Buyback versus Revenue Sharing Contracts: The Supplier’s Perspective

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Adviser: Dr. Karen Donohue

July, 2013

Acknowledgements

I would like to express my deepest gratitude to my adviser, Dr. Karen Donohue, for her mentoring, guidance, and support throughout my doctoral studies. Without her tireless feedback and encouragement, this dissertation would not have been possible. I am very grateful to Dr. Tony Haitao Cui for his advice and guidance in my research. I would also like to thank the rest of my committee members, Dr. Enno Siemsen and Dr. Saif Benjaafar for helpful suggestions and comments over these years.

Many thanks to my colleagues in the Carlson School of Management, in particular David Zepeda, Brent Moritz, Hung-Chung Su, and Yi-Su Chen, for many useful discussions and debates on a variety of research topics and for sharing our experience in graduate school. I also thank my friends in Minnesota, in particular Rowan Wang, Yibin Chen, Zhe Hou, and Qian Wang for the great times we had together, which I thoroughly enjoyed.

Special thanks to my parents, Chuanchen Zhang and Shuzhen Teng, for their continuous caring for me. All the support they have provided me over the years was the greatest gift anyone has ever given me.

Dedication

To my supporting parents, Chuanchen Zhang and Shuzhen Teng.

Abstract

Prior theory claims that buyback and revenue sharing contracts achieve equivalent channel-coordinating solutions when applied in a single supplier-buyer setting. This suggests that a supplier should be indifferent in choosing which contract to offer. However, the sequence and magnitude of costs and revenues (i.e., losses and gains) vary significantly between the two contracts, suggesting the supplier's preference of contract type, and associated contract parameter values, will vary with her level of loss aversion. We study this phenomenon from the supplier's perspective in three stages.

First, we investigate whether human suppliers are indeed indifferent between these two equivalent contracts. Using a controlled laboratory experiment, with human subjects taking on the role of supplier having to choose between the two contracts, we find that contract preferences change with the ratio of overage and underage costs for the channel (i.e., the newsvendor critical ratio). In particular, a buyback contract is preferred for products with low critical ratio while revenue sharing is preferred for products with high critical ratio. We show that these results are consistent with the behavioral tendency of loss aversion and are more significant for subjects that exhibit higher loss aversion tendencies in an out of context task.

Second, we examine differences in the performance of buyback and revenue sharing contracts when suppliers have the authority to set contract parameters. We find that the contract frame influences the way parameters are set and the critical ratio again plays an important role. More specifically, we find that in a high critical ratio environment revenue sharing contracts are more profitable for the supplier than buyback contracts while there is little difference in performance between the two contracts in a low critical ratio environment. We also find that adding prospective accounting tendencies into the behavioral model provides a stronger predictor of behavior in this setting than loss aversion alone.

Finally, we discuss how a retailer's behavioral tendencies may influence the supplier's contract decisions and contract performance. We find that the existence of bounded rationality and rejection risk at the retailer level can significantly reduce the supplier's expected profit but do not influence the relative performance of buyback versus revenue sharing. However, judgment biases (due to loss aversion and prospective accounting) may increase the supplier's expected profit in some situations and the supplier is more profitable under buyback contracts. This research can help inform supply managers on what types of contracts should be used in different critical ratio environments.

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Chapter 1:

Introduction

Supplier-based companies frequently need to make decisions on which types of contracts they should use with downstream business customers. Many considerations factor into these decisions, including the contract's financial return, ease of implementation, and fit with norms for the industry or type of business customer. In recent years, more companies have advocated the use of flexible supply contracts, such as buyback and revenue sharing arrangements, as a tool to share risks among business partners. These flexible contracts often lead to higher profit for the supply company and their buyers. As the number of companies adapting flexible contracts continues to grow (Doshi 2010), it is important to understand the relative performance of these contracts in order to decide which type of contract a supply company should offer to their buyers.

Prior theory claims that buyback and revenue sharing, two of the most commonly used flexible contracts (Cachon 2003), achieve equivalent channel-coordinating solutions when applied in a single supplier-buyer setting (Cachon and Lariviere 2005). This suggests that a supplier in this setting should be indifferent in choosing between these two contracts. However, this result assumes that the decision of which contract to adopt, and how the associated contract parameters should be set, is made by a supplier who is focused only on maximizing their final expected profit. We know from prior research in behavioral economics that this assumption may not hold, especially when final profit is determined by a sequence of financial transactions (Thaler 1999).

The sequence of financial transactions implied by the two contracts is surprisingly different, even though the final profit achieved may be the same. Revenue sharing has most notably been adopted within the video-rental industry where the lower initial investment required by a buyer (in this case, a video retailer) allows this level of the supply chain to manage its cash flow in an effective manner. Under a revenue sharing contract, the buyer initially pays the supplier a small unit wholesale price for each item acquired and later pays the supplier a fraction of the revenue earned for each item sold to the final customer. From the supplier's point of view, the initial wholesale price may not cover her manufacturing cost and so she maintains a negative cash flow until the buyer sells a sufficient number of items to the final customer. Normative theory suggests that the supplier will maximize her expected profit by setting the initial wholesale price to zero and the revenue sharing parameter to 100% (implying that she captures the full revenue margin for all items sold). In practice, video suppliers usually require some initial investment by video retailers and do not command the full margin on items sold.

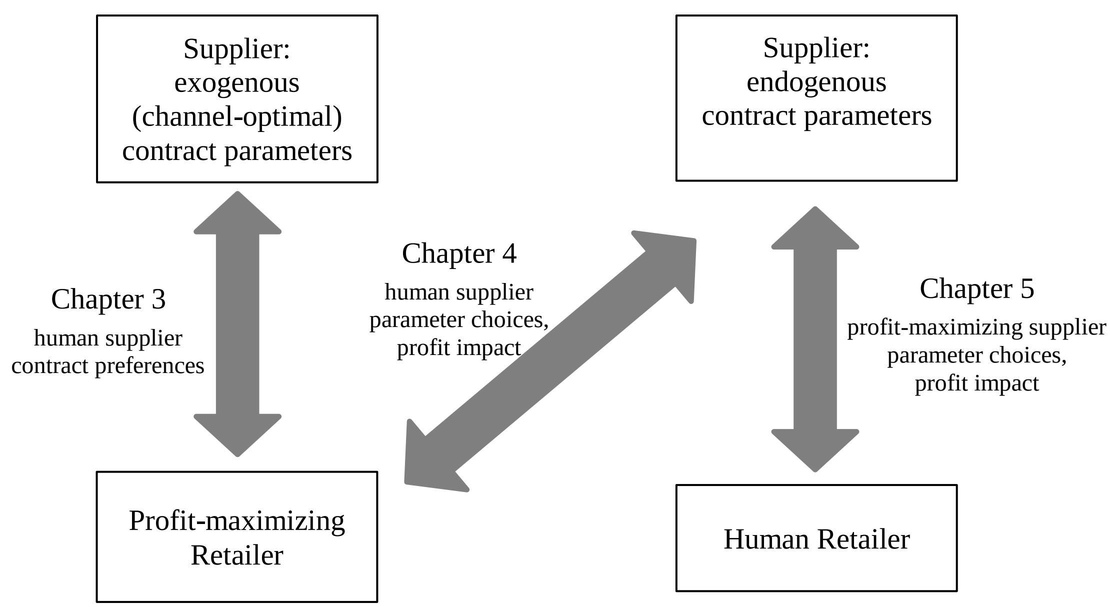
Buyback contracts have been adopted by a wider range of industries, including publishing, high-tech, and fashion apparel. Under a buyback contract the buyer also initially pays the supplier a wholesale price for each item acquired. However, rather than providing the supplier with a second payment stream, the buyer now receives a payment from the supplier for items remaining at the end of the season. This payment takes the form of a unit buyback price for each unsold item. Normative theory suggests that the supplier will set the initial wholesale price nearly equal to the buyer's retail price, with the buyback price set slightly lower. Compared with the revenue sharing contract, the buyback contract offers the supplier an initial flush of cash – but this flush is short lived. The supplier must be ready to give some money back to buyer at the end of the season. In practice, wholesale prices are usually set less aggressively than theory suggests.

At a conceptual level, the two contracts are equivalent in terms of their resulting profit realizations, yet the framing of the financial transactions are quite different. They differ in the relative magnitude of the expected loss and gain (even though the sum of the loss and gain is equivalent) and the sequence of the potential loss (before or after demand is realized). Research in both behavioral economics and psychology has found that human preferences of financial transactions are sensitive to the payment framing (Tversky and Kahneman 1981). One behavioral regularity that commonly emerges is that people appear to exhibit *loss aversion*; that is, they weigh the unit cost of a perceived loss more heavily than the benefit of a unit gain. The behavioral economics literature also suggests that when facing intertemporal choices (decisions involving trade-offs among costs and benefits occurring at different times) people tend to weight transactions differently across time. In some contexts, discounting future time periods is common

(Pannell and Schilizzi 2006), while discounting current time periods is common in others (Chen et al. 2012). It is unclear whether these behavioral regularities exist in a supply chain setting.

The goal of this dissertation is to provide insight into how these unique framing differences may influence a supplier's decision of which contract to adopt, how contract parameters for each contract are set, and ultimately whether final expected profit actually differs between the contracts once these behavioral factors are incorporated. We examine these issues in a series of three main studies. In the first two studies (Chapter 3 and 4), we focus on the supplier's contract decisions while controlling for the retailer's behavioral tendencies (i.e., assume a rational retailer who maximizes his expected profit). In Chapter 5, we investigate how adding the retailer's behavioral tendencies will change the supplier's contract decisions and resulting performance. The relationship between these three main chapters is illustrated in Figure 1.1.

Figure 1.1: Dissertation Structure



In Chapter 3, we investigate the supplier's preference between buyback and revenue sharing contracts, controlling for possible profit differences. In other words, we examine whether the supplier prefers one type of contract over the other, even if their achieved profit is identical under the two contracts. Using analytical models that incorporate loss aversion, we find that the supplier's preference over the two equivalent contracts varies with the critical ratio defined by the underlying channel-level newsvendor problem. More specifically, there exists a critical ratio threshold where the supplier's preferences switch, with the supplier preferring a buyback contract when the critical ratio is below this threshold but preferring a revenue sharing contract otherwise. We then test these theoretical predications using controlled laboratory experiments and find they are supported.

Chapter 4 investigates how suppliers set the contract parameters and the resulting profit for the two contracts. We first characterize the supplier's optimal contract parameters by incorporating loss aversion into the supplier's objective function. The analytical results suggest that the framing differences also influence the way the contract parameters are set, ultimately changing the contracts' associated profit levels. More specifically, we find that revenue sharing outperforms buyback in high critical ratio environments, while neither contract dominates in low critical ratio environments. We again test these predictions in a laboratory setting where the subjects now set contract parameter values for either revenue sharing or buyback contracts. The experimental results are again consistent with our theoretical predictions. While we control for timing effects in our experiments by having the sequence of payments take place without inserted delays, we do find some evidence of an interesting sequencing effect referred to as prospective accounting. We develop a behavioral model that incorporates both loss aversion and prospective accounting effects. This combined model provides a stronger fit to the experimental data than loss aversion alone.

Chapters 3 and 4 assume the retailer to be perfectly rational and profit maximizing. In Chapter 5, we relax this assumption and examine how the retailer's cognitive biases may further influence the supplier's contract decisions and resulting performance. We investigate three behavioral tendencies from the retailer's point of view: bounded rationality, rejection risk, and judgment biases (i.e., loss aversion and prospective accounting). We find that when a retailer makes random errors in setting order quantities or in evaluating whether to reject a contract offer, the supplier's expected profit reduces by the same amount under both contracts (i.e., neither contract dominates). However, the buyback contract is more profitable to the supplier than revenue sharing when accounting for the retailer's judgment biases. More interestingly, the retailer's judgment biases due to loss aversion and prospective accounting may increase the supplier's expected profit in some situations.

The dissertation continues in Chapter 2 with a literature review. This is followed by the three main studies described above, contained in Chapters 3, 4 and 5. In Chapter 6 we summarize the main findings, and discuss limitations and ideas for future research.

Chapter 2:

Literature Review

2.1 Introduction

Buyback and revenue sharing contracts allow supply chain members to share the risks and costs associated with mismatches between supply and demand. These contracts have been studied extensively in the context of newsvendor-type settings, where the selling season is short compared with the acquisition lead-time and demand uncertainty is high at the time that order quantity decisions must be made (see Cachon (2003) for an extensive review). The contracts are "channel-coordinating" in the sense that the contract parameters can be set to align the buyer's incentives to match that of a centrally coordinated channel and thus allow a first-best solution. The contracts have also been shown to be equivalent; that is, for any coordinating revenue sharing contract, there exists a unique buyback contract that generates the same distribution of profit between the two supply chain parties for any given realization of demand (Cachon and Lariviere 2005).

Most of the research on supply chain contracts has been normative in nature, providing guidance on the form of optimal decisions under the assumption of expected profit maximization. However, this research stream provides little evidence on how human decision makers actually make contract decisions (e.g., setting contract parameters, choosing order quantities). In recent years, a new research domain of "Behavioral Operations Management" has emerged to investigate how human behavioral tendencies, such as aversion to risks/loss, fairness concerns, or bounded rationality, impact operations decisions and outcomes. In a review article, Bendoly et al. (2006) classified behavioral operations management research into three categories based upon the nature of the behavioral assumptions for human decision makers' intention, action, and reaction. Our research studies assumptions regarding the intentions of a supplier in a supply chain contracting context. In other words, we investigate what behavioral tendencies may influence a supplier's intentions when setting the contract parameters for coordinating contracts.

Recently there has been a growing interest in understanding how supply chain contracts perform when subjected to human decision making errors and biases. These studies have examined human behavior from three perspectives: buyer's ordering decisions, supplier's contract decisions, and supplier-buyer interactions. The next three subsections examine each of the perspectives in turn. Our research is also related to the literature on loss aversion, which is discussed in a final subsection.

2.2 Behavioral Research from Buyer's Perspective

A large body of research within the inventory management literature examines decision biases that arise in setting an order quantity in response to different contract structures. Much of this research focuses on the buyer's behavior when faced with a wholesale price contract under a single decision period involving stochastic demand and fixed overage and underage costs (i.e., newsvendor problem). Schweitzer and Cachon (2000) is the first paper to uncover persistent decision biases in the order quantity decision under a newsvendor framework using laboratory experiments. They find that, at an aggregate level, buyers place orders for quantities between the theoretically optimal solution and the mean demand, a phenomenon referred as the "pull-to-center" effect. They propose several alternative theories in an attempt to explain this phenomenon and find that the pull-to-center effect can be explained by a preference to reduce *ex post* inventory error, along with a heuristic of anchoring on mean demand and insufficiently adjusting towards the optimal order quantity.

Building on Schweitzer and Cachon (2000), a number of papers investigate the robustness of the pull-to-center effect and different theories for why it exists. Some of these papers focus on learning aspects in repeated newsvendor decisions. For example, Bostian et al. (2008) replicate the newsvendor experiment and examine whether and how decision makers improve their decisions over time. They find that an adaptive learning model explains individual decisions better than the heuristics proposed by Schweitzer and Cachon (2000). In other words, decision biases can be improved with learning over time. Bolton and Katok (2008) find that providing feedback information to the subjects and limiting the timing of decision adjustments can significantly improve their order decision and expected profit. In a recent paper, Bolton et al. (2012) compare the order decisions made by experienced procurement managers versus students and find that managers exhibits the same pull-to-center bias as the students. They also find that classroom experience and on-the-spot training improves the performance of managers and students alike.

Several papers examine decision errors and cognitive reflection on newsvendor performance. Su (2008) examines the quantal choice model as a representation of bounded rationality and applies this model to the newsvendor decision. He finds that when decision makers make random errors, the order quantity exhibits the pull-to-center effect. Kremer et al. (2010) test the descriptive validity of the random error framework by Su (2008). In their experiment, one group of subjects faces a standard newsvendor problem and a second group faces a lottery choice experiment that offers identical profit distribution with no (newsvendor) context information. They find significant difference in behavior between the two groups. This result is inconsistent with the random error model and therefore provides empirically support for the decision heuristics proposed by Schweitzer and Cachon (2000). Moritz et al. (2012) investigate whether newsvendor performance is related to decision makers' level of cognitive reflection and find that individuals with higher level of cognitive reflection achieve better performance, particular in high critical ratio environment.

In addition to this rich body of behavioral research focused on the newsvendor problem under a wholesale price contract, there are several papers investigating buyer's behavior under other types of contracts. For example, Su (2008) also applies the quantal choice model to a series of classic inventory problems (in addition to the newsvendor problem), including the buyer's choice of order quantity under buyback and revenue sharing contracts. His research finds that bounded rationality causes the buyer to make decisions that are not first-best, even when the ratio of overage and underage costs between the buyer and centralized systems are perfectly aligned. Becker-Peth et al. (2013) examine the retailer's order behavior under a buyback contract through a series of lab experiments and compare the results against a wholesale contract. Their experiments show that individual factors, such as anchoring effect, loss aversion, and revenue evaluation, can be used to estimate how the retailer's order quantity decision changes with contract parameters. They also show how the supplier can use knowledge of these individual factors when setting her contract parameters to move the retailer's order quantity more in line with the channel optimal solution. Chen et al. (2012) also investigate the impact of payment timing and the framing of loss and gains on order quantity decisions. They consider three different frames that vary by who (the supplier, retailer, or customer) covers the initial inventory investment. They find that the retailers' average order quantity varies across the frames and the direction of the difference is consistent with principles of mental accounting. By assuming different psychological costs of leftovers and stockouts, Ho et al. (2010) incorporate reference dependence into the newsvendor framework to help explain the "pull-to-center" bias.

Our research differs from this stream in its point of view and focus. We examine contract behavior from the supplier's perceptive and focus not only on how contract parameters are set but also on which contract they prefer. Like Becker-Peth et al. (2013), we also find evidence that loss aversion contributes to decision making behavior, although our definition of loss aversion differs somewhat from theirs.

2.3 Behavioral Research from Supplier's Perspective

Compared with prior research on retailer behavior, studies of supplier behavior are somewhat limited. Katok and Wu (2009) are the first to examine how suppliers set contact parameters in a flexible contract setting where the buyer faces uncertain demand (in addition to examining the problem from the retailer's point of view). Their investigation, like ours, focuses on buyback and revenue sharing contracts. They conduct a series of controlled laboratory experiments where participants take on the role of either a buyer or supplier interacting with an automated partner. This allows them to control for the effect of interpersonal interactions (such as fairness concerns), which is not the focus of their study. Their results show that the two contracts do not fully coordinate the supply chain. They also allude that differences in the resulting order quantity outcomes across the two contracts appear consistent with loss aversion, although they do not present a formal model to prove this.

Niederhoff and Kouvelis (2013) examine supplier behavior under a revenue sharing contract and compare this with behavior under a non-coordinating wholesale price contract. Their study of revenue sharing contracts differs from Katok and Wu (2009) in that they focus on how individual factors, such as risk preference, altruism, and rejection risk considerations, influences contract efficiency and profit allocation. This is accomplished by testing for these factors outside the context of the contract task and then comparing the contract performance between clusters of individuals with similar factor levels. Our experiment also consists of an out-of-context test. In our case, we test the relative loss aversion levels of individuals.

Kalkanci et al. (2011) study quantity flexibility contracts in a newsvendor setting. In their experiment, subjects, taking the role of the supplier, interact with a computerized retailer and set contract price and quantity blocks. The results reveal that when demand information is asymmetric, quantity flexibility contracts do not increase the supplier's profit, contrary to the standard theoretical prediction. They suggest that as the contract complexity (number of price blocks) increases, human subjects tend to rely on simple heuristics when making decisions.

Our work contributes to this body of literature by providing a theoretical grounding for how the presence of loss aversion influences the supplier's contract preference and the choice of contract parameters. Studying contract preference (as we do in Chapter 3) provides a direct test of whether loss aversion actually exists within the supplier's decision context since the choice task is much simpler than the computational task of simultaneously setting two parameters for a given contract, as in Katok and Wu (2009) and Niederhoff and Kouvelis (2013). We also study the more complicating task of setting parameters from two stages: an intermediate stage where only the wholesale price is set and a final stage where both parameters are set (Chapter 4).

2.4 Behavioral Research on Supplier-Buyer Interaction

A number of papers consider the perceptive of both the buyer and supplier and how they interact under different contract structures. Most of this research focuses on social preferences, such as fairness and reputation. For example, Keser and Paleologo (2004) examine decision making in a simple supplier-retailer wholesale price contract. They observe that both the wholesale price and the order quantity are below the standard game-theoretical predictions. The supply chain's efficiency, however, is as predicted but profits are more equitably allocated. They find preliminary evidence that fairness might be a factor that drives the results, but they do not provide a formal model to prove this. Katok and Pavlov (2013) identify three causes of channel inefficiency: fairness concerns, bounded rationality, and incomplete information. They investigate the influence of these three factors on human behavior under a minimum-order-quantity (MOQ) contract and find that all three factors affect human behavior. Specifically, fairness concerns have the largest effect on retailer's behavior while the supplier's behavior is largely driven by incomplete information about the retailer's preferences for fairness. Decision errors have a larger impact on retailer's behavior versus supplier's behavior. Wu (2013) investigates the interactive behavior that develops over a long-term contractual relationship. She reports on an experiment where subjects are matched with a fixed partner and the two partners interact with each other over a long period of time (100 periods). Three types of contracts are studied: wholesale price contracts, buyback contracts and revenue sharing contracts. She finds that players exhibit stronger social preferences for fairness and reciprocity as time increases, which leads to an enhanced performance of the overall supply chain. Kalkanci et al. (2013) extend their first study (Kalkanci et al. 2011, which is discussed in section 2.2) by allowing a human supplier to interact with a human retailer. They find that, compared with the results in Kalkanci et al. (2011), although the supplier's fairness concerns are stronger, random decision errors (i.e., bounded rationality) are still the primary factor that influences supplier's contract decisions.

Our research in Chapter 5 contributes to this literature in two ways. First, we focus on investigating how retailer's judgment biases (different utility functions) and decision errors (bounded rationality) will influence a supplier's contract decisions and performance, while controlling for the effects of social preference. Secondly, we propose a general approach for modeling retailer's rejection risks, which captures the causes of rejection identified by prior literature (e.g., Katok and Pavlov 2013).

Several papers in the marketing literature study contract behavior in a companion setting to the newsvendor environment, where the retailer faces a deterministic demand and decides the retail price. For example, Cui et al. (2007) model a distribution channel where the retailer is concerned with distributive fairness. They find that the supplier can simply offer a wholesale price contract to coordinate the channel and equitably distribute the channel profit, if the retailer is sufficiently inequity averse. Katok et al. (2012) extend this research by assuming the retailer's fairness concern is private information. They show analytically that the wholesale price contract may be rejected by the retailer with some probability. This result is further confirmed by a series of laboratory experiments. Loch and Wu (2008) examine how social preferences affect supply chain performance under a wholesale price contract. They find that supply chain efficiency increases when players care about their relationship and decreases when players care about status. Ho and Zhang (2008) compare three channel contracts: wholesale price, two-part tariff, and quantity discount. They find that, for those contract offers accepted by the retailer, two-part tariff and quantity discount increase the efficiency of the channel in terms of channel profit compared with a wholesale price contract, but fail to coordinate the channel as theory predicts. Also, framing the fixed fee as a two-part tariff verses a quantity discount leads to different pricing decisions, consistent with a loss aversion preference. Lim and Ho (2007) study the impact of the number of tariff blocks on the pricing decision. Their experimental results reveal that a three price block contract yields higher profit for the supplier than a two price block contract. This contradicts normative theory, which suggests a two block contract is optimal. Our research is similar to this stream in that we also develop behavioral theory to explain how a behavioral regularity, in our case loss aversion, might influence contract preference and then test the behavioral theory in a laboratory setting.

2.5 Relevant Loss Aversion Literature

Economic analyses of decision under risk commonly assume that people maximize expected utility. However, much empirical evidence suggests that people systematically violate expected utility theory (Camerer 1995). One important reason why people deviate from expected utility is loss aversion. That is, people interpret outcomes as gains and losses relative to a reference point and are more sensitive to losses than to equal sized gains.

This concept lies at the heart of Prospect Theory (Kahneman and Tversky 1979) and has been shown to exist in many decision contexts. Its effects are well studied in behavioral economics and other business fields such as finance and marketing (Camerer 2000). Loss aversion can explain many phenomena including the endowment effect (Kahneman et al. 1990), downward-sloping labor supply (Camerer et al. 1997), the disposition effect (Shefrin and Statman 1985, Weber and Camerer 1998, Genesove and Meyer 2001), the equity premium puzzle (Mehra and Prescott 1985, Benartzi and Thaler 1995), asymmetric price elasticities (Putler 1992, Hardie et al. 1993), and insensitivity to bad income news (Shea 1995, Bowman et al. 1999).

In this dissertation we study two payment structures, where the sequence and magnitude of losses and gains differ, while their sum is equivalent. This combination of framing differences has not been studied previously in the loss aversion literature, and so our results contribute to this literature by showing that loss aversion is also influential in this unique context that arises from a classic operations management problem.

Recently, there have been a few studies attempting to model loss aversion in the newsvendor-based context from the buyer’s perspective. These studies are somewhat inconsistent in the definition of the reference point. In some models, reference point is defined by the wealth level. For example, Schweitzer and Cachon (2000) is the first paper to model loss aversion under the newsvendor problem. They define break-even sales as the reference point, and any profit below this reference point is coded as loss. Although their definition is somewhat unconventional, it provides an interesting angle to model loss aversion in this context. Later, Ho and Zhang (2008) modify Schweitzer and Cachon (2000)'s approach by defining a more conventional reference point, current (status quo) wealth level. Using this definition, they examine two equivalent contracts – two-part tariff and quantity discount, and find that the two contracts do not yield the same results because decision makers tend to be more loss averse under two-part tariff than quantity discount.

There are also some studies that use specific contractual or environmental parameters as the reference point. Although this is not the most common definition in behavioral economics, it does provide some interesting insights in explaining phenomena in the newsvendor context. For example, Ho et al. (2010) study loss aversion in the standard newsvendor problem and define the realized demand as the reference point. Under this definition, any incurred costs due to leftovers (order quantity above realized demand) and stockouts (order quantity below realized demand) are coded as losses. They also assume that the psychological aversion to these two types of loss is different. They show that this approach can also help explain the "pull-to-center" effect. Becker-Peth et al. (2013) model the effect of loss aversion (along with two other behavioral factors) on buyer's order quantity under a buyback contract. They define the initial wholesale price as the reference point for the buyer. Because the buyback price received from the supplier at the end of the selling season is always below the initial wholesale price, this price difference is coded as loss. They find that the behavioral model is consistent with the experiment results.

In our model, we follow this approach and define gains and losses relative to the status quo wealth level (the former approach), since this is a more common approach in behavioral economics research (Thaler 1999).

Chapter 3:

Contract Preferences for the Loss Averse Supplier

3.1 Introduction

In this chapter, we study how loss aversion and payment sequencing influence the supplier's preference between equivalent buyback and revenue sharing contracts. In other words, we examine whether the supplier prefers one type of contract over the other, even if the achieved profit is identical under the two contracts. The results of this study can help guide the decision of what contract a supply firm should choose for their contract managers. We begin by developing a theory based on an analytical model of how the supplier's preferences change in the presence of loss aversion. The results reveal that a loss averse supplier's preferences vary with the ratio of overage and underage costs of the channel. More specifically, the supplier's preference is a function of the critical ratio defined by the underlying channel-level newsvendor problem. We also find that there exists a critical ratio threshold where the supplier's preferences switch, with the supplier preferring a buyback contract in environments where the critical ratio is below this threshold and preferring a revenue sharing contract when the critical ratio is above this threshold.

This loss-aversion based theory is an important building block for the next stage of the research, which uses controlled laboratory experiments to test whether participants, acting in the role of supplier, consistently prefer one type of contract over the other. The treatments are carefully designed to test if preferences (when they exist) are consistent with our theory. The experimental design is novel in that it focuses on eliciting preferences rather than measuring the performance of specific operations decision tasks, such as setting contract parameters (which is the usual focus of behavioral supply chain research, see Donohue and Siemsen 2010). This allows us to isolate the impact of the two contract frames while controlling for cognitive limitations in setting the parameters themselves. In Chapter 4 we will focus on the decision biases exhibited by the supplier when setting the contract parameters, and its implication on the achieved profit.

The experiment consists of two separate tasks. In the first, participants take on the role of a supplier observing and then choosing between the two contracts under a specific critical ratio environment. In the second, participants answer a series of choice questions in a neutral (i.e., non-supply chain) context in order to elicit an individual out-of-context loss aversion coefficient. The experimental results confirm that suppliers are not indifferent between the seemingly equivalent contracts, and that their preferences are consistent with our theory. In particular, suppliers prefer revenue sharing contracts in high critical ratio environments, and buyback contracts in low critical ratio environments.

While we control for timing effects in our experiments by having the sequence of payments take place without inserted delays, we do find some evidence of an interesting sequencing effect referred to as prospective accounting. As a last step, we develop a behavioral model that incorporates both loss aversion and prospective accounting effects. This combined model provides a stronger fit to the experimental data than loss aversion alone. Together, these results suggest that contract choices are dependent on product attributes (the critical ratio environment) and the loss aversion profiles of contract managers.

The chapter continues in the next section with a brief setup of the main model. Section 3.3 introduces the theoretical results used to develop the two main hypotheses. Section 3.4 describes the experiment designed to test the hypotheses, followed by a report of the results in section 3.5. Section 3.6 provides some preliminary findings on the impact of sequencing effect. Section 3.7 summarizes our key findings and implications for future research.

3.2 Model Setup and Preliminaries

Consider a two-echelon supply chain where a supplier (S) offers contract terms to a retailer (R), who responds by setting an order quantity to cover demand over a single selling period. Under a buyback contract (BB), the supplier charges the retailer an initial wholesale price w_b for each item ordered and provides a buyback credit b for any items remaining at the end of the selling season. In the revenue sharing contract (RS), the supplier again charges an initial wholesale price w_r per unit ordered but now receives a portion of the retailer's revenue r for each unit sold.

The buyer responds to either contract by choosing an order quantity q with the intent to sell the items to the market at an exogenous price p. The supplier incurs a constant production cost c ($0 < c < p$) for each item produced. With no loss of generality, we assume the retailer incurs no additional selling cost and the product has no salvage value. The market demand D is uncertain but drawn from a known distribution that is common knowledge to both parties. Let $F(\bullet)$ denote the distribution function for demand over this selling period, which we assume is characterized by an Increasing Generalized Failure Rate[1].

Since our focus in this chapter is on the supplier's contract preferences, we hold the retailer's behavior fixed and thus control for possible additional behavioral factors introduced by the retailer. While it is interesting to consider how the supplier would react to a retailer with uncertain ordering behavior or who is guided by a utility function that the supplier learns over time, it is important to first understand how a supplier behaves when this additional uncertainty is controlled. Consequently, we assume the supplier knows with certainty that the retailer will choose a profit maximizing order quantity. To create a normative benchmark, we first review the optimal policy under the traditional assumption that supplier and retailer utilities are defined by their individual expected profit. Let q denote the order quantity chosen by the retailer and $S(q)$ denote the retailer's associated expected sales, where

$$S(q) = E[\min(q, D)] = q - \int_0^q F(x)dx.$$

Expected profit for the supplier and retailer under a buyback or a revenue sharing contract are then given as

$$E[\pi_{S_{BB}}] = (w_b - c)q - b\big(q - S(q)\big), \qquad E[\pi_{S_{RS}}] = (w_r - c)q + rS(q),$$

$$E[\pi_{R_{BB}}] = -w_b q + pS(q) + b\big(q - S(q)\big), \qquad E[\pi_{R_{RS}}] = -w_r q + (p - r)S(q).$$

Cachon and Lariviere (2005) showed that both contracts can maximize the sum of the retailer and supplier's profit (i.e., channel profit) if the contract parameters are set in a particular way.

[1] This is a common assumption in the supply chain literature and includes many of the most commonly used demand distributions including the normal, gamma, and uniform distributions.

Moreover, such a channel profit maximizing solution exists for any negotiated breakdown of profit between the buyer and supplier. Let λ represent the proportion of channel profit allocated to the supplier. The channel optimal contract parameters are defined as follows:

$$b^c = \lambda p, \quad w_b^c = c + \lambda(p - c); \quad r^c = \lambda p, \quad w_r^c = (1-\lambda)c. \tag{3.1}$$

When either the buyback or revenue sharing contract parameters are set according to (3.1), the resulting optimal order quantity for the retailer is $q^c = F^{-1}(Cr)$ where $Cr = (p - c) / p$ is the channel-level newsvendor critical ratio. Cachon and Lariviere (2005) proved that the two contracts are identical, in terms of the earnings achieved by each channel member for any given demand realization D, when $b^c = r^c$ and $w_b^c = w_r^c + b^c$. This implies that, for a given λ, the supplier should be indifferent between offering a buyback or revenue sharing contract if her utility is captured by expected profit. However, if the supplier's contract decisions are driven by a different utility function, this result may breakdown. The following example provides some insight into what factors, besides expected profit, might influence preferences between the two contracts.

Table 3.1 lists payment streams for four different pairs of buyback and revenue sharing contracts, ordered by increasing production cost, c. Demand for this example is uniformly distributed between 0 and 9, i.e., $D \sim U[0,9]$. The contract parameters for each buyback and revenue sharing contract are set according to equations (3.1), which implies that final profit for a given buyback/revenue sharing pair is equivalent for any demand realization. So, from a profit maximization perspective, the supplier should have no preference between the buyback and revenue sharing contracts within a given pair. However, if we compare the two contract columns, there are some clear framing differences.

Table 3.1: Financial transactions for the two contracts (p=\$80, λ = ¾, $D \sim U(0, 9)$).

