Supply Chain Management Models for Innovative Products

Xiuyan Ma

Doctoral Thesis at Yokohama National University

March 2015

ACKNOWLEDGEMENTS

First and foremost I would like to express my sincere gratitude and appreciation to my advisor, Professor Peijun Guo. He has been incredibly supportive since the days when I was an undergraduate student. Throughout these years, he is the academic supervisor and also a good example of research scientist to me. He offered me not only the research methodology but also the life philosophy. Without his constant concern and illuminating instruction, this dissertation would be far from completion.

I would like to express my heartfelt gratitude to my co-advisor Professor Yoshiki Matsui and Professor Ryo Sato for their guides of my research and care for my five-year studying at Yokohama National University. I heartily thank Professor Hirofumi Matsuo and Professor Hiroyuki Tsurumi for their helpful suggestions and discussions on my dissertation panel.

I would like to thank all members of Guo seminar and our doctoral seminar for their discussions and comments.

I also own my special thanks to China Scholarship Council (CSC) and Japan Student Services Organization (JASSO), which provided financial support that enables me to focus on the research.

Finally, I am deeply grateful to my parents and all of my family members for their constant support and encouragement.

Xiuyan Ma *March 2015*

Contents

Chapter 1

Introduction

In the increasingly fierce competitive environment, innovation has become a core competency of an industrial organization. Innovative products are featured by higher profit margins, intrinsically unpredictable demand and short life cycles (Fisher, 1997). Many researchers study the newsvendor problems and supply chain management problems for innovative products, such as fashion goods (see the review by Cachon, 2003). However, the intrinsic one-shot characteristic of the decision related to innovative products has not been taken into account yet. The research in this dissertation is on characterizing the one-shot feature of innovative products in the supply chain management models based on the one-shot decision theory (Guo, 2011). Speaking in detail, it can be divided into four parts, that is, 1: General solutions in the one-shot decision theory; 2: Newsvendor models for innovative products; 3: Price-setting newsvendor models for innovative products; 4: Wholesale price contracts in the supply chain for innovative products. The detailed introduction is as follows.

1: General solutions in the one-shot decision theory

Guo (2011) initially proposed the one-shot decision theory (OSDT) for the one-shot decision problem which is typical for a situation where a decision is made only once under uncertainty. The one-shot decision theory provides a scenario-based choice instead of the lottery-based choices in the existing decision theories. According to the one-shot decision theory, a person makes a one-shot decision based on some particular scenario (state) which is the most appropriate one for him/her while considering the satisfaction level incurred by this scenario and its likelihood. The one-shot decision process is separated into two steps. The first step is to seek an appropriate scenario from all possible states for each alternative. This scenario is called as the focus point of the alternative. The second step is to evaluate the alternatives by the satisfaction levels incurred by the focus points for obtaining the optimal alternative. By the one-shot decision theory, the one-shot decision problem is formulated as a bi-level optimization problem and there is no existing general optimization method for such problem. In this dissertation, with an assumption that the normalized likelihood function and the satisfaction function are quasi-concave, the general solutions of the focus points and the optimal alternatives are obtained and the existence theorem is established in the one-shot decision theory.

2: Newsvendor models for innovative products

The newsvendor problem is a well-known inventory management problem. It has the following common characteristics. Prior to the season, the retailer must decide the quantity of the product to purchase. The procurement lead-time tends to be quite long relative to the selling season so that there is often not enough opportunity to replenish inventory once the season has begun. Excess stock can only be salvaged at a loss once the season is over. As the life cycle of innovative product is usually shorter than the procurement lead times, determining optimal order quantities of such products is a typical one-shot decision problem for the retailer. Therefore, newsvendor models for innovative products are proposed based on the one-shot decision theory. In the models, for each order quantity, the retailer chooses one appropriate demand (focus point) amongst all possible demands while considering the satisfaction level caused by the occurrence of the demand

and the likelihood of the demand. The optimal order quantity corresponds to the maximum satisfaction level of its focus point. The proposed newsvendor model (newsvendor-OSDT) is fundamentally different from the subjective expected utility (SEU) based newsvendor model (newsvendor-SEU), because the core hypothesis of SEU is that selecting an alternative equals selecting a probability distribution whereas the core hypothesis of OSDT is that selecting an alternative corresponds to selecting one appropriate state (scenario). Therefore, the newsvendor-SEU is lottery-based whereas the newsvendor-OSDT is scenario-based.

