*}))}{p-r}$$

We can rewrite the above equation as

$$F\left(q_r^{\lambda,\alpha*}\right) - F\left(q_r^{\lambda*}\right) =$$

$$\frac{(\frac{1}{1+\alpha} - 1)w_r + (\lambda - 1)(\frac{1}{1+\alpha} - 1)w_r q_r^{\lambda,\alpha*} f\left(k_r\left(q_r^{\lambda,\alpha*}\right)\right)}{\frac{1}{1+\alpha}(p-r)}$$

$$+ \frac{(\lambda - 1)\frac{1}{1+\alpha} w_r \left[F\left(k_r\left(q_r^{\lambda*}\right)\right) - F\left(k_r\left(q_r^{\lambda,\alpha*}\right)\right)\right] - (\frac{\alpha}{1+\alpha})[\ (\lambda - 1) w_r\, F\left(k_r\left(q_r^{\lambda,\alpha*}\right)\right)]}{\frac{1}{1+\alpha}(p-r)}$$

Using proof by contradiction, let $q_r^{\lambda,\alpha*} = q_r^{\lambda*}$. The left hand side of the equation is 0 and the right hand side of the equation is negative, this contradicts our assumption. Let $q_r^{\lambda,\alpha*} > q_r^{\lambda*}$, then the left hand side of the equation is positive and the right hand side of equation is negative, this contradicts our assumption. ■

B. Parameter setting and rational order predictions

Round	Revenue shared	Buyback contract		Revenue sharing contract		Demand	Optimal orders
	∅	b	w_b	r	w_r		$q_r^* = q_b^*$
1	0.3	700	850	700	150	22	50
2	0.4	600	800	600	200	56	50
3	0.16	840	920	840	80	44	50
4	0.22	780	890	780	110	20	50
5	0.74	260	630	260	370	30	50
6	0.06	940	970	940	30	5	50
7	0.48	520	760	520	240	8	50
8	0.88	120	560	120	440	44	50
9	0.6	400	700	400	300	44	50
10	0.28	720	860	720	140	13	50
11	0.92	80	540	80	460	14	50
12	0.26	740	870	740	130	47	50
13	0.76	240	620	240	380	33	50
14	0.54	460	730	460	270	51	50
15	0.42	580	790	580	210	43	50
16	0.98	20	510	20	490	33	50
17	0.38	620	810	620	190	75	50
18	0.32	680	840	680	160	92	50
19	0.9	100	550	100	450	18	50
20	0.1	900	950	900	50	19	50

21	0.86	140	570	140	430	51	50
22	0.24	760	880	760	120	93	50
23	0.46	540	770	540	230	94	50
24	0.36	640	820	640	180	79	50
25	0.56	440	720	440	280	53	50
26	0.02	980	990	980	10	41	50
27	0.2	800	900	800	100	25	50
28	0.14	860	930	860	70	44	50
29	0.84	160	580	160	420	58	50
30	0.52	480	740	480	260	81	50
31	0.62	380	690	380	310	44	50
32	0.8	200	600	200	400	18	50
33	0.18	820	910	820	90	77	50
34	0.72	280	640	280	360	15	50
35	0.44	560	780	560	220	37	50
36	0.08	920	960	920	40	88	50
37	0.04	960	980	960	20	35	50
38	0.7	300	650	300	350	93	50
39	0.94	60	530	60	470	23	50
40	0.5	500	750	500	250	92	50
41	0.96	40	520	40	480	33	50
42	1	0	500	0	500	72	50
43	0.12	880	940	880	60	41	50
44	0.64	360	680	360	320	34	50
45	0.68	320	660	320	340	47	50
46	0.78	220	610	220	390	13	50
47	0.34	660	830	660	170	63	50
48	0.66	340	670	340	330	68	50
49	0.58	420	710	420	290	83	50
50	0.82	180	590	180	410	64	50

Note that $q_r^* = F^{-1}(\frac{p-w_r-r}{p-r}) = q_b^* = F^{-1}\left(\frac{p-w_b}{p-b}\right)$

C. Experimental instruction in English (The instruction handed to subjects is in local language)

Treatment 1: Buyback contract with feedback (Treatment 2 does not have the feedback of the profits in each period)

In today's study, you will participate in a game where you will earn money based on your own decisions. The experiment will take 1.5 hours approximately. If you follow the instructions carefully and make good decisions, you could earn a considerable amount of money. The unit of currency for this session is called an ECU (Experimental Currency Unit). The payment you receive at the end of the session is based on the converted accumulated profits you make, added to your participation fee of 50 NTD.