		Buyback		Revenue Sharing	
Cr	***c***	At order	After demand	At order	After demand
0.95	\$4	\$513	$-\$60*(9-D)^+$	-\$27	$\$60*\min(9,D)$
0.75	\$20	\$315	$-\$60*(7-D)^+$	-\$105	$\$60*\min(7,D)$
0.35	\$52	\$63	$-\$60*(3-D)^+$	-\$117	$\$60*\min(3,D)$
0.15	\$68	\$9	$-\$60*(1-D)^+$	-\$51	$\$60*\min(1,D)$

The buyback contract begins with a certain gain, followed by an uncertain loss. In contrast, the revenue sharing contract starts with a certain loss followed by an uncertain gain. Looking at the case of Cr=0.95, a revenue sharing contract may appear more attractive to a loss averse supplier since the sure loss ($27) is much smaller than the average loss under a buyback contract ($270 = E[-$60*(9-D)$^+$]). However, this same supplier may prefer a buyback contract for the case of Cr=0.15 since revenue sharing now yields a sure loss of -$51 versus a much smaller expected loss of -$6 under the buyback contract. In general, as Cr decreases, the optimal order quantity for the retailer decreases; this impacts the initial revenue and the probability of a gain or loss after demand realization. Under a buyback contract, a smaller order quantity implies a lower chance of having leftover inventory, so the supplier's buyback loss is reduced. On the other hand, under a revenue sharing contract, the supplier's initial loss, $w_r^c - c = -\lambda c$, becomes more salient with a smaller order quantity. This suggests that the relatively attractiveness of revenue sharing versus buyback may decrease with Cr.

This problem context differs from prior applications of loss aversion theory in that it is not only the relative magnitude of the gain and loss that changes across contracts, but also the ordering of gains and losses and which one is uncertain. In most previous laboratory studies involving loss aversion (see Abdellaoui et al. (2007) for a recent review), decision makers are asked to choose between two options which are both either a sure outcome or a lottery with certain probability of achieving some stated value. For this reason, it is important to first establish whether a supplier's preferences in this more complex problem context are consistent with loss aversion theory. This is one of the main objectives of this chapter, along with understanding how operational factors, such as the underlying critical ratio, interact with loss aversion to influence preferences. Once behavioral tendencies are established, Chapter 4 will utilize this theory to predict and test how suppliers actually set the corresponding contract parameters.

3.3 Theory and Hypotheses

Loss aversion is commonly modeled through a loss aversion coefficient γ, which represents the ratio of marginal utility of losses versus gains for the supplier (see Ho and Zhang 2008 and Schweitzer and Cachon 2000 for similar models). We adopt this same convention in our analysis, and assume $\gamma \geq 1$, where $\gamma = 1$ implies no loss aversion. We also follow prior research in defining a loss as any reduction in current wealth (i.e., reduction in status quo rather than reduction relative to a fixed threshold).

With these conventions, it is straight forward to specify a supplier's expected utility with loss aversion under a buyback contract as

$$U_{S_{BB}}(w_b, b \mid q) = (w_b - c)q - \gamma b(q - S(q)). \tag{3.2}$$

Note that because the first term is always a gain (since $w_b > c$ by definition), the loss aversion coefficient only applies to the buyback payment. In contrast, under a revenue sharing contract, the wholesale price w_r could be set less than c, in which case the supplier will experience an initial loss. However, if $w_r > c$, then no initial loss occurs. This implies the following utility function under revenue sharing

$$U_{S_{RS}}(w_r, r \mid q) = \begin{cases} \gamma(w_r - c)q + rS(q) & if\ w_r < c \\ (w_r - c)q + rS(q) & otherwise. \end{cases} \tag{3.3}$$

To generalize the results alluded to in the discussion of Table 3.1, we need to compare the supplier's utility under each contract when the contracts are equivalent from an expected profit perspective (i.e., when contract parameters are set according to conditions (3.1)). In this setting, $w_r^* = (1 - \lambda)c < c$ and so the supplier will always experience a loss in the initial transaction. In other words, only the first case of (3.3) is active. Plugging conditions (3.1) into equations (3.2) and (3.3), as well as substituting in the retailer's optimal order quantity $q^c = F^{-1}(Cr)$, results in the following expression

$$\Delta U_S = U_{S_{BB}} - U_{S_{RS}} = -\lambda p(\gamma - 1)\left[F^{-1}(Cr)Cr - S\left(F^{-1}(Cr)\right)\right], \tag{3.4}$$

where ΔU_S denotes the relative utility of the buyback contract over the revenue sharing contract. The sign of ΔU_S, and thus the supplier's contract preference, is clearly dependent on *Cr*. Proposition 2 establishes that a critical ratio threshold exists that divides the supplier's preference space into three regions.

Proposition 3.2: *If the contract parameters are set according to condition* (3.1)*, then there exists a Critical Ratio threshold, Cr^0, such that a loss averse supplier* ($\gamma > 1$) *will*

a) prefer a buyback contract when $0 < Cr < Cr^0$.

b) prefer a revenue sharing contract when $Cr^0 < Cr < 1$.

c) have no preference between buyback and revenue sharing when $Cr = Cr^0$.

Furthermore, Cr^0 is the unique solution to the equation $F^{-1}(Cr)Cr - S\left(F^{-1}(Cr)\right) = 0.$

Proposition 2 implies that a loss averse supplier will prefer the revenue sharing contract for products with a high critical ratio (larger than Cr^0), and prefer the buyback contract for products with a low critical ratio (smaller than Cr^0). This leads to our first set of testable hypotheses.

Hypothesis 3.1a: *Revenue sharing is preferred over buyback in high critical ratio environments ($Cr > Cr^0$) when parameters are set according to* (3.1).

Hypothesis 3.1b: *Buyback is preferred over revenue sharing in low critical ratio environments ($Cr < Cr^0$) when parameters are set according to* (3.1).

The solution to the critical ratio threshold (as shown in Proposition 2.1) implies that Cr^0 is a function of the demand distribution, but is not a function of the loss aversion coefficient (when $\gamma > 1$). However, we can see from equation (3.4) that the magnitude of ΔU_S increases with γ. This implies that, for a given critical ratio level, suppliers with higher levels of loss aversion will exhibit stronger preferences than suppliers with lower levels of loss aversion, and leads to our final hypotheses.

Hypothesis 3.2: *Individuals with high levels of loss aversion will more consistently prefer revenue sharing in high critical ratio environments and buyback in low critical ratio environments, compared with individuals having low levels of loss aversion.*

This hypothesis is also consistent with the quantal choice framework for modeling bounded rationality (e.g., Su 2008) which assumes that decision makers are more likely to make errors in choosing options that yield similar results than options that are clearly distinct.

3.4 Experimental Design and Implementation

We conducted a laboratory experiment to test these two hypotheses using a computer-based interface consisting of two separate tasks. In the first task, each participant took part in a simulation designed to elicit their preference between buyback and revenue sharing contracts. In the second task, we measured each participant's loss aversion level using an out of context procedure. This second task provided a means for grouping individuals by their loss aversion levels to test the relative effects of loss aversion.

The experiment was performed at the University of Minnesota, with participants recruited from the Carlson School subject pool. 193 students participated in this study. The majority of our participants were undergraduate students (78%) and the rest were graduate students. 97% of the participants had completed at least one college-level business or economics course. Participants were paid based on the outcome of both tasks, in addition to a $5 show up fee. The final payment ranged from $6 to $22 with a median of $14.

3.4.1 Contract Comparison Task

In the first task, participants witnessed financial transactions for the two contracts and then indicated which contract they preferred. We conducted two sets of experiments (experiment 1a and 1b, each with 8 treatments). The treatments varied by the order that the two contracts were presented (first BB or first RS) and the value of the critical ratio (Cr=0.15, 0.35, 0.75, 0.95) used in the problem context, leading to a (2 × 4) = 8 treatment design for each experiment. The demand in all cases was drawn from a discrete U[0,9] distribution, which implies a threshold critical ratio value of Cr^0=0.65. The four Cr environments included two above (0.95 and 0.75) and two below (0.35, and 0.15) the threshold. We set the retailer's profit equal to the associated profit the retailer would achieve if the supplier offered a wholesale price contract that maximizes the supplier's profit, which led to a constant profit split of $\lambda = 3/4$[2].

We used the same set of 14 demand streams in all treatments to control for any potential demand realization effects between treatments (which would not have been possible if different demand streams were used for each treatment). Each demand stream was randomly generated and consisted of 5 numbers used for the 5 trials of the option 1 contract, followed by the same 5 numbers used for trials of the option 2 presented in a different sequence. Using the same set of numbers for both contract options ensured that the total profit outcomes were the same for both, and that any preference between the contracts would be due to other factors than total profit. Within a treatment, each participant was randomly assigned to one of these fourteen demand streams.

In choosing the parameter values p and c to support the four critical ratios, we considered two approaches: (a) fixing p and varying c, and (b) varying both simultaneously while keeping $|\Delta U_S|$ fixed. While approach (b) is less straight-forward, it offers an important additional control for potential differences in the participants' ability to discern the sign of ΔU_S (and thus their ability to exhibit clear preferences between buyback or revenue sharing contracts) across Cr levels. This resulted in two sets of parameter values labeled as experiment 1a and 1b and

[2] See chapter 4 for details on the derivation of the retailer's profit level under a wholesale price contract.

summarized in Table 3.2. Recall that the associated contract parameters (w_b^c, b^c) and (w_r^c, r^c) are functions of (p, c) and computed from conditions (3.1). In experiment 1b, we also provided an initial endowment to cover the largest possible negative profit outcome for each *Cr* treatment. The number of participants in experiment 1 is listed in Table 3.3[3]. We utilized a between subject design, with each participant randomly assigned to only one treatment.

Table 3.2: Treatment Parameters

	Cr	***p***	***c***	w_b^c	b^c	w_r^c	r^c	q^c	***Endowment***	***Conversion rate***
Experiment 1a	**0.95**	80	4	61	60	1	60	9	---	0.01
	0.75	80	20	65	60	5	60	7	---	0.02
	0.35	80	52	73	60	13	60	3	---	0.05
	0.15	80	68	77	60	17	60	1	---	0.5
Experiment 1b	**0.95**	26.67	1.33	20.33	20	0.33	20	9	10	0.03
	0.75	106.67	26.67	86.67	80	6.67	80	7	150	0.01
	0.35	80	52	73	60	13	60	3	120	0.03
	0.15	144	122.67	138.67	108	30.67	108	1	100	0.04

Table 3.3: Summary of participants across treatments

	Experiment 1a			Experiment 1b		
Cr	BB→RS	RS→BB	**Total**	BB→RS	RS→BB	**Total**
0.95	13	12	25	14	13	27
0.75	10	13	23	13	11	24
0.35	11	10	21	13	12	25
0.15	11	9	20	14	14	28
Total	45	44	89	54	50	104

The specifics of the first task were as follows. Each participant was initially told they would be taking on the role of a cheese cake supplier for a local store, and that they would have a chance to choose between two possible financial contracts to offer to the store. The terms of each contact,

[3] Experiment 1a was conducted in Spring 2012 and experiment 1b was conducted in Spring 2011.

labeled option 1 and option 2, were then explained. The participant next experienced five trials of the option 1 contract, followed by five trails of the option 2 contract. For the buyback contract, a trial consisted of a first screen showing the order quantity q received by the retailer along with the associated payment \$$g\times q$ where g=w-c. A running account was also displayed near the bottom of the screen. After the participant clicked the "continue" button, a second screen then displayed the demand realization D and the buyback payment the participant incurred, \$$b\times(q\text{-}D)^+$. The participants were told that market demand is random and could be any integer from 0 to 9 with equal probability. There was no forced time delay between screens, and the running account was cleared after every trial. The revenue sharing contract trials were designed in a similar manner. Appendix C includes complete experimental instructions, along with screen shots.

After witnessing five trials of the two contracts, a summary screen was displayed that listed two tables side by side. The first table contained a summary of the payments in each period (before and after the demand realization) that the participant had experienced for all 5 trials of contract option 1. The second table provided similar information for contract option 2. At this point, the participants were asked which option they prefer and told they would be paid based on one last trial with the option selected. The participant's payment was computed by the profit they earned in this last trial times a conversion rate. The conversion rate varied by treatment in order to normalize the average payment across treatments (see last column of Table 3.2).

3.4.2 Loss Aversion Measurement Procedure

Several approaches have been developed in the literature to precisely measure the loss aversion coefficient at an individual level (e.g., Tversky and Kahneman 1992, Schmidt and Traub 2002, Abdellaoui et al. 2007, 2008). However, it can be challenging to implement some of these approaches since they often require individuals to answer hundreds of choice decisions, which is quite time consuming. We developed a simpler approach building off the elicitation procedure described in Abdellaoui et al. (2008) to assess each participant's loss aversion coefficient γ_i. Appendix B describes the reasoning behind this simplified elicitation procedure. Basically, the participants were asked to answer a series of 13 questions about their preferences between two options, labeled A and B. Option A was always a sure outcome. Option B contained two outcomes with probabilities p_r and (1- p_r). An example comparison might be:

Option A: Gaining \$525 for sure.

Option B: 39% probability of getting nothing (\$0) and 61% probability of gaining \$1,000.

Payment for this portion of the experiment was determined by randomly selecting one of the 13 questions and computing the outcome of the option the participant selected this question times a conversion rate of 0.01. For example, suppose the above question was selected. If a participant chose Option A, then the payment would be $525 * 0.01 = $5.25. If the choice was Option B, the payment would be determined by a random draw. In this case, a random integer between 1 and 100 with equal probability will be generated. If the number is less than or equal to 61 the participant would receive $1,000 * 0.01 = $10. Otherwise, the participant would receive $0.

3.5 Results

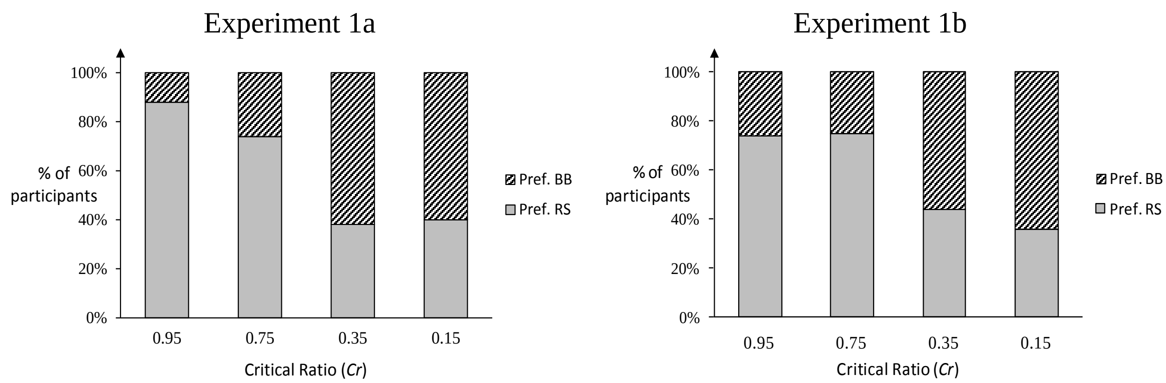
Table 3.4 presents a summary of the participants' preferences in each of the eight treatments for experiments 1a and 1b. Recall that our treatments were designed not only to test if there are changes in preferences for different critical ratio values, but also to determine if the order that the contracts were presented had any impact on the preference choice. We used a Likelihood Ratio Chi-square Test (LRT) to determine if there were any differences between the outcomes of the BB→RS versus RS→BB treatments for each experiment. The LRT reveals no ordering effects ($\chi^2(4)$=1.01, p=0.893 for experiment 1a; $\chi^2(4)$=0.21, p=0.995 for experiment 1b), and so we combined the data across presentation order for the remaining analysis.

Table 3.4: Supplier's contract preferences for all treatments

		Experiment 1a			Experiment 1b		
Order	*Cr*	# pref. BB	# pref. RS	Total	# pref. BB	# pref. RS	Total
BB → RS	**0.95**	2	11	13	4	10	14
	0.75	3	7	10	3	10	13
	0.35	6	5	11	7	6	13
	0.15	7	4	11	9	5	14
RS → BB	**0.95**	1	11	12	3	10	13
	0.75	3	10	13	3	8	11
	0.35	7	3	10	7	5	12
	0.15	5	4	9	9	5	14

Figure 3.1 plots the combined data, showing the breakdown of preferences by critical ratio. It appears that more participants prefer the revenue sharing contract in the high *Cr* treatments, while more participants prefer the buyback contract in low *Cr* treatments. We test these observations more rigorously in the next subsection.

Figure 3.1: Distribution of supplier preferences by *Cr* (pooling order treatment data)



3.5.1 Influence of Critical Ratio

To test the influence of critical ratio on preferences, we compute the percentage of participants who prefer the buyback contract for each critical ratio, $P_{BB}(Cr)$. We use LRT to examine whether this percentage is significantly smaller than 50% for high critical ratio treatments (Cr = 0.95, 0.75) and greater than 50% for low critical ratio treatments (Cr = 0.35, 0.15). Table 3.5 lists the results (see "pooled" column). For the high critical ratio treatments, the preferences are consistent with our model predictions. The percentages are significantly smaller than 50% for both experiment 1a and 1b, supporting H1a. However, for the low critical ratio treatments, the percentages are not significant. Participant preferences appear random in this case, which fails to support H1b.

Table 3.5: Percentage of participants preferring BB (P_{BB}) for all critical ratio treatments in both experiment 1a and 1b.

	Experiment 1a			Experiment 1b		
Cr	Pooled	Low γ	High γ	Pooled	Low γ	High γ
0.95	12.0% ***	14.3% **	9.1% **	25.9% *	50.0%	6.7% ***
0.75	26.1% *	33.3%	12.5% *	25.0% *	38.5%	0.0% ***
0.35	61.9%	50.0%	72.3%	56.0%	37.5%	64.7%
0.15	60.0%	37.5%	75.0% †	64.3%	41.7%	81.2% **

Note: *** p<0.001 ** p<0.01 * p<0.05 † p<0.1

3.5.2 Influence of Loss Aversion

To test the influence of loss aversion on the strength of contract preference, we examine the loss aversion tendencies of participants, revealed through their measured loss aversion coefficients γ_i from task 2 of the experiment. Figure 3.2 shows a histogram of γ_i across all 193 participants, with summary statistics provided in Table 3.6. To test whether preferences of participants with high levels of loss aversion differ from participants with low levels of loss aversion, we partitioned the participants into two groups by their measured loss aversion coefficients γ_i. We identified the median from the combined data, 1.64, as the dividing line since the median was consistent across the two experiments (Mann-Whitney *U* test of difference yields p=0.653). Participants with a loss aversion coefficient below the median (γ_i < 1.64) are categorized as having low loss aversion while participants with loss aversion coefficients greater or equal to the median are labeled as having high loss aversion[4].

[4] We also tried two other cutoffs (1.3 and 1.7) as well as more than 2 groups. In all cases, we found similar results. In subsection 3.5.3 we use a logit choice model to further justify that partitioning participants into 2 groups is sufficient for the analysis.

Figure 3.2: Histogram of participants' measured loss aversion coefficients (pooling both experiment 1a and 1b)

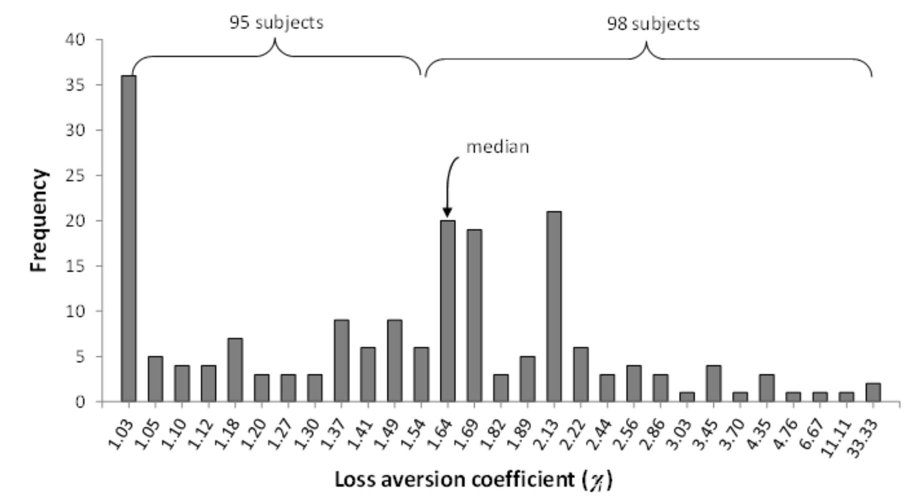


Table 3.6: Basic statistics of measured loss aversion coefficient (γ_i).

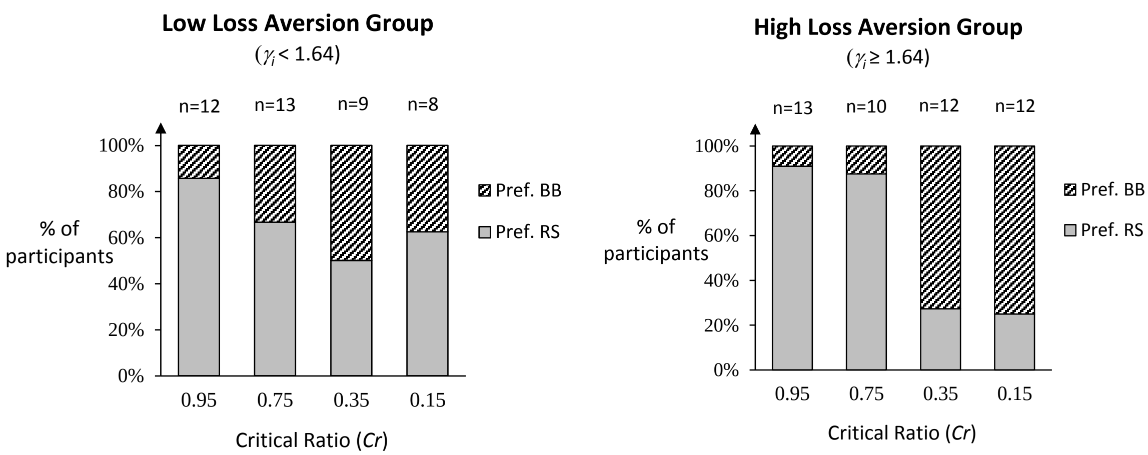
	Experiment 1a	Experiment 1b	Pooled
Mean	2.38	1.82	2.08
Median	1.54	1.64	1.64
Min	1.03	1.03	1.03
Max	33.33	11.11	33.33
s.d.	4.79	1.19	3.37

Figure 3.3 plots the breakdown of preferences across the four *Cr* treatments for the low and high loss aversion groups. The associated percentage of participants preferring the buyback contract, P_{BB}(Cr), are summarized in Table 3.5 under the columns labeled as “Low γ” and “High γ”. In the low loss aversion group, the percentages of participants preferring the buyback contract are indifferent from 50% for seven of the eight *Cr* levels. The only exception is in experiment 1b when Cr=0.95. In this treatment, because of the large value of p, the ΔU_S are very large even for individuals with a moderate level of loss aversion. As a result, individuals may be able to detect the difference between the two contracts and thus indicate a clear preference even at a low loss aversion level.

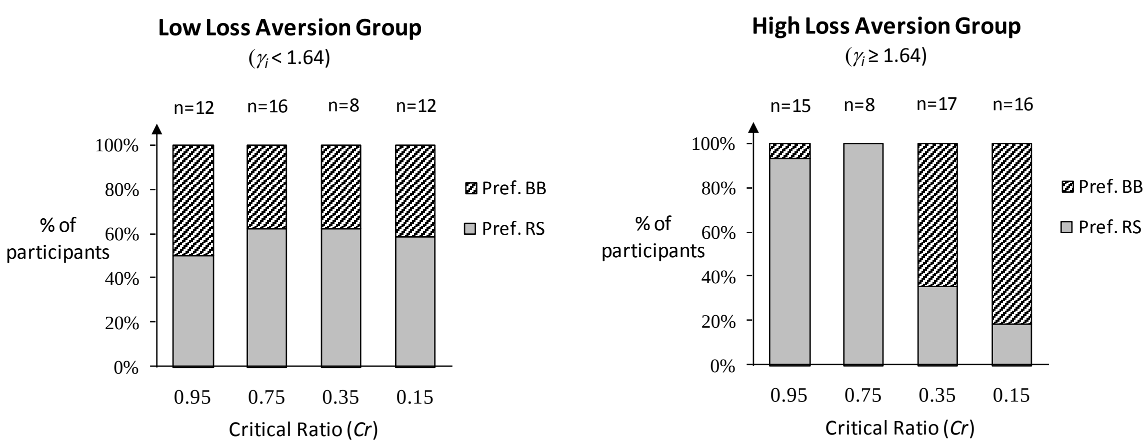
In contrast, the high loss aversion group reveals strong preferences which are sensitive to the critical ratio level (see right panel of Table 3.5). The percentages of participants preferring the buyback contract are significantly less than 50% (p<0.001) in the high critical ratio treatments, which is a stronger result than we found in the previous pooled analysis. For the low critical ratio treatments, the magnitude of P_{BB} has increased relative to the pooled analysis, and this percentage is now significantly greater than 50% in the Cr=0.15 treatment (compared with no significant result in the pooled analysis). These results suggest that loss aversion level influences contract choice, with participants having higher loss aversion exhibiting stronger preferences. This supports Hypothesis 3.2.

Figure 3.3: Distribution of preferences by *Cr* within each group.

Experiment 1a



Experiment 1b



This finding is consistent with the quantal choice framework for modeling bounded rationality (e.g., Su 2008) which suggests that decision makers are more likely to make errors in choosing options that yield similar results than options that are clearly distinct. In our context, individuals with a low level of loss aversion fail to distinguish buyback and revenue sharing contracts since in their eyes the two contracts are similar (i.e., the relative utility ΔU_S for the two contracts is arbitrarily small). As a result, they make random choices between the contracts. In contrast, individuals with a high level of loss aversion reveal a clear preference since the relative utility across contracts is fairly large.

3.5.3 Individual Analysis

In section 3.5.2 we measured contract preference by the percentage of participants preferring buyback contract and found that, at an aggregate level, this percentage depends on the level of loss aversion. We now examine at the individual level the likelihood that a participant chooses a buyback versus revenue sharing contract given their measured loss aversion coefficient γ_i. To do this we fit the data using a binomial logit model which accounts for loss aversion.

The binomial logit model estimates the probability of choosing one contract option over the other, subject to random errors resulting from the boundedly rational level of the decision makers (similar to the approach used by Su 2008). Using the logit form, the probability of choosing a buyback contract can be expressed as follows,

$$\Pr(BB) = \frac{e^{\rho U_{S_{BB}}}}{e^{\rho U_{S_{BB}}} + e^{\rho U_{S_{RS}}}} = \frac{e^{\rho \Delta U_S}}{e^{\rho \Delta U_S} + 1}, \tag{3.5}$$

where ΔU_S is defined by (3.4). The parameter ρ captures the decision maker's rationality level. When $\rho = 0$, the decision maker randomly chooses between the two contract options; when $\rho = +\infty$, the decision maker always chooses the contract with higher utility. Using the parameter values defined in Table 3.2, the values of ΔU_S for each *Cr* treatment are

$$\Delta U_S = U_{S_{BB}} - U_{S_{RS}} = \begin{cases} (\gamma-1)(-243), & for\ Cr = 0.95 \\ (\gamma-1)(-63), & for\ Cr = 0.75 \\ (\gamma-1)(81), & for\ Cr = 0.35 \\ (\gamma-1)(45), & for\ Cr = 0.15 \end{cases} \tag{3.6}$$

for experiment 1a, and

$$\Delta U_S = U_{S_{BB}} - U_{S_{RS}} = \begin{cases} (\gamma-1)(-81), & for\ Cr = 0.95 \\ (\gamma-1)(-84), & for\ Cr = 0.75 \\ (\gamma-1)81, & for\ Cr = 0.35 \\ (\gamma-1)81.2, & for\ Cr = 0.15 \end{cases} \tag{3.7}$$

for experiment 1b.

Using this model structure, we can estimate an aggregate $\rho(1-\gamma)$ using maximum-likelihood estimation. The result is summarized in the first column of panel (a) in Table 3.7. In both experiments 1a and 1b, the estimate is significantly different from zero, implying the sample loss aversion coefficient is significantly greater than one. This suggests that loss aversion does contribute to the probability of contract choice.

In Section 3.5.2 we saw that participants within the high loss aversion group exhibited stronger contract preferences than participants within the low loss aversion group. This suggests that a logit model incorporating individual level of loss aversion γ_i may fit the data better than the logit model assuming an aggregate level γ for all participants. We test this conjecture by fitting an alternative logit model with the measured individual loss aversion coefficient γ_i substituted for the single γ and comparing the fit of this alternative model. In this alternative model only μ is estimated since the individual γ_i estimates are now given (through the outcome of task 2). The estimation is shown in the second column of panel (a) in Table 3.7. The LRT shows that the model using individual loss aversion coefficient values fits the data better ($\chi^2(1) = 10.62$ for experiment 1a, and $\chi^2(1) = 12.47$ for experiment 1b, with both p-values smaller than 0.001).

Since an individual's level of loss aversion does appear to influence contract preference, we next examine how the model fit changes when we group individuals by their loss aversion levels and estimate aggregate parameters for each group. We start with the two groups used in our previous analysis, a low loss aversion group ($\gamma_i < 1.64$) and a high loss aversion group ($\gamma_i \geq 1.64$). Panels (b) and (c) in Table 3.7 summarize the results. In the low loss aversion group, only the model estimates for experiment 1a are significant. This is due to the fact that clear preferences toward buyback contract exist in the *Cr*=0.95 treatment (see Table 3.5 for detail), and thus loss aversion is able to predict contract preference. In contrast, the model estimates in the high loss aversion group are significant for both experiments. This result confirms that our loss aversion model better estimates contract preference for participants with a high level of loss aversion than participants with a low level of loss aversion.

Table 3.7: Logit model estimates

		(a) All participants		(b) γ_i <1.64		(c) γ_i ≥1.64	
		Using a single γ	Inserting individual γ_i	Using a single γ^l	Inserting individual γ_i	Using a single γ^h	Inserting individual γ_i
	Parameters	$\rho(1-\gamma)$	ρ	$\rho(1-\gamma^l)$	ρ	$\rho(1-\gamma^h)$	ρ
Experiment 1a	Estimate	0.0087***	0.0093**	0.0064*	0.0291*	0.0131**	0.0070*
	S.E.	0.0022	0.0034	0.0026	0.0129	0.0045	0.0031
	Log-likelihood (LL)	-58.5	-53.0	-28.7	-28.3	-23.9	-23.0
Experiment 1b	Estimate	0.0087***	0.0155***	0.0011	0.0173	0.0174***	0.0154***
	S.E.	0.0026	0.0040	0.0035	0.0144	0.0041	0.0041
	Log-likelihood (LL)	-65.7	-59.4	-33.2	-32.5	-27.7	-26.9

* p<0.05, ** p<0.01, *** p<0.001

More surprisingly, we find that in each group the model with one estimated coefficient (γ^l or γ^h) fits as well as the model that used individual γ_i values (in low loss aversion group, $\chi^2(1)$ = 0.72 for experiment 1a and $\chi^2(1)$ = 1.42 for experiment 1b, in high loss aversion group, $\chi^2(1)$ = 1.76 for experiment 1a and $\chi^2(1)$ = 1.50 for experiment 1b). Once we separate the participants into two groups based on their loss aversion level, the measured individual γ_i does not contribute as much because the preference pattern within each group is similar. This further suggests that dividing participants into two groups (low loss aversion vs. high loss aversion, separated by a median level of loss aversion) is sufficient for the model estimation and prediction.

This result has important managerial insights. In order to estimate the probability of a supplier's choice of buyback versus revenue sharing contracts, this data suggests that we only need to know which loss aversion group (high vs. low) the individual belongs to. The estimated probability using γ^l or γ^h does not significantly differ from the estimated probability using the individual γ_i.

3.6 Sequencing Effect

Thus far we have studied the supplier's contract preference through the lens of loss aversion and shown that the implications are mostly supported by the results from the laboratory experiments. However, there are a few cases where revenue sharing appeared more attractive than predicted. In this section, we extend our predictive model to incorporate the additional impact of the sequence of transactions (e.g., whether the loss takes place before or after demand is realized) in an attempt to explain these anomalies. The behavioral economics literature suggests that when facing intertemporal choices (decisions involving trade-offs among costs and benefits occurring at different times) people tend to weight transactions differently across time. In some contexts, discounting future time periods is common (Pannell and Schilizzi 2006), while discounting current time periods is common in others (Chen et al. 2012).

The idea of future time discounting originated in the discounted-utility model proposed by Paul Samuelson back in 1937. This concept has been widely used to explore intertemporal choices in normative economic theories. Although the discounted-utility framework is well justified, and can explain a wide range of economic phenomena, the assumptions underlying this model have been found to be invalid in some situations (see Frederick et al. 2002 for a critical review). As a result, a number of alternative models have been developed to account for these inconsistencies including many based on the concept of mental accounting (see Thaler 1999 for an overview). A recent paper by Chen et al. (2012) studies the influence of sequencing difference in financial transactions (before versus after demand realizations) on newsvendor's ordering decisions. They find that human newsvendors tend to discount early transactions, a behavior they referred as *prospective accounting*.

Prospective accounting has roots in mental accounting theory which suggests that the current "pain of paying" is buffered by thoughts of future gains, and that the current benefit of gaining is dampened by thoughts of future repayments (Prelec and Loewenstein 1998), leading decision makers to discount transactions that occur early. Since our context is similar to Chen et al. (2012) in that the supplier also experiences different financial transactions before and after demand realization, it is conceivable that a supplier might also discount early transactions when making contract decisions. If this is true, the initial cost under the revenue sharing contract or the initial benefit under the buyback contract may be discounted, making the revenue sharing contract more attractive. This appears consistent with the two anomaly cases in our data, as mentioned above.

To formally study the influence of prospective accounting on supplier's decisions, we introduce a parameter $\delta \leq 1$ to capture the degree to which people underweight early transactions (see Chen et al. 2012 for a similar model)[5]. This leads to the following refined expected utility function for a loss averse supplier under buyback and revenue sharing, respectively:

$$U_{S_{BB}}(w_b, b \mid q) = \delta(w_b - c)q - \gamma b(q - S(q)). \tag{3.8}$$

$$U_{S_{RS}}(w_r, r \mid q) = \begin{cases} \delta\gamma(w_r - c)q + rS(q) & if\ w_r < c \\ \delta(w_r - c)q + rS(q) & otherwise. \end{cases} \tag{3.9}$$

Under the buyback contract, prospective accounting leads the supplier to place less weight on initial revenue, making the buyback loss more salient. On the other hand, prospective accounting weakens the initial loss under the revenue sharing contract, making it less salient.