3: Price-setting newsvendor models for innovative products

In the classical newsvendor model, the retail price is considered as an exogenous value. It is only for a perfect competitive market where the retailers are price-takers. In a monopoly market, before the selling season, retail price and order quantity are set simultaneously, that is the price-setting newsvendor problem. This part examines the price-setting newsvendor problem for an innovative product in a monopoly market. Due to its short lifecycle, there is often only one opportunity for the retailer to order an innovative products. Hence, this dissertation highlights that for a retailer who sells an innovative product, how to determine the optimal order quantity is a one-shot decision problem which is typical for a situation where a decision is made once under uncertainty. The existing price-setting newsvendor models seek the optimal order quantities and retail prices to maximize the expected utilities or the probability measures of achieving target profits. They take into account all demand values when make a decision. However, only one demand will occur when selling an innovative product due to its short life cycle. Considering the one-shot feature of the retailer’s decision making for ordering an innovative product, we propose the price-setting newsvendor model with the one-shot decision theory. In the proposed models, each order quantity is evaluated only by the payoff of one selected demand (focus point) with considering the satisfaction level when this demand occurs and its occurrence likelihood. It is different from the expected utility based model in which the order quantity is evaluated by the average of the utilities caused by all demands. Hence, the proposed model is scenario-based which is fundamentally different for the existing models which is probability distribution based (lottery based).

4: Wholesale price contracts in the supply chain for innovative products

As a fundamental research of the supply chain management, a single manufacturer selling (innovative) products to a retailer who faces a newsvendor problem has been extensively researched (Lariviere and Porteus, 2001; Pasternack, 2008). This dissertation extended the existing literature mainly in the following three dimensions. Firstly, this dissertation considers the one-time feature of innovative products as follows: after observing the wholesale price, the retailer evaluating his/her order quantity only based on the selected demand (focus points). The optimal order quantity corresponds to the maximum satisfaction level of its focus point. Secondly, in the past decades, the value of information sharing in the supply chain has attracted much attention from both practitioners and researchers. But most of the works are focusing on the value of demand information sharing. Until now, the information sharing of participants' personalities in the supply chain is still on 'virgin territory'. In this dissertation, the retailer's personality information are considered. The optimal wholesale price contracts for the manufacturer when he/she is facing different personalities of retailers are obtained. Thirdly, this dissertation examine the wholesale price contract both in the make-to-order and make-to-stock supply chain.

The reminder of this dissertation is organized as follows.

In Chapter 2, the general solutions of active, passive, apprehensive and daring focus points and optimal alternatives are proposed and the existence theorem is established in the one-shot decision theory.

In Chapter 3, with considering the one-time feature of innovative products, we built the newsvendor models for innovative products for four types of retailers, i.e. active, passive, apprehensive and daring retailers; managerial insights into the behaviors of different types of retailers are gained by the theoretical analysis.

In Chapter 4, the price-setting newsvendor models with the one-shot decision theory which fit the one-time feature of the retailer's joint price/quantity decision are built. The theoretical analysis provides the managerial insights into the behaviors of different types of retailers in the monopoly market. The proposed methods provide a fundamentally different vehicle for analyzing the newsvendor problems in a monopoly market of an innovative product.

