

12-1-2012

# Analyzing Revenue Sharing and Buyback Contracts: An Experimental Study

Chinthana Ramaswamy  
*University of Massachusetts Boston*

Follow this and additional works at: [http://scholarworks.umb.edu/masters\\_theses](http://scholarworks.umb.edu/masters_theses)



Part of the [Business Administration, Management, and Operations Commons](#)

---

## Recommended Citation

Ramaswamy, Chinthana, "Analyzing Revenue Sharing and Buyback Contracts: An Experimental Study" (2012). *Graduate Masters Theses*. Paper 142.

This Open Access Thesis is brought to you for free and open access by the Doctoral Dissertations and Masters Theses at ScholarWorks at UMass Boston. It has been accepted for inclusion in Graduate Masters Theses by an authorized administrator of ScholarWorks at UMass Boston. For more information, please contact [library.uasc@umb.edu](mailto:library.uasc@umb.edu).

ANALYZING REVENUE SHARING AND BUYBACK CONTRACTS:  
AN EXPERIMENTAL STUDY

A Thesis Presented

by

CHINTHANA RAMASWAMY

Submitted to the office of Graduate Studies,  
University of Massachusetts Boston,  
In partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

December 2012

Business Administration and Management

© 2012 by Chinthana Ramaswamy  
All rights reserved

ANALYZING REVENUE SHARING AND BUYBACK CONTRACTS:  
AN EXPERIMENTAL STUDY

A Thesis Presented

by

CHINTHANA RAMASWAMY

Approved as to style and content by:

---

Ehsan Elahi, Assistant Professor  
Chairperson of the Committee

---

Davood Golmohammadi, Assistant Professor  
Member

---

Atreya Chakraborty, Associate Professor  
Member

---

Philip L. Quaglieri, Dean  
College of Management

---

Pratyush Bharati, Chairman  
Management Information Systems Department

## ABSTRACT

### ANALYZING REVENUE SHARING AND BUYBACK CONTRACTS: AN EXPERIMENTAL STUDY

December 2012

Chinthana Ramaswamy, B.E., Vishweshwaraiah Technological University (India)  
M.B.A., University of Massachusetts Boston

Directed by Dr. Ehsan Elahi

This paper considers a standard newsvendor problem in a two-echelon supply chain setup. We use an experimental approach to investigate the deviation of decision makers from choosing optimal values in the context of supply chain contracts. Literature suggests that the coordinating contracts, such as revenue sharing or buyback contracts, do not necessarily improve the performance. Approaches to improve the existing revenue sharing and buyback contracts are examined in this paper. A rational supplier, who is likely to commit decision errors, sets the contract parameters to a retailer. These approaches are observed in a laboratory setting where human subjects are used to verify the experimental studies. The results show that the revenue sharing contracts, with appropriate feedback, can reduce the demand-chasing characteristic, generally seen in decision makers. This paper also discusses limitations and provides suggestions to future research.

## ACKNOWLEDGEMENTS

I wish to express my heartfelt gratitude to my advisor, and mentor Dr. Ehsan Elahi for his continuous support, and invaluable guidance throughout this project. I am deeply indebted to Dr. Atreya Chakraborty for his efforts in facilitating this opportunity, for without his efforts, such work would have been unachievable. My special thanks to Dr. Davood Golmohammadi, who agreed to be a part of thesis evaluation panel. I would like to express my heartfelt gratitude towards my family and friends, for their continuous support, and encouragement during my journey so far.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS ..... vi

LIST OF FIGURES ..... ix

LIST OF TABLES ..... x

NOMENCLATURE ..... xi

CHAPTER Page

1. INTRODUCTION ..... 1

    1.1 Problem ..... 1

    1.2 Purpose of the Thesis ..... 2

    1.3 Method of Thesis ..... 2

    1.4 Structure of the Thesis ..... 4

2. LITERATURE REVIEW ..... 5

3. DESCRIPTIVE MODELS ..... 10

    3.1 The Newsvendor Problem ..... 10

    3.2 Revenue Sharing Contract ..... 12

    3.3 Buyback Contract ..... 13

    3.4 Combined Contract ..... 14

    3.5 Demand Pattern ..... 16

    3.6 Collective Feedback ..... 17

4. EXPERIMENTS ..... 19

    4.1 Experimental Design ..... 19

    4.2 Experimental Protocol ..... 20

    4.3 Implementation ..... 21

5. HYPOTHESIS ..... 23

6. RESULTS ..... 26

CHAPTER	Page
7. LIMITATIONS AND FUTURE RESEARCH.....	34
8. SUMMARY AND MANAGERIAL IMPLICATIONS .....	35
APPENDIX A.....	37
A.1 Newsvendor Problem .....	37
A.2 Optimal contract parameters in revenue sharing contract .....	38
A.3 Optimal contract parameters in buyback contract.....	40
A.4 Optimal contract parameters in combined contract.....	41
APPENDIX B .....	43
B.1. Experiment design .....	43
B.2. Average order quantities of subjects .....	46
REFERENCES .....	49

## LIST OF FIGURES

Figure	Page
1. Visualization of demand pattern (uniform distribution) .....	16
2. Average order quantities with would-be total profit feedback (revenue sharing). 30	
3. Average order quantities with would-be total profit feedback (buyback) .....	32
4. Screenshot of revenue sharing contract experiment.....	43
5. Screenshot of buyback contract experiment.....	43
6. Screenshot of combined contract experiment .....	44
7. Screenshot of revenue sharing with demand pattern experiment.....	44
8. Screenshot of revenue sharing with would-be total profit feedback experiment..	45
9. Average order quantities in a revenue sharing contract .....	46
10. Average order quantities in a buyback contract .....	46
11. Average order quantities in two combined contracts .....	47
12. Average order quantities in revenue sharing with demand pattern.....	47
13. Average order quantities in a revenue sharing with would-be total profit feedback.....	48
14. Average order quantities in a buyback with would-be total profit feedback .....	48

## LIST OF TABLES

Table	Page
1. Parameters and results of simple revenue sharing and simple buyback contracts	26
2. Parameters and results of the combined contracts.....	27
3. Parameters and results of simple contracts and contracts with would-be total profit feedback.....	29
4. Percentage of order quantity adjustments (for last 10 rounds).....	32

## NOMENCLATURE

$x$ :	Demand
$D$ :	Demand distribution
$a$ :	Minimum demand
$b$ :	Maximum demand
$f(x)$ :	Probability density function for demand $x$
$F(x)$ :	Cumulative distribution function for demand $x$
$Q$ :	Order quantity placed by the retailer
$Q^*$ :	Profit-maximizing order quantity
$p$ :	Selling price
$c$ :	Cost
$w$ :	Wholesale price
$E(S(Q))$ :	Expected sales with order quantity $Q$
$E(S(Q^*))$ :	Expected sales with optimal order quantity $Q^*$
$Q_{rs}^*$ :	Optimal order quantity in a revenue sharing contract
$w_{rs}^*$ :	Optimal selling price in a revenue sharing contract
$r$ :	Shared revenue price
$r_{rs}^*$ :	Optimal shared revenue price
$\lambda$ :	Retailer's share in supply chain profit
$(1 - \lambda)$ :	Supplier's share in supply chain profit
$\pi_{rs}^{*r}$ :	Optimal retailer's profit in a revenue sharing contract
$\pi_{rs}^{*s}$ :	Optimal supplier's profit in a revenue sharing contract
$Q_{bb}^*$ :	Optimal order quantity in a buyback contract
$w_{bb}^*$ :	Optimal selling price in a buyback contract
$b$ :	Buyback price
$b_{bb}^*$ :	Optimal buyback price

$\pi_{bb}^{*r}$ :	Optimal retailer's profit in a buyback contract
$\pi_{bb}^{*S}$ :	Optimal supplier's profit in a buyback contract
$Q_{com}^*$ :	Optimal order quantity in a combined contract
$w_{com}^*$ :	Optimal selling price in a combined contract
$r_{com}^*$ :	Optimal shared revenue price in a combined contract
$b_{com}^*$ :	Optimal buyback price in a combined contract

## CHAPTER 1

### INTRODUCTION

#### 1.1 Problem

Decision making plays a significant role in businesses that faces stochastic or uncertain demand. One such decision-making problem frequently observed is the newsvendor problem. Here, the newsvendor or the decision maker has to place an order quantity, which maximizes profit. However, the newsvendor has to place this order before the selling season and also faces uncertain demand. If the ordered quantity is less than the demand, then the newsvendor loses opportunity to sell. On contrary, if the ordered quantity is more than the demand, then the newsvendor will have unsold inventory. Since the demand is uncertain, the newsvendor will incur loss in all scenarios.

A large stream of research in this field considers a two-echelon supply chain, where the supplier sells the products to retailer, who in turn sells the product to end customers. In such a setup, the supplier and the retailer selling the products make profits individually. This results in high retail price and low overall profits for the channel, causing double marginalization. Also due to high wholesale price, the retailer tries to reduce the risk of unsold items and orders a lower quantity, thereby reducing the channel's profit. In order to avoid such issues, past studies by Cachon (2003) suggest that

with appropriate contracts, a better coordination can be seen between a retailer and a supplier.

To improve the coordination between the supplier and retailer, the supplier can offer a contract that provides the retailer with adequate economic incentives to order the quantity that maximizes the channel profit (a coordinating contract). In this thesis, two types of coordinating contracts, revenue sharing and buyback, are considered. In a revenue sharing contract, the supplier offers a relatively low wholesale price however, the retailer has to share part of the revenue for every item sold. In a buyback contract, the supplier buys back any unsold item from the retailer with a price lower than the wholesale price. In both contracts, the supplier shares part of the retailer's risk in facing a stochastic demand. Although the theoretical benefits of coordinating contracts have been widely studied, it is also known that retailers fail to place the optimal order quantities in practice (Katok & Wu 2009). Almost all the works in this field have focused on finding how and why this deviation happens (Katok 2011).

## 1.2 Purpose of the Thesis

The purpose of this thesis is to explore possible ways through which the performance of a supply chain can be improved by influencing the retailer to choose order quantities close to the channel's optimal order quantity.

## 1.3 Method of Thesis

The following steps are used throughout the thesis in order to analyze and improve the performance of the decision maker:

- All the experiments are designed using *Microsoft Excel* with *Visual Basic*. The experiments are conducted in a laboratory setting.
- The final outcomes of the experiments are analyzed and compared with the optimal values.
- Discussing the effects of different approaches on the decision maker.