In order to investigate the supplier's contract preference when prospective accounting is introduced, we compare the utility of the two contracts defined in (3.8) and (3.9) with the contract parameters set according to (3.1). The result is summarized in Proposition 3.2 based on the demand distribution used in the experiments.

[5] Consistent with Chen et al. (2012), we assume a common level of δ across all individuals.

Proposition 3.2: *When demand is U(0, B), there exists a critical ratio threshold, Cr^{δ}, such that a loss averse supplier* ($\gamma > 1$) *will*

a) prefer a buyback contract when $\gamma > 1/\delta$ *and* $0 < Cr < Cr^{\delta}$.

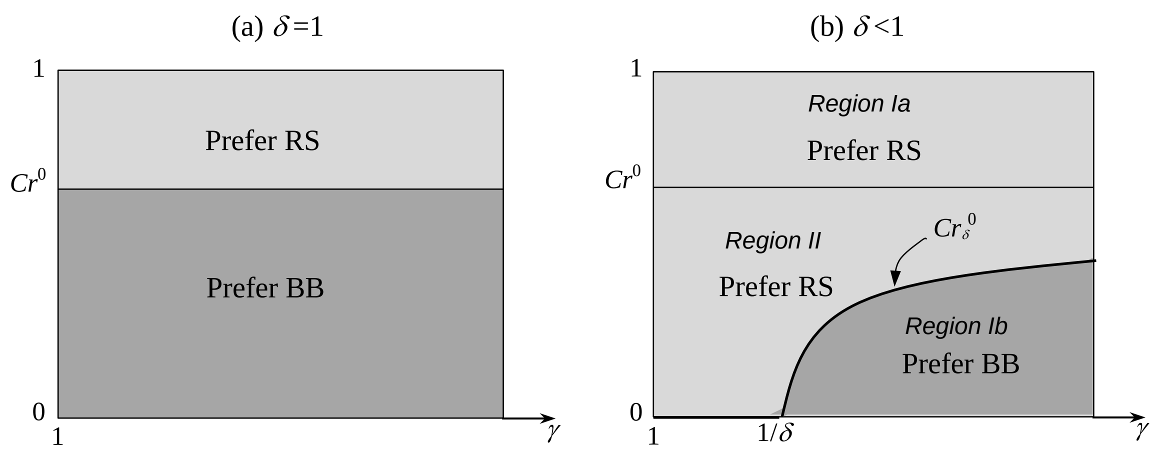
b) prefer a revenue sharing contract when $\gamma \leq 1/\delta$ *or when* $\gamma > 1/\delta$ *and* $Cr^{\delta} < Cr < 1$.

c) have no preference between buyback and revenue sharing when $\gamma > 1/\delta$ *and* $Cr = Cr^{\delta}$.

where $Cr^{\delta} = \dfrac{2(\delta\gamma - 1)}{(2\delta + 1)(\gamma - 1)} < Cr^{0}$.

Figure 3.4 illustrates how the supplier's contract preference changes when prospective accounting exists (δ <1 on the right) compared with when it does not (δ =1 on the left). As shown in Figure 3.4b, the existence of δ divides the preference region into three areas. In Regions Ia and Ib supplier preferences are not impacted by the value of δ (i.e., whether or not prospective accounting exists). However, in Region II preferences switch based on the value of δ. More specifically, a loss averse supplier not influenced by prospective accounting (δ=1) prefers a buyback contract, while a similar loss averse supplier who is influenced by prospective accounting (δ<1) prefers revenue sharing. Since the new threshold Cr^{δ} is smaller than Cr^{0}, prospective accounting always increases the attractiveness of revenue sharing.

Figure 3.4: Supplier preference regions under prospective accounting



This theoretical result is consistent with the experimental data. While the low critical ratio treatments show a directional preference towards buyback, 39.4% of participants (across experiment 1a and 1b) still chose the revenue sharing contract. This relatively high percentage is consistence with the conjecture that some participants are influenced, at least in part, by prospective accounting. On the other hand, prospective accounting does not change our original predictions for the high critical ratio treatments, and the results confirm that these predictions are more consistent (i.e., only 22.2% deviate by choosing, in this case, the buyback contract). Prospective accounting makes revenue sharing more attractive, and so the tendency to prefer a buyback contract in low *Cr* treatments is not as significant as the tendency to prefer a revenue sharing contract in high *Cr* treatments.

3.7 Concluding Remarks

The goal of this chapter was to determine whether suppliers are indifferent between buyback and revenue sharing contracts. Because the magnitude and sequence of losses and gains vary between the contracts, it is perhaps not surprising to find that preferences do exist. What is more surprising, and the main contribution of this study, is the direction of these preferences and the identification of factors that influence them. We find that a supplier's choice of contract is dependent on the underlying critical ratio, with revenue sharing preferred in high critical ratio environments and buyback preferred in low critical ratio environments. This result was suggested by our loss aversion theory and confirmed in the laboratory. We find that preference results are stronger for subjects with higher loss aversion levels, confirming that loss aversion exists in this problem context and influences contact preferences. We also find preliminary evidence that prospective accounting is at play and can further influence contract preferences.

Katok and Wu (2009) have already shown that unaided participants are not able to set buyback or revenue sharing contract parameters in a manner that coordinates the channel. However, it is not clear how a loss averse supplier should set contract parameters to maximize his utility and whether this results in channel coordination. Does the existence of loss aversion (as suggested here) imply that suppliers will set w_r, w_b, r, and b in a significantly different way than equation (3.1)? More importantly, which contract performs better when a loss averse supplier is tasked with setting the contract parameters? These questions are examined next in Chapter 4.

Chapter 4:

Contract Performance for a Loss Averse Supplier

4.1 Introduction

In this chapter we move from the question of which contract a loss averse supplier would prefer, to exploring how a supplier will set the contract parameters for buyback and revenue sharing contracts, acknowledging that loss aversion may be a contributing behavioral factor. We also examine how the expected profits resulting from these decisions compare across contracts.

Following the structure of Chapter 3, we first characterize the supplier's optimal contract parameters by incorporating loss aversion into the supplier's objective function. The analytical results suggest that the framing differences influence the way the contract parameters are set, ultimately changing the contracts' associated profit levels. More specifically, we find that revenue sharing outperforms buyback in high critical ratio environments, while neither contract dominates in low critical ratio environments. We again test these predictions in a laboratory setting where the subjects now set contract parameter values for either revenue sharing or buyback contracts. The experimental results are consistent with most of our theoretical predictions.

We next study a combined model which incorporates both loss aversion and prospective accounting and find this model provides a stronger explanation of the experimental data. We also structurally estimate the magnitude of loss aversion and discounting coefficients using the experimental data. The results indicate that the perceived loss under a buyback (versus revenue sharing) contract is more salient. This explains why revenue sharing contract yields greater profit for the supplier's firm in many cases.

In the final section, we identify three other factors – minimizing ex post inventory errors (MEPIE), different format of feedback information, and decision complexity – and investigate their influence on contract decisions. We find that the supplier tends to minimize ex post inventory error, leading the retailer's order quantity to exhibit the "pull-to-center" effect. This effect may or may not overpower the prospective accounting, depending on the format of feedback information. We also find that decision complexity (whether participants set one contract parameter or both) may also influence the expected profit comparison. Although these additional factors may influence supplier's contract decisions, loss aversion remains a dominant behavioral factor in explaining the experimental data.

This chapter is organized as follows. Section 4.2 introduces the theoretical results and develops three main hypotheses. Section 4.3 describes the experiment designed to test the hypotheses, followed by a report of the results in section 4.4. Section 4.5 provides results on the impact of prospective accounting. Section 4.6 discusses three additional behavioral tendencies and their impact on supplier's contract decisions. Section 4.7 summarizes our key findings and implications for future research.

4.2 Theory and Hypothesis

Our model setting follows the same assumptions as Chapter 3 (see section 3.2). Since we focus on behavioral tendencies exhibited by the supplier, we continue assuming that the suppliers know with certainty that the retailer will choose a profit maximizing order quantity. We also assume the retailer will only accept contract terms when his expected profit is at least M, where $M \geq 0$ is referred to as the retailer's reservation profit. The retailer's reservation profit level is known to the supplier and bounded above by the maximum expected profit of the channel as a whole.

To create a normative benchmark, we first characterize the supplier's contract decisions when the objective is to maximize her expected profit. Under a buyback contract, the profit maximizing supplier's problem is defined by

$$\max_{w_b, b} \pi_{S_{BB}}(w_b, b) = (w_b - c)q - b\big(q - S(q)\big) \qquad \textbf{(Problem BB)}$$

$$\text{s.t } \partial \pi_{R_{BB}}(q \mid w_b, b) / \partial q = 0$$

$$\pi_{R_{BB}}(q \mid w_b, b) \geq M$$

where $\pi_{R_{BB}}(q \mid w_b, b) = -w_b q + pS(q) + b\big(q - S(q)\big)$. The first constraint ensures the retailer chooses an order quantity, q, to maximize his own expected profit, while the second guarantees the retailer achieves his reservation profit. The profit maximizing supplier's problem under revenue sharing is similar

$$\max_{w_r, r} \pi_{S_{RS}}(w_r, r) = (w_r - c)q + rS(q) \qquad \textbf{(Problem RS)}$$

$$\text{s.t } \partial \pi_{R_{RS}}(q \mid w_r, r) / \partial q = 0$$

$$\pi_{R_{RS}}(q \mid w_r, r) \geq M$$

where $\pi_{R_{RS}}(q \mid w_r, r) = -w_r q + (p - r)S(q)$. The solution to these two problems is defined in Proposition 4.1.

Proposition 4.1: *The supplier's expected profit is maximized by setting*

$$w_b^c = c + \lambda(p - c), \quad b^c = \lambda p \tag{4.1}$$

for a buyback contract, and

$$w_r^c = (1 - \lambda)c, \quad r^c = \lambda p \tag{4.2}$$

for a revenue sharing contract, where $\lambda = 1 - \frac{M}{\pi^c}$ *and* π^c *is the optimal expected profit for the channel. Both solutions are efficient and the resulting two contracts are equivalent in terms of profits realized by the supplier and retailer.*

The contract parameter values defined in Proposition 4.1 are a special case of the efficient contract conditions provided by Pasternack (1985) and Cachon and Lariviere (2005) for buyback and revenue sharing contracts, respectively. In their analysis, the contract parameters were defined as functions that could divide profits between the buyer and supplier in a continuous range of allocations. In our formulation, the existence of a reservation profit (M) for the buyer dictates a unique allocation of the channel profit, with the supplier extracting $1 - \frac{M}{\pi^c}$. Since the contracts are efficient, the resulting retailer's order quantity is $q^c = F^{-1}(Cr)$ where $Cr = (p - c) / p$ is the channel-level newsvendor critical ratio.

Proposition 4.1 also implies that the achieved expected profit for a profit maximizing supplier is identical under buyback and revenue sharing contracts. However, if a supplier exhibits loss aversion, she might set the contract parameters differently than those defined in (4.1) and (4.2). We are interested in determining whether the resulting expected profit is also influenced by loss aversion, and if so, which contract yields a higher expected profit for the supplier's firm. To investigate these questions, we first establish theory for how a loss averse supplier would perform this task, namely solving problems (BB) and (RS). We then develop several hypotheses that will be tested using lab experiments.

While our focus is on comparing the performance of buyback and revenue sharing contracts, we will also consider the wholesale price contract as a default option for the supplier and retailer. With no loss in generality, we assume that the reservation profit for the retailer, M, is equal to the expected profit the retailer would achieve under the supplier's associated optimal wholesale price contract (i.e., a contract with only one parameter, w_p). To match our experimental setting, we also assume that market demand follows a U[0, B] distribution. Applying the results from Lariviere and Porteus (2001), it is easy to show that the optimal wholesale price for an expected profit maximizing supplier under a wholesale price contract is $w_p^* = (p + c) / 2$, and his resulting expected profit $E(\pi_p^*) = (p - c)^2 B / 4p$. The retailer's associated expected reservation profit is[6]

$$M = \frac{(p-c)^2}{8p} B. \tag{4.3}$$

Starting with the buyback contract, accounting for loss aversion requires solving problem (BB) with the supplier's profit equation replaced by the following utility function.

$$U_{S_{BB}}(w_b, b \mid q) = (w_b - c)q - \gamma b(q - S(q)). \tag{4.4}$$

The solution is defined as follows.

Proposition 4.2: (1) *The supplier's optimal wholesale price under a buyback contract, w_b^*, is non-increasing in γ, with a lower bound of w_p^*. Furthermore, $w_b^* = w_p^*$ for $\gamma \geq 2$. The optimal buyback parameter b^* for a given $w_b^*(\gamma)$ is*

[6] Under a wholesale price (WP) contract, the supplier's and retailer's profit is $\pi_{S_{WP}}(w_p) = (w_p - c)q$ and $\pi_{R_{WP}}(q|w_p) = -w_p q + pS(q)$, respectively. The supplier's optimal contract parameter w_p^* can be easily solved in this Stackelberg game setting. The associated optimal order quantity for an expected profit maximizing retailer is $q_p^* = (p - c)B / 2p$.

$$b^*(w_b^*) = p - \frac{4p(p-w_b^*)^2}{(p-c)^2}. \tag{4.5}$$

(2) *The supplier's expected profit* $E(\pi^*_{S_{BB}})$ *is non-increasing in* γ *, with a lower bound of* $E(\pi_p^*)$. *Furthermore,* $E(\pi^*_{S_{BB}}) = E(\pi_p^*)$ *for* $\gamma \geq 2$.

Proposition 4.2 suggests that under the buyback contract, a loss averse supplier will always set a lower wholesale price than a profit maximizing supplier. Loss aversion makes the buyback cost more salient compared to the initial revenue, which leads the supplier to reduce the buyback price. This lower buyback price requires the supplier to also reduce her wholesale price to maintain a retailer profit level greater or equal to *M*. The wholesale price decrease with γ as long as $\gamma < 2$. On the other hand, the resulting expected profit is also decreasing with γ because a loss averse supplier is willing to sacrifice his initial revenue to reduce the disutility resulting from the buyback cost. Once the level of loss aversion exceeds this threshold, the potential for higher profit is overcome by the disutility of a potential loss, leading the supplier to deactivate the buyback term and effectively offer a wholesale price contract.

In the case of revenue sharing, replacing the supplier's profit function by the utility with loss aversion

$$U_{S_{RS}}(w_r, r \mid q) = \begin{cases} \gamma(w_r - c)q + rS(q) & \text{if } w_r < c \\ (w_r - c)q + rS(q) & \text{otherwise.} \end{cases} \tag{4.6}$$

and solving problem (RS), we find that loss aversion influences the supplier's choice of parameter values (w_r^* and r^*) in a different way.

Proposition 4.3: (1) *The supplier's optimal wholesale price under a revenue sharing contract,* w_r^*, *is non-decreasing in* γ *, with a upper bound of c. Furthermore, there exists a loss aversion coefficient threshold* γ_0, *where* $w_r^* = c$ *for* $\gamma \geq \gamma_0$. *The optimal revenue sharing parameter* r^* *for a given* $w_r^*(\gamma)$ *is*

$$r^*(w_r^*) = (p - w_r^*) - \frac{(p-c) + \sqrt{(p-c)^2 + 16 w_r^* p}}{8p}(p-c). \tag{4.7}$$

(2) *The supplier's expected profit* $E(\pi^*_{S_{RS}})$ *is non-increasing in* γ, *with a lower bound of* $E[\pi_{S_{RS}}(w_r^* = c)]$. *Furthermore,* $E(\pi^*_{S_{RS}}) = E[\pi_{S_{RS}}(w_r^* = c)]$ *for* $\gamma \geq \gamma_0$.

Under the revenue sharing contract, a loss averse supplier with $\gamma < \gamma_0$ will still set w_r^* below the production cost c. However, this optimal wholesale price converges to c as γ increases, and thus the initial loss becomes smaller. This increase in wholesale price requires the supplier to set a low revenue share r, in order to ensure the retailer's profit level greater than or equal to M. As a result, the supplier's expected profit is also decreasing. Once γ exceeds the threshold γ_0, the supplier sets $w_r^* = c$ in order to avoid any initial loss, and the achieved expected stays at $E[\pi_{S_{RS}}(w_r^* = c)]$. Unlike the buyback contract where the loss aversion threshold is always 2, the threshold γ_0 varies with critical ratio. It is never in the supplier's interest to set w_r^* above c since this would decrease her total profit while providing no benefit in terms of reducing the initial loss. Also, unlike the buyback contract, the optimal revenue sharing contract always has an active revenue sharing term (i.e., the supplier never resorts to using a wholesale price contract).

Proposition 3 and 4 yield two sharp predictions about how the value of the wholesale price and achieved expected profit differ based on the supplier's loss aversion level.

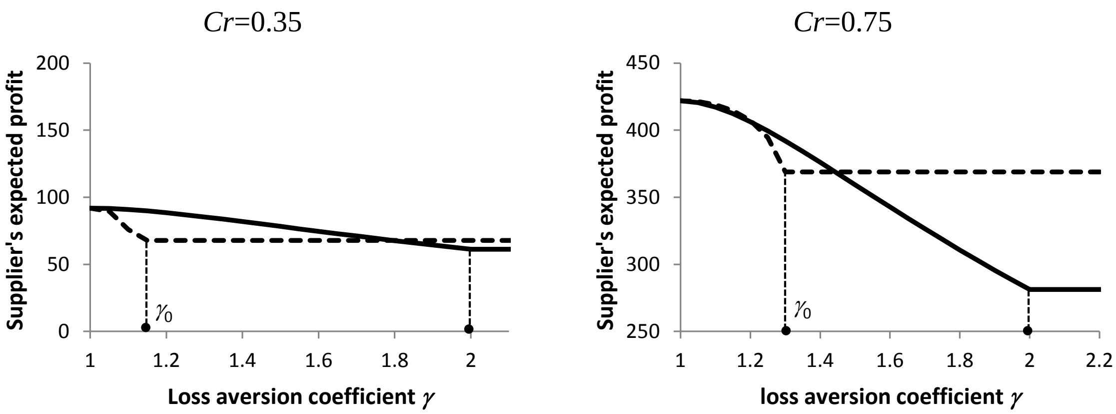
Hypothesis 4.1a: *Under the buyback contract, individuals with a high level of loss aversion will set a lower wholesale price than individuals with a low level of loss aversion.*

Hypothesis 4.1b: *Under the revenue sharing contract, individuals with a high level of loss aversion will set a higher wholesale price than individuals with a low level of loss aversion.*

Hypothesis 4.2: *Under either contract, the expected profit for individuals with a high level of loss aversion will be less than that for individuals with a low level of loss aversion.*

Now that we have characterized the optimal buyback and revenue sharing contract parameters, and how they change with the supplier's level of loss aversion, we can use these solutions to compare the profits achieved by the two contracts and determine which contract yields a higher expected profit for the supplier's company. Since there is not a closed form expression for profit under the revenue sharing contract, we study this comparison through a numerical example. Figure 4.1 plots the supplier's expected profit against possible loss aversion coefficients under low and high Cr levels (0.35 and 0.75) when p=20, which are the parameter values we use in our experiment 2. To illustrate the relative sensitivity of the supplier's expected profit in these examples, we scale the supplier's profit (y-axis) within the same range (i.e., (0, 200) for Cr=0.35, and (250, 450) for Cr=0.75).

Figure 4.1: Supplier's expected profit under buyback (solid) and revenue sharing (dashed).



As predicted in Proposition 4.2, the supplier's expected profit under the buyback contract (solid line) decreases with γ when $\gamma < 2$ and converts to a wholesale price contract for $\gamma \geq 2$. Also, as predicted in Proposition 4.3, the supplier's expected profit under a revenue sharing contract (dashed line) first decreases with γ but remains unchanged once $\gamma \geq \gamma_0$. The loss aversion threshold γ_0 is also greater for *Cr*=0.75 than *Cr*=0.35.

Comparing expected profits for the two contracts, we see in the *Cr*=0.35 case that while relative profits differ with γ, the profit difference is never very large (e.g., never more than 22.94 units). On the other hand, in the *Cr*=0.75 case the profit difference can grow as large as 87.61 units when γ is high, making the revenue sharing contract more attractive. However, the contract performance is somewhat indistinguishable for lower levels of γ. This example results in two testable hypotheses.

Hypothesis 4.3a: *For Cr=0.35, buyback and revenue sharing contracts yield equivalent expected profit levels irrespective of the loss aversion level of the supplier.*

Hypothesis 4.3b: *For Cr=0.75, buyback and revenue sharing contracts yield equivalent expect profit levels for suppliers with a low loss aversion level, but revenue sharing dominates for suppliers with a high loss aversion level.*

Testing these hypotheses will provide insight into which contract is most appropriate from a company perspective after accounting for the loss aversion profile of their contract managers.

4.3 Experimental Design

Experiment 2 followed a similar protocol to experiment 1 (described in section 3.4), with two tasks performed on a computer. In the first task, participants take the role of a supplier facing an automated retailer and set contract parameters for one of the two contracts. Once again, to be consistent with our theory, the retailer's role is programmed to maximize his own expected profit by choosing order quantity q^*[7]. In the second task, the participant's loss aversion level is assessed using the same procedure described in section 3.4.2. 48 participants were recruited from the Carlson School subject pool. 40 participants were undergraduate students and 8 were graduate students. 45 participants had completed at least one college-level business or economics course. All participants were paid based on performance from both tasks, plus a $5 show-up fee. The final payment to all participants ranged from $7 to $25 with a median payment of $13.

The experimental design for the first task is a 2 X 2 between subject design with 2 *Cr* levels (0.35 or 0.75) and 2 contract types (BB or RS). Similar to experiment 1, we use the same set of 14 demand streams for all four treatments, with D~U[0, 100]. Since we are using a between subject design, the participants only played with one contract form, and thus it is not meaningful to control for the relative utility of the two *Cr* level, as we did in experiment 1b. Therefore we followed the design in experiment 1a to keep the market price p=$20 constant across the two *Cr* treatments. The corresponding production cost, number of participants, and conversion rate for each treatment are summarized in Table 4.1.

Table 4.1: Parameter values.

			Buyback			Revenue sharing			
Cr	*p*	*c*	w_b^{lower}	w_b^{upper}	n	w_r^{lower}	w_r^{upper}	n	Conversion Rate
0.35	20	13	16.5	19.2	10	0.0	13.0	11	0.10
0.75	20	5	12.5	17.1	14	0.0	5.0	13	0.02

Setting contract parameters for buyback and revenue sharing contracts is a complex task since the contracts each have two parameters, (w_b, b) or (w_r, r). To simplify the task, we first limited the participant's decision to only choosing a desired wholesale price (w). Based on the participant's inputted w, the program then provides the associated optimal b or r, as defined by

[7] Solving the second constraint from problem (BB) and problem (RS) yields the retailer's optimal order quantities under both contracts are $q_b^*(w_b,b) = (p-w_b)B / (p-b)$, and $q_r^*(w_r,r) = (p-w_r-r)B / (p-r)$.

Equation (4.5) and (4.7), respectively. In other words, for the chosen wholesale price w, we provided a $b^*(w)$ or $r^*(w)$ that maximizes the supplier's expected profit while giving the retailer a profit of at least M [8]. Doing this allows us to examine how participant's contract decisions are influenced by their intention (i.e., utility function), while controlling the decision complexity, and thus potential decision errors resulting from bounded rationality or inability to optimize. Section 4.6.3 describes a follow-on experiment where this limitation is relaxed (i.e., both contract parameters are chosen). We also limit the choice of wholesale price by setting a lower and an upper bound for w_b and w_r as shown in Table 4.1. The lower bound for w_b is the optimal wholesale price under a wholesale price contract, w_p^*, according to Proposition 4.2. The upper bound is the largest possible w_b such that $w_b > b$[9]. As suggested by Proposition 4.3, the range of w_r is between 0 and c, inclusive[10].

In the first task, each participant was told they would be taking the role of a cheese cake supplier, and had to set the wholesale price for either a buyback or revenue sharing contract, which was offered to the local store. The specifics of the contract were then explained. The experiment lasted 20 rounds with the first 5 rounds indicated as a warm-up period for them to get familiar with the contract. They were paid based on the average profit they made in the last 15 rounds.

Participants were aided by a decision tool which appeared on the first screen of each round. For example, in the buyback contract treatment, a scrollbar was used to choose the initial wholesale price. Once a value was chosen, the associated unit buyback price and the store's order quantity were then displayed. The computer also displays the initial revenue at the beginning of the week, and the possible buyback cost at the end. Since the buyback cost is dependent on customer demand, which has not been revealed during the decision stage, the screen only displays the highest and lowest possible buyback costs (i.e., $b \times q$ and 0, respectively). This provides the participants with some knowledge about the range of the total possible buyback cost at the end of the week. All the feedback information is presented in words to make sure they are consistent across the two periods (i.e., beginning and end of the week). Later in Section 4.6.2 we report an experiment where feedback information is the form of a histogram for the second period. After

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[8] In fact, for a given wholesale price, under the optimal value of $b^*(w)$ or $r^*(w)$, the retailer's profit is exactly equal to the reservation profit M.

[9] By definition, buyback price b has to be below the wholesale price w_b. Otherwise, the retailer will make profit by ordering infinity.

[10] It is feasible for w_r to be greater than c, but we are interested in situations where the supplier experiences a cost upfront since this is typically how revenue sharing contracts work in practice. Also from the experiments results, we only observed 0.82% of decisions at w_r=c.

deciding on a wholesale price, participants then clicked on the “ok” button, and advanced to see a second screen showing the initial revenue, followed by a third screen showing the demand realization and total buyback cost. A history of contract parameters, retailer’s order quantity, demand information, and earnings before and after the demand realization was displayed on the bottom of each screen. The revenue sharing contract treatment is designed similarly. The instruction and experimental screen shots are included in Appendix D.

4.4 Results

Since all three hypotheses predict differences in outcome for individuals with high versus low loss aversion levels, we first grouped the data into two categories based the participants’ measured loss aversion coefficient from part 2 of the experiment, similar to the grouping described in 3.5.2. The measured loss aversion coefficients in experiment 2 have a mean of 1.76 and standard deviation of 0.67, with a maximum value of 4 and minimum value of 1.03. The Mann-Whitney *U* test suggests that the median is not significantly different from that in experiment 1 (p=0.493). Following the grouping approach in experiment 1, we continue using the median, 1.61, as the cut-off level to divide the data.

4.4.1 Influence of Loss Aversion on Wholesale Price

To test Hypothesis 4.1a and 4.1b, we fit the following regression model separately for buyback and revenue sharing treatments,

$$w_{i,t} = Intercept + \beta_{Cr} \times Cr + \beta_{H^\gamma} \times H^\gamma + \beta_{Cr \times H^\gamma} \times \left(Cr \times H^\gamma\right) + \mu_i + \varepsilon_{i,t}. \tag{4.8}$$

The dependent variable $w_{i,t}$ is subject i’s wholesale price in round t. The variable Cr is the dummy variable for the critical ratio level, with the value equal to 1 for the Cr=0.75 treatment. H^γ is a dummy variable for loss aversion level, which takes the value of 1 if the subject is in the high loss aversion group. The regression model includes the two main effects (critical ratio and loss aversion) as well as the interaction term ($Cr \times H^\gamma$). We use a random effect model to control for unobserved heterogeneity across individuals (μ_i)[11]. Both μ_i and $\varepsilon_{i,t}$ are assumed to be normally distributed with mean zero and standard deviation of σ_μ and σ_ε, respectively. We use the Feasible

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[11] μ_i also accounts for the differences in demand series each subjects may see.

Generalized Least Square (FGLS) procedure to estimate our model with the regression estimates shown in Table 4.2 under column (a).

Table 4.2: FGLS estimation for $w_{i,t}$ and $E(\pi)_{i,t}$

(a) $w_{i,t}$	BB	RS	(b) $E(\pi)_{i,t}$	Cr=0.35	Cr=0.75
Intercept	18.22*** (0.15)	3.73*** (0.58)	*Intercept*	86.87*** (1.47)	402.09*** (3.25)
Cr	-2.99*** (0.44)	-1.53* (0.62)	H^{γ}	-4.57† (2.60)	-8.30* (4.13)
H^{γ}	-0.69*** (0.21)	3.43** (1.11)	BB	-21.47 (12.07)	-30.97** (10.35)
$Cr \times H^{\gamma}$	-0.54 (0.54)	-2.17† (1.20)	$H^{\gamma} \times$ BB	19.39 (12.44)	-17.50 (16.36)
σ_{μ}	0.73***	1.50***	σ_{μ}	13.49***	20.93***

Note: *** p<0.001 ** p<0.01 * p<0.05 † p<0.1

Note: robust standard deviations are reported in parentheses.

$\beta_{H^{\gamma}}$ measures the difference in setting the wholesale price between individuals with low versus high loss aversion (Δw_i) in Cr=0.35 treatment, and ($\beta_{H^{\gamma}}$ + $\beta_{Cr \times H^{\gamma}}$) measure this difference for Cr=0.75 treatment. We use Wald test for linear restrictions to examine whether these two linear restrictions are significantly different than zero. Since we have already predicted the direction (both are hypothesized to be less than zero for BB and greater than zero for RS), we perform a one-tailed test with the results summarized in Table 4.3.

Table 4.3: Wald test for Δw_i.

	BB	RS
Cr=0.35	$\beta_{H^{\gamma}}$ = -0.69 p=0.001	$\beta_{H^{\gamma}}$ =3.43 p=0.001
Cr=0.75	$\beta_{H^{\gamma}} + \beta_{Cr \times H^{\gamma}}$ = -1.22 p=0.007	$\beta_{H^{\gamma}} + \beta_{Cr \times H^{\gamma}}$ = 1.25 p=0.003

Under the buyback treatment, both linear restrictions are significantly smaller than zero, implying that subjects with high loss aversion set a lower wholesale price than those with low loss aversion. This result supports Hypothesis 4.1a. Similarly, under the revenue sharing contract, the linear restrictions are significantly positive, suggesting that subjects with high loss aversion set the wholesale price higher than those with low loss aversion, supporting Hypothesis 4.1b.

4.4.2 Influence of Loss Aversion on Expected Profit

We apply the following regression model to compare expected profit under the buyback and revenue sharing contracts for each of the *Cr* treatments,

$$E(\Pi)_{i,t} = Intercept + \beta_{H^{\gamma}} \times H^{\gamma} + \beta_{BB} \times BB + \beta_{H^{\gamma} \times BB} \times \left(H^{\gamma} \times BB\right) + \mu_i + \varepsilon_{i,t} \tag{4.9}$$

where BB takes a value of 1 for buyback and 0 for revenue sharing. The regression fits are summarized in Table 4.2 under column (b).

In this regression model, $\beta_{H^{\gamma}}$ measures the expected profit difference $\Delta E(\pi)$ between individuals with high versus low level of loss aversion under revenue sharing contract, and ($\beta_{H^{\gamma}} + \beta_{H^{\gamma} \times BB}$) measures the profit difference under buyback contract. Both linear constraints are hypothesized to be negative if the expected profit decreases with the level of loss aversion. The results for the one-tailed Wald test are summarized in Table 4.4.

Table 4.4: Wald test for $\Delta E(\pi)$ by loss aversion groups.

	BB	RS
Cr=0.35	$\beta_{H^{\gamma}} + \beta_{H^{\gamma} \times BB}$ =14.82 p=0.888	$\beta_{H^{\gamma}}$ = -4.57 p=0.040
Cr=0.75	$\beta_{H^{\gamma}} + \beta_{H^{\gamma} \times BB}$ = -25.80 p=0.040	$\beta_{H^{\gamma}}$ = -8.30 p=0.022

For the *Cr*=0.75 treatment, we find both linear constraints are significantly negative, suggesting that participants in the low loss aversion group achieve higher expected profit than those in the high loss aversion group. However, for the *Cr*=0.35 treatment, the coefficient is significantly negative only under the revenue sharing contract. This suggests that expected profit is decreasing with the participants' loss aversion level under revenue sharing, but indistinguishable under buyback. These results partially support Hypothesis 4.2.

To test Hypothesis 4.3a and 4.3b, we need to examine whether β_{BB} and (β_{BB} + $\beta_{H^{\gamma}\times\text{BB}}$) are significantly different from zero. The former coefficient measures the expected profit difference between the two contracts for the low loss aversion group, while the latter linear constraint measures the profit difference for the high loss aversion group. The results of the one-tailed Wald test for linear restriction are summarized in Table 4.5.

Table 4.5: Wald test for $\Delta E(\pi)$ by contract types.

	Cr=0.35	*Cr*=0.75
Low γ	β_{BB} = -21.47 p=0.076	$\beta_{H^{\gamma}}$ = -30.97 p=0.003
High γ	β_{BB} + $\beta_{H^{\gamma}\times\text{BB}}$ = -2.08 p=0.487	$\beta_{H^{\gamma}}$ + $\beta_{H^{\gamma}\times\text{BB}}$ = -48.47 p=0.000

In the *Cr*=0.35 treatment, expected profit under revenue sharing contract is marginally (p<0.1) significantly greater than buyback contract for the low loss aversion group, while for the high loss aversion group, expected profit is not significantly different. This result partially supports Hypothesis 4.3a, as our theory predicts that the two contracts yield similar profit. In contrast, for the *Cr*=0.75 treatment, both linear constraints are significantly negative, suggesting that expected profit is higher under the revenue sharing contract for both low and high loss aversion groups. This result also shows partial support for Hypothesis 4.3b. While our theory predicted that revenue sharing would dominate in this high critical ratio setting only for high loss aversion levels, we find that it dominates for low loss aversion levels as well.

4.5 Sequencing Effect

Thus far we have studied the supplier's contract decisions and achieved contract profit through the lens of loss aversion and found that most of the implications are supported with the experimental data. However, there are a few places where the revenue sharing contract appears to be more dominant in terms of achieved profit, compared to our theory prediction. In Chapter 3 we uncovered preliminary evidence that the effect of prospective accounting makes revenue sharing more attractive. In this section, we again extend the predictive model to incorporate prospective accounting in an attempt to explain these anomalies.