Your task

In this game, you will play the role of Retailer's purchasing manager who decides the order quantities in multiple weeks (rounds). The supplier is automated. The Retailer buys product A from the Supplier and sells product A to the customer at 1000 ECU per unit. In each week, product A are ordered before you find out the actual customer demand.

Your task is to determine how many product A to order for each week (rounds). Your order always has to be an integer from 1 to 100. The number of units you order is called Q.

Customer Demand

The customer demand per week, which we will call D, is randomly drawn from 1 to 100, that means any demand between 1 to 100 is equally likely (i.e. there is a 1/100 chance that additional demand will be any one of the integers from 1 to 100). The demand drawn for any one week is independent of the demand for the earlier weeks.

How you will be paid

In the experiment, you will make order decision in 55 weeks. The first 5 weeks are warm-up weeks, during which you can practice and get familiar with the transactions. Your total earnings from the experiment will equal the summation of the endowment of 10000 ECU given to you before the game starts and the accumulated profit you earn from the next 50 weeks times a conversion rate of: 1300 ECU = 1 NTD. You will receive cash in NTD at the end of the session.

For example, if your accumulated profit is 300000 ECU, you will receive: (10000 ECU + 300000 ECU)*1/1300 = 238.5 NTD

Important note: Please make careful decisions to avoid going bankrupt (the summation of the endowment of 10000 ECU and your total accumulated profit becomes ≤ 0 ECU)

Buyback Contract Game

Contract terms

At the beginning of each week, you order from the supplier and pay a wholesale price of X ECU for each unit you order. During the week, demand occurs and you sell each unit for 1000 ECU per unit. At the end of the week, if there are unsold units, the supplier will buy back those unsold units at a buyback price of Y ECU per unit.

X and Y will vary over weeks (rounds)

Calculating Your Profit

For example:

Selling price	1000 ECU/unit
Wholesale price	X=700 ECU/unit

Buyback price Y=400 ECU/unit

Your profit is calculated based on the number of units you order and sell.

When your order Q turns out to be the same or lower than the additional customer demand D, your total profit for the week is:

Your Profit = 1000× Q – 700 × Q

For example, if you order 40 units, the realized demand is 60 units:

Units sold: 40 units

Units unsold: 0 units

Profit = 1000×40 -700×40 ECU = 12000 ECU

Note that when the number of product A ordered is less than demand, you lose opportunities for sales.

When your order Q turns out to be higher than the additional customer demand D, your total profit for the week is:

Your Profit =1000 × D + 400× (Q-D) - 700× Q

For example, if you order 60 units and the realized demand is 40 units

Units sold: 40 units

Units unsold: 20 units

Profit = 1000×40 + 400 × (60 - 40) – 700 × 60 = 6000 ECU

Note that when the number of product A ordered exceeds demand, you must dispose of the unsold units (since extra product A go stale after a week, and cannot be carried as inventory into future weeks)

Exercise questions

Before you start ordering, we will provide you with 6 questions to test your understandings of the game. Please enter your answer for each question. If you have at least one incorrect answer, you will be asked to answer again. You will be provided with the correct answers for those questions afterwards.

Ordering decisions making

On the decision making screen, you will be reminded of the market and contract information. On the upper right column, you can also view your order history. Before making your order decision, you can try placing different order quantities and see the expected profits for those different order quantities. Expected profit is calculated as each potential profit, weighted by the probability of it happening. To make your order decision, you need to input your order quantity in the box and press "OK".

You will go through 5 trial periods first. After 5 trial periods, you will start playing the official rounds (50 rounds).