In Chapter 5, the Stackelberg equilibriums are obtained for the optimal wholesale price of manufacturer and the optimal order quantity of retailer both in the make-to-order and make-to-stock supply chain for innovative products. Different types of retailers lead to different Stackelberg equilibriums. The managerial insights into the changes of behaviours of manufacturer and retailer when market grows are discussed. This chapter presents the first formal analysis of wholesale pricing of innovative products when the instinct one-time feature of the innovative product and the retailer's personality information are considered. Our analysis shows the differences of the wholesale price contracts for the retailers with different personalities and the importance of personality information sharing.

Finally, we summarize the obtained results of this dissertation in Chapter 6.

Chapter 2

General Solutions in the One-Shot Decision Theory

2.1 Introduction

Guo (2011) initially proposed the one-shot decision theory (OSDT) for the one-shot decision problem which is typical for a situation where a decision is made only once under uncertainty. The one-shot decision theory provides a scenario-based choice instead of the lottery-based choices in the existing decision theories. As the applications, a duopoly market of a new product with a short life cycle and the private real estate investment were analyzed (Guo, 2010a; Guo, 2010b; Guo et al., 2010). Recently, the research (Guo, 2014) clarified the fundamental differences between the one-shot decision theory and other decision theories under uncertainty and pointed out the instinct problems in other decision theories to show that the one-shot decision theory is necessary to solve one-shot decision problems and manifested the relationship between the one-shot decision theory and the probabilistic decision methods. Guo and Li (2014) proposed multistage one-shot decision making approaches and analyzed the optimal stopping problem.

Different from the probabilistic decision methods in which selecting an alternative equals selecting a probability distribution, in the one-shot decision theory, a person makes a one-shot decision based on some particular scenario (state) which is the most appropriate one for him/her while considering the satisfaction level incurred by this scenario and its likelihood. The one-shot decision process is separated into two steps. The first step is to seek an appropriate scenario from all possible states for each alternative. This scenario is called as the focus point of the alternative.

The second step is to evaluate the alternatives by the satisfaction levels incurred by the focus points for obtaining the optimal alternative. Different from the expected utility based models in which the different behaviors of the decision makers are assumed to be caused by the different utility functions of the decision makers, i.e., convex, concave and linear ones, we argue that the different behaviors of the decision makers result from the different personalities of them. We divide the decision makers into four types, i.e., active, passive, apprehensive and daring according to which type of focus point (scenario) they choose. Such idea is intuitively well-accepted. By the one-shot decision theory, the one-shot decision problem is formulated as a bi-level optimization problem and there is no existing general optimization method for such problem. Guo and Ma (2014) gave the general solutions and the existence theorem in the one-shot decision theory;

In this chapter, with an assumption that the normalized likelihood function and the satisfaction function are quasi-concave, the general solutions of the focus points and the optimal alternatives are obtained and the existence theorem is established in the one-shot decision theory.

2.2 Four Types of Focus Points

The set of a state x is S. The state x is a random variable X with the probability density function $f(x)$. The normalized likelihood function of X is given as below.

Definition 2.1. Given the probability density function $f(x)$, the normalized likelihood function $\pi(x)$ is

$$\pi(x) = \frac{f(x)}{\max f(x)}. \tag{2.1}$$

$\pi(x)$ can be regarded as the normalized probability density function and is used to represent the relative position of the likelihood of x. If X is a discrete random variable, the normalized likelihood function can be obtained as the normalized probability mass function. Clearly, the smaller the normalized likelihood of a demand x is, the more surprising the occurrence of x is.

The set of an alternative a is A. The consequence resulting from the combination of an alternative a and a state x is referred to as a payoff, denoted as $v(x,a)$. The set of a payoff is V. The satisfaction level of a decision maker for a payoff is expressed by a satisfaction function, as defined below.