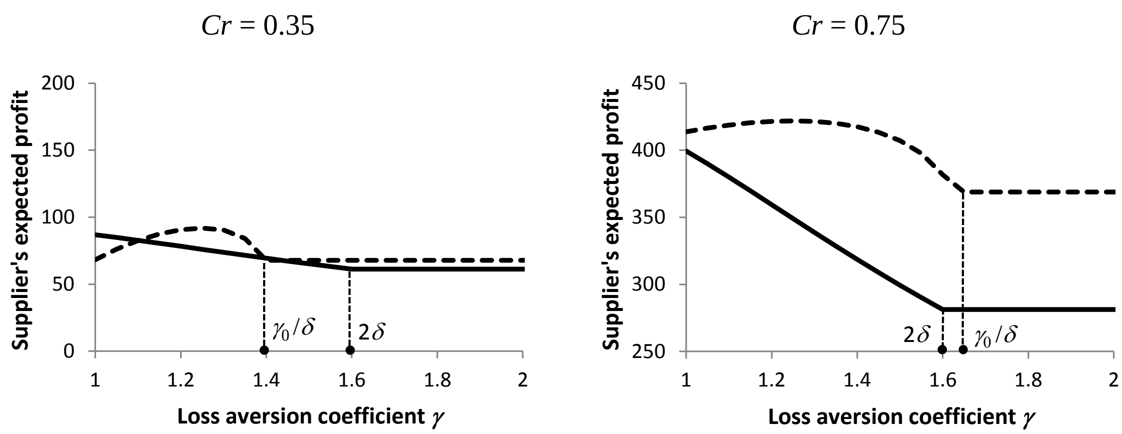
We continue using the utility functions that incorporate both loss aversion and prospective accounting, defined in section 3.6, for our analysis:

$$U_{S_{BB}}(w_b, b \mid q) = \delta(w_b - c)q - \gamma b(q - S(q)). \tag{4.10}$$

$$U_{S_{RS}}(w_r, r \mid q) = \begin{cases} \delta\gamma(w_r - c)q + rS(q) & \text{if } w_r < c \\ \delta(w_r - c)q + rS(q) & \text{otherwise.} \end{cases} \tag{4.11}$$

Figure 4.2 illustrates how the prior numerical example from Figure 4.1 changes when δ=0.8, which is a reasonable discount value based on prior research (e.g., Chen et al. 2012).

Figure 4.2: Supplier's expected profit under buyback (solid) and revenue sharing (dashed) contract with δ = 0.8.



Consistent with Proposition 4.2 and 4.3, the buyback contract now reduces to a wholesale price contract when $\gamma \geq 2\delta$ and the revenue sharing contract converges to $w_r = c$ when $\gamma \geq \gamma_0 / \delta$. In comparing the resulting expected profit across the two contracts, we see that the prediction for *Cr*=0.35 (Hypothesis 4.3a) continues to hold, while the prediction for *Cr*=0.75 (Hypothesis 4.3b) changes in a direction more consistent with the data (recall that Hypothesis 4.3b was previously only partially supported). For *Cr*=0.75, Figure 4.2 suggests that prospective accounting leads to an increase in the relative value of revenue sharing, and this dominance is significant for a wider range of loss aversion values (i.e., not only the high group). This prediction is consistent with our findings in experiment 2 where the revenue sharing contract yielded a higher expected profit than the buyback contract in the *Cr*=0.75 treatment for both low and high loss aversion groups.

4.5.1 Parameter Estimation

To determine the relative influence of loss aversion and prospective accounting on contract decisions, we estimate the value of γ and δ by fitting the experimental data to a behavior model. Following the approach used in prior research (e.g., Ho and Zhang 2008, Ho et al. 2010), we assume the observed wholesale price $w_{i,t}$ follows a normal distribution with mean $w^*(\gamma,\delta)$ and certain variance σ^2, where $w^*(\gamma,\delta)$ is the optimal wholesale price given γ, and δ (which can be computed numerically by solving the supplier's problem). We assume a separate variance for all four treatments, since the range of the wholesale prices differs with the contract type and critical ratio (Table 4.1). Based on these assumptions, the log-likelihood function for all four treatments takes the following form.

$$LL(\gamma,\delta,\sigma^2)=\sum_{i=1}^{n}\sum_{t=1}^{15}\left\{-\frac{1}{2}\ln 2\pi-\frac{1}{2}\ln\sigma^2-\frac{1}{2\sigma^2}\left(w_{i,t}-w^*(\gamma,\delta)\right)\right\}, \tag{4.12}$$

where n is the number of participants in each treatment (see Table 4.1). Note that the values of γ and δ are fixed across treatments while the values of σ^2 differ. We utilize Maximum Likelihood Estimation (MLE) to estimate γ, δ and the four variances. Table 4.6 reports the estimation results for this model, which we denote as Model-γ,δ.

The loss aversion coefficient γ is 1.20 which is significantly greater than 1 ($p<0.001$)[12]. This means for every dollar lost, the supplier needs to receive \$1.20 to be indifferent. The estimated prospective accounting factor $\delta = 0.90$, which is significantly smaller than 1 ($p<0.001$)[13], suggests that receiving one dollar before demand realization is equivalent to receiving \$0.90 after demand realization. These two estimated values provide interesting insights for understanding the framing of the two contracts. Under a revenue sharing contract, the supplier's initial loss is amplified by a factor of 1.20 due to loss aversion, but it is also discounted since the loss occurs before the sales, and thus the overall effect of this loss is $\gamma^{\delta}_{\mathrm{RS}} = \gamma * \delta = 1.08$. In other words, the supplier needs \$1.08 from the retailer after the selling season to compensate every dollar short at the beginning. On the other hand, under a buyback contract, since the discounted initial revenue makes the buyback loss more salient (an overall effect for the loss $\gamma^{\delta}_{\mathrm{BB}} = \gamma/\delta = 1.33$), the supplier now

[12] The estimated loss aversion coefficient in previous literature ranges from 1.27 to 3.06, suggesting that the estimated loss aversion coefficient is very context specific. However, in a similar context Ho and Zhang (2008) compare two-part tariff and quantity discount contracts and estimate the loss aversion coefficient to be 1.27 and 1.37, which is quite close to our estimate.

[13] In a similar context, Chen et al. (2012) estimate the prospective accounting factor for three payment schemes in a variety of situations. Their estimates range from 0.68 to 1.08 with a median of 0.80, which is also close to our estimate.

Table 4.6: MLE results for γ, δ, and variances.

	Model-γ,δ		Model-γ		Model-δ			Model-γ^h,γ^l,δ	
	Est.	S.E	Est.	S.E	Est.	S.E		Est.	S.E
γ	1.20	0.01	1.08	0.00	–	–	γ^l	1.12	0.03
							γ^h	1.25	0.01
δ	0.90	0.01	–	–	1.06	0.01		0.87	0.01
$\sigma^2_{BB,Cr=0.35}$	0.53	0.07	0.47	0.05	0.53	0.05		0.46	0.06
$\sigma^2_{BB,Cr=0.75}$	1.86	0.19	3.52	0.34	4.28	0.36		1.58	0.17
$\sigma^2_{RS,Cr=0.35}$	9.99	1.11	10.22	1.16	18.10	2.74		7.47	0.89
$\sigma^2_{RS,Cr=0.75}$	3.53	0.36	3.49	0.36	4.65	0.58		3.79	0.41
–LL	1,352.12		1,411.08		1,492.93			1,307.67	
BIC	2,743.72		2,855.06		3,018.76			2,629.34	
Likelihood Ratio Test:									
(test against Mode-γ,δ)			$\chi^2(1)$=117.9***		$\chi^2(1)$=123.6***			$\chi^2(1)$=-88.9***	

Note: ***p<0.001

requires \$1.33 as initial revenue to compensate every \$1 of buyback loss in the subsequent period. This result suggests that human suppliers perceive loss in different ways under buyback and revenue sharing contracts, due to the sequence in which loss occurs (before or after demand is realized). Specifically, the perceived buyback loss is 1.33/1.08 = 1.23 times greater than the initial revenue loss under revenue sharing.

To assess the relative importance of loss aversion and prospective accounting, we also estimate two nested models where we restrict $\gamma = 1$ (Model-δ) or $\delta = 1$ (Model-γ). To account for the problem of increase in the likelihood due to adding parameters (i.e., model overfitting), we use the Bayesian Information Criterion (BIC) index to compare fit between different models,

$$BIC = -2LL + k \log N, \tag{4.13}$$

where k is the number of free parameters to be estimated and N is the sample size. The BIC resolves the model overfitting problem by introducing a penalty term for the number of parameters in the model. The smaller the BIC index, the better the model fits the data. The model estimations for the two nested models are summarized in Table 4.6 ordered by the BIC index. The χ^2 values and the LRT test against Model-γ,δ are reported on the bottom.

The comparison between the two nested models and the full model (Model-γ,δ) provides us two interesting insights. First, both nested models are rejected at p=0.001 level, suggesting both loss aversion and prospective accounting are necessary for explaining the data. Secondly, since the model restricting $\delta = 1$ provides a better fit than the model restricting $\gamma = 1$ (the BIC index of Model-γ is smaller than that of Model-δ), loss aversion has a greater explanatory power than prospective accounting. Moreover, the estimated value of δ in Model-δ is larger than 1, which contradicts the prospective accounting theory that decision makers tend to underweigh current period transactions. This result further supports that prospective accounting along cannot fully explain the experimental data.

Table 4.6 also reports the results of a model (Model-γ^h,γ^l,δ) that fits a separate γ for the two loss aversion groups (low and high)[14]. The estimated γ is 1.25 for the high loss aversion group and 1.12 for the low loss aversion group. Compared with Model-γ,δ, the model fit significantly improves (p=0.000). It is not surprising that the estimated value of the loss aversion coefficient in contract decision experiment (task 1) is different from the measured individual loss aversion coefficient (task 2), since these values are sensitive to the problem context. What matters is that

[14] Recall that the grouping is based on measured loss aversion coefficient from task 2 using out-of-context questionnaire.

the *relative* level of loss aversion remains consistent across the two tasks. In other words, participants exhibiting high loss aversion in the individual loss aversion calibration task also exhibit higher loss aversion in the setting contract parameters task.

4.6 Other Behavioral and Environmental Tendencies

The experimental results corroborate the predictions of our model incorporating both loss aversion and prospective accounting. Although our model is rooted from well-established theories and the values of the behavioral parameters are reasonable, we recognize that there may be other factors that could also impact supplier behavior. In this section, we first identify one additional behavioral factor, minimizing ex post inventory error (MEPIE), and study its impact on supplier's contract decisions. We then examine the influence of two experimental factors, format of feedback information and decision complexity, through two new experiments.

4.6.1 Minimize Ex Post Inventory Error (MEPIE)

In the newsvendor context, the order quantity chosen by human decision makers tend to regress towards to the mean demand level, a phenomenon referred as "pull-to-center" effect (see section 2.1 for a complete literature review). Previous research has shown that this pull-to-center effect may be generated, in part, from the decision maker's tendency to minimize *ex post* inventory error. That is, decision makers anticipate regret or disappointment from not matching the realized demand (i.e., *ex post* inventory error), and try to reduce this regret. In our decision context, when making decisions on contract parameters, the supplier also experience regret from the retailer's *ex post* inventory error. For example, under a buyback contract, the supplier may regret if the retailer has either leftovers (incurring loss due to buyback cost) or stockouts (incurring loss due to lost sales)[15]. If such a phenomenon exists, it is conceivable that the supplier will choose contract parameters in a manner that minimizes her *ex post* inventory error (MEPIE).

We first examine whether the experimental data is consistent with the existence of an MEPIE effect. This is determined by computing the average of the retailer's order quantity (q^*) for each of the four treatments and comparing how much, in percentage, the observed average order quantity deviates from the channel optimal order quantity q^c. The results, summarized in Table 4.7, reveal that the difference between q^* and q^c for the Cr=0.75 treatments is significantly larger

[15] Ho et al. (2010) refer the loss due to leftovers as actual loss, and the loss due to stockouts as forgone loss.

than for the Cr=0.35 treatments (23.6% vs. 0.86% for buyback; 12.8% vs. 7.14% for revenue sharing).

Table 4.7: Resulting retailer's order quantity (q^*).

	Buyback		Revenue sharing	
	q^*	% vs q^c	q^*	% vs q^c
Cr=0.35	34.7	0.86%	32.5	7.14%
Cr=0.75	57.3	23.6%	65.4	12.8%

Note: q^c=35 for Cr=0.35 and q^c=75 for Cr=0.75.

This asymmetric deviation of the resulting order quantity across the two critical ratios is consistent with the MEPIE effect. For example, under a buyback contract, Proposition 4.2 predicts that a loss averse supplier will set the wholesale price below the channel optimal value, w^c, causing the retailer to order less than q^c. In the low critical ratio environment, since the optimal order quantity is below the mean demand, the effect of MEPIE pushes the supplier to adjust her parameter choices such that the resulting retailer's order quantity is closer to the mean demand. These two effect could counteract with each other, leading the resulting order quantity q^* close to q^c. In contrast, under high critical ratio environments, since the retailer's order quantity is already above the mean demand, MEPIE and loss aversion reinforce each other and move the retailer's order quantity further below q^c.

This reasoning can also explain why the decrease in expected profit with loss aversion is much stronger in the Cr=0.75 treatment than in the Cr=0.35 treatment (see Table 4.4 and the discussion in section 4.4.2 for detail). In the Cr=0.35 treatment, the contract parameters set by a supplier with low loss aversion are close to the channel optimal, resulting in a close to optimal expected profit. However, the effect of MEPIE could lead them to deviate from this nearly optimal solution in order to increase the order quantity (since the original order quantity is below the mean demand), thus resulting in a decrease in the expected profit. On the other hand, for a highly loss averse supplier, the effect of loss aversion dominates MEPIE, and so the supplier chooses to reduce losses. This leads a decrease in both the resulting retailer's order quantity and expected profit (as suggested in Proposition 4.2). This is consistent with our data: there is no significant difference in expected profit between loss aversion levels for the Cr=0.35 treatment. On the contrary, in the Cr=0.75 treatment, our theory predicts that the effect of MEPIE will reduce the order quantity and thus the supplier's expected profit regardless of the loss aversion level. As a result, MEPIE will have no significant influence on the supplier's expected profit comparison across loss aversion groups. In other words, a supplier with low loss aversion will still achieve a higher profit, compared with a supplier with low loss aversion. This is also consistent with our data.

We next structurally estimate the value of the MEPIE effect to determine its relative impact compared with loss aversion and prospective accounting. To expand supplier's utility function to incorporate the MEPIE effect, let $Er(q)$ be the expected value of the ex post inventory error at order quantity q where

$$Er(q) = \int_0^\infty |q - x| \, f(x) dx. \tag{4.14}$$

Also, let α denote the magnitude of the disutility from not matching the demand (i.e., ex post inventory error). Schweitzer and Cachon (2000) allows this penalty term to be any increasing function of the inventory error. Bostian et al. (2008) estimated several MEPIE models with different power form (i.e., $|q - x|$, $|q - x|^2$, $|q - x|^3$, etc.) using data from newsvendor experiments and found that linear form (power of one) and quadratic form (power of two) perform almost identically while higher powers fit even worse. Thus, in our model, we use the linear parameterization. The supplier's new utility function, incorporating loss aversion, prospective accounting, and MEPIE, is then

$$U_{S_{BB}}(w_b, b \mid q) = \delta(w_b - c)q - \gamma b(q - S(q)) - \alpha Er(q), \tag{4.15}$$

$$U_{S_{RS}}(w_r, r \mid q) = \begin{cases} \delta\gamma(w_r - c)q + rS(q) - \alpha Er(q) & \text{if } w_r < c \\ \delta(w_r - c)q + rS(q) - \alpha Er(q) & \text{otherwise.} \end{cases} \tag{4.16}$$

Following the estimation procedures described in section 4.5.1, we fit the full model containing all three behavioral parameters (Model-γ,δ,α) with the results summarized in Table 4.8. The table also contains six nested models: three two-parameter models with each restricting one behavioral parameter to its default value ($\gamma = 1$, $\delta = 1$ or $\alpha = 0$), and three one-parameter models that restricts two parameters to their default value. All seven models are ordered by their BIC value, calculated using formula (4.13). The three models with $\alpha = 0$ (Model-γ,δ, Model-γ, and Model-δ) are identical to those reported in Table 4.6.

Table 4.8: MLE results for γ, δ, α and variances.

	Model-γ,δ,α		Model-γ,α		Model-γ,δ		Model-γ	
	Est.	S.E	Est.	S.E	Est.	S.E	Est.	S.E
γ	1.27	0.01	1.16	0.01	1.20	0.01	1.08	0.00
δ	0.90	0.01	–	–	0.90	0.01	–	–
α	0.17	0.01	0.20	0.01	–	–	–	–
$\sigma^2_{\mathrm{BB,Cr=0.35}}$	0.44	0.05	0.54	0.06	0.53	0.07	0.47	0.05
$\sigma^2_{\mathrm{BB,Cr=0.75}}$	1.74	0.17	2.33	0.23	1.86	0.19	3.52	0.34
$\sigma^2_{\mathrm{RS,Cr=0.35}}$	9.90	1.09	9.92	1.09	9.99	1.11	10.22	1.16
$\sigma^2_{\mathrm{RS,Cr=0.75}}$	2.18	0.22	2.22	0.23	3.53	0.36	3.49	0.36
–LL	1,283.97		1,332.22		1,352.12		1,411.08	
BIC	2,613.99		2,709.92		2,743.72		2,855.06	
Likelihood Ratio Test: (test against Model-γ,δ,α)			$\chi^2(1)$=96.5***		$\chi^2(1)$=136.3 ***		$\chi^2(2)$=254.2***	

Note: ***p<0.001

Table 4.8 (continued)

	Model-δ,α		Model-α		Model-δ	
	Est.	S.E	Est.	S.E	Est.	S.E
γ	–	–	–	–	–	–
δ	1.14	0.01	–	–	1.06	0.01
α	0.18	0.02	0.58	0.04	–	–
$\sigma^2_{BB,Cr=0.35}$	0.83	0.10	0.82	0.09	0.53	0.05
$\sigma^2_{BB,Cr=0.75}$	4.45	0.44	2.51	0.26	4.28	0.36
$\sigma^2_{RS,Cr=0.35}$	10.02	1.12	25.60	2.77	18.10	2.74
$\sigma^2_{RS,Cr=0.75}$	2.18	0.22	2.19	0.22	4.65	0.58
–LL	1,431.13		1,446.48		1,492.93	
BIC	2,901.74		2,925.86		3,018.76	
Likelihood Ratio Test: (test against Model-γ,δ,α)	$\chi^2(1)=294.3$***		$\chi^2(2)=325.0$***		$\chi^2(2)=417.9$***	

Note: ***$p<0.001$

All six nested models are rejected at the p=0.001 level (using the LRT test against the full Model-γ,δ,α), suggesting all three behavioral effects, loss aversion, prospective accounting, and MEPIE are necessary for explaining the data. Among the three two-parameter models, Model-δ,α fits the worst, meaning that restricting γ = 1 significantly reduces the explanatory power, compared to models restricting δ = 1 or α = 0. This suggests that loss aversion is the most important factor for explaining the experimental data. Additionally, since the model without prospective accounting (Model-γ,α) fits better than the model without MEPIE (Model-γ,δ), MEPIE appears to be the second most dominant factor. The model fit for one-parameter models also confirms this conclusion (Model-γ fits better than Model-α, which fits than Model-δ).

4.6.2 Information Feedback

So far we have identified three behavioral parameters (loss aversion, prospective accounting and MEPIE) and found that loss aversion is the most influential factor while prospective accounting is the least. In this section, we conduct a new set of treatments, labeled as experiment 3a, which are designed to emphasize the effect of prospective accounting by changing the format of information feedback. This allows us to test whether prospective accounting is indeed a contributing factor, rather than simply being consistent with the data.

Recall that in experiment 2 we described the financial transactions that would occur before and after demand is realized *in words* (see last paragraph in section 4.3 for detail). In experiment 3a, we continue using words to describe the transaction in the first period (before demand realization, top panel of Figure 4.3), but present the possible outcomes for the second period (after demand is realized) in graphical format. For example, in the buyback contract treatment, instead of using words to state the minimum and maximum value of the possible buyback cost (Figure 4.3 left panel on the bottom), we use a histogram that contains 101 rectangles with each corresponding to the buyback cost for one demand realization[16] (Figure 4.3 right panel on the bottom). The histogram for the revenue sharing contract treatment follows a similar format.

[16] Recall that the demand follows $U(0,100)$, resulting in 101 possible demand outcomes.

Figure 4.3: Feedback information for experiment 2 and experiment 3a

Buyback contract

Information feedback for period 1

At the beginning of the week,

The store orders	**75** units.
You incur a unit production cost of	$5, and receive an initial unit payment of $16.2.
So you have	($16.2 - $5) / unit X 75 units= $840.0

Information feedback for period 2

Experiment 2

At the end of the week,

You will pay the store	$14.9 for each unit of inventory leftover.
When demand is less than	75 , you pay the store $14.9 X (75 - Demand).
	(in the range of [$0.0 , $1117.5]).
When demand is greater than or equal to	75 , you pay the store $14.9 X 0 = $0.

Experiment 3a

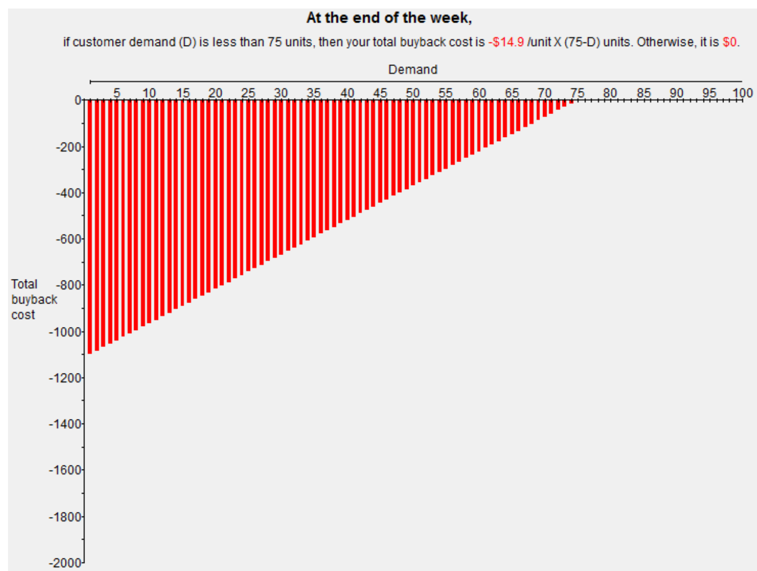


Figure 4.3: (continue)

Revenue sharing contract

Information feedback for period 1

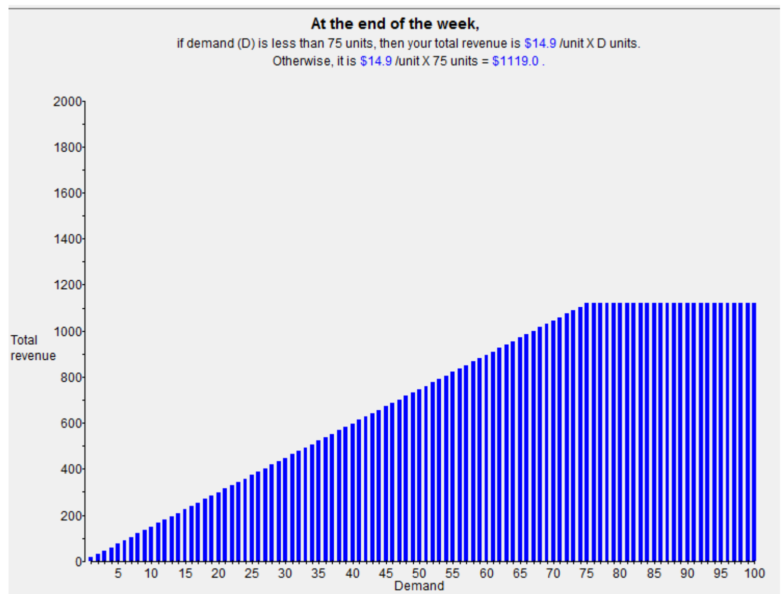
At the beginning of the week,	
the store orders	**75** units
You incur a unit production cost of	$5, and receive an initial unit payment of $1.3.
So you have	($1.3 - $5) / unit X 75 units= -$277.5

Information feedback for period 2

Experiment 2

At the end of the week,	
You will receive from the store	$14.9 for each unit of inventory sold.
When demand is less than	75 , you receive from the store $14.9 X Demand.
	(*in the range of [$0 , $1119.0]*).
When demand is greater than or equal to	75 , you receive from the store $14.9 X 75 = $1119.

Experiment 3a



Using a histogram helps highlight the full range of outcomes that could occur in the second period, instead of just the minimum and maximum values. This more comprehensive feedback information further emphasizes the actual uncertainty involved in the second period, and thus may lead the supplier to focus more on this uncertainty. In other words, it amplifies the effect of prospective accounting, and thus we expect prospective accounting will play a greater role in this situation.

The remaining design and protocol for experiment 3a are identical to experiment 2. Detailed instruction and experimental screen shots are included in Appendix E. 49 participants were recruited from the Carlson School subject pool and were paid based on their performance, similar to experiment 2.

Following the estimation procedures described in section 4.5.1, we again estimate seven behavioral models, and the results are summarized in Table 4.9. The models are ordered based on the BIC index with smaller BIC values indicating a better fit. Compared with the model estimation for experiment 2 (Table 4.8), we observe a smaller value of prospective accounting parameter (δ = 0.81 for experiment 3a and 0.90 for experiment 2). This result confirms our prediction that the effect of prospective accounting is stronger. Moreover, the two-parameter nested model restricting $\alpha = 0$ (Model-γ,δ) fits better than the model restricting $\delta = 1$ (Model-γ,α), suggesting that prospective accounting now has greater explanatory power than MEPIE (recall that in experiment 2, MEPIE has greater explanatory than prospective accounting). The two one-parameter models, Model-α and Model-δ, perform almost identical (the difference in BIC index is as small as 3.92), while in experiment 2 Model-α clearly outperforms Model-δ (BIC difference of 92.90). This evidence further confirms that prospective accounting plays a more important role in explaining the experimental data. On the other hand, loss aversion still has the greatest explanatory power.

We finally fit the two regression models defined in (4.8) and (4.9), with the results included in Table F.1 in Appendix F. The regression models provide very similar results to those in experiment 2. Prospective accounting has little influence on how contract parameters and the resulting expected profits change with loss aversion.

Table 4.9: MLE results for γ, δ, α_0 and variances for experiment 3a

	Model-γ,δ,α		Model-γ,δ		Model-γ,α		Model-γ	
	Est.	S.E	Est.	S.E	Est.	S.E	Est.	S.E
γ	1.39	0.01	1.29	0.01	1.14	0.01	1.06	0.00
δ	0.81	0.01	0.82	0.01	–	–	–	–
α	0.23	0.02	–	–	0.21	0.01	–	–
$\sigma^2_{\mathrm{BB,Cr=0.35}}$	0.46	0.05	0.84	0.11	0.61	0.06	0.51	0.05
$\sigma^2_{\mathrm{BB,Cr=0.75}}$	1.01	0.11	1.21	0.16	4.30	0.49	6.78	0.75
$\sigma^2_{\mathrm{RS,Cr=0.35}}$	8.82	0.84	8.85	0.84	8.83	0.84	9.09	0.88
$\sigma^2_{\mathrm{RS,Cr=0.75}}$	1.88	0.21	3.18	0.35	1.88	0.21	3.11	0.34
–LL	1,271.99		1,383.36		1,415.67		1,481.45	
BIC	2,590.18		2,806.32		2,870.94		2,995.90	
Likelihood Ratio Test:								
(test against Model-γ,δ,α)			$\chi^2(1)$=222.74***		$\chi^2(1)$=287.36***		$\chi^2(2)$=418.92***	

Note: ***p<0.001

Table 4.9 (continued)

	Model-δ,α		Model-α		Model-δ	
	Est.	S.E	Est.	S.E	Est.	S.E
γ	–	–	–	–	–	–
δ	1.11	0.01	–	–	1.05	0.01
α	0.18	0.02	0.44	0.02	–	–
$\sigma^2_{\mathrm{BB,Cr=0.35}}$	0.89	0.10	0.88	0.08	0.64	0.07
$\sigma^2_{\mathrm{BB,Cr=0.75}}$	7.64	0.86	4.75	0.44	8.85	0.98
$\sigma^2_{\mathrm{RS,Cr=0.35}}$	8.85	0.84	16.06	1.33	8.79	0.83
$\sigma^2_{\mathrm{RS,Cr=0.75}}$	1.85	0.21	1.85	0.17	3.28	0.37
–LL	1,495.85		1,523.10		1,525.06	
BIC	3,031.30		3,079.20		3,083.12	
Likelihood Ratio Test:						
(test against Model-γ,δ,α)	$\chi^2(1)=447.72$***		$\chi^2(2)=502.22$***		$\chi^2(2)=506.14$***	

Note: ***$p<0.001$

4.6.3 Decision Complexity

In experiment 2, participants chose the wholesale price *w* while the associated optimal *b* or *r* was optimized for them. This task design allowed us to examine how contract decisions are influenced by decision maker's judgment biases by controlling for the decision complexity so that derivations from normative theory could be more likely be attributed to the decision makers preferences (utility function). However, it is interesting to examine how contract performance differs when decision makers are free to set both parameters. This is the main purpose of experiment 3b.

In experiment 3b we follow the same protocol as experiment 2 (with consistent format of information feedback for the two periods), except that we now allow participants to set both parameters. For example, under the buyback contract, the participants were given two scrollbars, one to set the initial wholesale price *w* and the other to set the buyback parameter *b*. In order to match our theory that the supplier must provide a minimum level of profit to the retailer, we provided the participants a lowest possible value for the buyback parameter, b_{min}, which is calculated using formula (4.5). If a participant sets *b* below this value, his order quantity and profit default to 0. For the revenue sharing contract, there is a highest possible value for the revenue sharing parameter, r_{max}, calculated using (4.7), and the participants were restricted to set the revenue sharing parameter *r* below this maximum. The instruction and experimental screen shots are included in Appendix E. 48 new participants were recruited from the Carlson School subject pool for this experiment and were paid based on their performance, similar to experiment 2.

We examine how decision complexity influences the supplier's contract decisions and the profit comparison between contracts by fitting the two regression models defined in (4.8) and (4.9). The model fits are summarized in Table 4.10.

Table 4.10: FGLS estimation for $w_{i,t}$ and $E(\pi)_{i,t}$ for experiment 3b.

(a) $w_{i,t}$			(b) $E(\pi)_{i,t}$		
	BB	RS		Cr=0.35	Cr=0.75
Intercept	17.98*** (0.12)	4.19*** (0.31)	*Intercept*	50.17** (18.86)	392.82*** (7.89)
Cr	-2.64*** (0.30)	-1.36** (0.41)	H^{γ}	20.72 (19.44)	-11.29 (10.17)
H^{γ}	-0.29 (0.18)	2.36* (1.14)	BB	18.15 (19.85)	-5.38 (11.15)
$Cr \times H^{\gamma}$	-0.66† (0.40)	-1.45 (1.21)	$H^{\gamma} \times$ BB	-14.11 (21.24)	-21.51 (13.55)
σ_{μ}	0.47***	1.62***	σ_{μ}	22.14***	13.81***

Note: *** p<0.001 ** p<0.01 * p<0.05 † p<0.1

Note: robust standard deviations are reported in parentheses.

Following the same steps in section 4.4, we test Hypothesis 4.1-3 using this new experimental data set. We first examine whether the wholesale price changes with loss aversion (Hypothesis 4.1) by testing two linear constraints, $\beta_{H^{\gamma}}$ and $\beta_{H^{\gamma}} + \beta_{Cr \times H^{\gamma}}$. From the results summarized in Table 4.11, we see that Hypothesis 4.1 is supported, though at a less significant level, compared with the results in experiment 2 (Table 4.3). This suggests that decision complexity does have an impact, but loss aversion can still predict contract decisions when complexity is higher. This result is consistent with the findings in Ho and Zhang (2008) where they compared two theoretical equivalent contracts – two part tariff and quantity discount – and found that loss aversion had greater explanatory power than contract complexity.

Table 4.11: Wald test for Δw_i for experiment 3a.

	BB	RS
Cr=0.35	$\beta_{H^{\gamma}}$ = -0.29 p=0.059	$\beta_{H^{\gamma}}$ =2.36 p=0.020
Cr=0.75	$\beta_{H^{\gamma}} + \beta_{Cr \times H^{\gamma}}$ = -0.95 p=0.004	$\beta_{H^{\gamma}} + \beta_{Cr \times H^{\gamma}}$ = 0.91 p=0.013

We next examine how the achieved profit changes with loss aversion (Hypothesis 4.2) and with the type of contact (Hypothesis 4.3). The results for the linear constraint test are summarized in Table 4.12 and Table 4.13. For the *Cr*=0.35 treatments, consistent with experiment 2, the supplier's expected profit does not significantly differ either across loss aversion groups or between the buyback and revenue sharing contracts.

Table 4.12: Wald test for $\Delta E(\pi)$ by loss aversion groups for experiment 3b.

	BB	RS
Cr=0.35	$\beta_{H^\gamma} + \beta_{H^\gamma \times BB}$ =6.61 p=0.220	β_{H^γ} = 20.72 p=0.144
Cr=0.75	$\beta_{H^\gamma} + \beta_{H^\gamma \times BB}$ = -32.80 p=0.000	β_{H^γ} = -11.29 p=0.134

Table 4.13: Wald test for $\Delta E(\pi)$ by contract types for experiment 3b.

	Cr=0.35	*Cr*=0.75
Low γ	β_{BB} = 18.15 p=0.361	β_{H^γ} = -5.38 p=0.630
High γ	$\beta_{\mathrm{BB}} + \beta_{H^\gamma \times \mathrm{BB}}$ = 4.04 p=0.593	$\beta_{H^\gamma} + \beta_{Cr \times H^\gamma}$ = -26.89 p=0.001

In contrast, the impact of decision complexity influences the *Cr*=0.75 treatments in two interesting ways. First, under the revenue sharing contract, participants achieve similar profits regardless of their loss aversion level (β_{H^γ} is not significantly negative as shown in Table 4.12), while under the buyback contract, participants with a low loss aversion level achieve a higher profit level, and profit difference is more significant compared to the results in experiment 2. This implies that decision complexity diminishes the explanatory power of loss aversion under the revenue sharing contract but increases it under the buyback contract. Secondly, as shown in Table 4.13, revenue sharing yield higher expected profit than buyback for the high loss aversion group, but no longer for the low loss aversion group[17].