To improve the performance of the decision maker or the retailer, various approaches have been used. However, all the approaches used are variations of revenue sharing and buyback contracts. Initially two experiments, simple revenue sharing and simple buyback contracts, are conducted which yield results similar to Katok & Wu (2009). Although theory says that the coordinating contracts improve the performance of the decision makers, it is not the case in reality. These experiments display a popular phenomenon illustrated in Schweitzer & Cachon (2000), known as “pull to center”.

In all the experiments conducted, the supplier, assumed to be rational, sets the parameters of the contract according to the theoretical optimal values. The retailer, however, is assumed to be prone to behavioral misjudgments and errors. Therefore, the order quantities chosen by the retailer can systematically deviate from the optimal values. This suboptimal decision has a negative impact on the profitability of the retailer, supplier and the channel. Hence, the supplier tries to design the contract terms or offer additional information to address the inefficiency in the retailer’s decision and in turn improving the performance. Three approaches are explored in this thesis, which could possibly improve the performance of a revenue sharing or buyback contract. The effectiveness of each approach is verified through laboratory experiments. One of these

approaches concern the contract terms, which the supplier offers the retailer. The other two approaches are concerned with providing the retailer with additional information or feedback that might help the retailer to make better decisions. In the first approach, a new type of contract, which is a combination of revenue sharing and buyback contracts, is considered. In the second, the impact of providing the retailer with visual information about the nature of demand uncertainty is observed. This could possibly discourage the retailer to follow shortsighted strategies such as demand chasing. In the last approach, a new performance measure, *would-be* total profit, is provided to the retailer. This new information is expected to discourage the retailer to follow a demand chasing strategy.

#### 1.4 Structure of the Thesis

The next chapter revisits the studies in the supply chain contracts and behavioral studies. Chapter 3 explains the analytical models that are used in this thesis. Experimental design, protocol and implementation are discussed in Chapter 4, followed by hypotheses in Chapter 5. Detailed results are discussed in Chapter 6 and limitations and future research are discussed in Chapter 7. Chapter 8 concludes the paper with a summary of the results.

## CHAPTER 2

### LITERATURE REVIEW

A newsvendor problem focuses on placing an order, which maximizes the total supply chain profit. Studies have shown that using coordinating contracts such as revenue sharing and buyback contracts can mitigate the newsvendor problem. Empirical studies have concentrated on newsvendor problem from different perspectives. Behavioral studies are one such area, which considers newsvendor problem as a challenge.

In this research we study a two-echelon supply chain consisting of a supplier and a retailer, in which the retailer faces a classical newsvendor problem. Newsvendor problem has a lengthy history and is widely studied in operations management. See Qin et al (2011) for a recent review of the literature. The newsvendor problem not only has many applications in the business world, but it is also the building block for many other inventory problems.

Although the elegant structure of the newsvendor problem has let the researchers develop analytical solutions for different variants of the problem, it has been known for a while that decision makers facing this problem deviate from the theoretical optimal solution in practice. For instance, see Fisher & Raman (1996) and Corbett & Fransoo (2007). These observations have attracted many researchers' attention as to how and why this deviation happens. There are many works, which try to explore this behavior through

laboratory experiments. Schweitzer & Cachon (2000), in a set of laboratory experiments, observe that the subjects' order quantity always fall between the average demand and the optimal value. That is, for a high profit margin product, for which the optimal order quantity is higher than the average demand, the subjects' average order quantity is also higher than the average demand, but lower than the optimal value.

For low profit margin products, for which the optimal order quantity is lower than the average demand, the subjects' average order quantity is lower than the average demand, but higher than the optimal value. This behavior is known as "pull to center." Schweitzer & Cachon (2000) attribute this behavior to *ex-post* inventory error and anchoring and insufficient adjustment. Through their experimental analysis, they rule out the influential impacts of other factors like risk aversion, loss aversion, prospect theory preferences, waste aversion, and stock-out aversion. Lamba & Sharma (2011) also show that risk aversion is not a possible explanation for suboptimal performance in a revenue sharing contract. Building on Schweitzer & Cachon's (2000) model, Bostian et al (2008) use an adaptive learning algorithm to justify the pull to center behavior. Unlike Schweitzer & Cachon (2000), Bostian et al (2008) find that subjects' average order quantity is very close to the mean demand at the first round of decisions. However, order quantities diverge from the mean demand in successive decision rounds. The authors' adaptive learning model explains the pull to center behavior and show that subjects respond to recent gains and losses.

Using a model based on quantal choice theory, Kremer et al (2010) show that decision makers' random error cannot be the main source of deviation from the optimal

order quantity. They show that context dependent strategies such as anchoring, chasing, or inventory error minimizing play more influential roles in the decision making process.

Bolton & Katok (2008) study the impact of experience and feedback on the subjects' behavior. The authors show that subjects' decisions improve over the 100 rounds of decisions in their experiments. However, they report a very slow rate of improvement. They also show that restricting subjects' decisions to 10 rounds of standing orders can improve the quality of decisions (they increased the number of order quantities to 1000 rounds in this experiment). Among other results, they show that limiting the number of options from 100 possible order quantities in each decision round to 9 or 3 options cannot improve the quality of decisions. Their other results include examining the impacts of providing the subjects with extra information such as the payoff for the foregone options or providing payoff statistics for different decision options at the beginning of the experiment. They show that none of these information and feedbacks can improve the outcome.

Lurie & Swaminathan (2009) also use laboratory experiments to study the impact of feedback frequency on the quality of decisions in a newsvendor problem. More specifically, they examine the performance of a newsvendor when an order quantity decision is standing for a set of rounds and the profit feedback is provided at the end of each set of rounds. They show that the newsvendor's profit can increase with a decrease in feedback frequency. They also find that introducing costs to making changes in successive decisions does not improve the newsvendor performance when the feedback frequency is high. The authors show when the feedback frequency is high, decision

makers tend to limit their information access to the most recent set of presented data, hence, they are more prone to overreacting to noisy feedback. They also show feedback frequency plays a more influential role than decision frequency.

Different types of supply chain contracts have been studied under different experimental settings. Keser & Paleologo (2004) and Luch & Wu (2008) study wholesale price contracts. Coordinating contracts are studied by Ho & Zhang (2008), Katok & Wu (2009), and Davis (2010). Two-part tariffs and quantity discount contracts are studied by Ho & Zhang (2009). Katok & Wu (2009) study buyback and revenue sharing contracts. Davis (2010) investigates pull contracts (both wholesale price and coordinating). The common result in all these papers is that these contracts fail to coordinate the supply chain in experimental setups. A review of this stream of research can be found in Katok (2011).

Katok & Wu (2009) separate the interaction of supplier and retailers by letting subjects play the role of retailers against computerized (fully rational) suppliers, or the role of suppliers against computerized retailers. In this way they can avoid the fairness effect, which appears when human retailers interact with human suppliers. They find that the way demand distribution is presented (framed) to subjects' affects their decision quality. They also show that in a high demand situation, the retailer performs better under a buyback contract than under a revenue sharing contract. The difference, however, decreases and disappears with experience.

Similar to the present research, Becker-Peth et al (2011) try to improve the performance of a newsvendor buyer in a coordinating contract. The authors consider a

buyback contract and show that a newsvendor retailer responds differently to different contract parameters even if these parameters result in the same critical ratio. They build a behavioral model, which depends on buyer's anchoring to mean demand, loss aversion, and different valuation of income. The authors first estimate the parameters of the model through subjects' responses to a wide range of contract parameters and then find a contract, which could result in the channel optimal solution. They also show that the contract can be customized for each subject. The model, however, cannot control the share of supplier's profit from the channel's profit.

Through a series of experiments, Shampanier et al (2007) show that people usually perceive the benefits associated with free products to be higher than what classical economics predicts. They attribute this behavior to the difficulty people have in mapping their utility. So, they are more inclined toward a free product since it is an option with no downside. Lamba & Sharma (2011) show that offering free items increase the order quantity; thereby improving the performance of the decision maker in a revenue sharing contract. They also observe that the adjusted revenue sharing contract helps in reducing the variations seen in the order quantities of the subjects. Through this research, it can be noted that the decision makers are influenced by the incentives offered. This forms the base for the combined contract approach in this thesis.

## CHAPTER 3

### DESCRIPTIVE MODELS

This section introduces the analytical details of the newsvendor problem, the revenue sharing contract, the buyback contract and the combined contract. The concept of showing demand pattern and providing collective feedback are also discussed in this section.

#### 3.1 The Newsvendor Problem

In a typical newsvendor problem, the decision maker faces an uncertain demand,  $x$  for any product to be sold. The decision maker has to place an order quantity,  $Q$  before the beginning of the shopping season. Each unit is purchased at cost 'c' and sells at price 'p', where  $p > c$ . For the purview of this paper we assume that:

- The salvage value of any item unsold is zero.
- The demand is uniformly distributed as  $D \sim U(a,b)$
- Any unsold items cannot be carried over to the next season.
- The supplier sets the wholesale price and all the contract parameters.

Based on the above assumptions, if the order quantity ( $Q$ ) is greater than the demand ( $x$ ), then there are unsold items, incurring the loss of 'c' per item. If the

order quantity (Q) is less than the demand (x), then there is a lost opportunity to sell the item, incurring the loss of 'p-c'.

Assume probability density function as f(x) and the cumulative function as F(x), then the optimal order quantity  $Q^*$  can be written as,

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

For a uniform distribution  $D \sim U(a, b)$ ,

$$Q^* = a + (b - a) \left( \frac{p - c}{p} \right) \quad (1)$$

The ratio  $\left( \frac{p - c}{p} \right)$  is termed as critical fractile. The critical fractile is the ratio of underage costs to overage costs.

(For proof see *Appendix A*)

Now consider a two-echelon supply chain with a supplier providing the inventory to the retailer, who sells the products to the final customer. In this case, the retailer is the decision maker and faces the newsvendor problem. Each unit will be sold to retailer at wholesale price 'w' and retailer sells the product to the final customer at the price 'p'. The supplier incurs the cost 'c' for manufacturing each product. The expected profit of the retailer in this setup is:

$$E(\pi_r) = p E(S(Q)) - wQ \quad (2)$$

where  $E(S(Q))$  is the expected sales when the retailer places an order quantity, Q.