Definition 2.2. The satisfaction function of the decision maker is the following continuous strictly increasing function of the payoff *v*,

$$u : V \to [0,1]. \tag{2.2}$$

Because the payoff is a function of x and a, we write the satisfaction function as $u(x,a)$. Since one and only one state will come up for a one-shot decision problem, a decision maker should decide which state ought to be considered for making a one-shot decision. How to determine focus points (focused states) depends on his/her attitudes about likelihood and satisfaction. We take into account four types of states for each alternative with considering the likelihood degree and the satisfaction level, that is, the state with a higher satisfaction and a higher likelihood (Type A), a lower satisfaction and a higher likelihood (Type B), a higher satisfaction and a lower likelihood (Type C), a lower satisfaction and a lower likelihood (Type D). It is intuitively acceptable that active, passive, daring and apprehensive decision makers are inclined to take into account Type A, Type B, Type C and Type D states, respectively. Therefore, Type A, Type B, Type C and Type D states are called as active, passive, daring and apprehensive focus points, respectively (shown in Table I).

		satisfaction	
		higher	lower
likelihood	higher	active focus point	passive focus point
	lower	daring focus point	apprehensive focus point

Table 2.1. Four types of focus points

For characterizing the focus points, we introduce the following operators.

Definition 2.3. Given a vector $[b_1, b_2, \cdots, b_n]$, $lower[b_1, b_2, \cdots, b_n]$ and $upper[b_1, b_2, \cdots, b_n]$ are defined as follows:

$$lower[b_1, b_2, \cdots, b_n] = [\underset{i=1,\cdots n}{\wedge} b_i, \underset{i=1,\cdots n}{\wedge} b_i, \cdots, \underset{i=1,\cdots n}{\wedge} b_i], \tag{2.3}$$

$$upper[b_1, b_2, \cdots, b_n] = [\underset{i=1,\cdots n}{\vee} b_i, \underset{i=1,\cdots n}{\vee} b_i, \cdots, \underset{i=1,\cdots n}{\vee} b_i]. \tag{2.4}$$

$lower[b_1, b_2, \cdots, b_n]$ and $upper[b_1, b_2, \cdots, b_n]$ are the lower and upper bounds of $[b_1, b_2, \cdots, b_n]$, respectively. For example, the normalized likelihood degree and the satisfaction level of a state x are 0.3 and 0.8, respectively, which is represented as $[0.3, 0.8]$. $lower[0.3, 0.8] = [0.3, 0.3]$ and $upper[0.3, 0.8] = [0.8, 0.8]$ represent that x has at least 0.3 normalized likelihood degree and 0.3 satisfaction level and x has at most 0.8 normalized likelihood degree and 0.8 satisfaction level.

In the following, we consider four types of focus points.

Active focus point: The state (scenario) with the higher likelihood and the higher satisfaction level is obtained as

$$x_1(a) \in \arg\max_{x \in S} lower[\pi(x), u(x, a)]. \tag{2.5}$$

$x_1(a)$ is called an active focus point of an alternative a. $\arg\max_{x \in S} lower[\pi(x), u(x, a)]$

represents an element of S which maximizes $lower[\pi(x),u(x,a)]$ with $x \in S$. Because $lower[\pi(x),u(x,a)]$ represents the lower bound of the vector $[\pi(x),u(x,a)]$, maximizing $lower[\pi(x),u(x,a)]$ ($\max_{x\in S} lower[\pi(x),u(x,a)]$) will increase the likelihood and the satisfaction level simultaneously. Therefore, $\arg\max_{x\in S} lower[\pi(x),u(x,a)]$ is for seeking the state that has the higher likelihood and the higher satisfaction level.