Finally, we estimate the behavioral models described in section 4.6.1. The models provide similar insights as experiment 2. Detailed model estimations are included in Table F.2 in Appendix F. Note that we are not able to quantify the magnitude of decision complexity on performance using our experimental data. We have tried using the quantal response framework

[17] Recall that in experiment 2 we found revenue sharing dominates buyback for both low and high loss aversion groups.

developed by Su (2008), but this model does not provide reasonable values for all the behavioral parameters. Part of the reason is that having so many behavioral factors in one experiment makes it hard to identify the impact of each factor on contract decisions, since several behavioral tendencies may be confounded with each other. Nevertheless, experiment 3b provide a starting point for investigating how decision errors due to contract complexity will influence the comparison between buyback and revenue sharing contracts. We leave more rigorous studies for future research.

4.7 Concluding Remarks

The goal of this chapter was to determine how framing differences between buyback and revenue sharing contracts influence a supplier's decisions on how contract parameters are set, and ultimately which contract results in higher final expected profit for the supplier's firm (after accounting for the supplier's parameter-specification behavior). We find differences in performance between the two contracts when suppliers have the authority to set contract parameters. Revenue sharing is more profitable for the supplier in high critical ratio environments while the contracts perform equally well in low critical ratio environments. These insights appear to be primarily driven, or at least are consistent with, the presence of loss aversion. Prospective accounting also appears to have a supporting role.

A unique feature for risk-sharing contracts, such as buyback and revenue sharing, is that the inventory risks (due to demand uncertainty) are properly shared between supplier chain members. As a result, the supplier's actual profit is influenced by any mismatch between retailer's order quantity and the realized market demand (i.e., *ex post* inventory error). Due to this demand uncertainty, the supplier tends to minimize *ex post* inventory error, causing the retailer's order quantity to exhibit the "pull-to-center" effect. While the pull-to-center effect is a well-known phenomenon in the newsvendor context when buyers make ordering decisions, we are the first to document that this phenomenon also exists in the supplier's contract decisions.

We finally examine whether and how the supplier's decisions and contract performance are affected by two environmental factors – format of information feedback and decision complexity. We find that when demand uncertainty is emphasized, decision makers tend to put more weight on transactions in the later period, and thus the effect of prospective accounting becomes stronger. This makes revenue sharing more attractive to the supplier. In contrast, decision complexity diminishes the attractiveness of the revenue sharing contract, making the two contracts indistinguishable in many situations. Despite the influence of these two environment factors, loss aversion remains the predominant behavioral factor in explaining the supplier's decisions and contract performance.

Chapter 5:

Influence of a Retailer's Behavioral Tendencies on the Supplier's Contract Problem

5.1 Introduction

In chapters 3 and 4 we examined the supplier's contract decisions by solving the following problem from the supplier's point of view.

$$\max U_S$$

$$\text{s.t} \quad \partial \pi_R(q) / \partial q = 0 \tag{5.1}$$

$$\pi_R(q) \geq M. \tag{5.2}$$

We also identified the optimal contract parameters set by the profit maximizing supplier to be

$$w_b^c = c + \lambda(p-c), \quad b^c = \lambda p; \quad w_r^c = (1-\lambda)c, \quad r^c = \lambda p. \tag{5.3}$$

Under the optimal contract, the supplier extracts $\lambda = 1 - \frac{M}{\pi^c}$ share of the channel profit.

This problem formulation is based on three critical assumptions. First, as implied by constraint (5.1), the retailer is perfectly rational and always able to optimize his utility (profit). Secondly, the supplier knows the exact value of the retailer's reservation profit, and thus is able to design a contract that will always be accepted by the retailer, implied by constraint (5.2). Finally, the retailer only cares about expected profit without any judgment biases (such as loss aversion and prospective accounting). In other words, assuming π_R rather than the more general U_R.

In this chapter, we identify possible ways to relax each of the three assumptions, drawing from the existing literature and empirical evidence. We also investigate how these changes in assumptions may influence the supplier's contract problem, assuming the supplier is a profit maximizer. In other words, assuming that the supplier's decisions are not impacted by behavioral regularities. The results for each assumption are summarized in sections 5.2, 5.3, and 5.4. We comment on how these retailer induced factors may impact the more general supplier's problem, where the supplier is also subject to behavioral tendencies.

5.2 Bounded Rationality

Recent experimental studies have shown that human decision makers often make errors when attempting to optimize. In other words, they are boundedly rational. One possible way of capturing bounded rationality is quantal choice theory. This theory suggests that decision makers do not always choose the utility-maximizing option. Instead, they treat all possible solution alternatives as candidates for selection, and alternatives with higher utility are chosen with larger probabilities. This probabilistic choice setup implies that decision makers are subject to decision noise, which may result in suboptimal decisions. Su (2008) applied this quantal choice framework to several newsvendor-type inventory settings, including supply chain coordination and contracting problems, and found the results are consistent with a wide range of experimental observations. In this section, we adopt Su's approach to illustrate how the introduction of bounded rationality at the retailer level may influence the supplier's problem.

When setting the order quantity q, quantal choice theory suggests that rather following constraint (5.1), a boundedly rational retailer assign probabilities to all the possible order quantity choices from 0 to B. Applying the multinomial logit choice model by Su (2008), we can obtain the probability density function of the order quantity chosen by a boundedly rational retailer, q_{BR}, which is given by

$$\psi(q) = \frac{e^{\rho \pi_R(q)}}{\int_0^B e^{\rho \pi_R(q)} f(v) dv}. \tag{5.4}$$

The order decision q_{BR} represents the general order quantity that is independent of whether the contract is buyback or revenue sharing. In this density function, ρ captures the decision maker's rationality level. As $\rho \to 0$, the choice distribution converges to a uniform distribution. In this case, the decision maker makes random choices over all the options with equal probabilities. On the other hand, as $\rho \to +\infty$, the choice distribution becomes entirely concentrated on the utility maximizing option that a perfectly rational decision maker would choose. Unlike the profit maximizing retailer who will always set $q^c = Cr$B, the order quantity chosen by a boundedly rational retailer, q_{BR}, is now a random variable.

Su (2008) shows that if D ~ U[0, B], q_{BR} follows truncated normal distribution over [0, B], with mean μ and variance σ^2 given by

$$\mu = q^c, \tag{5.5}$$

$$\sigma^2 = \frac{B}{\rho p}. \tag{5.6}$$

The expected value of q_{BR} is

$$Eq_{BR} = \mu - \sigma \cdot \frac{\phi\left(\frac{B-\mu}{\sigma}\right) - \phi\left(\frac{0-\mu}{\sigma}\right)}{\Phi\left(\frac{B-\mu}{\sigma}\right) - \Phi\left(\frac{0-\mu}{\sigma}\right)}, \tag{5.7}$$

where $\phi(\bullet)$ and $\Phi(\bullet)$ denote the standard normal density and distribution functions. The parameter μ is consistent with the optimal order quantity q^c, because q^c maximizes the retailer's expected profit and thus should be the mode of the solution. Moreover, the variance σ^2 is inversely proportional to ρ because bounded rationality (smaller ρ) increases noise in the decision making process. These solutions suggest that if $Cr \neq 0.5$, the mean order quantity chosen by the boundedly rational retailer always deviates from the optimal solution q^c. When $Cr = 0.5$, although the mean order quantity Eq_{BR} coincides with the optimal solution q^c, the actual q_{BR} can still differ from q^c due to randomness.

We next examine how this retailer behavior influences the contract parameter decision for a supplier who wishes to maximize her local profit. Consider first the case where $Cr = 0.5$. In this case, although the order quantity of the boundedly rational is random, the mean value is still q^c and thus the retailer's expected profit level will not change. Consequently, the supplier does not have any incentive to deviate from the optimal contract parameters defined in (5.3).

However, when $Cr \neq 0.5$, under the contract parameters defined in (5.3), the retailer's expected order quantity will deviate from the optimal q^c due to bounded rationality. This leads the retailer's expected profit to be lower than *M*, which violates the constraint (5.2)[18]. Therefore, the supplier must adjust the contract parameters to ensure the retailer's expected profit $\pi_R(Eq_{BR})$ is at least *M*, which decreases her own share of the channel profit. In other words, the supplier will set a lower λ, which leads to a decrease in wholesale price for buyback contract and an increase in wholesale price for the revenue sharing contract.

The magnitude of the bounded rationality parameter ρ will also influence the contract performance. When the retailer becomes less rational (ρ increases), the variance of the order decisions increases. This larger decision noise causes the mean order quantity Eq_{BR} to move further away from the optimal solution q^c, leading to a much smaller expected profit achieved by the retailer. As a result, the supplier must give up more share of her profit in order to ensure the retailer's expected profit $\pi_R(Eq_{BR})$ to be at least *M*. Thus, the supplier's profit decreases as the retailer becomes more irrational.

This modified ordering behavior may also impact the retailer's evaluation of the reservation profit *M*. For example, *M* could be represented by the profit the retailer achieves under a wholesale price contract. In this case, a boundedly rational retailer is likely to achieve a different profit level than a profit maximizing retailer, leading to a change in the evaluation of *M*. If the supplier is not aware of this difference, she may make an inappropriate offer, which in turn results in a reduced profit.

Introducing retailer's bounded rationality does not influence the supplier's comparison between buyback and revenue sharing contracts. In other words, the two contracts are still equivalent in terms of expected profit achieved by the supplier, as long as the retailers under both contracts share the same bounded rationality parameter ρ. This is because the bounded rationality affects the distribution of the retailer's order quantity but is independent of the contract type. Su (2008) studied the influence of bounded rationality on supply chain coordination and found that "the model of bounded rationality explains why coordination does not occur, but does not distinguish between different contractual forms that align incentives in the same way." Our finding is consistent with Su's conclusion.

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[18] Recall that under (5.3), a profit maximizing retailer will order q^c and the resulting expected is equal to *M*.

5.3 Rejection Risk

In our prior model, we defined a known and constant reservation profit (M) for the retailer, and assumed the retailer would only accept contract terms when his expected profit is at least M. This assumption is the basis for establishing constraint (5.2). Under this formulation, we find that the supplier will set contract terms such that the retailer's profit is exactly equal to M and the retailer will never reject such a contract.

In this section, we modify this assumption by allowing the retailer's reservation M to be random, capturing the possibility that the supplier does not know the exact value of M due to information asymmetry, but has knowledge of how M is distributed. Under this modification, it becomes possible that the supplier's perception of M is below the real M. As a result, a contract offered by the supplier based on this undervalued perception may be rejected by the retailer, introducing the notion of *rejection risk*.

In additional to information asymmetry, prior research points out two alternative reasons that a retailer may reject a contract offer. First, the retailer may have fairness concerns (Fehr and Schmidt 1999; Katok et al. 2012). As such, he cares not only about his own profit level, but also about the relative profit level of the supplier. This may lead a fair-minded retailer to reject a contract due to its resulting disutility from the profit inequity (i.e., the profit difference between the two players). Secondly, the retailer may make errors in assessing his profit potential and thus mistakenly reject contracts that provide a profit level above M (Katok and Pavlov 2013). This is consistent with the assumption that decision makers are boundedly rational (discussed in section 5.2) and not be able to optimize.

Recent behavioral research has found that in buyer-supplier interaction experiments, human retailers do reject seemingly profitable contract offers with some probability (e.g., Katok and Pavlov 2013, Katok et al. 2012, Ho and Zhang 2008, Wu 2012). In these papers, the empirical rejection rate ranges from 0.43% to 25.76%, depending on the type of contract, resulting profit allocation between supply chain members, and nature of the interaction (e.g., whether people interact with the same or different partners over time). This experimental evidence confirms that the supplier will face rejection risks from the downstream retailers, and therefore their contract offers will not always be accepted.

In this section, we will investigate what impact rejection risk has on the supplier's contract parameter decision and resulting expected profit. To do this, we introduce a new constraint that captures the uncertainty of the retailer's reservation profit M. Let $g(\bullet)$ denote the density function of the distribution of M, and $G(\bullet)$ denote the distribution function. We assume the support of $g(\bullet)$ is positive and bounded above by the maximum expected profit of the channel (i.e., $0 \le M \le \pi^c$). Let η denote the probability that a retailer will accept the contract offer for a given π_R. In other words, the probability that π_R is equal to or greater than M is given by

$$\eta = \Pr\left(M \le \pi_R\right) = G\left(\pi_R\right), \tag{5.8}$$

where $(1-\eta)$ then denotes the probability of rejection.

This definition of rejection risk represents the situation where M is retailer's private information and the supplier's only knows its distribution (i.e., information asymmetry). However, this characterization is rather general and can capture the two additional reasons that rejection risk may occur as mentioned above, namely, fairness concern and bounded rationality. For example, if a retailer is fair-minded, his utility function may be modified as follows (adapting the classic fairness model of Fehr and Schmidt 1999),

$$U_R(\bullet) = \pi_R - a_1 \max(b\pi_S - \pi_R, 0) - a_2 \max(\pi_R - b\pi_S, 0), \tag{5.9}$$

where a_1 and a_2 are the retailer's fairness parameters. We can then define the retailer's reservation profit as:

$$M = a_1 \max(b\pi_S - \pi_R, 0) + a_2 \max(\pi_R - b\pi_S, 0), \tag{5.10}$$

which is equivalent to the retailer's disutility from profit inequity. If M is greater than π_R, the retailer's utility U_R is negative, and so he will be better off rejecting the contract offer. Moreover, if the values of a_1 and a_2 are retailer's private information (Katok et al. 2012), M will be a random variable with density function $g(\bullet)$, which is determined by the supplier's belief on a_1 and a_2 .

Secondly, if the retailer is boundedly rational, the retailer will make errors causing them to mistakenly reject favorable contracts. Using Su (2008)'s formulation, the probability that the retailer will accept the contract is

$$\eta = G(\pi_R) = \frac{e^{\rho(\pi_R - M)}}{e^{\rho(\pi_R - M)} + 1}. \tag{5.11}$$

The distribution function $G(\bullet)$ is then determined by the retailer's rationality parameter ρ.

Incorporating rejection risk into the supplier's problem requires changing the definition of utility. The utility function is now:

$$U_S = \pi_S \times \eta = \pi_S G\left(\pi_R\right), \tag{5.12}$$

which is simply the supplier's profit (if the contract is accepted) multiplied by the probability that the contract is accepted. Recall that under conditions (5.3) the supplier's share of the channel profit is determined by the parameter λ. The supplier's utility function can also be expressed as a function of λ:

$$U_S(\lambda) = \lambda\pi^c \times G\Big((1-\lambda)\pi^c\Big). \tag{5.13}$$

Solving for the supplier's optimal contract parameters (w_b^*, b^*) and (w_r^*, r^*) that maximize her utility, it is equivalent to finding the optimal λ^*. The optimal contract parameters can then be obtained by plugging λ^* into (5.3).

To gain insight into the value of λ^*, consider how the supplier's utility changes with λ. When the supplier choose to retain a large portion of the channel profit ($\lambda \to 1$), the likelihood of the contract being accepted by the retailer is very small. This implies that the supplier will get zero profit with high probability, leading to a low expected profit level for the supplier. On the other hand, if the supplier offers a large portion of the profit to the retailer ($\lambda \to 0$), it is clear that her expected profit is also very small. Thus there exists some optimal λ (between 0 and 1) under which the supplier's utility is maximized.

To gain more insights into the structure of the optimal λ^* we need to make more specific assumptions about the distribution of M. For example, consider the case where M follows a uniform distribution $U[\underline{M}, \overline{M}]$ with lower and upper bounds of $\underline{M} = \theta_1\pi^c$ and $\overline{M} = \theta_2\pi^c$, respectively, where $0 \leq \theta_1 < \theta_2 \leq 1$. Further, let $\theta_0 = (\theta_1 + \theta_2) / 2$ be the mean of θ_1 and θ_2, and $2\theta = (\theta_2 - \theta_1)$ be the range. The lower and upper bounds can then be rewritten as

$$\underline{M} = (\theta_0 - \theta)\pi^c, \text{ and } \overline{M} = (\theta_0 + \theta)\pi^c. \tag{5.14}$$

Note that when $\theta = 0$, which implies a deterministic M, the retailer will never reject the supplier's contract offers. However, as θ increases, the probability of rejection increases as well. Thus θ is a measurement of the rejection risk from the downside retailer. Proposition 5.1 suggests that λ^* is a function of the rejection risk measured by θ.

Proposition 5.1: *When the retailer's reservation M follows a uniform distribution with lower and upper bounds defined by (5.14), there exists a threshold,* $\theta^m = \frac{1-\theta_0}{3}$*, where:*

a) $\lambda^* = 1-(\theta_0+\theta)$ *when* $\theta \le \theta^m$. *The retailer will always accept the contract offer (*$\eta^* = 1$*), and the supplier's profit is* $\pi_S^* = \eta^* \lambda^* \pi^c = \left[1-(\theta_0+\theta)\right]\pi^c$.

b) $\lambda^* = \frac{1-(\theta_0-\theta)}{2}$ *when* $\theta > \theta^m$. *The retailer will accept the contract offer with probability* $\eta^* = \frac{1-(\theta_0-\theta)}{4\theta}$*, and the supplier's profit is* $\pi_S^* = \eta^* \lambda^* \pi^c = \frac{\left[1-(\theta_0-\theta)\right]^2}{8\theta}\pi^c$.

When the rejection risk is smaller than the threshold, θ^m, the supplier should offer a "safe" contract that is never rejected by the retailer. Under the safe contract, the supplier will retain a profit level of $\pi_S^* = \left[1-(\theta_0+\theta)\right]\pi^c = \pi^c - \overline{M}$ and leave the retailer with $\overline{M}$. On the other hand, when the rejection risk is greater than this threshold, it is optimal for the supplier to offer a more "risky" contract that provides a greater expected profit level but with the possibility of rejection.

It is interesting to note that the threshold θ^m decreases with θ_0 (a measure of the mean value of *M*), which implies that the supplier is more likely to offer a risky contract. As the retailer's reservation profit level increases, the supplier's profit potential decreases. Compared with a safe contract that provides a small assured profit level, the supplier may prefer a risky contract where the benefit of a higher profit (when the contract is accepted) overcomes the cost of rejection.

The following corollary identifies sufficient conditions where the supplier will always offer either a risky or a safe contract, regardless of θ_0.

Corollary 5.1:

(1) When $\overline{M} - \underline{M} > \pi^c/2$*, the supplier will always offer a risky contract.*

(2) When $\overline{M} \le \pi^c/2$*, the supplier will always offer a safe contract.*

Corollary 5.1 implies that when the range of *M* is very large (larger than 50% of the channel profit π^c), a risky contract is always beneficial to the supplier. On the other hand, when the upper bound of *M* is relatively small (smaller than 50% of π^c), the supplier will always choose to offer a safe contract.

We next examine how the supplier's profit changes with the range of the retailer's reservation profit. The following proposition is a direct result of the supplier's profit expressions defined in Proposition 5.1.

Proposition 5.2: *The supplier's optimal expected profit,* π_S^*, *decreases with both* θ *and* θ_0 .

Proposition 5.2 highlights the negative influence of rejection risk on the supplier's expected profit. As the range of *M* increases, the retailer's reservation profit becomes more uncertain to the supplier. Although the supplier can leverage this uncertain by offering a risky contract, her expected profit will always suffer.

We finally examine what would happen if rejection risk exists but the supplier makes decisions without taking this risk into account. To do this we first check the supplier's profit level under the contract terms defined in equations (5.3), but when rejection risk exists (i.e., profit "optimal" when setting parameters without accounting for rejection risks). This profit is denoted by π_S^{no}. We then compare π_S^{no} with the optimal profit π_S^* as expressed in Proposition 5.1. It is not surprising that π_S^{no} is always smaller than π_S^*. In other words, the suboptimal decisions lead to a reduced profit. What is more interesting is that the profit difference in absolute value, $|\pi_S^{no} - \pi_S^*|$, decreases with the range of *M*. This result suggests that when the rejection risk is low, the supplier will incur a much larger profit loss due to rejection. To mitigate this loss, the supplier must ensure an appropriate profit level for the retailer so that the contract offer is always accepted. On the other hand, when the rejection risk is high, a risky contract is already optimal (as suggested by Proposition 5.1), and thus the profit loss due to rejection is not as large.

Although the retailer's rejection risk has an impact on the supplier's contract decisions and resulting profit, it does not influence the supplier's preference between buyback and revenue sharing contracts, which is similar to the effect of the retailer's bounded rationality examined in section 5.2. This finding suggests that both behavioral tendencies affect the retailer's behavior under two contracts in the same way. In the next section, we will examine the supplier's contract decisions when the retailer's utility is affected by possible judgment biases.

5.4 Retailer's Other Judgment Biases

Prior research has identified several judgment biases that may influence the retailer's utility when making ordering decisions under newsvendor-type context. The most prominent include minimizing *ex post* inventory error (e.g., Schweitzer and Cachon 2000), prospective accounting (Chen et al. 2012), and loss aversion (Backer-Peth et al. 2013). Although these judgment biases are well studied, it is not clear how they may influence the supplier's contract problem, In particular, how the supplier should modify her parameter choices and whether buyback or revenue sharing contracts yield higher profit for the supplier once these factors are taken into account.

5.4.1 Minimizing Ex Post Inventory Error

We start by examining how the supplier's decision under the buyback and revenue sharing contracts is affected by the retailer's tendency to minimize *ex post* inventory error (MEPIE). Following the approach described in section 4.6.1, the expected value of the *ex post* inventory error at order quantity q can be expressed as

$$\begin{aligned} Er(q) &= E\left(|\, q - D\,|\right) \\ &= E\left(-2\min(q,D) + q + D\right) \\ &= -2S(q) + q + \mu_D, \end{aligned} \tag{5.15}$$

where μ_D is the mean value of the market demand. The retailer's new utility function is defined as follows,

$$U_R = \pi_R - \alpha Er(q), \tag{5.16}$$

where α is the magnitude of the disutility from *ex post* inventory error (i.e., difference between order quantity and realized demand). If the contract parameters are defined according to (5.3), the order quantity that maximizes the retailer's utility (5.16) is

$$q_\alpha^* = F^{-1}\left(\frac{(1-\lambda)(p-c)+\alpha}{(1-\lambda)p+2\alpha}\right). \tag{5.17}$$

This order quantity is the same for both buyback and revenue sharing. It is straightforward to show that if $Cr < 1/2$, then $q^c < q_\alpha^* < \mu_D$ and q_α^* increases with λ (i.e., the supplier's profit share).

On the other hand, if Cr > 1/2, then $\mu_D < q_\alpha^* < q^c$ and q_α^* decreases with λ. This result implies that the order quantity exhibits a pull-to-center effect, which causes the retailer's expected profit to reduce. Moreover, this effect is much stronger (deviation between q^* and q_α^* is larger) when the retailer's profit share is small.

The retailer solution defined in (5.17) provides some insight into how the supplier should adjust the contract parameters to maximize her expected profit when MEPIE is present. When $Cr \neq 1/2$, if the supplier continues offering the contract defined in (5.3), her profit will be reduced because q is set suboptimally by the retailer. In the meantime, the retailer's profit will also be below his reservation profit M. This implies that the supplier must further decrease her share of the channel profit (λ) and give more profit to the retailer to ensure the contract is accepted. Therefore, the supplier will achieve a reduced expected profit level when the retailer exhibits MEPIE.

Although the presence of MEPIE does impact the supplier's contract parameters, the supplier's associated expected profit remains the same whether buyback or revenue sharing is used. Similar to the effects of bounded rationality and rejection risk, the presence of MEPIE alone will not induce a contract preference for the supplier.

5.4.2 Loss Aversion and Prospective Accounting

We next establish how loss aversion and prospective accounting may affect the retailer's perception for the two contracts. The retailer's view of the payment streams differs from the supplier's in that the retailer experiences an additional payment transaction at the intermediate selling period. Table 5.1 summarizes the retailer's sequence of financial transactions under the two contracts.

Table 5.1: Retailer's financial transactions under buyback and revenue sharing contracts.

	Sequencing of payments		
Contract type	Before	During	After
Buyback	$-w_b q$	$+pS(q)$	$+b(q\text{-}S(q))$
Revenue sharing	$-w_r q$	$+pS(q)$	$-rS(q)$

Following the definition in Chapter 3, we use $\gamma_R \geq 1$ and $\delta_R \leq 1$ to denote the retailer's loss aversion coefficient and level of prospective accounting, respectively. To measure relative gains and losses, we define the current (status quo) wealth level as the reference point, similar to the approach used for the supplier (which was justified in Chapter 3). Later, in section 5.4.3, we report on an experiment to justify this assumption.

Consider the utility a buyer achieves at the time of purchase. The retailer pays the supplier a unit wholesale price w for an order of q items, incurring a total payment of $-wq$. Research has demonstrated that the money given up in purchases (in exchange for future benefits) is not subject to loss aversion (Kahneman and Tversky 1984, Movemsky and Kahneman 2005). In our framework, the retailer acquires the products at a unit cost of w, but also sells them at a higher price p ($>w$) during the selling season. As a result, we make the following assumption, which will be tested in section 5.4.3 through an experiment.

Assumption 5.1: *Retailer's initial purchasing cost is not subject to loss aversion.*

On the other hand, prospective accounting will continue underweighing the early period, causing this initial payment to be further discounted (Chen et al. 2012). Based on this reasoning, the retailer's utility under a buyback contract, takes the following form,

$$U_{R_{BB}}(q \mid w_b, b) = -\delta_R w_b q + pS(q) + b\big(q - S(q)\big) \tag{5.18}$$

Under a revenue sharing contract, the retailer may experience a loss at the end of the selling season when giving up the shared portion of revenue. This implies the following utility function under revenue sharing,

$$U_{R_{RS}}(q \mid w_r, r) = -\delta_R w_r q + pS(q) - \gamma_R rS(q). \tag{5.19}$$

We next investigate how this will affect the supplier's problem assuming the supplier is an expected profit maximizer. This involves substituting the retailer's utility functions defined in (5.18) and (5.19) into the supplier's problem. Consistent with Chapter 4, we use the retailer's utility under a wholesale price contract as the reservation utility (M) for the buyback and revenue sharing contracts. The retailer's utility under a wholesale price contract is:

$$U_R(q \mid w) = -\delta_R wq + pS(q). \tag{5.20}$$

We continue assuming that market demand follows a U[0,B] distribution, which yields the following simplified expression for the reservation utility (M),

$$M = \frac{(p - \delta_R c)^2}{8p} B. \tag{5.21}$$

Starting with the buyback contract, accounting for the retailer's loss aversion and prospective accounting requires solving the supplier's problem with the retailer's profit function replaced by utility function (5.18). The solution is

$$w_b^*(\delta_R) = \frac{(4 - \delta_R)p + \delta_R^2 c}{4\delta_R}, \quad b^*(\delta_R) = \left(1 - \frac{\delta_R^2}{4}\right) p, \tag{5.22}$$

The corresponding expected profit for the supplier is then

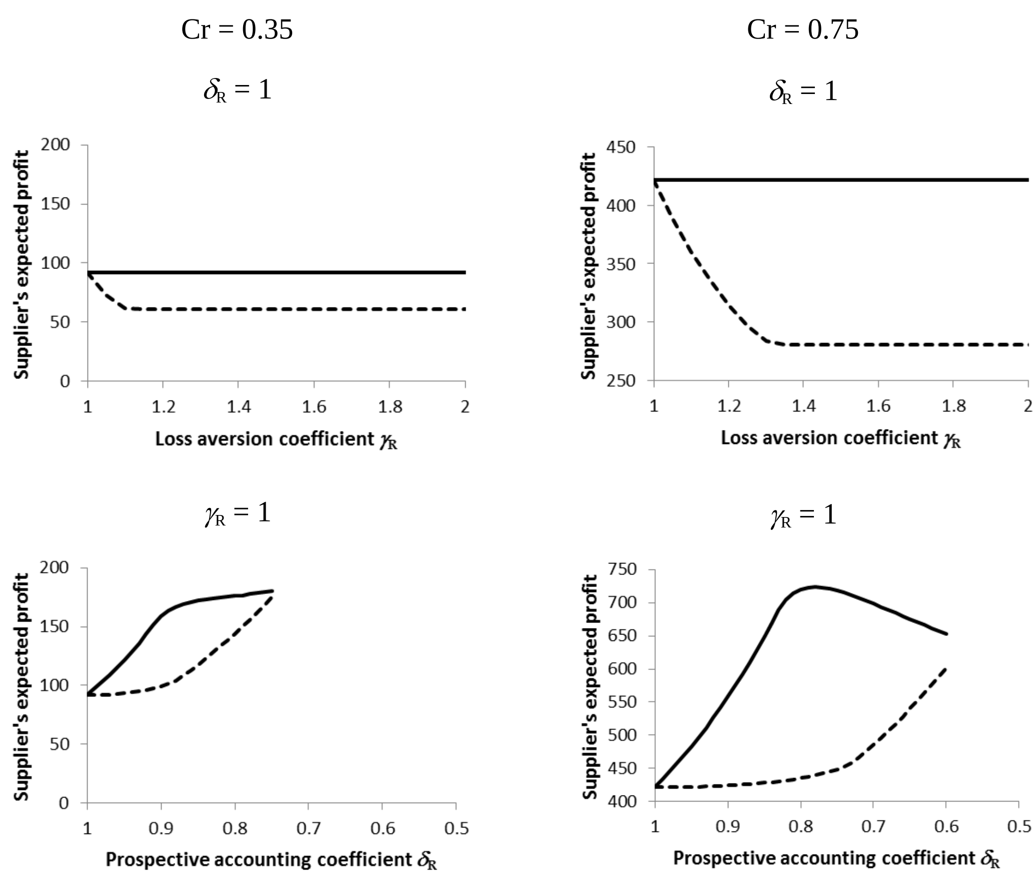
$$E(\pi_{S_{BB}}^*) = \frac{(\delta_R^2 - 2\delta_R + 4)(p - \delta_R c)^2}{8\delta_R^2 p} B. \tag{5.23}$$

It is easy to prove that as δ_R decreases, both contract parameters increase towards p, and the supplier's expected profit also increases. A smaller δ_R causes the retailer to further discount the initial purchase cost, which increases his utility. In other words, the utility of a retailer with prospective accounting is higher than a profit maximizing retailer. As a result, the supplier can take advantage of this phenomenon by setting a higher wholesale and buyback price, effectively capturing higher profit while still meeting the retailer's participation constraint.

In the case of revenue sharing, we cannot obtain closed-form expressions for the supplier's optimal contract parameters. Numerical analysis shows that the wholesale price increases and the revenue sharing parameter decreases with the retailer's loss aversion coefficient γ_R. Since loss aversion makes the retailer's revenue sharing loss more salient, the supplier must offer a small revenue sharing amount. This lower amount further leads the supplier to increase the wholesale price to cover some portion of this revenue reduction. As a result, the supplier's expected profit decreases. On the other hand, similar to the buyback contract, as the retailer discounts the initial purchase cost (i.e., δ_R decreases from 1), the supplier will increase both the wholesale price and revenue sharing to retain a higher profit level. In other words, the supplier's expected profit increases with the retailer's δ_R.

Now that we have characterized the optimal buyback and revenue sharing contract parameters, and how they change with the retailer's loss aversion and prospective accounting, we can use these solutions to compare the profits achieved by the two contracts and determine which contract yields a higher expected profit for the supplier. Since there is no closed form expression for profit under the revenue sharing contract, we illustrate this comparison through a numerical example. Figure 5.1 plots the supplier's expected profit against the retailer's loss aversion coefficient (assuming δ_R=1), and the retailer's prospective accounting coefficient (assuming γ_R=1), under low and high *Cr* levels (0.35 and 0.75) when *p*=20.

Figure 5.1: Supplier's expected profit under buyback (solid) and revenue sharing (dashed).



First consider how profit varies with the retailer's loss aversion level (upper panel). Under the buyback contract, since the retailer's loss aversion coefficient has no impact on the supplier's decisions, the supplier's expected profit does not change. However, the retailer's loss aversion has a negative impact on the supplier's profit for the revenue sharing contract. Therefore a buyback contract yields higher profit for the supplier than a revenue sharing contract. This profit difference is much larger in the high critical ratio environment (*Cr*=0.75), compared with the low critical ratio environment (*Cr*=0.35)

In contrast, as the retailer's prospective accounting level increases (δ_R decreases from 1), the supplier's profit increases under both contracts (lower panel). However, the profit increase under the buyback contract is much larger than under revenue sharing, which again makes the buyback contract more profitable for the supplier. Also, the profit difference for *Cr*=0.75 is much larger than for *Cr*=0.35.

Recall that in Chapter 4 we discovered that if the supplier exhibits loss aversion and prospective accounting, she will achieve higher profit under a revenue sharing contract in most cases. In this section we find that the retailer's loss aversion and prospective accounting tendencies can lead the supplier's expected profit in a different direction. Specifically, the buyback contract outperforms revenue sharing in most cases. Section 5.5 discusses what would happen if these behavioral tendencies are considered for both players.

As noted in the beginning of this section, the retailer's utility functions, and thus the supplier results, are developed based on Assumption 5.1. Therefore, it is important to test its validity through an experiment, which is reported in the next section. This experiment will also help test whether that the reference point approach used for the supplier's problem (chapters 3 and 4) continues to apply in the retailer case.

5.4.3 Experiment on Retailer's Contract Preference

The main idea of the experiment is similar to that described in Chapter 3. That is, we examine whether preferences exist between two contracts that yield equivalent profits, this time from the retailer's perspective (i.e., contract parameters are set according to (5.3)). To establish research hypotheses, we need to examine which contract yields a higher utility for the retailer once loss aversion and prospect accounting affects are incorporated. Plugging conditions (5.3) into (5.18) and (5.19), as well as substituting in the retailer's optimal order quantity $q^c = F^{-1}(Cr)$, yields an expression for the relative utility of the buyback contract over the revenue sharing contract:

$$\Delta U_R = \lambda p\left[(1-\delta_R)F^{-1}(Cr)+(\gamma_R-1)S\left(F^{-1}(Cr)\right)\right]. \tag{5.24}$$

This expression implies that the relative utility ΔU_R is always positive as long as $\delta_R < 1$ or $\gamma_R > 1$. So, the buyback contract always provides a higher utility and thus should be preferred by the retailer. Loss aversion inflates the revenue sharing loss (which occurs at the end of the selling season) but does not affect the retailer's utility on the buyback contract, making buyback more attractive. On the other hand, the initial payment under the buyback contract is much larger ($w_b > w_r$) and therefore is discounted to a greater extent, compared with that under revenue sharing. This suggests that prospective accounting makes buyback even more attractive. In addition, since the magnitude of ΔU_{R} increases with γ_{R}, we would expect that retailers with higher levels of loss aversion will exhibit stronger preferences than retailers with lower levels of loss aversion. These theoretical results lead to two testable hypotheses.