Similarly, the suppliers expected profit is:

$$E(\pi_s) = (w - c)Q \quad (3)$$

The value of expected sales  $E(S(Q))$  is expressed as:

$$E(S(Q)) = \frac{1}{(b - a)} \left( \frac{2bQ - (Q^2 + a^2)}{2} \right)$$

The sections 3.2 and 3.3 discuss two popular contracts used in day-to-day business. Section 3.3 discusses about the contract formed by combining revenue sharing and buyback contracts.

### 3.2 Revenue Sharing Contract

In order to coordinate the supply chain, many contracts are used frequently. One such coordinating contract is the revenue sharing contract. With this contract, the supplier incentivizes the retailer by offering a very low wholesale price ' $w_{rs}$ ', where  $w_{rs} < c$ . In return, the retailer shares part of the revenue, ' $r$ ', for every item sold. Let the retailer's share of the supply chain profit be  $\lambda$  and  $(1-\lambda)$  be the supplier's share of the supply chain profit, where  $\lambda \in [0,1]$ .

Based on the contract parameters, the optimal order quantity for revenue sharing contracts can be expressed as:

$$Q_{rs}^* = a + (b - a) \left( \frac{p - w_{rs}^* - r_{rs}^*}{p - r_{rs}^*} \right) \quad (4)$$

The values for selling price and the shared revenue can be determined by:

$$w_{rs}^* = \lambda c \quad (5)$$

$$r_{rs}^* = (1 - \lambda)p \quad (6)$$

The expected profit of the retailer,  $E(\pi_{rs}^r) = (p - r) E(S(Q)) - wQ$

When the retailer places the optimal order quantity,  $Q_{rs}^*$ , the the above equation can be rewritten as:

$$E(\pi_{rs}^{*r}) = (p - r_{rs}^*) E(S(Q_{rs}^*)) - w_{rs}^* Q_{rs}^* \quad (7)$$

The expected profit of the supplier,  $E(\pi_{rs}^s) = (w - c)Q + rE(S(Q))$

When the retailer places the optimal order quantity,  $Q_{rs}^*$ , the above equation can be rewritten as:

$$E(\pi_{rs}^{*s}) = (w_{rs}^* - c)Q_{rs}^* + r_{rs}^* E(S(Q_{rs}^*)) \quad (8)$$

### 3.3 Buyback Contract

Another coordinating contract used in many businesses is buyback contract. In a buyback contract, the retailer pays a higher wholesale price ‘ $w_{bb}$ ’ when compared to revenue sharing contract. However, the supplier buys back all the unsold items at price ‘ $b$ ’ at the end of the selling season.

Based on the contract parameters, the optimal order quantity for buyback contracts can be expressed as:

$$Q_{bb}^* = a + (b - a) \left( \frac{p - w_{bb}^*}{p - b_{bb}^*} \right) \quad (9)$$

The values for selling price and the buyback price can be determined by:

$$w_{bb}^* = b + \lambda c \quad (10)$$

$$b_{bb}^* = (1 - \lambda)p \quad (11)$$

The expected profit of the retailer,  $E(\pi_{bb}^r) = pE(S(Q)) - wQ + b(Q - E(S(Q)))$

The expected profit of the supplier,  $E(\pi_{bb}^s) = (w - c)Q - b(Q - E(S(Q)))$

When the retailer places the optimal order quantity,  $Q_{rs}^*$ , the above equations can be rewritten as:

$$E(\pi_{bb}^{*r}) = pE(S(Q_{bb}^*)) - w_{bb}^* Q_{bb}^* + b_{bb}^* (Q_{bb}^* - E(S(Q_{bb}^*))) \quad (12)$$

$$E(\pi_{bb}^{*s}) = (w_{bb}^* - c)Q_{bb}^* - b_{bb}^* (Q_{bb}^* - E(S(Q_{bb}^*))) \quad (13)$$

### 3.4 Combined Contract

Although revenue sharing and buyback contracts can improve the performance of the supply chain, improvement is not as much as the theory predicts. The idea behind this approach comes from the observation that each of these two contracts can individually improve the performance of the supply chain to some extent. So, would there be a further improvement in the performance of the decision maker with a combination of these two

contracts? A combined revenue sharing and buyback contract is a contract where the supplier offers a relatively low wholesale price ' $w_{com}$ ' and in return the retailer shares a part of the revenue ' $r_{com}$ ' for each item sold. In addition, the supplier buys back the unsold items at a price ' $b_{com}$ ' lower than the wholesale price.

Cachon & Lariviere (2005) show buyback and revenue sharing contracts are theoretically equivalent. That is, they result in the same profits for the retailer and the supplier for any realization of the random demand. Although the literature reports the theoretical equivalence of the two contracts, they are always treated as two distinct contracts. We also observe that these two contracts are the two ends of a spectrum of combined contracts as we defined above.

The optimal order quantity, which maximizes the retailer's profit, can be expressed as:

$$Q_{com}^* = a + (b - a) \left( \frac{p - w_{com}^* - r_{com}^*}{p - b_{com}^* - r_{com}^*} \right) \quad (14)$$

For any chosen wholesale price,  $w_{com} \in [\lambda c, \lambda c + (1 - \lambda)p]$ , the following set of shared revenue and buyback prices can coordinate the supply chain and result in an order quantity equal to the optimal channel order quantity.

$$r_{com}^* = (1 - \lambda)p + \lambda c - w_{com}^* \quad (15)$$

$$b_{com}^* = w_{com}^* - \lambda c \quad (16)$$

The combined contract turns into a pure revenue sharing contract if we choose the lowest range of wholesale price  $w_{com} = \lambda c$ . Similarly, the combined contract turns into a pure

buyback contract, if we choose the highest range of wholesale price  $w_{com} = \lambda c + (1 - \lambda)p$ .

### 3.5 Demand Pattern

One of the reasons behind subjects' suboptimal decisions is argued to be subjects' focus on the most recent demand which could in turn lead to a demand chasing pattern (Schweitzer & Cachon 2000, Bostian et al, 2008, and Lurie & Swaminathan, 2009). Subjects' focus on the most recent demands could be due to their inability to comprehend the true nature of demand uncertainty. In all experiments conducted for this thesis, we informed the subjects that the demand was uniformly distributed between 100 and 300. However, they did not have any visual explanation as to how the demand might have occurred. This is the case in almost all other similar research works. In this experiment, an additional graph that has a sample demand history for 50 shopping seasons is shown to the subjects. With this experiment, an effort is made to improve the performance of the decision maker in a revenue sharing contract set up.

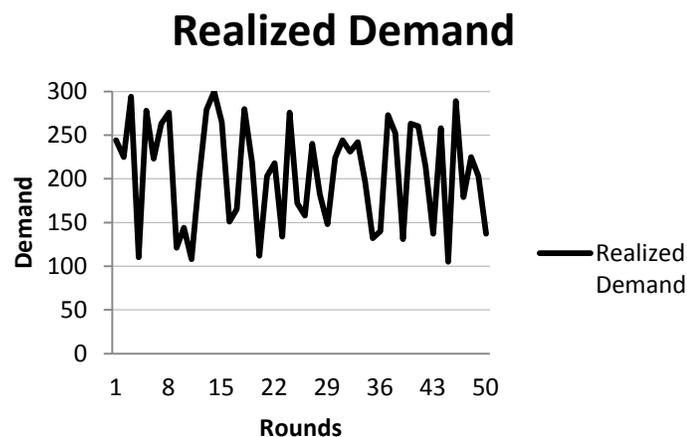


Figure 1: Visualization of demand pattern (uniform distribution)

### 3.6 Collective Feedback

Both Bolton & Katok (2008) and Lurie & Swaminathan (2009) show that the performance of a newsvendor can be improved by restricting a decision to stand for a set of rounds. That is, when the retailer makes a decision in a shopping season (round), then the same decision will be applied for a set of successive shopping seasons. The result of this decision (feedback) is revealed to the retailer only after the demand is realized for all these shopping seasons. Standing order reduces the frequency of decision making opportunities. Therefore, the subjects know that each order quantity decision impacts more than one round. This could encourage them to look at the demand randomness in a more collective way, which in turn might reduce their tendency for demand chasing. On the other hand, standing orders reduces the feedback frequency too. Hence, each feedback contains the collective impacts of an order quantity on the profit of more than one realized demands. This collective measure, in a sense, reduces the randomness in demand and shows a more accurate value of each order quantity. The experiments by Lurie & Swaminathan (2009) suggest that the improvement in a standing order setup is mainly due to a reduction in feedback frequency (not a reduction in order frequency).

Although standing orders can result in average order quantities, which are closer to the optimal value, it has the practical limitation of preventing the retailer to place an order for each shopping period. Such orders will have the limitation of preventing the retailer to access the result of a decision at the end of each period. As a result, applying standing order might not be practical in many business situations. In order to address this restriction, the concept of would-be total profit is introduced.

In this approach, once a subject chooses an order quantity, a total profit, which would be earned if the chosen order quantity were chosen for all previous rounds, is presented. For example, if a subject chooses an order quantity of 230 in the 20th round, then the would-be total profit will show the total profit if 230 were the chosen order quantity for all the first 20 rounds. Hence, the would-be total profit provides a feedback in every round, which is identical to the feedback provided in a regular standing order. In the new approach, however, the retailer does not face the limitations of a standing order. That is, in the new approach the retailer can make a decision for every round and access the feedback at the end of each round.

## CHAPTER 4

### EXPERIMENTS

#### 4.1 Experimental Design

We use laboratory experiments to investigate the effectiveness of the different approaches that we propose in order to prove the performance of revenue sharing and buyback contracts. In all these experiments, we assume that the supplier's production cost is  $c=4$ , the retailer's selling price is  $p=20$ , and the demand is uniformly distributed between 100 and 300 ( $D \sim U(100,300)$ ).

Since the benefit of coordination is larger for high profit margin products ( $(p - c) / p > 0.5$ ), we focus only on this category of products. Moreover, for a low profit margin product, subjects' more than optimal order quantities can in fact increase the supplier's profit. So, there is no incentive for the supplier to try to lower the order quantities to the supply chain optimal level. There are seven different experimental treatments – simple revenue sharing, simple buyback, two combined contract experiments, revenue sharing with demand pattern, revenue sharing with collective feedback and buyback with collective feedback.

In our experiments, the subjects respond to the contracts offered by a supplier. We assume the supplier is rational and risk-neutral. As a result, the supplier's decisions are

always consistent with the theoretical optimal solutions. For the revenue sharing and buyback contracts we always set the contract parameters such that the retailer's theoretical share of total profit is  $\lambda=1/4$ .