In order to facilitate understanding (2.5), let us give an example. For four states $S=\{x_1,x_2,x_3,x_4\}$, we have $\pi(x_1)=0.1$, $\pi(x_2)=0.3$, $\pi(x_3)=1.0$, $\pi(x_4)=0.6$, $u(x_1,a)=0.6$, $u(x_2,a)=0.2$, $u(x_3,a)=0.3$ and $u(x_4,a)=0.8$. $[\pi(x),u(x,a)]$, $x \in S$ are four vectors: $[0.1,0.6]$, $[0.3,0.2]$, $[1.0,0.3]$ and $[0.6,0.8]$ represented by *A*, *B*, *C* and *D*, respectively (shown in Fig. 2.1.). $lower[\pi(x),u(x,a)]$ transfers *A*, *B*, *C* and *D* into A', B', C' and D', which are $[0.1,0.1]$, $[0.2,0.2]$, $[0.3,0.3]$ and $[0.6,0.6]$, respectively. $\max_{x\in S} lower[\pi(x),u(x,a)]$ is $\max([0.1,0.1],[0.2,0.2],[0.3,0.3],[0.6,0.6])=[0.6,0.6]$ which corresponds to D'. Thus, $\arg\max_{x\in S} lower[\pi(x),u(x,a)]$ is x_4. It is obvious that x_4 have a higher likelihood (0.6) and a higher satisfaction level (0.8).

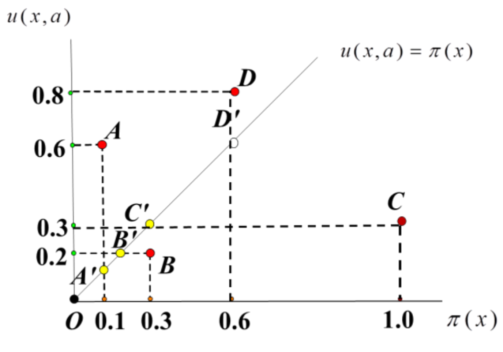

Fig.2.1 The explanation of the formula (2.5)

Passive focus point: The state (scenario) with the higher likelihood and the lower satisfaction level is obtained as

$$x_2(a) \in \arg\min_{x\in S} upper[1-\pi(x), u(x,a)]\,. \tag{2.6}$$

$x_2(a)$ is called a passive focus point of an alternative a.

Apprehensive focus point: The state (scenario) with the lower likelihood and the lower satisfaction level is obtained as

$$x_3(a) \in \arg\min_{x\in S} upper[\pi(x), u(x,a)]\,. \tag{2.7}$$

$x_3(a)$ is called an apprehensive focus point of an alternative a.

Daring focus point: The state (scenario) with the lower likelihood and the higher satisfaction level is obtained as

$$x_4(a) \in \arg\min_{x\in S} upper[\pi(x), 1-u(x,a)]\,. \tag{2.8}$$

$x_4(a)$ is called a daring focus point of an alternative a.

Comments:

1. (2.5) to (2.8) are from four bi-objective optimization problems ($\max \pi(x), \max u(x,a)$; $\max \pi(x), \min u(x,a)$; $\min \pi(x), \min u(x,a)$; $\min \pi(x), \max u(x,a)$). They are for seeking the state of natures that have the higher likelihood and higher satisfaction, the higher likelihood and the lower satisfaction, the lower likelihood and the lower satisfaction and the lower likelihood and the higher satisfaction, respectively. From (2.5) to (2.8), we know that no other $[\pi(x), u(x,a)]$ satisfies $\pi(x) > \pi(x_1(a))$ and $u(x,a) > u(x_1(a),a)$; or $\pi(x) > \pi(x_2(a))$ and $u(x,a) < u(x_2(a),a)$; or $\pi(x) < \pi(x_3(a))$ and $u(x,a) < u(x_3(a),a)$; or

$\pi(x) < \pi(x_4(a))$ and $u(x,a) > u(x_4(a),a)$. In other words, there is no state which has a higher likelihood and a higher satisfaction degree than the active focus point; a higher likelihood and a lower satisfaction level than the passive focus point; a lower likelihood and a lower satisfaction level than the apprehensive focus point; a lower likelihood and a higher satisfaction level than the daring focus point.

2. The normalized likelihood degrees and the satisfaction levels are treated equally. We take the active focus points as an example. Equation (2.5) is equivalent to the following equation.

$$x_1(a) = \arg\max_{x \in S} \frac{\pi(x) + u(x,a) - |\pi(x) - u(x,a)|}{2}. \tag{2.9}$$

From (2.9), we know that to seek the active focus point is to increase the sum of the normalized likelihood degree and the satisfaction level and to decrease the differences between them.