Hypothesis 5.1: *Buyback is always preferred over revenue sharing when parameters are set according to* (5.3).

Hypothesis 5.2: *Individuals with high levels of loss aversion will more consistently prefer buyback, compared with individuals with low levels of loss aversion.*

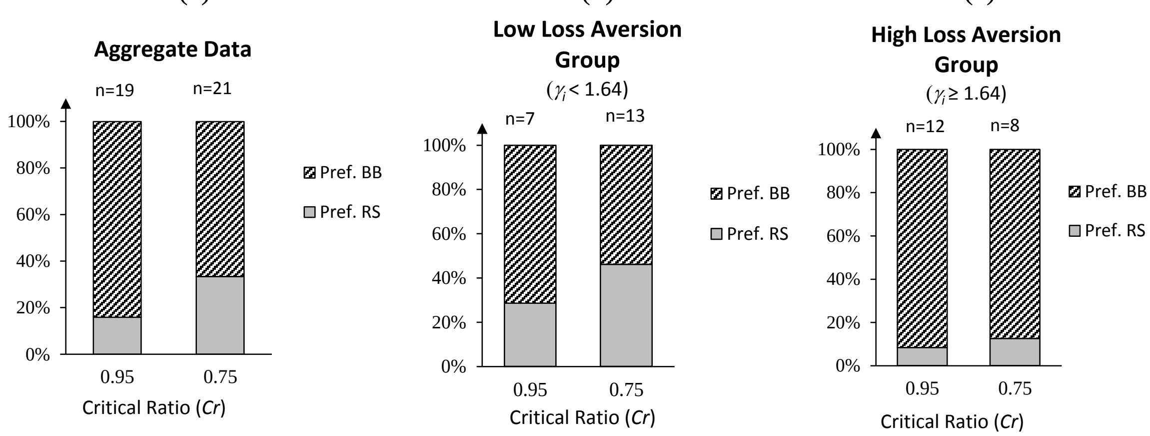
Note that if the retailer's purchasing cost incurred in the early period is indeed subject to loss aversion (i.e., Assumption 5.1 is invalid), it becomes possible that $\delta_{\mathrm{R}} > 1$, which increases with γ_{R}. This implies that in high *Cr* environment, the relative utility, ΔU_{R}, is likely to be negative, suggesting that revenue sharing will be preferred. Moreover, since $|\Delta U_{\mathrm{R}}|$ is increasing with γ_{R}, we expect that individuals with high levels of loss aversion will more consistently prefer the revenue sharing contract. If the experiment result does not reveal a preference towards revenue sharing contract (i.e., Hypotheses 5.1 and 5.2 are supported), we can conclude that Assumption 5.1 is valid.

The design and protocol for the retailer's experiment are similar to experiment 1 (described in Chapter 3). Participants first witnessed 5 rounds of financial transactions for the two contracts and then indicated which contract they preferred. We conducted the experiment under *Cr*=0.95 and *Cr*=0.75, because participants are more likely to prefer revenue sharing in high *Cr* environments if Assumption 5.1 is invalid. In other words, Hypotheses 5.1 and 5.2 are mostly likely to be disapproved. We also measured each participant's loss aversion level using the procedure outlined in section 3.4.2. Participants were recruited from the Carlson School subject pool and were paid based on their performance, similar to experiment 1.

Figure 5.2 plots the breakdown of preferences by critical ratio under column (a). The percentage choosing buyback is significantly above 50% for both *Cr* levels (*p*=0.000 for *Cr*=0.95; *p*=0.048 for *Cr*=0.75), which supports Hypothesis 5.1. To test Hypothesis 5.2, we group the participants based on their measured loss aversion coefficient using median as the dividing point. Figure 5.2 under columns (b) and (c) plots the breakdown of preferences across the two *Cr* treatments for the low and high loss aversion groups. Participants with low level of loss aversion do not exhibit any preferences (*p*=0.210 for *Cr*=0.95; *p*=0.781 for *Cr*=0.75). For participants with high level of loss aversion, buyback is strongly preferred in both *Cr* treatments (*p*=0.000 for *Cr*=0.95; *p*=0.001 for *Cr*=0.75). This result supports Hypothesis 5.2. The experiment results confirm the validity of Assumption 5.1.

Figure 5.2: Distribution of preferences in percentage by *Cr*.

(a) (b) (c)



5.5 Discussion

So far we have established how a human retailer's behavioral tendencies may influence a profit maximizing supplier's decisions and performance under the buyback and revenue sharing contracts. Specific behavioral tendencies we have examined consists of retailer's bounded rationality, rejection risk, and judgment biases including minimizing *ex post* inventory error (MEPIE), loss aversion and prospective accounting. Although the supplier's expected profit is negatively affected by retailer bounded rationality, rejection risk, and MEPIE, these factors do not make one contract more attractive than the other from the point of view of a profit maximizing supplier.

In contrast, the two contracts yield different profit outcomes for the supplier if the retailer exhibits tendencies of loss aversion and prospective accounting. More specifically, a buyback contract yields a higher profit in most cases and should be employed by the supplier if the supplier herself does not exhibit loss aversion and prospective accounting tendencies. For example, if the supplier's contract parameters are set through an automated system, while the retailer's order quantity decision involves human judgment. Future research is required to test which elements of our theory of retailer behavior holds.

When both players exhibit behavioral tendencies, it becomes less obvious which contract provides higher profit for the supplier. Prior research has demonstrated that when supplier and buyer interact, social preference, such as fairness concerns, may influence people's behavior. However, social preference affects the profit distribution between supply chain members, but may not lead to different outcomes between "equivalent" contracts. It is important to understand how contracts are framed, because different framing can change the human decision makers' perception (utility) on various contracts, which in turn influences contract performance. For example, Ho and Zhang (2008) studied two equivalent contracts – two-part tariff and quantity discount – in laboratory setting and found that a more salient framing of the fixed fee payment induces the decision makers to be more loss averse and thus decreases the contract performance for a two-part tariff. Fairness concerns led the profit to be distributed more evenly between the supplier and buyer but could not explain the different contract outcome.

In comparing buyback and revenue sharing contracts, it is important to understand what behavioral tendencies may arise due the framing difference. We have demonstrated that loss aversion and prospective accounting are reasonable behavioral factors (arising from framing difference) and will lead to different contract outcome for the supplier. Specifically, the supplier's tendencies toward loss aversion and prospective accounting make revenue sharing more attractive in most situations (Chapter 4), while the retailer's tendencies make buyback more attractive for the supplier. When both players' behavioral tendencies are concerned, preliminary numerical analysis (Figure F.1 in Appendix F) shows that the buyback contract yields higher expected profit for the supplier. This suggests that the retailer's loss aversion and prospective accounting impact may dominate the supplier's when determining the relative performance between buyback and revenue sharing contracts. This insight is consistent with a recent paper by Wu (2013) where she studied how supplier and buyer interact under buyback and revenue sharing contracts in repeated games. The experimental results reveal that the buyback contract yields higher profit for both the supplier and retailer. She infers that this phenomenon is due to framing difference in that buyback is framed as providing protection (refund) for unfortunate event (leftovers), which may sound more “positive” to the retailer. We confirm her hypothesis by providing a comprehensive theoretical analysis on how supplier’s expected profit is impacted by the framing effect due to loss aversion and prospective accounting.

Our preliminary analysis implies that taking into account the retailer’s behavioral tendencies is critical for the supplier. If the supplier does not consider the retailer’s behavior, she may choose a revenue sharing contract. However, revenue sharing may perform worse than buyback if the retailer also exhibits loss aversion and prospective accounting. Future research is required to test these insights in a more rigorous way.

Chapter 6:

Conclusion

The goal of this dissertation was to determine how framing differences between buyback and revenue sharing contracts influence a supplier's decisions on which contract to adopt, how contract parameters for each contract are set, and ultimately which contract results in higher expected profit (after accounting for the supplier's parameter-specification behavior). While profit maximization is a common goal at the firm level, the execution of contract terms is often conducted at the individual level, by human decision makers who may exhibit behavioral tendencies such as loss aversion or prospective accounting. This study has uncovered how the performance of the two contracts may differ once such behavioral tendencies are factored in.

When human suppliers are asked to choose between buyback and revenue sharing contracts that yield identical profit, we find that their preference is dependent on the underlying critical ratio, with revenue sharing preferred in high critical ratio environments and buyback preferred in low critical ratio environments. We also find differences in performance of the two contracts when suppliers have the authority to set contract parameters. Revenue sharing is more profitable for the supplier in high critical ratio environments while the contracts perform equally well in low critical ratio environments. These insights appear to be driven, or at least are consistent with, the presence of loss aversion. Prospective accounting also appears to have a supporting role.

We also examine how a retailer's behavioral tendencies may influence the supplier's contract decision and performance. We find that a retailer's decision errors due to bounded rationality, rejection risk, and tendency of minimizing *ex post* inventory error have a similar, negative influence on a supplier's profit under both revenue sharing and buy back contracts. However, the existence of loss aversion and prospective accounting at the retailer level has a different impact on the supplier's profit level under buyback versus revenue sharing. Preliminary analysis shows that the buyback contract yields higher profit for the supplier in this case.

These results can help guide supply firms in mapping contract options to environments where they perform best. When framing effects exist, contract managers should consider the impact of the underlying critical ratio on their contract decisions. For instance, the most cited use of revenue sharing is in the movie rental industry, which is arguably a high critical ratio environment. The flow of transactions in revenue sharing is also similar to consignment or vendor managed inventory schemes where the supplier incurs an initial loss but holds out for the possibility of a significant future gain. These schemes are usually offered with a high service level guarantee, which implies a high critical ratio environment. It is more difficult to find industry examples that fit the profile of a low critical ratio environment. Nevertheless, empirically it appears that buyback contracts are much more prevalent than revenue sharing contracts in industry. This observation appears consistent with our finding that buyback may yields higher profit than revenue sharing once additional retail level factors are included.

From a theoretical perspective, our research contributes to the behavioral literature in two ways. First, the financial flows inherent in buyback and revenue sharing contracts provide an interesting context for comparison, with a combination of structures not previously examined in the loss aversion literature. We contribute to this literature by showing that loss aversion is also influential in this unique operations management context where the magnitude and sequencing of losses and gains differ while the sum remains the same.

Secondly, we introduced a simple out-of-context approach (see Appendix B) for measuring individual loss aversion coefficients that is easy to implement. It is important to clarify that our approach calculates the loss aversion value based on only one set of parameters, compared to more complex procedures (e.g., Abdellaoui et al. 2007, 2008) which use a number of parameter combinations. We acknowledge that our simplified approach provides a less calibrated measure of loss aversion tendencies compared to the more complex procedures. However, we believe that such a simplified measure is sufficient in this (and similar) studies where the unit of analysis is the group level (i.e., the goal is to partition individuals into groups with similar loss aversion levels rather than precisely compute the loss aversion level for a given individual).

Several directions for future research are possible. The most obvious is to fine tune the retailer's theory. For example, future research could establish theoretical results for how buyback and revenue sharing contracts compare from the retailer's point of view with carefully designed experiments to test the associated theoretical predictions. This direction includes investigating the retailer's preference over equivalent contracts (expanding our preliminary experimental study in section 5.4.3), and how the retailers set order quantities. Having a full understanding of the retailer's problem can help establish a utility function that better describes the retailer's contract behavior.

After understanding how a supplier and buyer makes decisions individually, future research is required to study how social preferences, such as fairness concerns, influence the contract performance for both players. Previous studies have already shown that social preferences influence supply chain transactions and the resulting profit allocation (Cui et al. 2007, Loch and Wu 2008). However, it is unclear whether social preferences reveal further differences between buyback and revenue sharing contracts, including how the supplier sets contract terms and which terms are accepted by the retailer. For example, our analysis suggests that the supplier may retain higher profit under the buyback contract, which leads to an uneven profit allocation between supply chain members. As a result, buyback contract are more likely to be rejected by the retailer due to fairness concerns and thus may reduce the supplier's overall expected profit, making buyback less attractive.

Finally, our model can be extended to consider other flexible contracts such as quantity flexibility contracts, option contacts, and sale-rebate contracts. Framing differences between these contracts may suggest the influence of other behavioral factors in addition to loss aversion and prospective accounting. This will provide a comprehensive understanding of why certain contracts are more commonly adopted in specific industries.

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Appendix A

Proofs

A.1 Proof for Proposition 3.1

To prove the existence of a unique threshold value, $Cr^0 \in (0,1)$, we need to show that the sign of ΔU_S switches only once as Cr increases. To show this, we first us rewrite ΔU_S as $\Delta U_S = -\lambda p(\gamma - 1)\left(qF(q) - S(q)\right)$ where $q = F^{-1}(Cr)$. Since q is a monotonically increasing function of Cr, we can shift our focus to determining whether ΔU_S only changes sign once with q. The first factor of ΔU_S, $-\lambda p(\gamma - 1)$ is strictly negative, so we can further shift our attention to the second factor, $qF(q) - S(q)$.

To establish that $qF(q) - S(q)$ has a unique zero point, we need to show that the function $\phi(q) = qF(q) - S(q)$ crosses the horizontal axis once and only once. Let $[\underline{q}, +\infty)$ for $\underline{q} \geq 0$ be the support of F and $\bar{q} \leq +\infty$ be the supremum (the least-upper-bound) of the set that contains all elements satisfying $F(q) < 1$. We can then state that $0<Cr<1$ (equivalently $0<F(q)<1$), implies $\underline{q} < q < \bar{q}$ and expected sales $S(q)$ can be rewritten as

$$S(q) = q - \int_{\underline{q}}^{q} F(x)dx.$$

We first consider the limit of the two ending points of $\phi(q)$:

$$\lim_{q \downarrow \underline{q}} \phi(q) = -S(\underline{q}) \leq 0 \quad \text{and}$$

$$\lim_{q \uparrow \bar{q}} \phi(q) = \bar{q} - S(\bar{q}) > 0.$$

The upper limit is always strictly greater than zero, and so the behavior of $\phi(q)$ depends on whether $\underline{q}$ is equal to or strictly greater than zero. We examine each case in turn.

Case 1: $\underline{q} = 0$) In this case, we need to determine whether $\phi(q)$ crosses the horizontal axis at all (and if so, whether it crosses it only one time). Taking the first derivative of $\phi(q)$, we have

$$\phi'(q) = 2F(q) - 1 + qf(q) = (1 - F(q))\left(g(q) + \frac{1}{1 - F(q)} - 2\right) \quad \text{(A.1)}$$

where $g(q) = \dfrac{qf(q)}{1 - F(q)}$ is the generalized failure rate of $F(q)$, which is assumed to be increasing in q. As a result, $g(q) + \dfrac{1}{1 - F(q)} - 2$ is increasing in q, and thus can be equal to 0 at only one point. Also, the upper limit of $\phi'(q)$, $\lim_{q \uparrow \bar{q}} \phi'(q) = 1 + \bar{q}f(\bar{q})$, is strictly positive while the lower limit, $\lim_{q \downarrow 0} \phi'(q) = -1$, is strictly negative. This implies that $\phi'(q) < 0$ when q is small and switches to $\phi'(q) > 0$ as q increases. Thus, the function $\phi(q)$ is quasiconvex, first decreases and then increases in q.. Since we also know that the lower limit of $\phi(q)$ is zero and the upper limit is greater than zero, this implies that $\phi(q)$ crosses the horizontal axis once and only once, and therefore has a unique zero point.

Case 2: $\underline{q} > 0$) In this case, it is easy to see that the lower limits of $\phi(q)$ is smaller than zero, so $\phi(q)$ will cross the horizontal axis at least once. Turning to the first derivative of $\phi(q)$ defined in (A.1), we now find that the lower limit of $\phi'(q)$, $\lim_{q \downarrow \underline{q}} \phi'(q) = -1 + \underline{q}f(\underline{q})$, could be negative or positive. This implies that $\phi(q)$ is either a quasiconvex or increasing function of q and, in either case, so crosses the horizontal axis once and only once, implying a unique zero point.

Combining the results of cases 1 and 2, $\phi(q)$ has a unique zero point, q^0 that solves $\phi(q^0)$=0, and a corresponding Cr^0 that solves $F^{-1}(Cr^0)Cr^0 - S\left(F^{-1}(Cr^0)\right) = 0$. This leads to the following:

a) For $0 < Cr < Cr^0$ (or equivalently $\underline{q} < q < q^0$), $\phi(q) < 0$ and $\Delta U_S > 0$ which implies that suppliers prefer the buyback contract.

b) For $Cr^0 < Cr < 1$ (or equivalently $q^0 < q < \bar{q}$), $\phi(q) > 0$ and $\Delta U_S < 0$ which implies suppliers prefer a revenue sharing contract.

c) For $Cr = Cr^0$ (or equivalently $q = q^0$), $\phi(q) = 0$ and $\Delta U_S = 0$ which implies that suppliers are indifferent between a buyback and a revenue sharing contract.

QED

A.2 Proof for Proposition 3.2

To prove these results, we need to examine the sign of $\Delta U_S(\gamma|\delta)$ changes with γ and δ, where

$$\Delta U_S(\gamma \mid \delta) = -\lambda p(\gamma-1)\left[\left(\tfrac{1-\delta}{\gamma-1}\gamma + \delta Cr\right)F^{-1}(Cr) - S\left(F^{-1}(Cr)\right)\right]. \tag{A.2}$$

Given that the demand distribution is U(0,B), it is easy to obtain $F^{-1}(Cr) = CrB$ and $S\left(F^{-1}(Cr)\right) = CrB(1-Cr/2)$. Plugging the two expressions into (A.2), $\Delta U_S(\gamma \mid \delta)$ simplifies to

$$\Delta U_S(\gamma \mid \delta) = -\lambda p(\gamma-1)\left[\tfrac{2\delta+1}{2}CrB\left(Cr - Cr^{\delta}\right)\right],$$

where $Cr^{\delta} = \dfrac{2(\delta\gamma-1)}{(2\delta+1)(\gamma-1)}$. It is easy to show that $Cr^{\delta} < 1$.

We now consider the following two cases.

Case 1: $\gamma \le 1/\delta$) In this case, it is easy to show that $Cr^{\delta} \le 0$, which implies $\Delta U_S(\gamma|\delta) < 0$. Thus the supplier will always prefer a revenue sharing contract.

Case 2: $\gamma > 1/\delta$) In this case, $0 < Cr^{\delta} < 1$. The sign of $\Delta U_S(\gamma|\delta)$ now depends on the value of Cr which suggests the following results.

a) When $0 < Cr < Cr^{\delta}$, we have $\Delta U_S(\gamma|\delta) > 0$ and so the supplier will prefer a buyback contract.

b) When $Cr^{\delta} < Cr < 1$, we have $\Delta U_S(\gamma|\delta) < 0$ and so the supplier will prefer a revenue sharing contract.

c) When $Cr = Cr^{\delta}$, we have $\Delta U_S(\gamma|\delta) = 0$ and so the supplier will be indifferent between a buyback and a revenue sharing contract.

Finally, since $Cr^{\delta} - Cr^0 = \dfrac{2(\delta\gamma-1)}{(2\delta+1)(\gamma-1)} - \dfrac{2}{3} = \dfrac{2(\gamma+2)(\delta-1)}{3(2\delta+1)(\gamma-1)} < 0$, we have $Cr^{\delta} < Cr^0$.

QED.

A.3 Proof for Proposition 4.1

We use proof by contradiction to show that $\{b^c = \lambda p,\ w_b^c = c + \lambda(p-c)\}$ and $\{r^c = \lambda p,\ w_r^c = (1-\lambda)c\}$ are optimal solutions to the supplier's problem. Focusing first on the buyback contract, we can plug in contract conditions (1) into the supplier and buyer profit functions to reveal $\pi_{S_{BB}}(w_b^c, b^c) = \pi^c - M$ and $\pi_{R_{BB}}(w_b^c, b^c) = M$. Suppose there exists a different pair of parameters, ($\overline{w}_b$, $\overline{b}$), which achieves higher profit level for the supplier, i.e. $\pi_{S_{BB}}(\overline{w}_b, \overline{b}) > \pi^c - M$. By definition, the sum of the supplier's and retailer's profits cannot exceed the maximum channel profit, i.e., $\pi_{S_{BB}}(\overline{w}_b, \overline{b}) + \pi_{R_{BB}}(\overline{w}_b, \overline{b}) \le \pi^c$. This implies $\pi_{R_{BB}}(\overline{w}_b, \overline{b}) \le \pi^c - \pi_{S_{BB}}(\overline{w}_b, \overline{b}) < M$, which violates the first condition in Problem BB. The proof for revenue sharing follows the same logic. The proof of equivalency and efficiency follows the arguments for Theorem 1 and 2 in Cachon and Lariviere (2005).

A.4 Proof for Proposition 4.2

Proving this proposition requires characterizing the optimal contract parameters that solve problem (BB) when the supplier's objective function is replaced by utility function (4.4). Substituting the optimal order quantity for the retailer, $q^*(w_b, b)$, into this optimization problem yields the following modified formulation:

$$\max_{w_b, b} U_{S_{BB}}(w_b, b) = \max_{w_b, b}\Big((w_b - c)q^*(w_b, b) - \gamma b\Big(q - S(q^*(w_b, b))\Big)\Big) \qquad \text{(BB-L)}$$

$$\text{s.t} \qquad \pi_{R_{BB}}(w_b, b) \ge M$$

where $q^*(w_b, b) = \dfrac{p - w_b}{p - b}B$, $M = \dfrac{(p-c)^2}{8p}B$, and

$$\pi_{R_{BB}}(w_b, b) = -w_b q^*(w_b, b) + pS(q^*(w_b, b)) + b\Big(q^*(w_b, b) - S(q^*(w_b, b))\Big).$$

We can construct the Lagrangean of problem (BB-L) as follows,

$$L(w_b, b; l) = (w_b - c)q^*(w_b, b) - \gamma b\Big(q^*(w_b, b) - S(q^*(w_b, b))\Big) + l\Big(\pi_{R_{BB}}(w_b, b) - M\Big) \qquad \text{(A.3)}$$

where l is a Kuhn-Tucker multiplier. The optimal solution to (BB-L) must satisfy the following conditions.

$$\frac{\partial L(w_b,b;l)}{\partial w_b}=0, \tag{A.4}$$

$$\frac{\partial L(w_b,b;l)}{\partial b}=0, \tag{A.5}$$

$$\frac{\partial L(w_b,b;l)}{\partial l}\geq 0, \tag{A.6}$$

$$l\geq 0, \quad \text{and} \tag{A.7}$$

$$l\frac{\partial L(w_b,b;l)}{\partial l}=0. \tag{A.8}$$

Equation (A.8) implies either $l=0$ or $\partial L(w_b,b;l)/\partial l=0$. We examine both cases.

Case 1: l=0) In this case, we need to solve the system of equations consist of (A.4) and (A.5), and check if these solutions satisfy the condition (A.6). Solving (A.4) and (A.5), we obtain one solution at $w_b^*=p$ and $b^*=p$. This solution cannot be the optimal contract parameters for the supplier since she extracts the entire channel profit and leaves zero profit for the retailer, which clearly violates condition (A.6). Therefore, the optimal contract parameters cannot be obtained in this case.

Case 2: $\partial L(w_b,b;l)/\partial l=0$) In this case, we need to solve the system of equations consisting of (A.4), (A.5), to identify any critical points, and then check if the solution satisfies condition (A.7). Solving the problem, we obtain the following solution:

$$w_b^*=p-\frac{p-c}{4}\gamma,\ b^*=\frac{4-\gamma^2}{4}p,\ \text{and}\ l^*=-\gamma+2. \tag{A.9}$$

When $l^*\geq 0$ or $\gamma\leq 2$, the supplier's optimal contract parameters are defined in (A.9). When $l^*<0$ or $\gamma>2$, the optimal solution is obtained at the boundary where $b^*=0$ and $w_b^*=(p+c)/2=w_p^*$. It is easy to show that the optimal wholesale price w_b^* first decreases with γ and then stays at w_p^* when $\gamma>2$, implying a nonincreasing function of γ. Furthermore, solving $\partial L(w_b,b;l)/\partial l=0$ we obtain a relationship between the two optimal contract parameters:

$$b^*=p-\frac{4p(p-w_b^*)^2}{(p-c)^2}. \tag{A.10}$$

The supplier's expected profit can be expressed as

$$\begin{aligned}E(\pi^*_{S_{BB}})&=(w_b^*-c)q^*-b\left(q-S(q^*)\right)\\&=pS(q^*)-cq^*-M,\end{aligned} \tag{A.11}$$

where $q^* = \frac{p - w_b^*}{p - b^*} B$. Note that $pS(q^*) - cq^*$ is the expected channel profit, which is maximized when $q^* = q^c$ (i.e., $\gamma = 1$). When $\gamma > 2$, it is clear that the supplier's expected profit is always equal to $E(\pi_p^*)$. When $\gamma \le 2$, to prove $E(\pi_{S_{BB}}^*)$ decreases with γ, it is equivalent to show that q^* is decreasing with γ. Taking the first derivative of q^* with respect to γ yields $\frac{\partial q^*}{\partial \gamma} = -\frac{p-c}{\gamma^2 p} < 0$. Therefore, the supplier's optimal expected profit $E(\pi_{S_{BB}}^*)$ first decreases with γ and then and then stays at $E(\pi_p^*)$ when $\gamma > 2$, implying a nonincreasing function of γ.

QED.

A.5 Proof for Proposition 4.3

The proof of Proposition 4.3 is similar to the proof of Proposition 4.2. In the interest of brevity, we will only highlight major differences in the proof. Since the retailer is now offered a revenue sharing contract, his optimal order quantity is given by the new expression:

$$q^*(w_r, r) = \frac{p - w_r - r}{p - r} B. \tag{A.12}$$

The supplier's objective function is now dependent on whether w_r is greater r less than c, and so we discuss the two cases separately.

Case 1: $w_r < c$) By constructing a Lagrangean function and solving the Kuhn-Tucker conditions, we can show that the optimal r^* is given by the root of a polynomial equation

$$\left(p - (\gamma - 1)(p - r^*) - \gamma c\right)^2 (p - r^*) = \frac{(p-c)^2 p}{4} \tag{A.13}$$

and the optimal wholesale price is

$$w_r^* = \frac{(\gamma - 1)(p - r^*)^2 + \gamma c(p - r^*)}{p}. \tag{A.14}$$

The direct relationship between the two optimal contract parameters is

$$r^* = (p - w_r^*) - \frac{(p-c) + \sqrt{(p-c)^2 + 16 w_r^* p}}{8p}(p-c). \tag{A.15}$$

Further, we can rewrite the equation (A.13) to obtain γ as a function of r^*, which is[19]

$$\gamma = \frac{2p - r^* - \frac{p-c}{2}\sqrt{\frac{p}{p-r^*}}}{p - r^* + c} \tag{A.16}$$

Define r_0 to be the value of r^* when $w^*=c$, and γ_0 be the value of γ when $r^*=r_0$. Plugging these values into (A.15) and (A.16) we get

$$r_0 = (p-c) - \frac{(p-c)+\sqrt{(p-c)^2+16pc}}{8p}(p-c), \text{ and} \tag{A.17}$$

$$\gamma_0 = \frac{2p - r_0 - \frac{p-c}{2}\sqrt{\frac{p}{p-r_0}}}{p - r_0 + c}. \tag{A.18}$$

Lemma 1 (included after this proof) suggests that γ strictly decreases with r^* for $r^*>r_0$. This is equivalent to saying that r^* strictly decreases with γ, for $\gamma < \gamma_0$. Furthermore, from (A.15) we can easily show that r^* strictly decreases with w_r^* by examining the first derivation. Therefore, w_r^* strictly increases with γ for $\gamma < \gamma_0$. For $\gamma \geq \gamma_0$, the optimal wholesale price can only be obtained when $w_r \geq c$, which leads to the second case.

Case 2: $w_r \geq c$) Solving the Kuhn-Tucker conditions, we obtain $w_{r1}=c/4$, and $r_1=3p/4$. This solution violates condition $w_r \geq c$, and thus cannot be the optimal solution to the supplier's problem. Therefore, the optimal solution is obtained at the boundary where $w_r^* = c$ and $r^* = r_0$.

Combining the results from cases 1 and 2, it is clear that the optimal wholesale price w_r^* first increases with γ for $\gamma < \gamma_0$, and then equals c when $\gamma \geq \gamma_0$, implying a nondecreasing function of γ. The relationship between w_r^* and r^* is defined by (A.15). The proof of the expected profit nonincreasing with γ follows the same logic as the proof for buyback contract (Proposition 4.2).

QED.

Lemma 1: γ is strictly decreasing in r^* for $r^* > r_0$.

Proof: From (A.16), taking the first derivative of γ with respect to r^*, we get

$$\frac{d\gamma}{dr^*} = \varphi(r^*)\frac{p-c}{(p-r^*+c)^2}\sqrt{\frac{p}{p-r^*}}, \tag{A.19}$$

where

[19] In order for the retailer to make positive profit, the optimal contract parameters w_r^* and r^* must satisfy $p\text{-}w_r^*\text{-}r^*>0$. This implies $p\text{-}(\gamma\text{-}1)(p\text{-}r^*)\text{-}\gamma c>0$. Therefore, only one solution for γ, as a function or r^* can be obtained.

$$\varphi(r^*) = -\frac{c}{4(p-r^*)} + \sqrt{\frac{p-r^*}{p}} - \frac{3}{4}. \tag{A.20}$$

We need to prove $d\gamma/dr^*$ is negative, or equivalently $\varphi(r^*) < 0$ for $r^* > r_0$. Define $\tilde{r} = (p-c)/2$. We can easily check that $\tilde{r} < r_0$ and $\varphi(\tilde{r}) < 0$. From (A.20) we see that $\varphi(r^*)$ decreases with r^*, and thus $\tilde{r} < r_0 < r^*$ implies $\varphi(r^*) < \varphi(r_0) < \varphi(\tilde{r}) < 0$.

QED.

A.6 Proof for Proposition 5.1

Proving this proposition requires solving for the optimal λ that maximizes the supplier's utility function defined in (5.13). The probability distribution function $G(\bullet)$ for the retailer's reservation profit M under the uniform distribution is

$$G(x) = \frac{x - \underline{M}}{\overline{M} - \underline{M}}, \tag{A.21}$$

where $\underline{M}$ and $\overline{M}$ are the lower and upper bounds of M, which are defined as

$$\underline{M} = (\theta_0 - \theta)\pi^c, \text{ and } \overline{M} = (\theta_0 + \theta)\pi^c. \tag{A.22}$$

Note that the retailer's reservation profit M is positive and bounded above by the maximum expected profit of the channel. This implies that $\theta_0 - \theta \geq 0$ and $\theta_0 + \theta \leq 1$. The probability of acceptance can then be rewritten as

$$\eta = G(\pi_R) = \frac{(1-\lambda) - (\theta_0 - \theta)}{2\theta}. \tag{A.23}$$

Plugging (A.21) and (A.22) into (5.13), the supplier utility function is further simplified as

$$U_S(\lambda) = \frac{-\lambda^2 + [1 - (\theta_0 - \theta)]\lambda}{2\theta}\pi^c. \tag{A.24}$$

Under the optimal contract parameters the retailer's profit π_R must fall between $\underline{M}$ and $\overline{M}$ (i.e., $\underline{M} \leq \pi_R \leq \overline{M}$)[20], which implies $\underline{\lambda} \leq \lambda \leq \overline{\lambda}$, where $\underline{\lambda} = 1 - (\theta_0 + \theta)$ and $\overline{\lambda} = 1 - (\theta_0 - \theta)$. Our objective is to find λ^* that maximizes (A.24) in this range. Solving the first order condition $dU_S(\lambda)/d\lambda = 0$ yields

[20] If the retailer's profit share π_R is strictly greater than $\overline{M}$, the supplier can increase her profit share by setting a higher λ, which leads π_R equal to $\overline{M}$. The same logic applies when $\pi_R < \underline{M}$.

$$\lambda_0 = \frac{1-(\theta_0 - \theta)}{2}. \tag{A.25}$$

To determine whether this solution is optimal, we need to compare λ_0 with its lower and upper bounds ($\underline{\lambda}$ and $\overline{\lambda}$), which leads to the following three cases.

Case 1: $\lambda_0 > \overline{\lambda}$) This condition implies that $\overline{\lambda} < 0$, which can never occur. Therefore this solution is infeasible.

Case 2: $\lambda_0 \leq \underline{\lambda}$ or equivalently $\theta \leq \frac{1-\theta_0}{3}$) In this case, the optimal solution is obtained at the lower bound, i.e., $\lambda^* = 1 - (\theta_0 + \theta)$. The probability of acceptance is $\eta^* = 1$, which implies that the retailer will always accept the contract offer. The supplier's resulting expected profit is $\pi_S^* = [1-(\theta_0 + \theta)]\pi^c$.

Case 3: $\underline{\lambda} < \lambda_0 \leq \overline{\lambda}$ or equivalently $\theta > \frac{1-\theta_0}{3}$) In this case, the optimal solution is obtained at λ_0, i.e., $\lambda^* = \frac{1-(\theta_0-\theta)}{2}$. the retailer will accept the contract offer with probability $\eta^* = \frac{1-(\theta_0-\theta)}{4\theta} < 1$. The supplier's resulting expected profit is $\pi_S^* = \frac{[1-(\theta_0-\theta)]^2}{8\theta}\pi^c$.

QED.

A.7 Proof for Corollary 5.1

To prove the first corollary we need to show $\theta > \frac{1-\theta_0}{3}$, or equivalently $3\theta + \theta_0 > 1$, is always satisfied under the condition $\overline{M} - \underline{M} > \pi^c/2$. Substituting (A.22) into this condition we have $\theta > 1/4$. Recall that the lower bound $\underline{M}$ must be positive, implying $\theta_0 \geq \theta$. It then follows that $3\theta + \theta_0 \geq 3\theta + \theta = 4\theta > 1$.

In the second corollary, the condition $\overline{M} \leq \pi^c/2$ implies $\theta + \theta_0 \leq 1/2$. It then follows that $3\theta + \theta_0 \leq 2\theta + 2\theta_0 \leq 1$, or equivalently $\theta \leq \frac{1-\theta_0}{3}$.

QED.