All the experiments are designed using Microsoft Excel combined with macros, which are added using Visual Basic. The excel sheet shows the selling price  $w$ , revenue-sharing price  $r$ , for all RS experiments. The revenue-sharing price is replaced by buyback price  $b$ , in BB experiments. Once the subject chose the order quantity for a shopping period (round), the demand is realized (a draw from a uniformly distributed random variable). Then, this demand along with the profit for the shopping period, the accumulated profit so far, the cost of overstocking, and the cost of under-stocking for that round were shown to the subject. Two graphs on the screen showed the history of decisions made (order quantities) accompanied by the realized demand and the history of profits in earlier rounds. A screenshot of the user interface can be found in *Appendix B*.

#### 4.2 Experimental Protocol

All the subjects were College of Management students at the University of Massachusetts, Boston. We conducted the experiments in different management classes. The instructors of selected course permitted us to run the experiments in their classes as a required class activity. We conducted the experiments in a mix of graduate and undergraduate classes in four semesters during academic years of 2010-11 and 2011-12. To make sure that the results from undergraduate and graduate classes are comparable, we conducted the experiment on simple revenue sharing contract in a graduate and in an undergraduate class. The results were statistically equivalent to Katok & Wu (2009) with

the equivalence of the responses from undergraduate and graduate students in their experiments.

At the beginning of each experiment session, the supply chain setup is explained to subjects using PowerPoint presentation. The presentation, which usually took around 20 minutes, included simple numerical examples and how the subjects can interact with the software. A summary of the numerical values of the experiment parameters was visible on top of the screen at all times during the experiment.

To incentivize students we presented the experiment as a contest through which the students could find out how good they were at making decisions under uncertain environment (demand). Moreover, cash prizes to the top three students with the best total performance (\$40, \$30, and \$20) were offered. Subjects played the role of retailer's purchasing manager who decides about the order quantities for different shopping periods (rounds). Therefore, each subject's performance was measured by the retailer's total profit after 50 rounds of decision-making.

#### 4.3 Implementation

In all the experiments,  $\lambda$  is considered to be retailer's share of the supply chain profit and the supplier's share is considered as  $(1-\lambda)$ . We set  $\lambda=1/4$  in all the experiments (*see Appendix A*).

For all revenue sharing treatments, the optimal value of shared revenue,  $r^*=15$ , is calculated using Equation (6) and the selling price,  $w^*=1$ , is calculated using Equation (5). Based on these parameters, the profit-maximizing order-quantity for revenue sharing

experiments is  $Q^* = 260$ .

For all buyback treatments, the optimal value of buyback price,  $b^* = 15$ , is calculated using Equation (11) and the selling price,  $w^* = 16$ , is calculated using Equation (10). Based on these parameters, the profit-maximizing order-quantity for buyback experiments is  $Q^* = 260$ .

We conducted two combined contract experiments where the incentives from two contracts, revenue sharing and buyback contract, were combined. Here the revenue sharing and buyback contracts were considered as two ends of the spectrum. One combined contract had  $w_{com1} = 4.75$ , which was closer to revenue sharing end and another combined contract has  $w_{com2} = 12.25$ , which was closer to buyback end of the spectrum. The values of shared revenue,  $r_{com1} = 11.25$  and  $r_{com2} = 3.75$ , and buyback price,  $b_{com1} = 3.75$  and  $b_{com2} = 11.25$ , were calculated using the Equations (15) and (16) respectively.

## CHAPTER 5

### HYPOTHESIS

In all the experimental setups, the subjects played the role of a retailer or decision maker. These decision makers chose the order quantities, one season at a time, and profits are generated based on these decisions.

We first conducted two experiments on simple revenue sharing and simple buyback contracts. Theory shows that these contracts coordinate the supply chain by incentivizing the retailer to place the profit maximizing order quantity. Hypothesis 1 verifies whether these contracts will help in coordinating the supply chain as seen in theory.

Hypothesis 1: The average order quantity placed by the retailer in simple revenue sharing and simple buyback contracts will be 260.

We conducted the next two experiments on combined contract. The idea behind this approach is that a contract which has the appealing features of both revenue sharing and buyback contracts might inspire more confidence in subjects and encourage them to place higher order quantities. Another theory behind these experiments is that revenue sharing and buyback contracts are two ends of the spectrum. The two combined contracts are formed by altering values of selling price  $w$ , shared revenue  $r$  and buyback price  $b$ .

It is made sure that these sets of values can coordinate the supply chain. Hypothesis 2 is used to verify the theoretical results that predict the same order quantities for the family of combined contracts with the same value of  $\lambda$ .

Hypothesis 2: All contracts in a family of combined contracts with the same value of  $\lambda$  result in the same average order quantity.

The idea behind our next approach is to provide visual information about the demand pattern to help the subjects to better understand the random nature of the demand and discourage them to chase the demand. Hypothesis 3 is stated to investigate the impact of providing visual information about the demand pattern.

Hypothesis 3: The average order quantity of a revenue sharing contract with additional (visual) information about the demand pattern will be 260.

In order to avoid the standing orders, where each decision impacts more than one round, a concept of *would-be* total profit is introduced in our next two experiments. The value of this *would-be* total profit is negligible in the starting rounds of the experiment. However, as the number of rounds increases, the value of information provided by this number also increases. In other words, in the higher rounds, this *would-be* total profit (and its comparison with the actual total profit) is a good measure for the real value of the selected order quantity. Since the buyer usually focuses on the feedbacks of the latest round, this piece of information should be under retailer's attention range. As a result, we can expect a learning pattern in retailer's decision process and observe better decisions toward the final rounds.

We try to verify this conjecture through the following two hypotheses.

Hypothesis 4A: The average order quantity of a revenue sharing contract, with would-be total profit feedback, will be 260.

Hypothesis 4B: The average order quantity of a buyback contract, with would-be total profit feedback, will be 260.

## CHAPTER 6

### RESULTS

As discussed earlier, the subjects played the role of decision maker or the retailer in all the experiments. A total of seven experiments were conducted with a total of 126 subjects. The final outcome of these experiments was the order quantity, which affected the overall profit of the retailer. The results from these experiments were tested using Wilcoxon rank sum test (Berenson, Krehbiel, Levine & Stephan 2008), where the medians are used to test for the difference. T-test was avoided since the sample size in each experiment was lesser than 30 and normality could not be assumed. The value of “p” is calculated using the two-tailed tests with 95% confidence interval ( $\alpha = 0.05$  significance level).

Hypothesis 1: The first two experiments conducted verify the existing results in the literature. This hypothesis tests the average order quantity of the retailer in revenue sharing and buyback contracts.

Contract	Sample Size	$w$	$r$	$b$	Optimal Order Quantity(Q*)	Average Order Quantity (Q)
Simple Revenue Sharing	14	\$1.00	\$15.00	--	260	228.9
Simple Buyback	20	\$16.00	--	\$15.00	260	225

Table 1: Parameters and results of simple revenue sharing and simple buyback contracts

The average order quantities in both revenue sharing (228.9) and buyback contract (225) are less than the optimal order quantity (260). The two-tail tests show that p value is  $0.001 < 0.05$  (for revenue sharing contract) and  $0.0001 < 0.05$  (for buyback contract). Hence we reject the hypothesis 1, which states that the average order quantities of revenue sharing and buyback contracts will be 260. The Figure 10 in *Appendix B* shows the “pull to center” phenomenon, where the subjects gradually adjust the order quantities around the mean demand (200).

Hypothesis 2: The next two experiments conducted are the two variations of combined contracts. In order to test this hypothesis, four contracts in the family of combined contracts are compared.

Contract	Sample Size	$w$	$r$	$b$	Optimal Order Quantity( $Q^*$ )	Average Order Quantity (Q)
Simple Revenue Sharing	14	\$1.00	\$15.00	--	260	228.9
Combined 1	18	\$4.75	\$11.25	\$3.75	260	227.5
Combined 2	18	\$12.25	\$3.75	\$11.25	260	226.1
Simple Buyback	20	\$16.00	--	\$15.00	260	225

Table 2: Parameters and results of the combined contracts

As mentioned in Chapter 3, the revenue sharing and buyback contracts are considered to be the two ends of the spectrum. The new contracts, combined 1 and combined 2, are formed by altering the  $w$ ,  $r$  and  $b$  values. As seen in the Table 2, revenue sharing contract is the beginning of the spectrum. As the buyback and wholesale price increases, we reach the other end of the spectrum where the combined contract turns into

pure buyback. This hypothesis is tested in 2 steps. In the first step the average order quantities of the simple revenue sharing and combined 1 are compared, where the p value is  $0.12 > 0.05$ . In the second step, the average order quantities of the simple buyback and combined 2 are compared, where the p value is  $0.12 > 0.05$ . This shows that we do not have enough evidence to reject the hypothesis 4, which states that the average order quantities will be same in a family of combined contracts.

Katok & Wu (2009) observe differences between the average order quantities in simple buyback and simple revenue sharing contracts. They observe that depending on the demand range and the way the contract is framed, the buyback contracts can result in higher or lower average order quantities. They attribute this observation to loss aversion behavior of subjects. They also show that the difference between the average order quantities of the two contracts decreases and disappears with experience. This means that in general the subjects do not react to different forms of combined contracts. One explanation could be the possibility that the subjects do not respond to detailed contract terms but they react mainly to the resulting overage and underage costs, which are same in all these contracts. Hence, using combined contract is not an effective approach to influence the retailers to place optimal order quantities.

Hypothesis 3: The results show that the average order quantity of a revenue sharing contract with the demand pattern (228.3) is almost the same as the average order quantity in simple revenue sharing contract (228.9). The p value is  $0.0006 < 0.005$ , which means that the hypothesis can be rejected. This implies that creating better understanding about the demand behavior through visualization cannot improve the quality of retailer's

decisions. The subjects still concentrate on the latest demand realized and the inventory error. One possible explanation could be the possibility that being exposed to the demand pattern is not enough to create a better comprehension of the collective behavior of the demand.

Hypothesis 4A: In order to make sure that subject's clearly understood the concept of *would-be* total profit, they were asked to write a sentence or two about the concept.