Treatment 3: Revenue Sharing contract with feedback (Treatment 4 does not have the feedback of the profits in each period)

In today's study, you will participate in a game where you will earn money based on your own decisions. The experiment will take 1.5 hours approximately. If you follow the instructions carefully and make good decisions, you could earn a considerable amount of money. The unit of currency for this session is called an ECU (Experimental Currency Unit). The payment you receive at the end of the session is based on the converted accumulated profits you make, added to your participation fee of 50 NTD.

Your task

In this game, you will play the role of Retailer's purchasing manager who decides the order quantities in multiple weeks (rounds). The supplier is automated. The Retailer buys product A from the Supplier and sells product A to the customer at 1000 ECU per unit. In each week, product A are ordered before you find out the actual customer demand.

Your task is to determine how many product A to order for each week (rounds). Your order always has to be an integer from 1 to 100. The number of units you order is called Q.

Customer Demand

The customer demand per week, which we will call D, is randomly drawn from 1 to 100, that means any demand between 1 to 100 is equally likely (i.e.: there is a 1/100 chance that additional demand will be any one of the integers from 1 to 100). The demand drawn for any one week is independent of the demand for the earlier weeks.

How you will be paid

In the experiment, you will make order decision in 55 weeks. The first 5 weeks are warm-up weeks, during which you can practice and get familiar with the transactions. Your total earnings from the experiment will equal the summation of the endowment of 10000 ECU given to you before the game starts and the accumulated profit you earn from the next 50 weeks times a conversion rate of: 1300 ECU = 1 NTD. You will receive cash in NTD at the end of the session.

For example, if your accumulated profit is 300000 ECU, you will receive: (10000 ECU + 300000 ECU)*1/1300 = 238.5 NTD

Important note: Please make careful decisions to avoid going bankrupt (the summation of the endowment of 10000 ECU and your total accumulated profit becomes ≤ 0 ECU)

Revenue-Sharing Contract Game

Contract terms

At the beginning of each week, you order from the supplier and pay a wholesale price of X ECU for each unit you order. During the week, demand occurs and you sell each unit for 1000 ECU per unit. At the end of the week, you will share the revenue you generate with the supplier. The supplier will receive Y ECU for each unit you sell.

X and Y will vary over weeks (rounds)

Calculating Your Profit

For example:

Selling price	1000 ECU/unit
Wholesale price	X = 300 ECU/unit

Revenue share Y = 400 ECU/Unit

When your order Q turns out to be the same or lower than the additional customer demand D, your total profit for the week is:

Your Profit = 1000 × Q – 400 × Q – 300 × Q

For example, if you order 40 units and the realized demand is 60 units

Units sold: 40 units

Units unsold: 0 units

Profit = 1000×40 - 400×40 - 300×40 = 12000 ECU

Note that when the number of product A ordered is less than demand, you lose opportunities for sales.

When your order Q turns out to be higher than the additional customer demand D, your total profit for the week is:

Your Profit = 1000 × D – 400 × D – 300 × Q

For example, if you order 60 units and the realized demand is 40 units

Units sold: 40 units

Units unsold: 20 units

Profit = 1000×40 – 400×40 – 300 × 60 = 6000 ECU

Note that when the number of product A ordered exceeds demand, you must dispose of the unsold units (since extra product A go stale after a week, and cannot be carried as inventory into future weeks)

Exercise questions

Before you start ordering, we will provide you with 6 questions to test your understandings of the game. Please enter your answer for each question. If you have at least one incorrect answer, you will be asked to answer again. You will be provided with the correct answers for those questions afterwards.

Ordering decisions making

On the decision making screen, you will be reminded of the market and contract information. On the upper right column, you can also view your order history. Before making your order decision, you can try placing different order quantities and see the expected profits for those different order quantities. Expected profit is calculated as each potential profit, weighted by the probability of it happening. To make your order decision, you need to input your order quantity in the box and press “OK”.

You will go through 5 trial periods first. After 5 trial periods, you will start playing the official rounds (50 rounds).