A.8 Proof for Proposition 5.2

To prove this proposition we need to show that the derivatives of π_S^* with respective to θ and θ_0 are negative. When $\theta \le \theta^m$, $\partial\pi_S^* / \partial\theta = -\pi^c < 0$ and $\partial\pi_S^* / \partial\theta_0 = -\pi^c < 0$. When $\theta > \theta^m$, $\partial\pi_S^* / \partial\theta = -\frac{[1-(\theta_0-\theta)][1-(\theta_0+\theta)]}{8\theta^2} < 0$ and $\partial\pi_S^* / \partial\theta_0 = -\frac{[1-(\theta_0-\theta)]}{4\theta} < 0$.

QED.

Appendix B

The Simplified Elicitation Procedure

Let (x, p_r; y) denote a prospect in which outcome x is received with probability p_r and y is received with probability $1 - p_r$. Then the simplified elicitation procedure consists of two steps. In the first step, for a given g_0, a loss l_0 is elicited such that a participant is indifferent between a sure payoff of 0 and a prospect (g_0, 0.5; l_0), i.e., (g_0, 0.5, l_0) ~ 0. Suppose that $u(g_0) = a$, it follows that

$$0.5u(g_0) + 0.5u(l_0) = 0 \;\Rightarrow\; u(l_0) = -u(g_0) = -a\,.$$

Figure B.1 illustrates this relation. In the second step, the utility of $-l_0$ is determined by the elicitation of probability p_{r0} such that a participant is indifferent between a sure payoff of $-l_0$ and a prospect (g_0, p_{r0}, 0), i.e., $-l_0$ ~ (g_0, p_0; 0). It follows that

$$u(-l_0) = p_{r0}u(g_0) + (1 - p_{r0})u(0) = p_{r0}a\,.$$

The loss aversion coefficient γ follows

$$\gamma = \frac{-u(l_0)}{u(-l_0)} = \frac{1}{p_{r0}}\,.$$

All indifferences are elicited using a bisection process (Abdellaoui et al. 2007, 2008), which consists of a series of binary choice questions. This process is illustrated in Table B.1 for l_0 and p_{r0}. The values of l_0 and p_{r0} are elicited in eight and five iterations, respectively. The prospect that is chosen is shown in bold. The starting value of l_0 is $-g_0$ and the starting value of p_{r0} is 1/2.

Depending on the choice made in an iteration, the value is increased or decreased by a size equal to half the size of change in the previous iteration. After the final iteration, an interval is obtained in which the true indifferent value should lie. The value is then calculated by taking the midpoint of the resulting interval. For example, the value of p_{r0} should lie between 0.60 and 0.63 and we take 0.615 as the final value of p_{r0}, which implies that the loss aversion coefficient for this participant i is γ_i = 1/0.615 = 1.63.

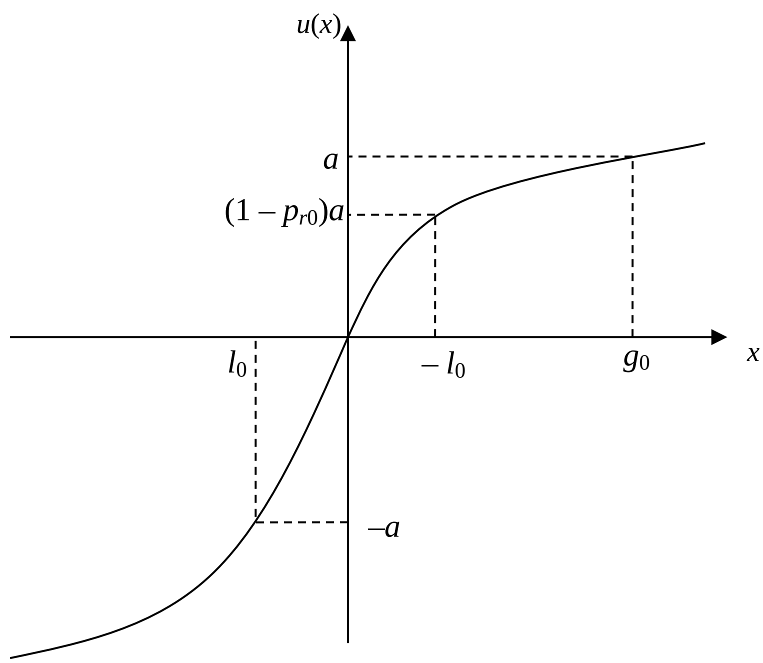


Figure B.1 The simplified elicitation procedure

Table B.1. An example of the bisection approach

Iteration	Choices in elicitation of l_0	Choices in elicitation of p_{r0}
1	**0** vs. (1,000, 0.5; –1000)	**598** vs. (1,000, 0.5; 0)
2	0 vs. **(1,000, 0.5; –500)**	598 vs. **(1,000, 0.75; 0)**
3	**0** vs. (1,000, 0.5; –750)	598 vs. **(1,000, 0.63; 0)**
4	**0** vs. (1,000, 0.5; –625)	**598** vs. (1,000, 0.57; 0)
5	0 vs. **(1,000, 0.5; –563)**	**598** vs. (1,000, 0.60; 0)
6	0 vs. **(1,000, 0.5; –594)**	–
7	**0** vs. (1,000, 0.5; –609)	–
8	**0** vs. (1,000, 0.5; –602)	–
Indifferent value	–598	0.615

Appendix C

Instructions and Screen Shots for Experiment 1

The following instructions and screen shots are for the Cr=0.95 treatment under Experiment 1a. Protocol was identical for the other treatments, expect for the contract parameters used and/or order that the contract options were presented.

Contract Preference Game Instructions

You are a manager of a cheesecake manufacturer which produces cheesecakes and sells them through a local store. At the beginning of each week, the local store places an order for 9 cheesecakes, which are then delivered to the store for sale. At the end of the week, any unsold cakes are thrown away and have no value. Each week customer demand at the store is equally likely to be any integer between 0 and 9 (i.e., 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 are equally likely).

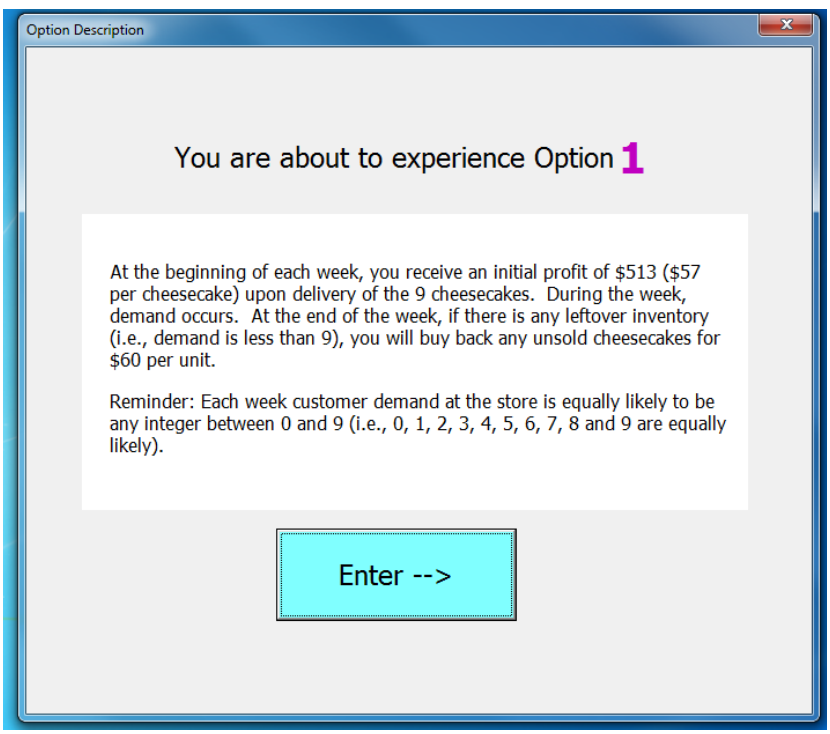
As the manager of the cheesecake manufacturer, you will be choosing which of the two payment options you want to offer to the store. The store will continue to order 9 cheesecakes each week no matter which payment option you choose. You incur a unit cost in producing the cheesecakes which may or may not be covered by the initial wholesale price paid by the store. The two options below describe different cash flows of profit and loss net of this production cost.

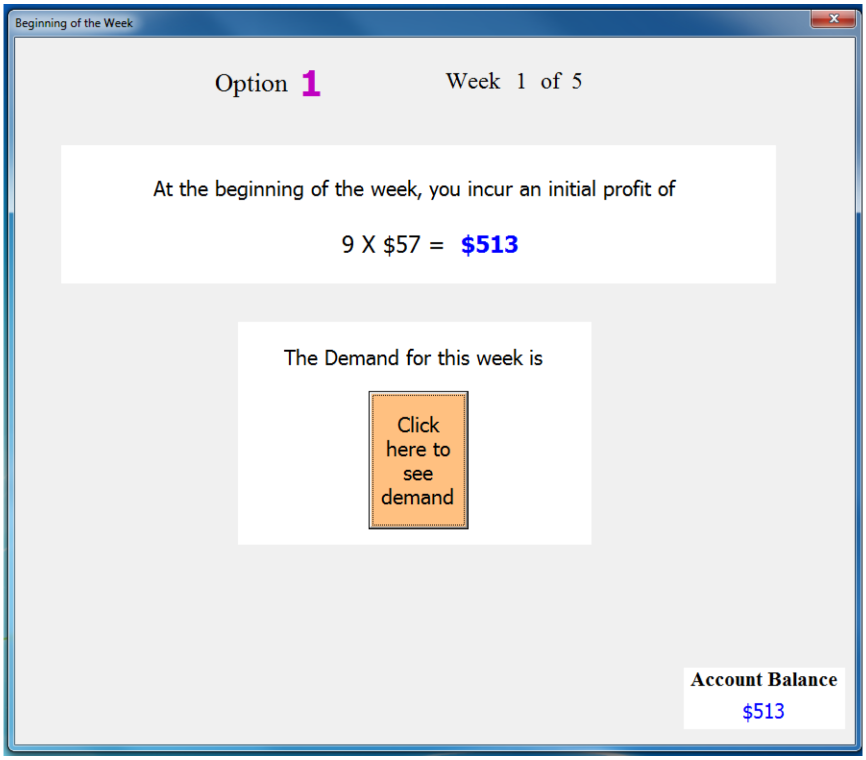
Option 1: At the beginning of each week, you receive an initial **profit** of $513 ($57 per cheesecake) upon delivery of the 9 cheesecakes. During the week, demand occurs. At the end of the week, if there is any leftover inventory (i.e., demand is less than 9), you will buy back any unsold cheesecakes for $60 per unit.

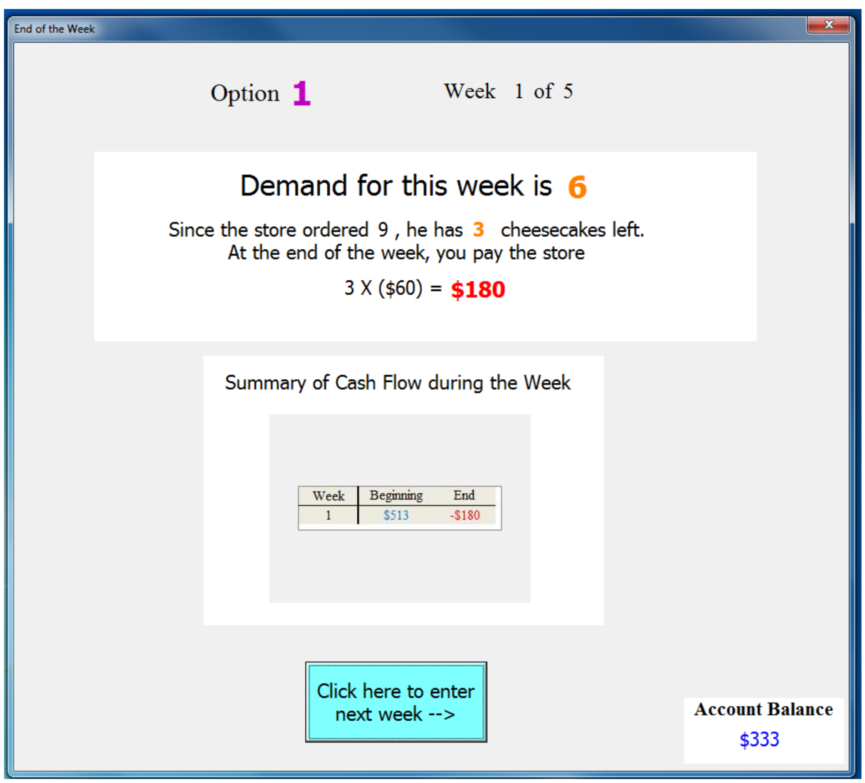
Option 2: At the beginning of each week, you initially incur a **cost** of $27 ($-3 per cheesecake) upon delivery of the 9 cheesecakes. During the week, demand occurs. At the end of the week, the store will give you $60 for each cheesecake sold.

To better understand these two options, you will first witness a simulation of the cash flow under each option over a 5-week period. After the simulation, you will be asked which option you prefer. Your preferred option will then be simulated for one additional week and you will be paid based on the outcome of this week. Your payout from part 1 of the experiment equals the profit you earn in the final week times a conversion rate of 0.01. For example, if your final profit for this week is $400, you will receive $400 * 0.01 = $4.00 from part 1.

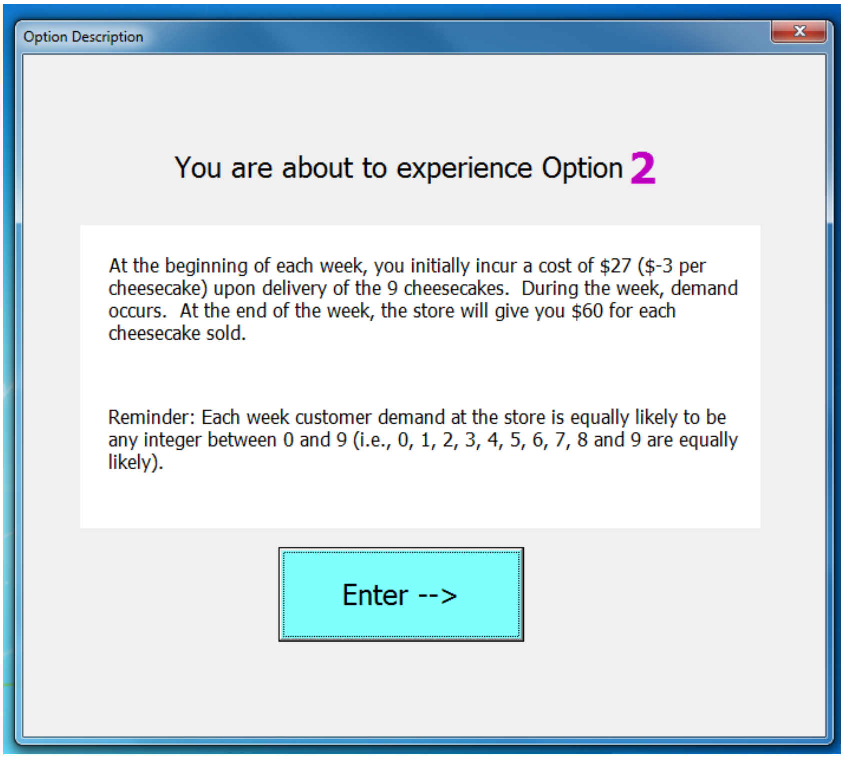
Contract Preference Game Screen Shots

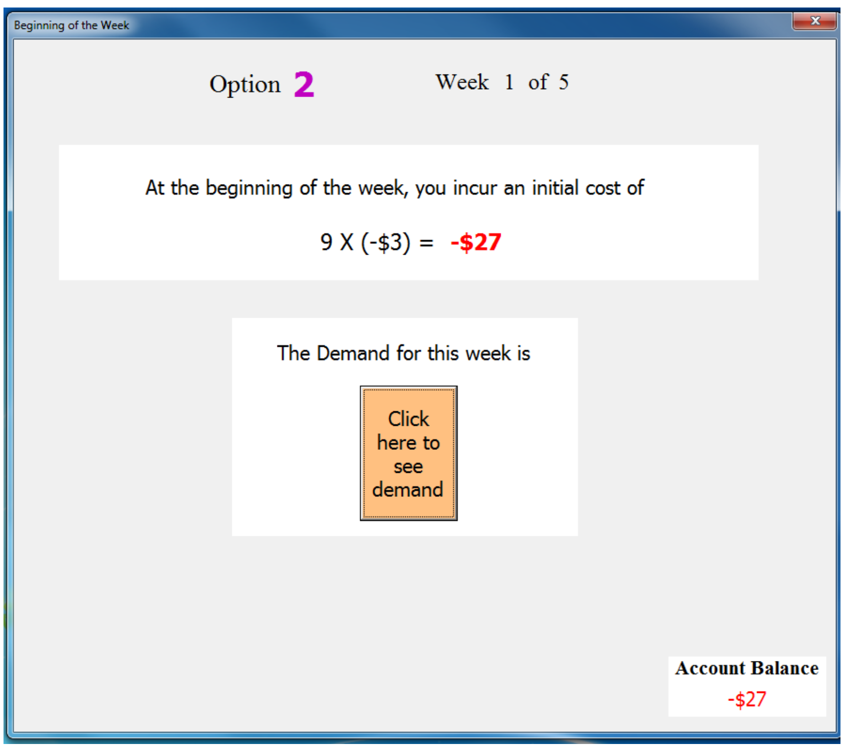


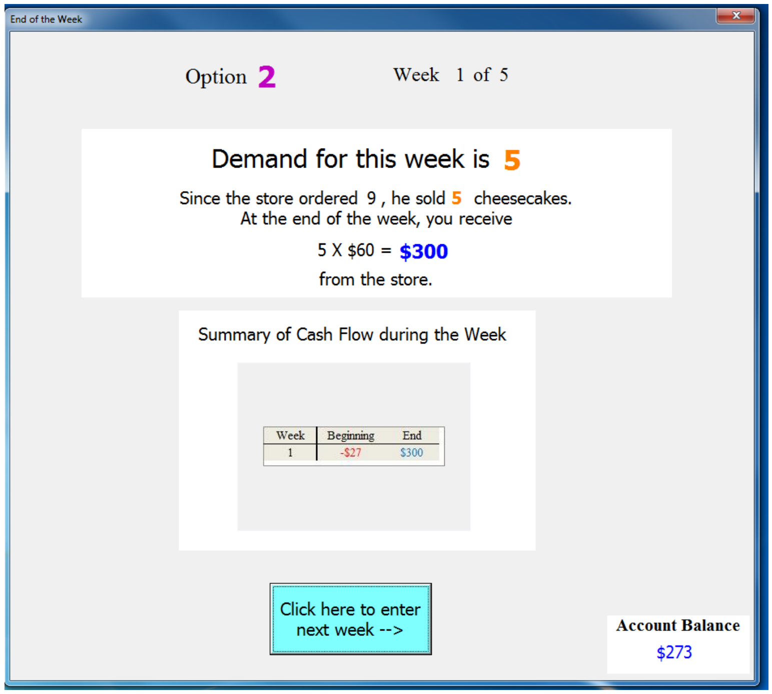

Beginning of the Week
Option 1
Week 1 of 5
At the beginning of the week, you incur an initial profit of
9 X $57 = $513
The Demand for this week is
Click here to see demand
Account Balance
$513


End of the Week
Option 1
Week 1 of 5
Demand for this week is 6
Since the store ordered 9 , he has 3 cheesecakes left.
At the end of the week, you pay the store
3 X ($60) = $180
Summary of Cash Flow during the Week
Week
Beginning
End
1
$513
-$180
Click here to enter next week -->
Account Balance
$333

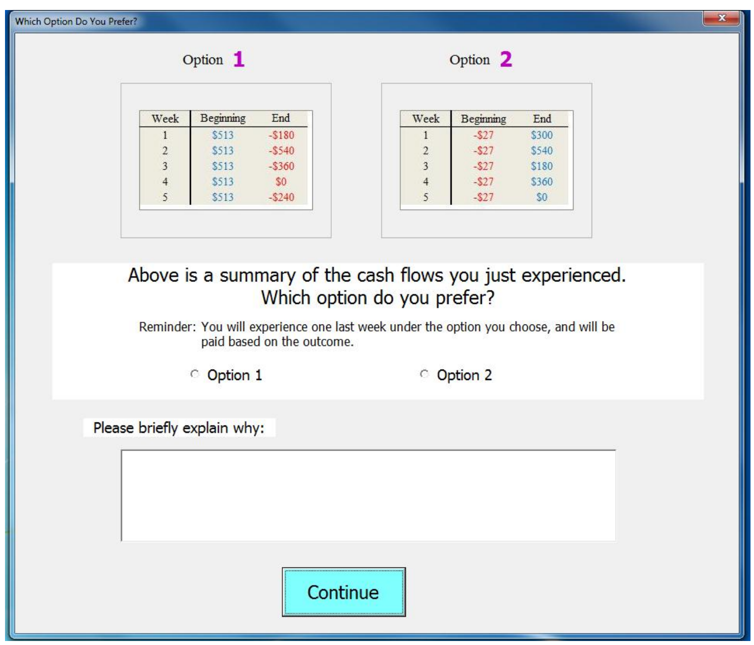
After participants experience 5 weeks of contract 1, they are introduced to contract 2.







After participants experience both contract options, they are shown a summary of the cash flows and asked for their preference between the two options.



After indicating their preferences, the participants experienced one additional week for the contract option they chose.

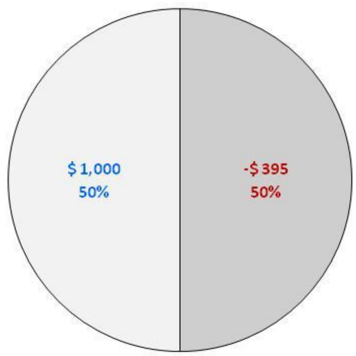
<u>General Decision Making Game</u>

Introductions

In this part, you will be asked 13 questions. In each question, you will to asked to choose between two options, labeled A and B. Option A is always a sure outcome. Option B is displayed as a pie chart with the area of each pie slice corresponding to the likelihood (i.e., probability) of achieving some stated value. The following examples illustrate the general format.

<u>Example Question 1:</u>

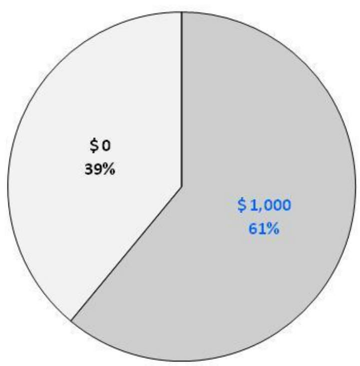
Option A	Option B
$0 For sure	



Option A corresponds to getting nothing ($0) for sure while under Option B there is a 50% probability of gaining $1,000 and 50% probability of losing $395.

<u>Example Question 2:</u>

Option A	Option B
$525 For sure	



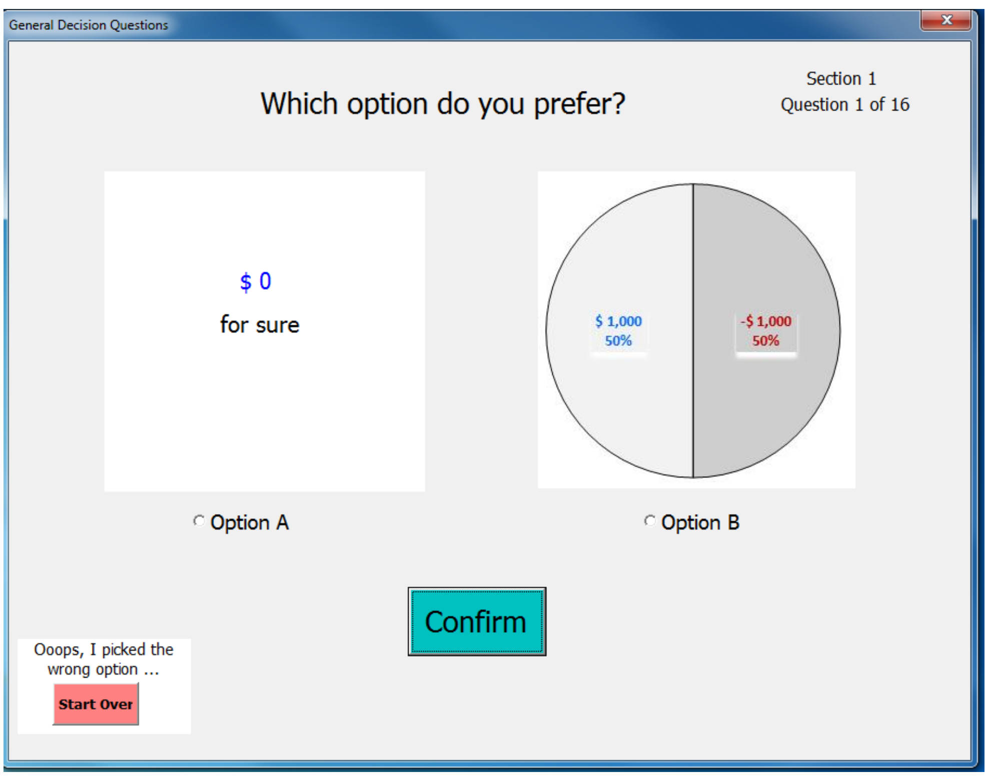
Option A corresponds to receiving $525 for sure while under Option B there is a 39% probability of getting nothing ($0) and a 61% probability of gaining $1,000.

After answering 13 questions of this type, one of these questions will be randomly selected and used to determine your final payment for Part 2. Your payment will equal the outcome of the option you choose for this question times a conversion rate of 0.01. To illustrate, suppose question 1 above was randomly selected. If your choice for this question was Option A, your payment would be $0 * 0.01 = $0. If your choice was Option B, your payment would be determined by random draw. In this case, a random integer between 1 and 100 with equal probability will be generated. If the number is less or equal to 50 you will receive $1,000 * 0.01 = $10. Otherwise, you will receive -$395 * 0.01 = -$3.95.

Question: Under example question 2, suppose you prefer Option B. The random integer is 50, what is your final payout?

If you make a mistake in one of the first five questions, you can click the box on the bottom left corner of the screen to start this part over. This box will disappear once you proceed beyond the fifth question.

Choice Game Screen Shots



Appendix D

Instructions and Screen Shots for Experiment 2

The following instructions and screen shots are for the Cr=0.75 treatment. Protocol was identical for the Cr=0.35 treatment, expect that different contract parameters were used.

Background

You are a manager of a cheesecake manufacturer which produces cheesecakes and sells them through a local store. At the beginning of each week, the local store places an order for **q** cheesecakes, which are then delivered to the store for sale. At the end of the week, any unsold cakes are thrown away and have no value. Each week customer demand (**D**) at the store is equally likely to be any integer from 1 to 100 (i.e., there is a 1/100 chance that **D** will be any one of the integers from 1 to 100.).

As the manager of the cheesecake manufacturer, you will determine the terms for one possible payment option that specifies the transfer payments between you and the store. The store will decide how many units of cheesecake to order given the terms you offered, and then sell them to the customer. In this experiment, the store is automated. The store has been programmed to place orders to maximize its own expected profit subject to the terms you offer. Your task is to set the terms this payment option to maximize your total profit.

How you will get paid?

In the experiment you will experience this payment option which lasts 20 weeks. The first 5 weeks (week -4 to 0) are warm-up weeks, during which you can practice and get familiar with the payment flows. Your payout for each option will equal the average profit you earn from the next 15 weeks (week 1 to 15) times a conversion rate of 0.01. For example, if your average profit is $500, you will receive $500 * 0.01 = $5.

Instruction for the Buyback Contract

Contract terms

You will offer a contract to the store consisting of two terms: 1) a unit wholesale price (**w**) that you charge for each unit the store orders, and 2) a unit rebate (**b**) that you pay the store for each unit left in the store at the end of the week. Once these terms are specified by you, the store then sets the order quantity (**q**) that maximizes its own expected profit.

The payment flows for the week are as follows. At the beginning of each week, you incur a production cost of $5 and an initial payment of **w** for each cheesecake the store orders. This gives you $\underline{(w - \$5) \times q}$ at the beginning of the week. During the week, customer demand occurs. At the end of the week, if there are any leftover cheesecakes (i.e., customer demand **D** is less than the store's order **q**), you will pay the store a total amount of $\underline{b \times (q - D)}$. On the other hand, if cheesecakes are sold out (i.e., customer demand **D** is greater or equal to the store's order **q**), you pay the store $\underline{0}$ at the end of the week. Recall that the customer demand D is equally likely to be any integer from 0 to 100.

Question: Suppose the unit wholesale price **w** is $15, and the unit rebate **b** is $12. The store places an order **q** of 50 units. How much do you have at the beginning of the week? If the customer demand **D** is 40, how much do you pay to the store at the end of the week? What if the customer demand is 60?

Recall that this contract consists of two elements: the wholesale price **w** and the unit rebate **b**. Your task is to set the unit wholesale price **w** within a given range to maximize your profit. The unit rebate **b** will be optimized based on your choice of **w**. Note that the higher the wholesale price you set, the higher the unit rebate will be, and the higher the quantity the store will order, and *vise versa*.

Decision Tools

We will provide feedback information feedback information on the first screen of each week to help you make your decision. In the middle of the screen, a scrollbar is used to choose your unit wholesale price. Once a wholesale price is chosen, the optimal value for the unit rebate is then displayed. The computer will also display the store's order quantity, your transactions at the beginning of the week, and your payment to the store at the end of the week. After confirming your decision, you will receive information on the realized customer demand, and the payments for that week. The computer will also display the history of the above information for all previous weeks

Instruction for the Revenue Sharing Contract

Contract terms

You will offer a contract to the store consisting of two terms: 1) a wholesale price (**w**) that you charge for each unit the store orders, and 2) a revenue share (**r**) that you receive from the store for each unit sold by the store at the end of the week. Under this contract form, you are required to set the wholesale price **w** below your unit production cost (**$5**). Once these terms are specified by you, the store then sets the order quantity (**q**) that maximizes its own expected profit.

The payment flows for the week are as follows. At the beginning of each week, you incur a production cost of $5 and an initial payment of **w** for each cheesecake the store orders. This gives you <u>(w – $5) × q</u> at the beginning of the week. During the week, customer demand occurs. At the end of the week, if the customer demand **D** is less than the store's order **q**, you will receive from the store a total amount of <u>r × D</u>. On the other hand, if cheesecakes are sold out (i.e., customer demand **D** is greater or equal to the store's order **q**), you will receive <u>r × q</u> at the end of the week. Recall that the customer demand D is equally likely to be any integer from 0 to 100.

Question: Suppose the unit wholesale price **w** is $3, and the unit revenue share **r** is $12. The store places an order **q** of 50 units. How much do you have at the beginning of the week? If the customer demand **D** is 40, how much do you receive from the store at the end of the week? What if the customer demand is 60?

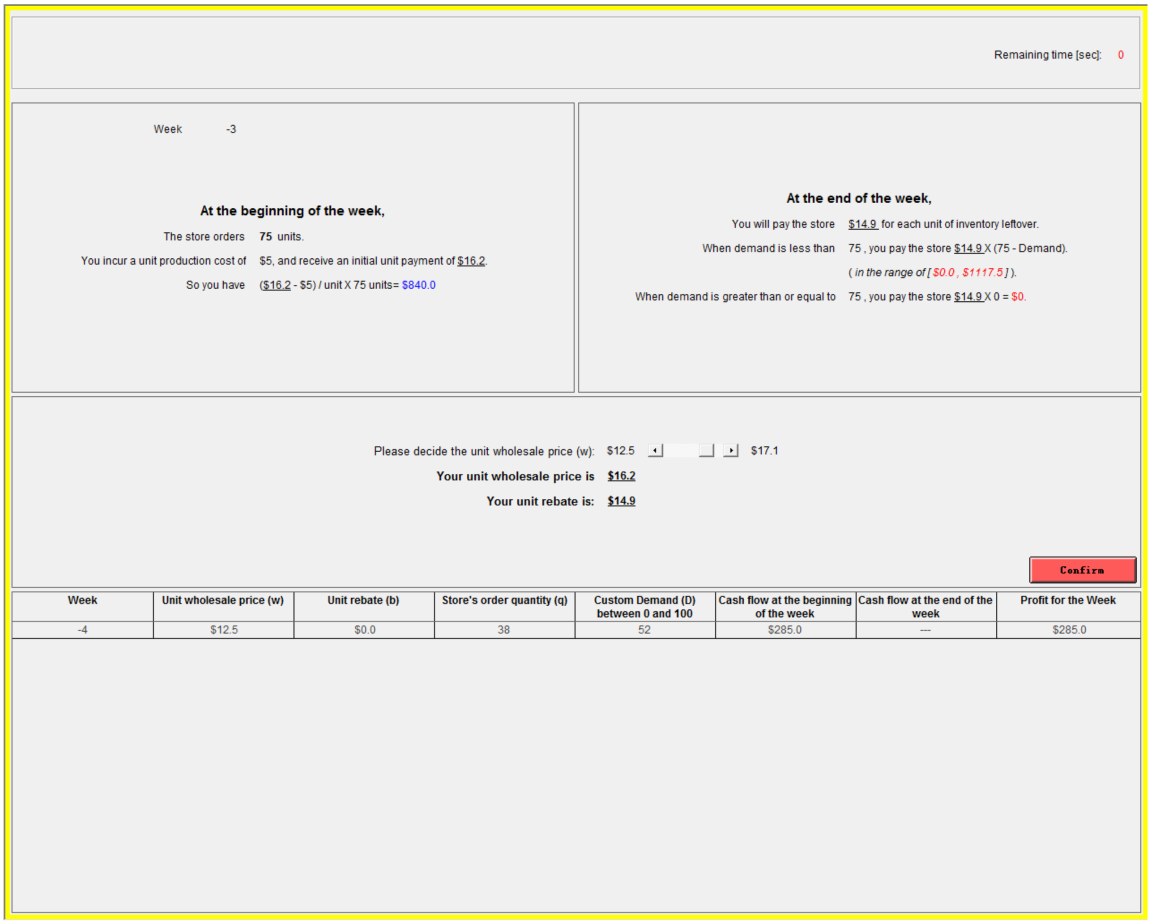
Recall that this contract consists of two elements: the wholesale price **w** and the unit revenue share **r**. Your task is to both the unit wholesale price **w** within a given range to maximize your profit. The unit revenue share **r** will be optimized based on your choice of **w**. Note that the higher the wholesale price you set, the lower the unit revenue share will be, and the lower the quantity the store will order, and *vise versa*.