Contract	Sample Size	$w$	$r$	$b$	Optimal Order Quantity(Q*)	Average Order Quantity (Q) (last 10 rounds)
Simple revenue sharing	14	\$1.00	\$15.00	--	260	214.8
Revenue sharing with <i>would-be</i> total profit	18	\$1.00	\$15.00	--	260	239.1
Simple buyback	20	\$16.00	--	\$15.00	260	221.1
Buyback with <i>would-be</i> total profit	15	\$16.00	--	\$15.00	260	225.3

Table 3: Parameters and results of simple contracts and contracts with would-be total profit feedback

Before examining the hypothesis, linear regression is used to verify if there is an increasing trend in the subjects average order quantities. Since the sample size in each experiment is small, the regression assumptions have to be verified before performing the regression. The data sets are checked for normality, linearity and homoscedasticity. The data used in the experiments do not show any deviation from the assumptions.

The linear regression equation is expressed as:

$$y = 0.58x + 217.47$$

The results in the revenue sharing contract with feedback show a significant increasing trend (0.58 units per round,  $p < 0.001$ ). Figure 2 shows the average order quantities across the 50 round of our experiment. Such an increasing trend does not exist in the simple revenue sharing experiment. This lack of considerable learning trend in simple contracts is consistent with the prior research works. Schweitzer & Cachon (2000) did not observe a learning trend in their newsvendor experiment with 15 rounds of decisions. Bolton & Katok (2008) observe a learning trend in the newsvendors' decisions in their extended experiment with 100 rounds of decisions. However, they reported a very low rate of increase in the average order quantities (0.13 units per round).

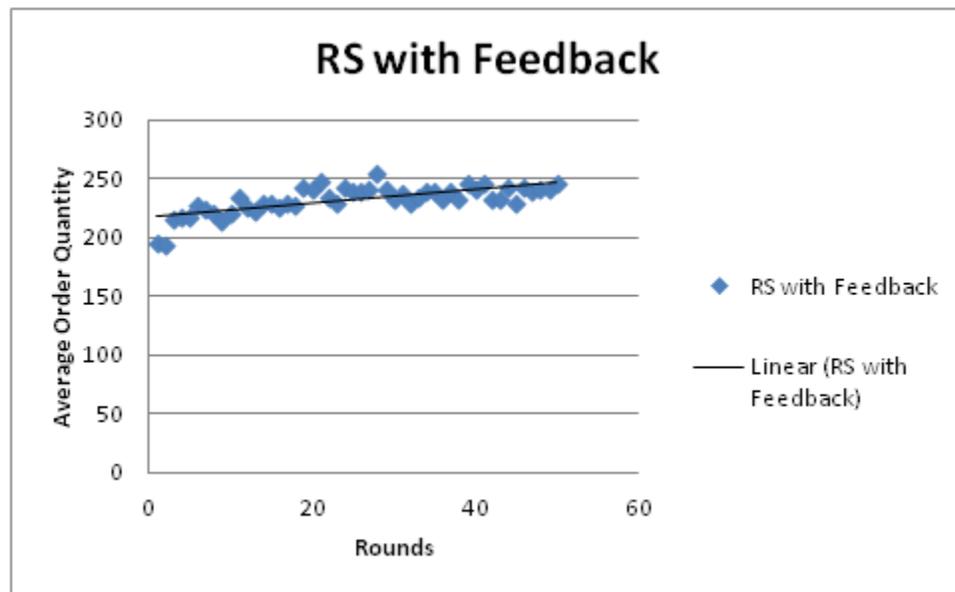


Figure 2: Average order quantities with would-be total profit feedback (revenue sharing)

Considering the learning trend in the revenue sharing experiment with the *would-be* total profit feedback, the last 10 rounds of the experiment are used to verify hypothesis 4A and also to observe the impact of the learning process. The parameters and results of the experiments are presented in Table 3. Results show that the average order quantity (last 10 rounds) of the experiment with the *would-be* total profit feedback (239.1) has increased significantly ( $p=0.01 < 0.05$ ) compared to the corresponding value for a simple revenue sharing experiment (214.8). Although average of the last 10 rounds is still short of the optimal value (260), the difference is not statistically significant ( $p=0.7 > 0.05$ ). Hence, there is not enough evidence to reject hypothesis 4A. This learning trend suggests that, in a revenue sharing contract, the retailer could eventually choose order quantities very close to the optimal value when he is provided with this type of feedback.

Hypothesis 4B: The linear regression equation is expressed as:

$$y = 0.18x + 221.9$$

The results in the buyback contract with feedback do not show any significant increasing trend (0.18 units per round,  $p > 0.05$ ). Figure 3 shows the average order quantities across the 50 round of the buyback experiment. The regression analysis shows no significant slope in the average order quantities placed by the subjects through the 50 rounds of the experiment. The comparison of the last 10 rounds of this experiment with the corresponding value for a simple buyback contract does not show any improvement either (225.3). Therefore, we can strongly reject hypothesis 4B ( $p=0.016 < 0.05$ ).

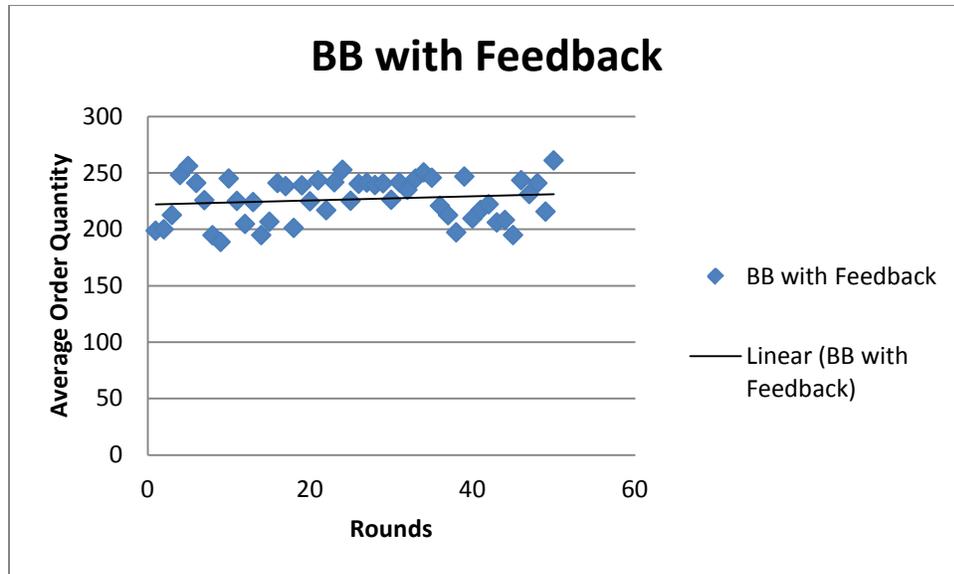


Figure 3: Average order quantities with would-be total profit feedback (buyback)

Schweitzer and Cachon (2000) use the order quantity adjustments to observe the demand chasing heuristic. The adjustment scores are defined by:

$$\frac{(q_t - q_{t-1})}{(d_{t-1} - q_{t-1})}$$

where  $q_t$  and  $d_t$  are order quantity and realized demand, respectively, in round  $t$ .

Contract	No Change	Toward	Away
Simple Revenue Sharing	50%	42.85%	7.14%
Revenue Sharing With <i>would-be</i> Total Profit	55.55%	22.22%	22.22%
Simple Buyback	55%	35%	10%
Buyback With <i>would-be</i> Total Profit	73.33%	26.66%	0%

Table 4: Percentage of order quantity adjustments (for last 10 rounds)

Table 4 shows the results of the order quantity adjustments. The demand chasing in revenue sharing with *would-be* total profit (22.22%) is significantly low when compared to the simple revenue sharing contract (42.85%) with p value  $0.009 < 0.05$ . The subjects tend to move away from the prior demand in this case. A possible explanation could be the positive learning seen in revenue sharing with *would-be* total profit contract. Even though there is no significant difference ( $p = 0.06 > 0.05$ ) between the demand chasing in buyback with *would-be* total profit (26.66%) and simple buyback contract (42.85%), the subjects tend to stabilize the order quantities towards the last rounds (73.33%). These results show that the *would-be* total profit feedback can be used to reduce demand chasing characteristic in subjects.

## CHAPTER 7

### LIMITATIONS AND FUTURE RESEARCH

Considering the constraints under which this thesis has been undertaken, there are myriad possible future directions for research in this area. The first limitation is the subject pool that was used for experiments. Graduate and under graduate students who were pursuing operations management at University of Massachusetts Boston were chosen as subjects for the experiments. There were some subjects who had prior experience of similar experiments. Although effort was made to separate such subjects, complete success cannot be guaranteed. Another question that might open up area for new research is to determine the differences of the experience levels between Graduate and Undergraduate students. Another limitation that might have affected the results is the number of rounds used in the experiments. As mention in Chapter 6, the revenue sharing contract with *would-be* total profit as the feedback mechanism has shown positive learning towards the end. An interesting research question would be: Will this learning pattern continue and lead the decision makers chose the optimal order quantities? This needs further research to see if increasing rounds can improve the performance.

Further, exploring the possible approaches that can improve other contracts, such as quantity discount, in practice could be a possible avenue for future research.

## CHAPTER 8

### SUMMARY AND MANAGERIAL IMPLICATIONS

Revenue sharing and buyback contracts are two types of coordinating contracts and yield maximum profit in the supply chain. However, even with these contracts the decision makers fail to choose optimal order quantities. This thesis considers a two-echelon supply chain, where a rational supplier offers optimal contract parameters to a retailer who is prone to behavioral errors and misjudgments. The retailer fails to place an order with optimal quantity, which in turn results in less than optimal profits for all parties in the supply chain.

In order to improve the performance of the retailer, this paper suggests three approaches. The first approach is the combined contract. This contract includes the advantage of low wholesale price as well as supplier buying the unsold items at the end of shopping season. Even though this approach does not influence the retailer to order optimal order quantities, a spectrum of combined contracts is introduced. This paper proves that revenue sharing and buyback are two ends of a spectrum and based on the wholesale price chosen, a set of combined contracts can be formed.

In the second approach the demand pattern is shown in form of a graph in order to ensure that the retailers understand the random behavior of demand. Even with this information, the results show that the performance of the retailers does not improve.

The third approach shows that the *would-be* total profit can create positive learning in a revenue sharing contract. The decision makers learn from their prior decisions and eventually place order quantities close to optimal values. The revenue sharing contract with the feedback also reduces the demand chasing characteristic in decision makers. Even though the buyback contracts with feedback do not show any positive learning, results show that the retailers tend to stabilize the order quantities towards the last rounds of the experiment.