3. For one alternative, more than one state might exist as one type of focus point. We denote the sets of four types of focus points of an alternative a as $X_1(a)$, $X_2(a)$, $X_3(a)$ and $X_4(a)$, respectively.

In a one-shot decision problem, a decision maker contemplates that the focus points are the most appropriate scenarios for him/her. After determining the focus points of each alternative, the decision maker will make a decision only based on the focus points and chooses the optimal alternative which can bring about the highest satisfaction level once its focus point comes true. The four kinds of optimal alternatives are obtained as follows:

$$a_1^* \in \arg\max_{a \in A} \max_{x_1(a) \in X_1(a)} u(x_1(a), a), \tag{2.10}$$

$$a_2^* \in \arg\max_{a \in A} \min_{x_2(a) \in X_2(a)} u(x_2(a), a), \tag{2.11}$$

$$a_3^* \in \arg\max_{a \in A} \min_{x_3(a) \in X_3(a)} u(x_3(a), a), \tag{2.12}$$

$$a_4^* \in \arg\max_{a \in A} \max_{x_4(a) \in X_4(a)} u(x_4(a), a). \quad (2.13)$$

In the case where multiple active focus points of an alternative a exist, $\max_{x_1(a) \in X_1(a)} u(x_1(a), a)$ is used to represent the highest satisfaction level amongst all active focus points of a. It reflects an optimistic attitude of a decision maker whereas $\min_{x_2(a) \in X_2(a)} u(x_2(a), a)$ describes a conservative attitude of a decision maker. a_1^*, a_2^*, a_3^* and a_4^* are called optimal active, passive, apprehensive and daring alternatives, respectively. Setting $x_1^* = x_1(a_1^*)$, $x_2^* = x_2(a_2^*)$, $x_3^* = x_3(a_3^*)$ and $x_4^* = x_4(a_4^*)$, x_1^*, x_2^*, x_3^* and x_4^* are called optimal active, passive, apprehensive and daring focus points, respectively.

2.3 General Solutions of Focus Points and Optimal Alternatives

If S and A are nonempty finite sets, there are always solutions of (2.5)-(2.13). For the continuous cases, let us consider the solutions of (2.5)-(2.13) with the following conditions.

Basic Assumptions: In the following parts, we suppose

(1) The sets of states and alternatives are $S = [l, h]$ and $A = [a_l, a_h]$, respectively.

(2) $\pi(x)$ is a strictly quasi-concave continuous function (see the definition in the book (Madden, 1986)), $\exists c \in (l, h)$, $\pi(c) = 1$, $\pi(l) = 0$ and $\pi(h) = 0$.

(3) $v(x, a)$ is continuous and strictly quasi-concave in x.

Clearly, $\pi(x)$ is strictly increasing within $[l, c]$ and strictly decreasing within $[c, h]$. $u(x, a)$ is continuous and strictly quasi-concave in x. $\forall a$ $u(x, a)$ attains its maximum at a unique state $\hat{x}(a) = \arg\max_{x \in [l, h]} u(x, a)$ and is strictly increasing within $[l, \hat{x}(a)]$ for $\hat{x}(a) \neq l$

and strictly decreasing within $[\hat{x}(a), h]$ for $\hat{x}(a) \neq h$.

We have the following theorems.

Theorem 2.1. The active focus point of an alternative a, $x_1(a)$, is as follows:

(1) if $u(\hat{x}(a), a) \leq \pi(\hat{x}(a))$, then $x_1(a) = \hat{x}(a)$;

(2) if $u(\hat{x}(a), a) \geq \pi(\hat{x}(a))$ and $\hat{x}(a) \leq c$, then $x_1(a) = x_{ol}(a)$;

(3) if $u(\hat{x}(a), a) \geq \pi(\hat{x}(a))$ and $\hat{x}(a) \geq c$, then $x_1(a) = x_{ou}(a)$.