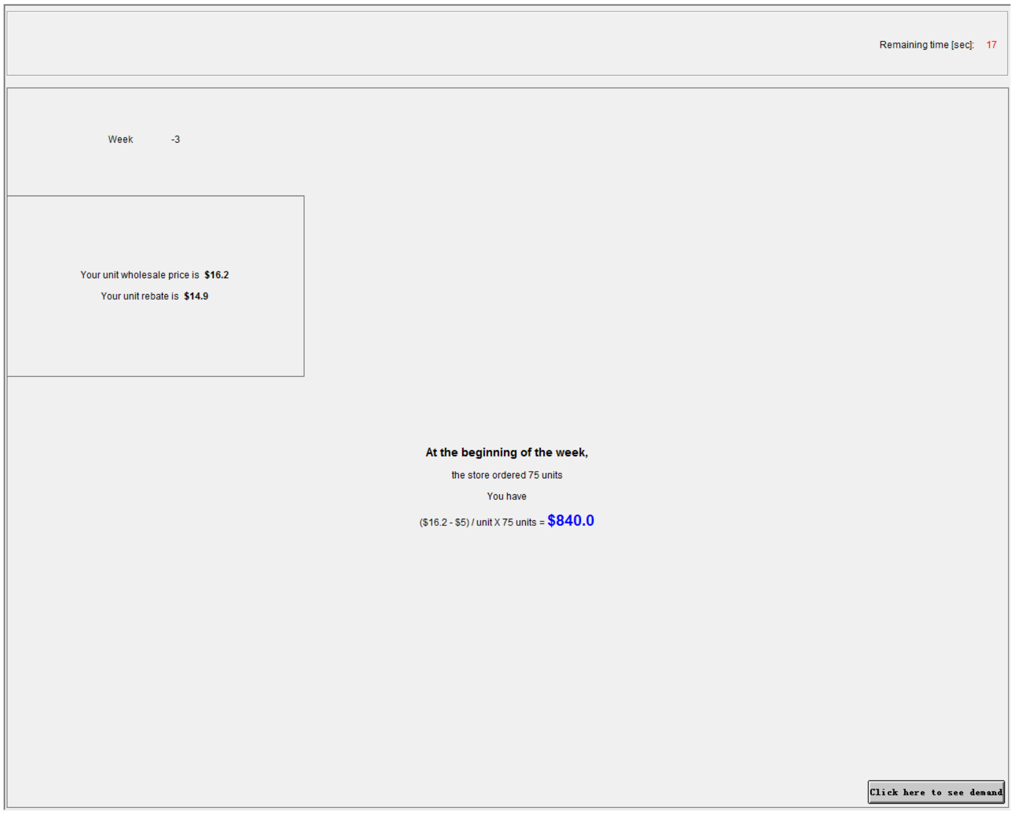
Decision Tools

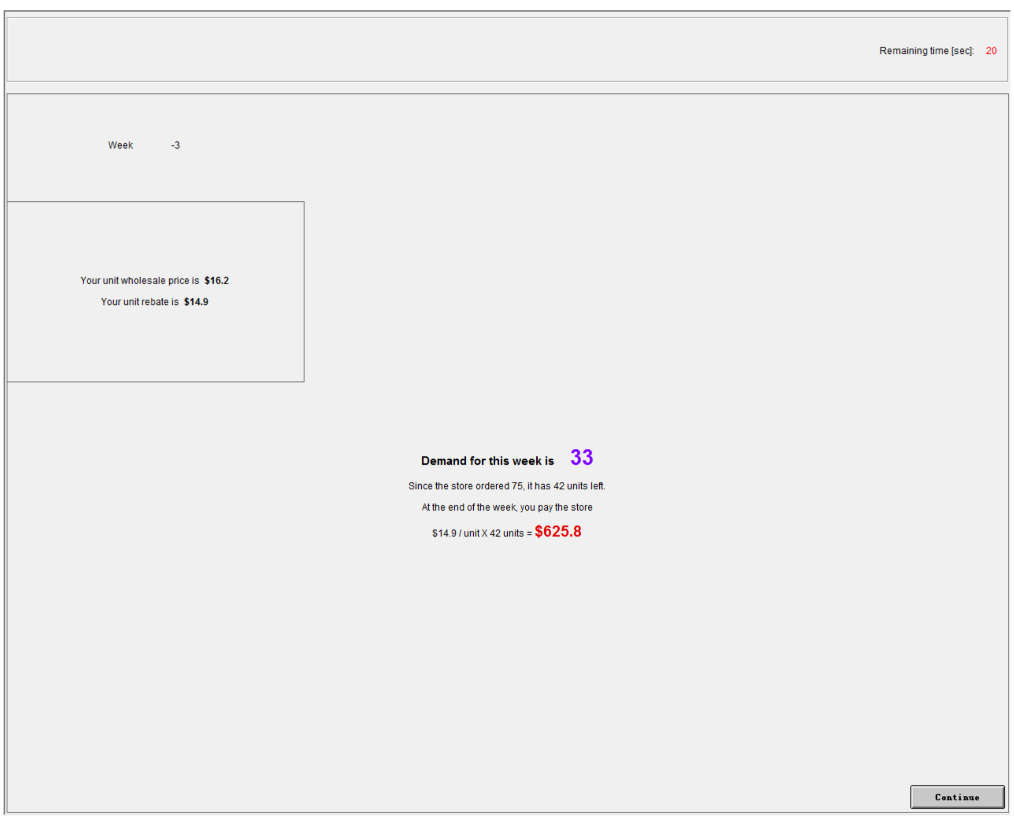
We will provide feedback information on the first screen of each week to help you make your decision. In the middle of the screen, a scrollbar is used to choose your unit wholesale price. Once a wholesale price is chosen, the optimal value for the unit revenue share is then displayed. The computer will also display the store's order quantity, your transactions at the beginning of the week, and your payment received from the store at the end of the week. After confirming your decision, you will receive information on the realized customer demand, and the payments for that week. The computer will also display the history of the above information for all previous weeks.

Contract Parameter Decision Game Screen Shots

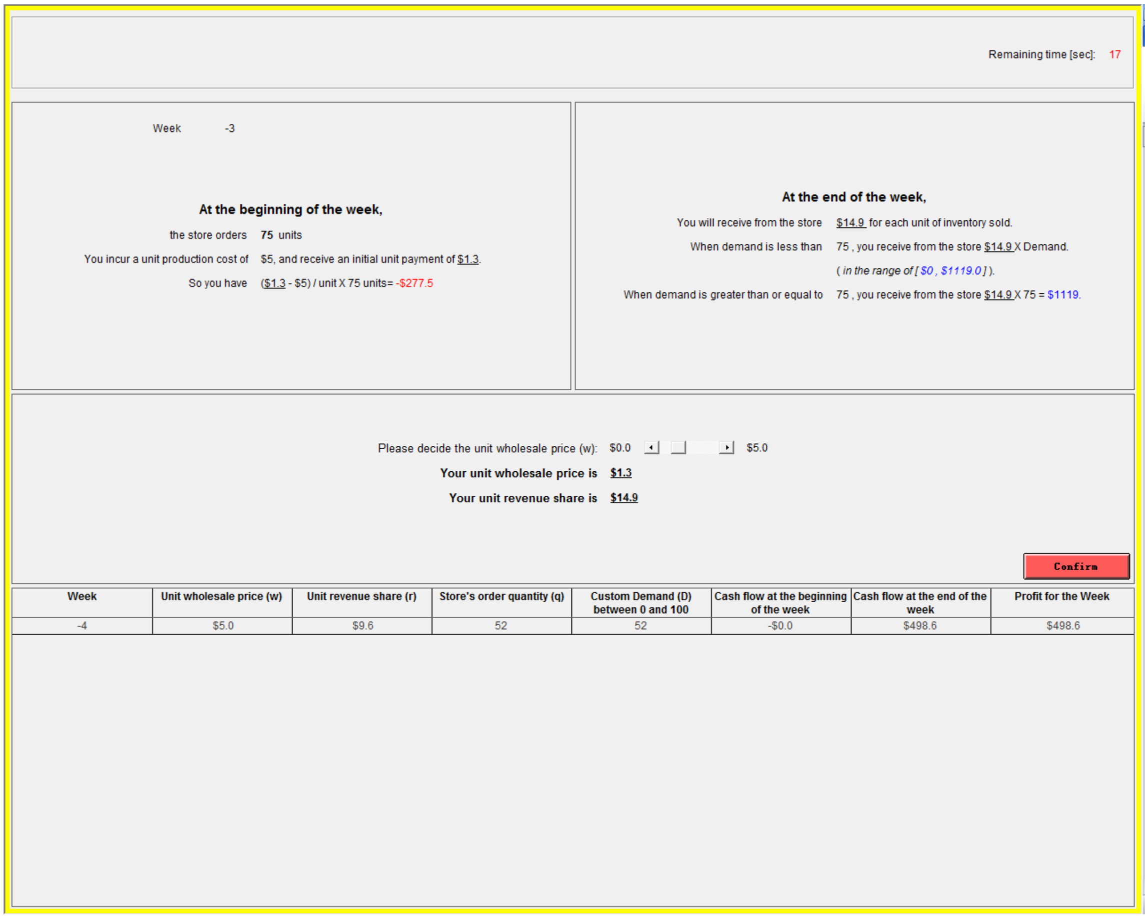
Buyback contract

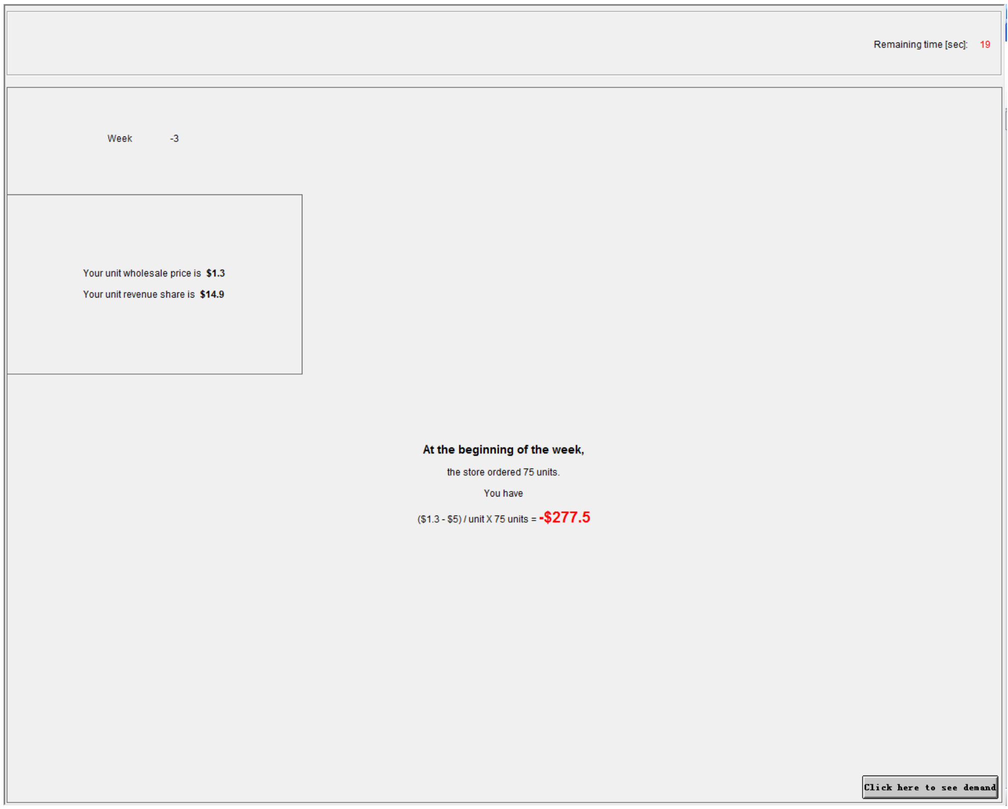


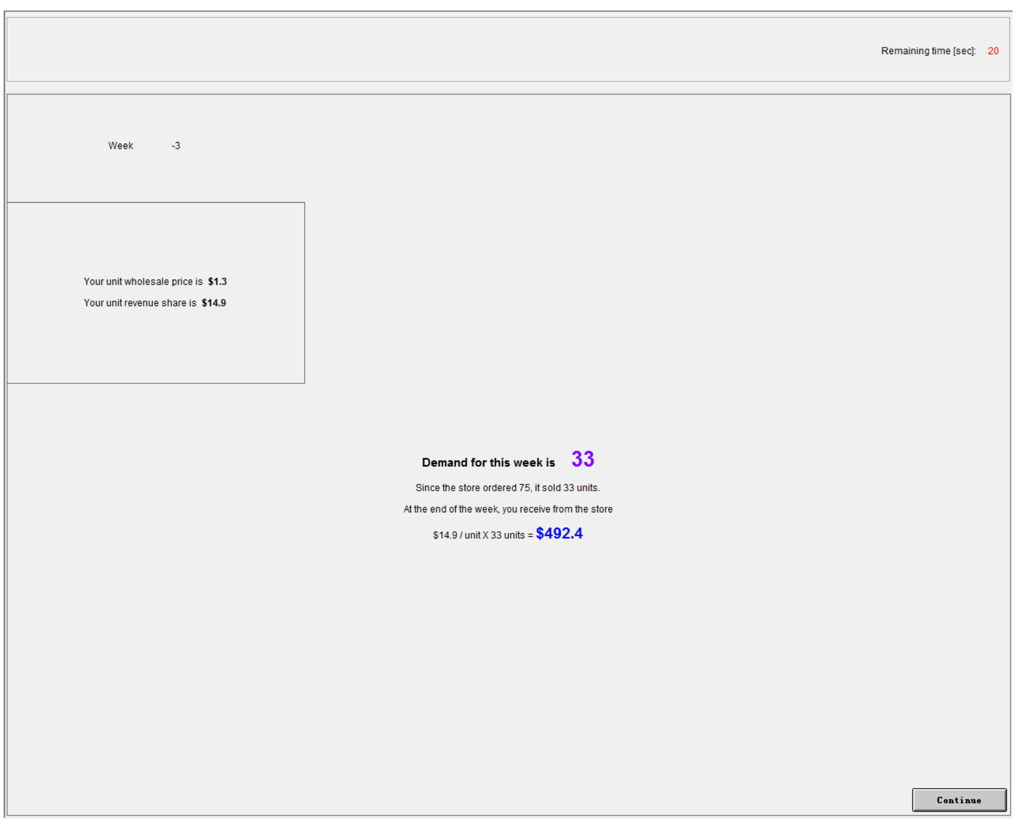

Remaining time [sec]: 17
Week -3
Your unit wholesale price is $16.2
Your unit rebate is $14.9
At the beginning of the week,
the store ordered 75 units
You have
($16.2 - $5) / unit X 75 units = $840.0
Click here to see demand


Remaining time [sec]: 20
Week -3
Your unit wholesale price is $16.2
Your unit rebate is $14.9
Demand for this week is 33
Since the store ordered 75, it has 42 units left.
At the end of the week, you pay the store
$14.9 / unit X 42 units = $625.8
Continue

Revenue sharing contract




Remaining time [sec]: 19
Week -3
Your unit wholesale price is $1.3
Your unit revenue share is $14.9
At the beginning of the week,
the store ordered 75 units.
You have
($1.3 - $5) / unit X 75 units = -$277.5
Click here to see demand


Remaining time [sec]: 20
Week -3
Your unit wholesale price is $1.3
Your unit revenue share is $14.9
Demand for this week is 33
Since the store ordered 75, it sold 33 units.
At the end of the week, you receive from the store
$14.9 / unit X 33 units = $492.4
Continue

Appendix E

Instructions and Screen Shots for Experiment 3a and 3b

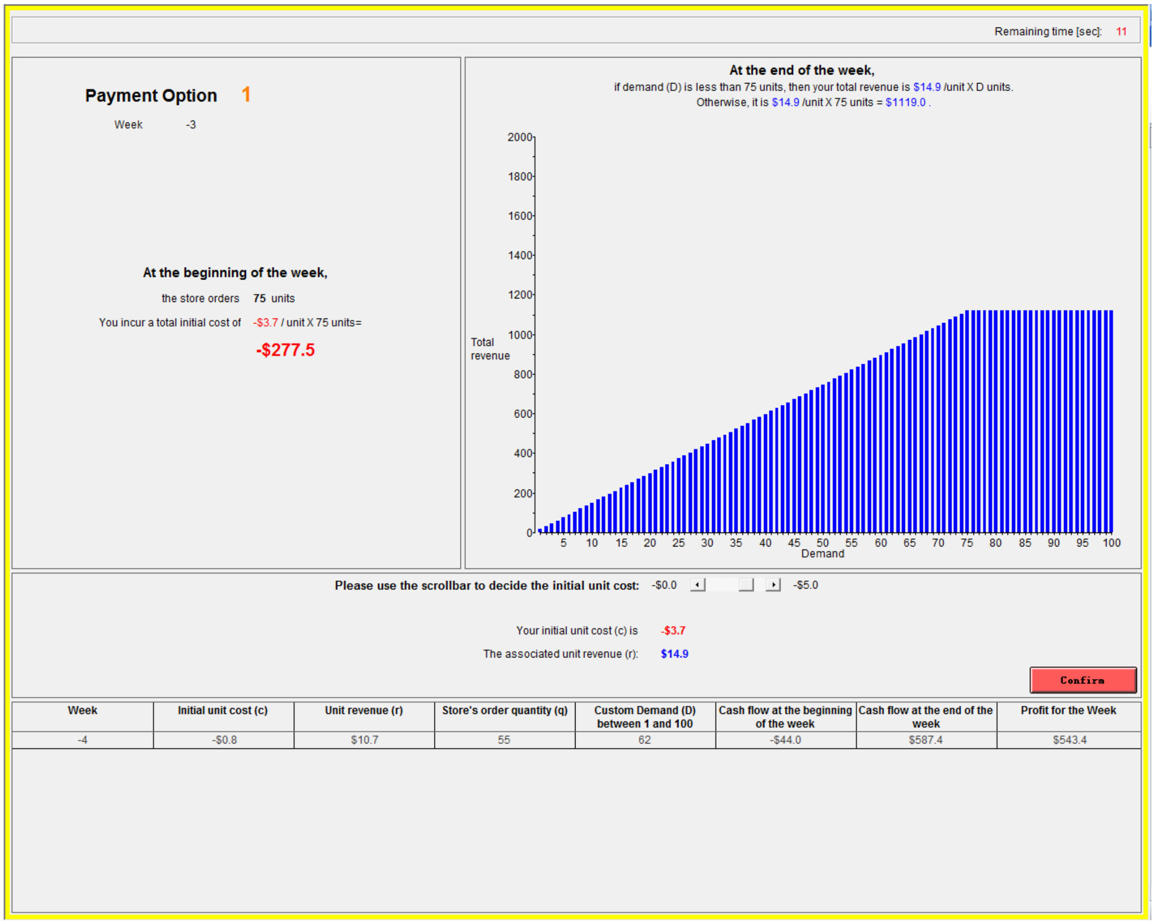
<u>Experiment 3a</u>

The instructions are the same as those for experiment 2, which are included in Appendix C.

The following screen shots are for the Cr=0.75 treatment. Protocol was identical for the Cr=0.35 treatment, expect that different contract parameters were used.

Buyback contract

Revenue sharing contract



Experiment 3b

The following instructions and screen shots are for the Cr=0.75 treatment. Protocol was identical for the Cr=0.35 treatment, expect that different contract parameters were used.

Instruction for the Buyback Contract

Contract terms

You will offer a contract to the store consisting of two terms: 1) a unit wholesale price (**w**) that you charge for each unit the store orders, and 2) a unit rebate (**b**) that you pay the store for each unit left in the store at the end of the week. Once these terms are specified by you, the store then sets the order quantity (**q**) that maximizes its own expected profit.

The payment flows for the week are as follows. At the beginning of each week, you incur a production cost of $5 and an initial payment of **w** for each cheesecake the store orders. This gives you (w – $5) × q at the beginning of the week. During the week, customer demand occurs. At the end of the week, if there are any leftover cheesecakes (i.e., customer demand **D** is less than the store's order **q**), you will pay the store a total amount of b × (q - D). On the other hand, if cheesecakes are sold out (i.e., customer demand **D** is greater or equal to the store's order **q**), you pay the store 0 at the end of the week. Recall that the customer demand D is equally likely to be any integer from 0 to 100.

Question: Suppose the unit wholesale price **w** is $15, and the unit rebate **b** is $12. The store places an order **q** of 50 units. How much do you have at the beginning of the week? If the customer demand **D** is 40, how much do you pay to the store at the end of the week? What if the customer demand is 60?

Your task is to set both the unit wholesale price **w** and the unit rebate **b** to maximize your profit. For any given **w**, there is a lowest possible value for the unit rebate $\mathbf{b_{min}}$, where setting **b** lower than this value causes the store to order nothing. You will be informed about the value $\mathbf{b_{min}}$ for whatever wholesale price **w** you select and will be restricted to set your unit rebate **b** above this minimum.

Decision Tools

We will provide feedback information on the first screen of each week to help you make your decision. In the middle of the screen, two scrollbars are used to choose your unit wholesale price and unit rebate. Once a wholesale price is chosen, the screen will display the lowest possible value for the unit rebate ($\mathbf{b_{min}}$), and you must set a unit rebate above this value. The computer will also display the store's order quantity, your transactions at the beginning of the week, and your payment to the store at the end of the week. After confirming your decision, you will receive information on the realized customer demand, and the payments for that week. The computer will also display the history of the above information for all previous weeks.

Instruction for the Revenue Sharing Contract

Contract terms

You will offer a contract to the store consisting of two terms: 1) a wholesale price (**w**) that you charge for each unit the store orders, and 2) a revenue share (**r**) that you receive from the store for each unit sold by the store at the end of the week. Under this contract form, you are required to set the wholesale price **w** below your unit production cost (**$5**). Once these terms are specified by you, the store then sets the order quantity (**q**) that maximizes its own expected profit.

The payment flows for the week are as follows. At the beginning of each week, you incur a production cost of $5 and an initial payment of w for each cheesecake the store orders. This gives you $\underline{(w - \$5) \times q}$ at the beginning of the week. During the week, customer demand occurs. At the end of the week, if the customer demand **D** is less than the store's order **q**, you will receive from the store a total amount of $\underline{r \times D}$. On the other hand, if cheesecakes are sold out (i.e., customer demand **D** is greater or equal to the store's order **q**), you will receive $\underline{r \times q}$ at the end of the week. Recall that the customer demand D is equally likely to be any integer from 0 to 100.

Question: Suppose the unit wholesale price **w** is $3, and the unit revenue share **r** is $12. The store places an order **q** of 50 units. How much do you have at the beginning of the week? If the customer demand **D** is 40, how much do you receive from the store at the end of the week? What if the customer demand is 60?

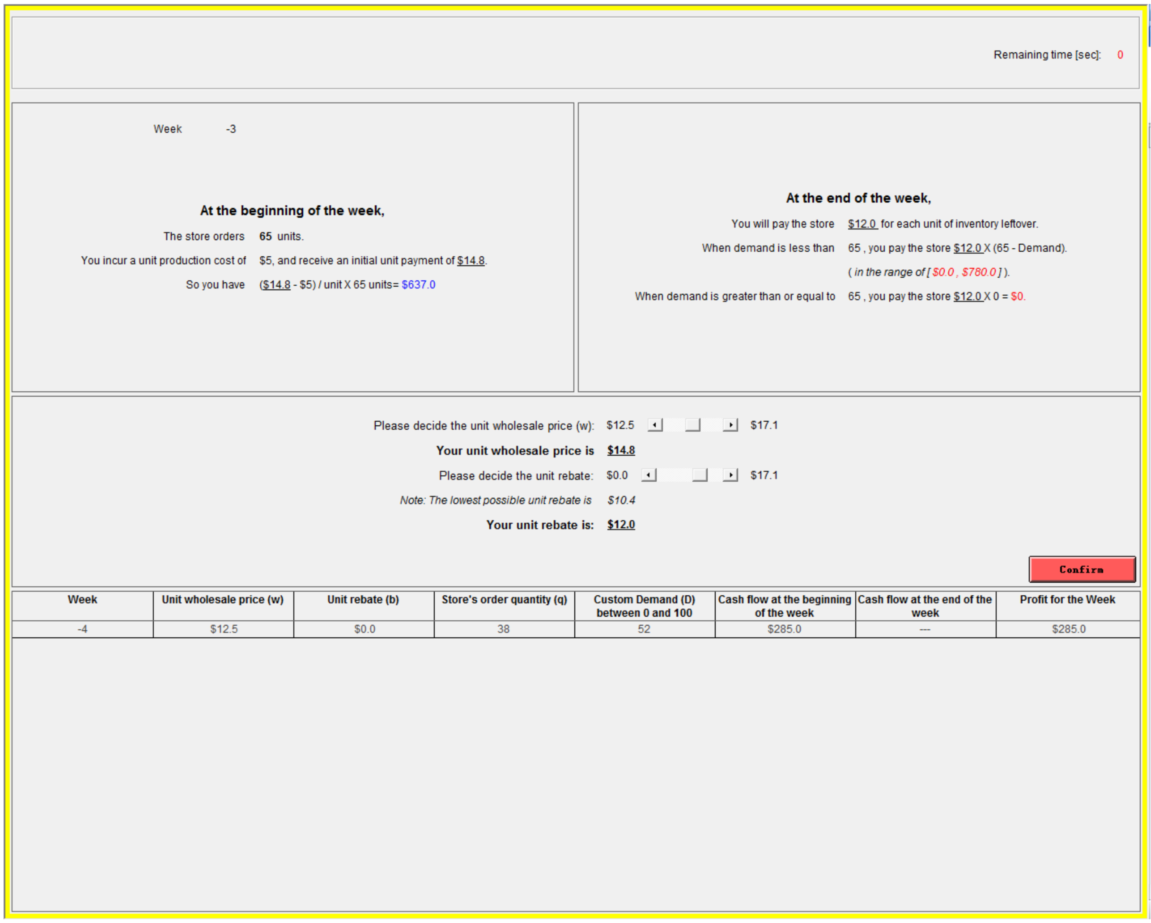
Your task is to set both the unit wholesale price **w** and the unit revenue share **r** to maximize your profit. For any given **w**, there is a highest possible value for the unit revenue share $\mathbf{r}_{max}$, where setting **r** higher than this value causes the store to order nothing. You will be informed about the value $\mathbf{r}_{max}$ for whatever wholesale price **w** you select and will be restricted to set your unit revenue share **r** below this maximum.

Decision Tools

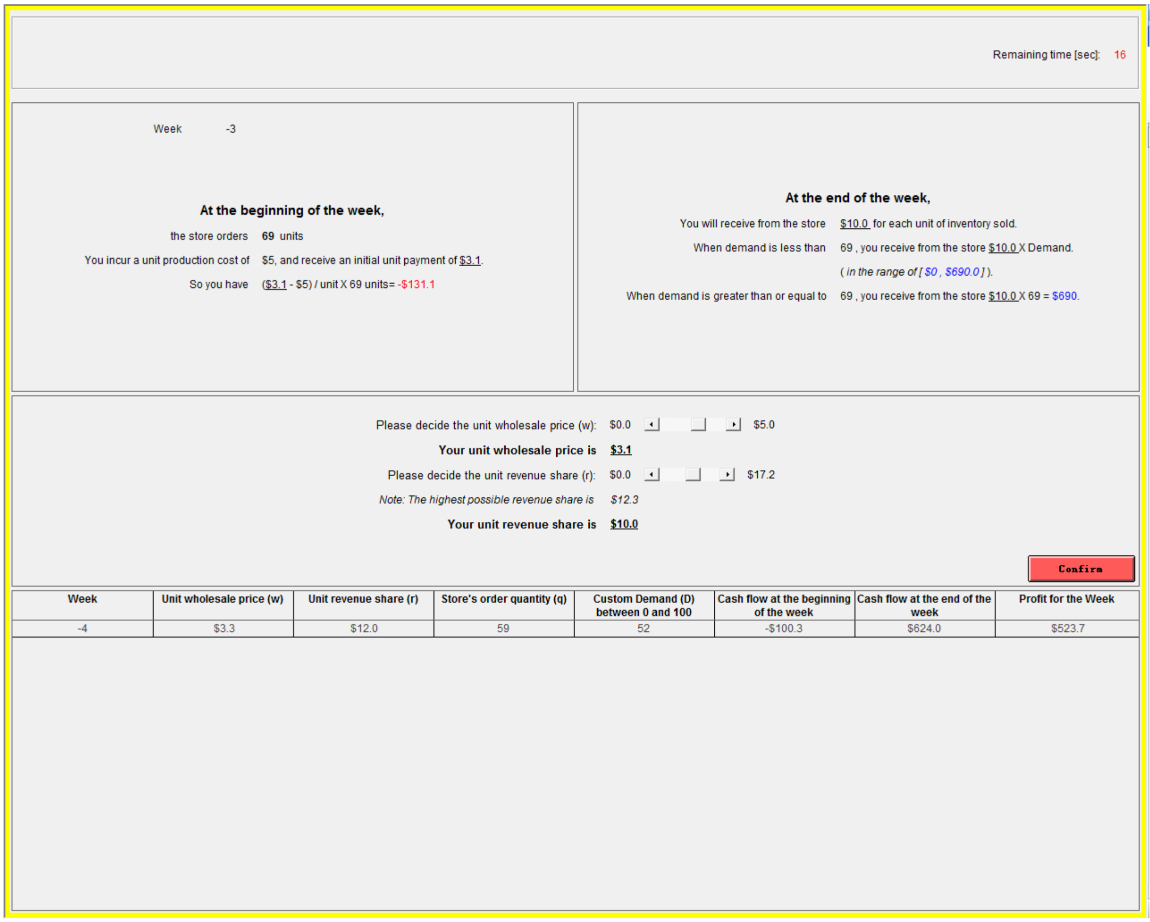
We will provide feedback information on the first screen of each week to help you make your decision. In the middle of the screen, two scrollbars are used to choose your unit wholesale price and unit revenue share. Once a wholesale price is chosen, the screen will display the highest possible value for the unit revenue share ($\mathbf{r}_{min}$), and you must set a unit revenue share below this value. The computer will also display the store's order quantity, your transactions at the beginning of the week, and your payment received from the store at the end of the week. After confirming your decision, you will receive information on the realized customer demand, and the payments for that week. The computer will also display the history of the above information for all previous weeks.

Screen shots

Buyback contract



Revenue sharing contract



Appendix F

Additional Tables and Figures

Table F.1: FGLS estimation for $w_{i,t}$ and $E(\pi)_{i,t}$ for experiment 3a.

(a) $w_{i,t}$			(b) $E(\pi)_{i,t}$		
	BB	RS		Cr=0.35	Cr=0.75
Intercept	18.08*** (0.08)	3.86*** (0.67)	*Intercept*	73.28*** (4.34)	407.84*** (3.87)
Cr	-3.89*** (0.12)	-1.87* (0.83)	H^{γ}	10.00 (6.91)	-12.06* (5.33)
H^{γ}	-0.41** (0.13)	1.58† (0.92)	BB	-1.71 (10.92)	-55.91*** (4.76)
$Cr \times H^{\gamma}$	-0.50* (0.23)	-0.36 (1.08)	$H^{\gamma} \times$ BB	-2.53 (11.14)	-23.09* (8.97)
σ_{μ}	0.23***	1.39***	σ_{μ}	11.05***	10.06***

Note: *** p<0.001 ** p<0.01 * p<0.05 † p<0.1

Note: robust standard deviations are reported in parentheses.

Table F.2: MLE results for γ, δ, α and variances for experiment 3b.

	Model-γ,δ,α		Model-γ,α		Model-γ,δ		Model-δ,α	
	Est.	S.E	Est.	S.E	Est.	S.E	Est.	S.E
γ	1.29	0.01	1.18	0.01	1.19	0.01	–	–
δ	0.91	0.01	–	–	0.90	0.01	1.17	0.01
α	0.25	0.01	0.27	0.02	–	–	0.28	0.02
$\sigma^2_{BB,Cr=0.35}$	0.37	0.04	0.53	0.06	0.35	0.04	0.94	0.11
$\sigma^2_{BB,Cr=0.75}$	1.39	0.14	1.52	0.16	1.40	0.15	3.06	0.32
$\sigma^2_{RS,Cr=0.35}$	9.48	0.96	9.49	0.97	9.55	0.95	9.57	0.98
$\sigma^2_{RS,Cr=0.75}$	1.33	0.14	1.32	0.14	4.48	0.48	1.32	0.14
–LL	1,223.55		1,259.76		1,330.22		1,370.89	
BIC	2,493.15		2,559.00		2,699.92		2,781.26	
Likelihood Ratio Test: (test against Model-γ,δ,α)			$\chi^2(1)=74.42^{***}$		$\chi^2(1)=213.34^{***}$		$\chi^2(1)=294.68^{***}$	

Note: ***$p<0.001$

Table F.2: (continued)

	Model-α		Model-γ		Model-δ	
	Est.	S.E	Est.	S.E	Est.	S.E
γ	–	–	1.07	0.00	–	–
δ	–	–	–	–	1.06	0.00
α_0	0.92	0.05	–	–	–	–
$\sigma^2_{BB,Cr=0.35}$	0.94	0.11	0.40	0.05	0.59	0.07
$\sigma^2_{BB,Cr=0.75}$	1.49	0.15	2.64	0.27	4.02	0.41
$\sigma^2_{RS,Cr=0.35}$	23.67	2.40	9.83	1.03	9.46	0.96
$\sigma^2_{RS,Cr=0.75}$	1.32	0.14	4.39	0.47	4.61	0.49
–LL	1,389.65		1,403.80		1,473.67	
BIC	2,812.20		2,840.50		2,980.24	
Likelihood Ratio Test:						
(test against Model-γ,δ,α)	$\chi^2(2)$=332.20***		$\chi^2(2)$=360.50***		$\chi^2(2)$=500.24***	

Note: ****p*<0.001

Figure F.1: Supplier's expected profit under buyback (solid) and revenue sharing (dashed).

Assuming loss aversion and prospective accounting coefficients are the same for both players (i.e., $\gamma_S=\gamma_R=\gamma$, $\delta_S=\delta_R=\delta$)