The results observed in this thesis have significant managerial implications. The collective feedback (*would-be* total profit) can be used as a decision support tool, which can increase the effectiveness of a revenue sharing contract.

## APPENDIX A

### A.1 Newsvendor Problem

Consider, 'x' as a random demand variable. Let the probability density function be  $f(x)$  and cumulative demand distribution be  $F(x)$ .

$$F(x) = \int_0^Q f(x)dx \text{ and } \int_0^\infty f(x)dx = 1$$

Consider 'Q' to be the order quantity. Let  $C_o$  be the cost of unsold items (overage costs) and  $C_u$  be the cost lost opportunity (underage costs). Then, the newsvendor problem can be expressed as:

$$\text{if } x < Q \text{ then } C_o = Q - x$$

$$\text{if } x > Q \text{ then } C_u = p - c$$

Then the expected profit of the newsvendor is:

$$E(\pi(Q)) = \int_0^Q (px - cQ)f(x)dx + \int_Q^\infty ((p - c)Q)f(x)dx$$

To get the optimal order quantity  $Q^*$ ,

$$\frac{d(E(\pi(Q)))}{dQ} = \int_0^Q -cf(x)dx + \int_Q^\infty (p - c)f(x)dx + \int_0^Q (p - c)f(x)dx = 0$$

$$-cF(Q^*) + (p - c) - (p - c)F(Q^*) = 0$$

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

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

With the uniform distribution  $D \sim U(a,b)$ , the cumulative demand distribution can be expressed as:

$$F(x) = \begin{cases} 0, & x < a \\ \frac{x-a}{b-a}, & a \leq x \leq b \\ 1, & x \geq b \end{cases}$$

$$F(Q^*) = \left(\frac{p-c}{p}\right) = \left(\frac{Q^* - a}{b-a}\right)$$

$$Q^* = a + (b-a)\left(\frac{p-c}{p}\right)$$

The expected sales is expressed as,

$$\begin{aligned} E(S(Q)) &= \int_a^Q xf(x)dx + \int_Q^b Qf(x)dx \\ &= \frac{1}{b-a} \left( \left[ \frac{x^2}{2} \right]_a^Q + [Qx]_Q^b \right) \\ &= \frac{1}{b-a} \left( \frac{2bQ - (Q^2 + a^2)}{2} \right) \end{aligned}$$

## A.2 Optimal contract parameters in revenue sharing contract

Let 'w' and 'r' be the selling price and shared revenue price respectively. Let 'λ' be the retailer's share of the supply chain profit and '(1-λ)' be supplier's share of supply chain profit, where  $\lambda \in [0,1]$ .

$$\lambda = \left(1 - \frac{r}{p}\right)$$

The factors for obtaining critical fractile ratio in revenue sharing contract can be expressed by:

$$\text{Overage cost, } C_o = (w - c)$$

$$\text{Underage cost, } C_u = (p - w - r)$$

With the optimal wholesale price ' $w_{rs}^*$ ' and the optimal shared revenue price ' $r_{rs}^*$ ', the critical fractile with revenue sharing contract is;

$$F(Q^*) = \left(\frac{p - w_{rs}^* - r_{rs}^*}{p - r_{rs}^*}\right)$$

For revenue sharing to be a coordinating contract, then the critical fractile obtained in the newsvendor problem should be equal to the critical fractile obtained in revenue sharing contract.

$$\left(\frac{p - w_{rs}^* - r_{rs}^*}{p - r_{rs}^*}\right) = \left(\frac{p - c}{p}\right)$$

$$w_{rs}^* = c \left(1 - \frac{r_{rs}^*}{p}\right)$$

Hence, the optimal values for selling price and the shared revenue are:

$$w_{rs}^* = \lambda c$$

$$r_{rs}^* = (1 - \lambda)p$$

### A.3 Optimal contract parameters in buyback contract

Let 'w' and 'b' be the selling price and buyback price respectively. Let 'λ' be the retailer's share of the supply chain profit and '(1-λ)' be supplier's share of supply chain profit, where  $\lambda \in [0,1]$ .

$$\lambda = \left(1 - \frac{b}{p}\right)$$

The factors for obtaining critical fractile ratio in buyback contract can be expressed by:

$$\text{Overage cost, } C_o = (w - b)$$

$$\text{Underage cost, } C_u = (p - w)$$

With the optimal wholesale price ' $w_{bb}^*$ ' and the optimal buyback price ' $b_{bb}^*$ ', the critical fractile with buyback contract is;

$$F(Q^*) = \left(\frac{p - w_{bb}^*}{p - b_{bb}^*}\right)$$

For buyback to be a coordinating contract, then the critical fractile obtained in the newsvendor problem should be equal to the critical fractile obtained in buyback contract.

$$\left(\frac{p - w_{bb}^*}{p - b_{bb}^*}\right) = \left(\frac{p - c}{p}\right)$$

$$w_{bb}^* = b + c \left(1 - \frac{b_{bb}^*}{p}\right)$$

Hence, the optimal values for selling price and the buyback price are:

$$w_{bb}^* = b_{bb}^* + \lambda c$$

$$b_{bb}^* = (1 - \lambda)p$$

#### A.4 Optimal contract parameters in combined contract

Let 'w', 'r' and 'b' be the selling price, shared revenue price and buyback price respectively. Let 'λ' be the retailer's share of the supply chain profit and '(1-λ)' be supplier's share of supply chain profit, where  $\lambda \in [0,1]$ .

The factors for obtaining critical fractile ratio in combined contract can be expressed by:

$$\text{Overage cost, } C_o = (w - b)$$

$$\text{Underage cost, } C_u = (p - w - r)$$

With the optimal wholesale price ' $w_{com}^*$ ', optimal shared revenue ' $r_{com}^*$ ' and the optimal buyback price ' $b_{com}^*$ ', the critical fractile with combined contract is:

$$F(Q^*) = \left( \frac{p - w_{com}^* - r_{com}^*}{p - r_{com}^* - b_{com}^*} \right)$$

or

$$F(Q^*) = \left( \frac{p - (w_{com}^* + r_{com}^*)}{p - (r_{com}^* + b_{com}^*)} \right) \quad (1a)$$

Consider the critical fractile with buyback contract:

$$\left( \frac{p - w}{p - b} \right)$$

Substitute the optimal values for 'w' and 'b' in the above equation:

$$\left( \frac{p - [(1 - \lambda)p + \lambda c]}{p - [(1 - \lambda)p]} \right)$$

Replace the above values in Equation (1a)

$$w_{com}^* + r_{com}^* = (1 - \lambda)p + \lambda c$$

$$\therefore r_{com}^* = (1 - \lambda)p + \lambda c - w_{com}^*$$

*and*

$$(r_{com}^* + b_{com}^*) = (1 - \lambda)p$$

$$\Rightarrow b_{com}^* = (1 - \lambda)p - r_{com}^*$$

$$\therefore b_{com}^* = w_{com}^* - \lambda c$$

## APPENDIX B

### B.1. Experiment design

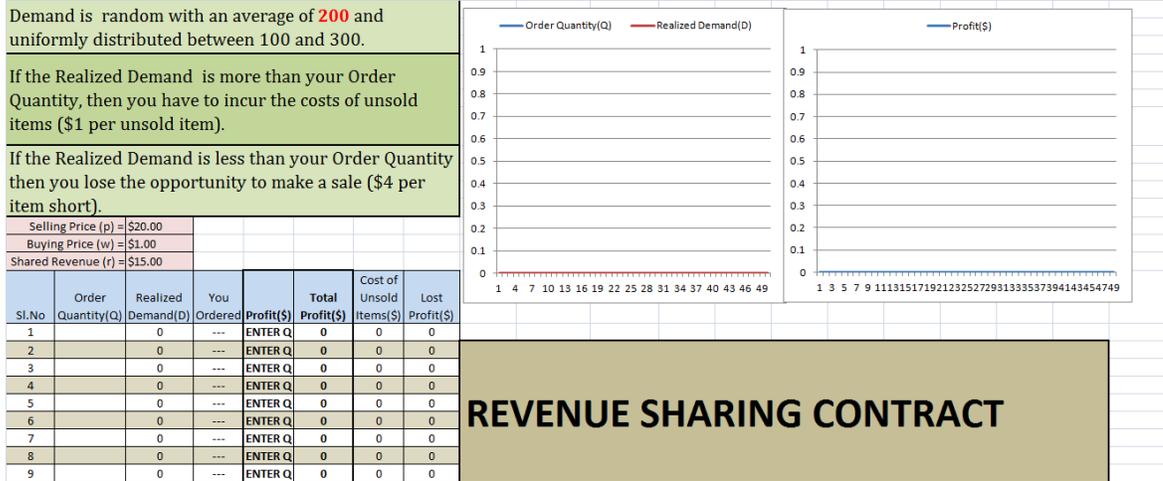


Figure 4: Screenshot of revenue sharing contract experiment

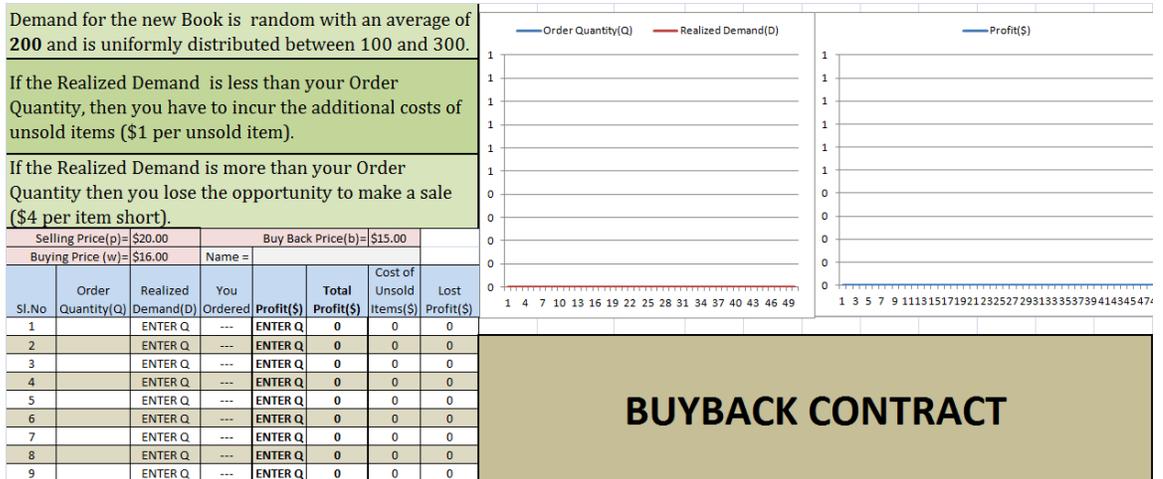


Figure 5: Screenshot of buyback contract experiment



Figure 6: Screenshot of combined contract experiment

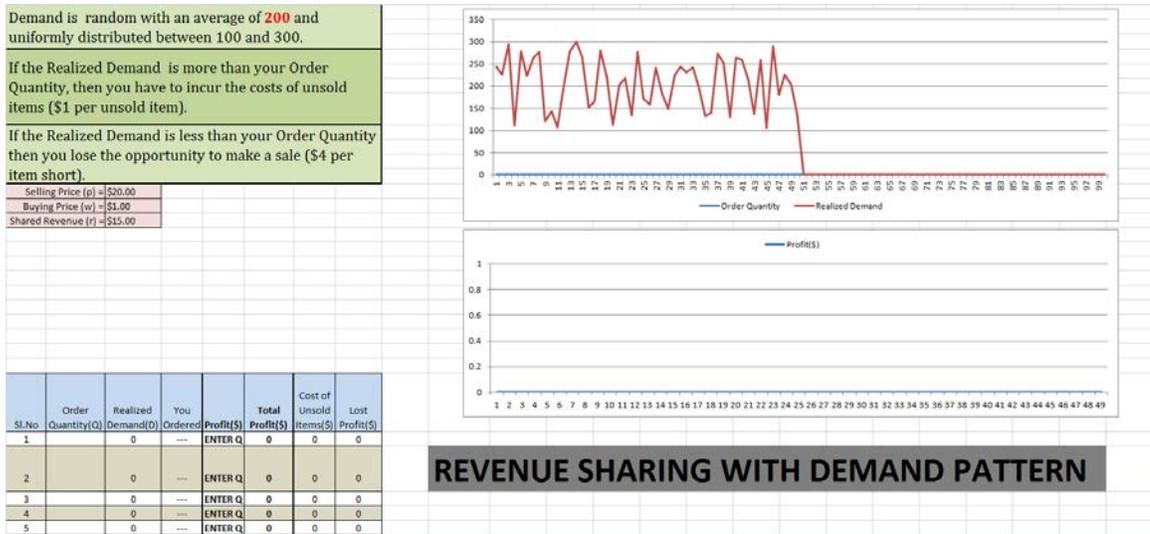


Figure 7: Screenshot of revenue sharing with demand pattern experiment



Figure 8: Screenshot of revenue sharing with would-be total profit feedback experiment

B.2. Average order quantities of subjects

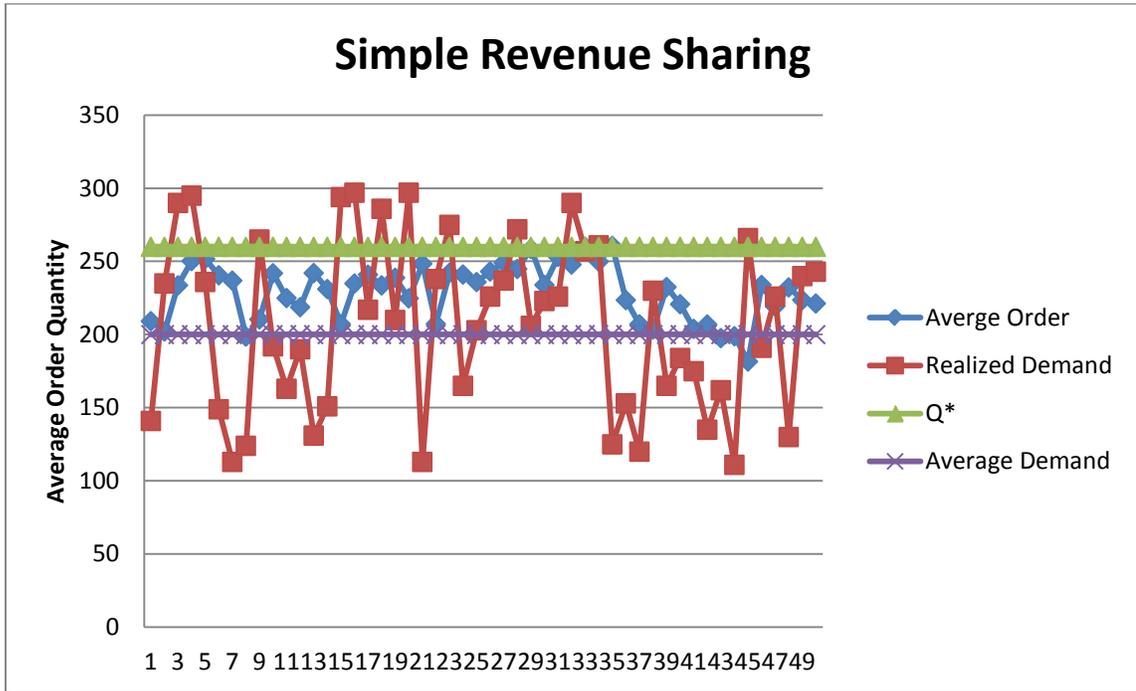


Figure 9: Average order quantities in a revenue sharing contract

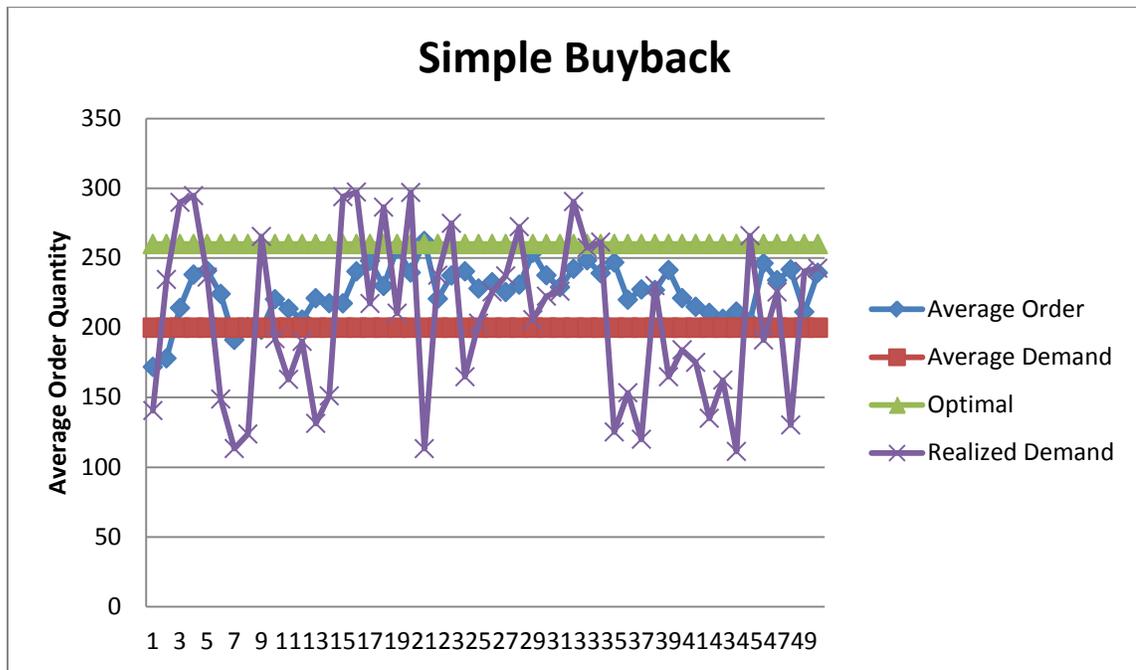


Figure 10: Average order quantities in a buyback contract

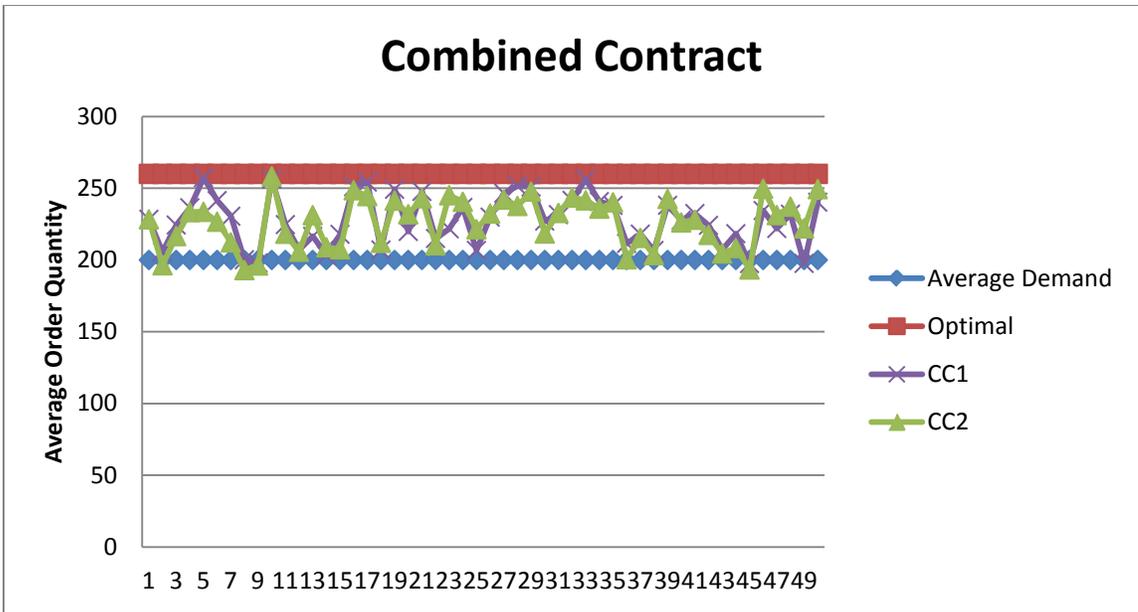


Figure 11: Average order quantities in two combined contracts

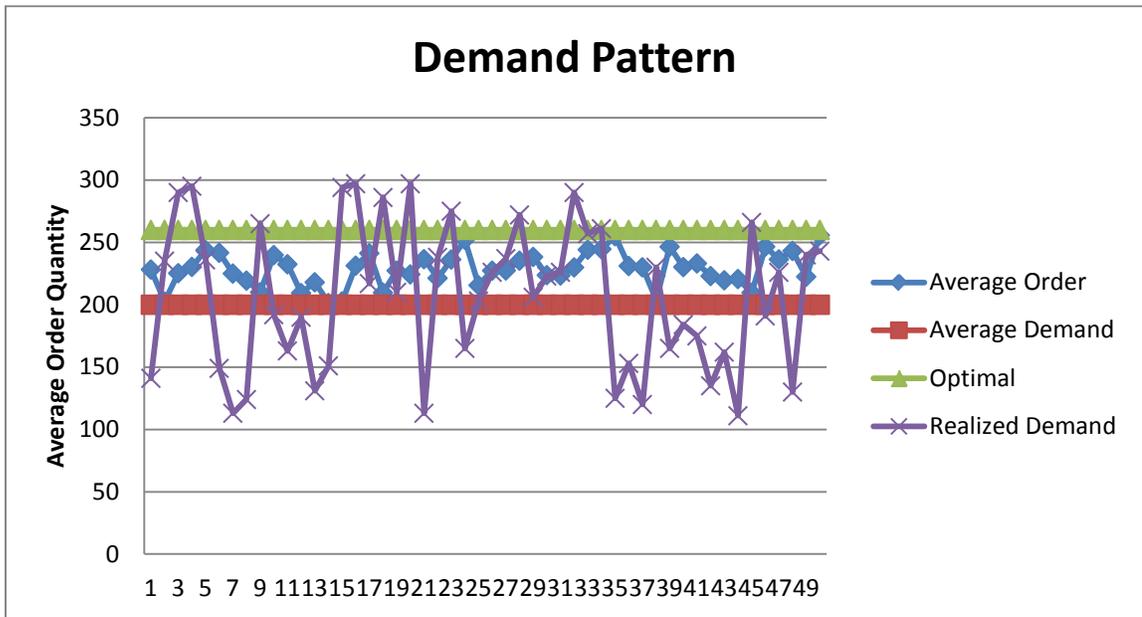


Figure 12: Average order quantities in revenue sharing with demand pattern

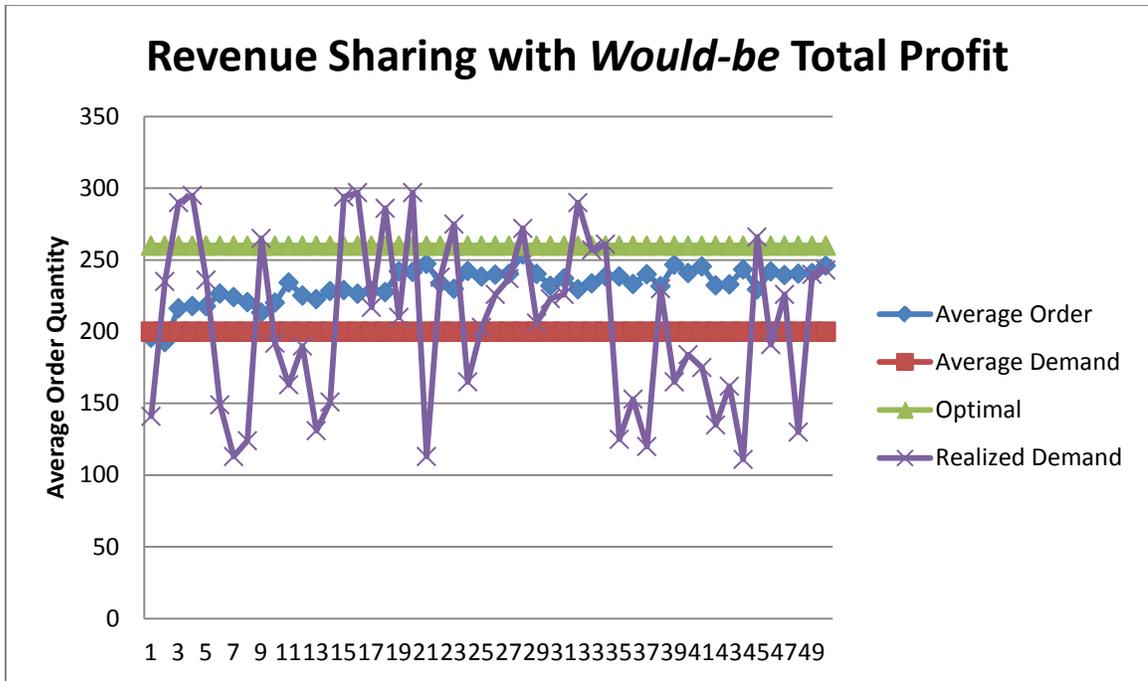


Figure 13: Average order quantities in a revenue sharing with would-be total profit feedback

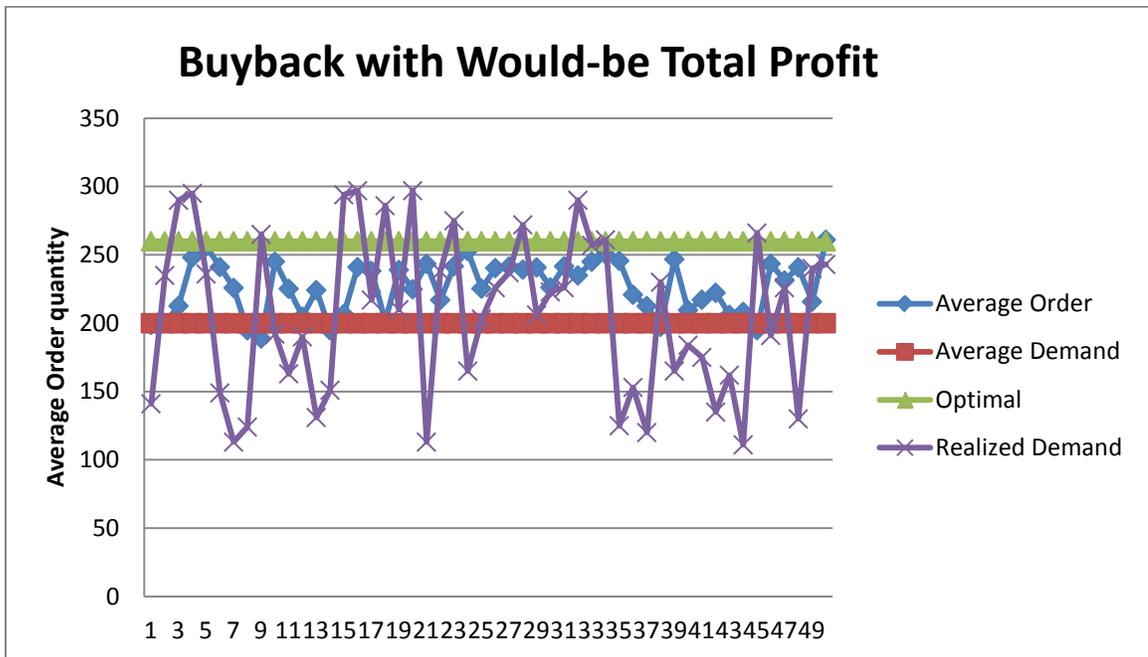


Figure 14: Average order quantities in a buyback with would-be total profit feedback

## REFERENCES

- Ariely, D., Shampanier, K., & Mazar, N. (2007). Zero as a special price: The true value of free products. *Marketing Science*, Vol. 26, No. 6, 742-57.
- Becker-Peth, M., Katok, E., Thonemann, U.W., 2011. Designing Contracts for Irrational but Predictable Newsvendors. *Working Paper*.
- Bolton, G. E., & Katok, E. (2008). Learning by Doing in the Newsvendor Problem: A Laboratory Investigation of the Role of Experience and Feedback. *Manufacturing & Service Operations Management*, Vol. 10, No. 3, 519-538.
- Bostian, A. A., Holt, C. A., & Smith, A. M. (2008). Newsvendor "Pull-to-Center" Effect: Adaptive Learning in a Laboratory Experiment. *Manufacturing & Services Operations Management*, Vol. 10, No. 4 , 590-608.
- Cachon, G. P. (2003). Supply chain coordination with contracts. In S. Graves, & T. d. Kok, *Handbooks in Operations Research and Management Science: Supply Chain Management*, Vol. 11. Cambridge: North-Holland.
- Cachon, G. P., & Lariviere, M. A. (2005). Supply Chain Coordination with Revenue-Sharing Contracts: Strengths and Limitations. *Management Science*, Vol. 51, No. 1, 30-44.
- Corbett, C.J., Fransoo, J.C., 2007. Entrepreneurs and newsvendors: Do small businesses follow the newsvendor logic when making inventory decisions? *Working Paper*, University of California, Los Angeles.
- Davis, A. M. (2010). An Experimental Investigation of Pull Contracts. *Manufacturing and Services Operations Mgmt*.
- Fisher, M., & Raman, A. (1996). Reducing the Cost of Demand Uncertainty Through Accurate Response to Early Sales. *Operations Research*, Vol. 44, No. 1, 87-99.
- Ho, T., Zhang, J, 2008. Designing pricing contracts for boundedly rational customers: Does the framing of the fixed fee matter? *Management Science* 54 (4), 686-700.

Katok, E., 2011. Using Laboratory Experiments to Build Better Operations Management Models. Foundations and Trends in Technology, *Information and Operations Management* 5 (1), 1-86.

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

Keser, C., & Paleologo, G. A. (2004, Nov). Experimental investigation of supplier-retailer contracts: The wholesale price contract. *CIRANO, Working Paper*.

Kremer, M., Minner, S., & Wassenhove, V. L. (2010). Do Random Errors Explain Newsvendor Behavior? *Manufacturing and Services Operations Management*, Vol. 12, No. 4, 673-81.

Lamba, N., & Sharma, M. (2011). Correcting Decision Outcomes of a Decision Maker in a Revenue Sharing Contract. *ProQuest Central*, University of Massachusetts Boston.

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

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

Qin, Y., Wang, R., Vakharia, A.J., Chen, Y., Seref M.H., 2011. The newsvendor problem: Review and directions for future research, *European Journal of Operational Research* 213 (2), 361-374.

Schweitzer, M., Cachon, G., 2000. Decision bias in the newsvendor problem: Experimental evidence. *Management Science* 46 (3), 404-420.