$x_{ol}(a)$ and $x_{ou}(a)$ are the solutions of $u(x, a) = \pi(x)$ within $[\hat{x}(a), c]$ and $[c, \hat{x}(a)]$, respectively.

Proof.

(1) We have

$$\max_{x \in [l,h]} lower[\pi(x), u(x, a)] \leq \max_{x \in [l,h]} [u(x, a), u(x, a)] = [u(\hat{x}(a), a), u(\hat{x}(a), a)]. \tag{2.14}$$

$lower[\pi(x), u(x, a)]$ attains its maximum $[u(\hat{x}(a), a), u(\hat{x}(a), a)]$ if and only if $x = \hat{x}(a)$. It means $x_1(a) = \hat{x}(a)$.

(2) First, let us consider the cases satisfying $\hat{x}(a) \neq c$. We have that $F(x) = u(x, a) - \pi(x)$ is strictly decreasing continuous within $[\hat{x}(a), c]$, $F(\hat{x}(a)) = u(\hat{x}(a), a) - \pi(\hat{x}(a)) \geq 0$ and $F(c) = u(c, a) - \pi(c) = u(c, a) - 1 < 0$. Therefore $F(x) = u(x, a) - \pi(x) = 0$ has a unique solution within $[\hat{x}(a), c]$, that is $x_{ol}(a)$. $\forall x \in [l, x_{ol}(a))$, $\pi(x)$ is strictly increasing so that

$$lower[\pi(x), u(x, a)] \leq [\pi(x), \pi(x)] < [\pi(x_{ol}(a)), \pi(x_{ol}(a))]. \tag{2.15}$$

$\forall x \in (x_{ol}(a), h]$, $u(x, a)$ is a strictly decreasing function of x so that

$$lower[\pi(x), u(x, a)] \leq [u(x, a), u(x, a)] < [u(x_{ol}(a), a), u(x_{ol}(a), a)]. \tag{2.16}$$

Recalling $\pi(x_{ol}(a)) = u(x_{ol}(a), a)$, we have

$$x_1(a) = \arg\max_{x\in[l,h]} lower[(\pi(x), u(x,a)] = x_{ol}(a). \tag{2.17}$$

We can directly check that (2.16) also holds for $\hat{x}(a) = c$.

(3) Similarly, we have $x_1(a) = x_{ou}(a)$. $x_{ou}(a)$ is the solution of $u(x,a) = \pi(x)$ within $[c, \hat{x}(a)]$. □

Theorem 2.2. The passive focus point of an alternative a, $x_2(a)$, is as follows:

(1) if $u(\hat{x}(a), a) \geq 1 - \pi(\hat{x}(a))$, then $x_2(a) = \arg\min_{x\in\{x_{pl}(a), x_{pu}(a)\}} u(x,a)$;

(2) if $u(\hat{x}(a), a) \leq 1 - \pi(\hat{x}(a))$ and $\hat{x}(a) > c$, then $x_2(a) = x_{pl}(a)$;

(3) if $u(\hat{x}(a), a) \leq 1 - \pi(\hat{x}(a))$ and $\hat{x}(a) < c$, then $x_2(a) = x_{pu}(a)$.

$x_{pl}(a)$ and $x_{pu}(a)$ are the solutions of $u(x,a) = 1 - \pi(x)$ within $[l, \min(\hat{x}(a), c)]$ and $[\max(\hat{x}(a), c), h]$, respectively.

Proof.

(1) First, let us consider the cases satisfying $\hat{x}(a) \neq l$, $\hat{x}(a) \neq h$ and $u(\hat{x}(a), a) \neq 1 - \pi(\hat{x}(a))$. We have that $F(x) = u(x,a) - (1 - \pi(x))$ is strictly increasing continuous within $[l, \min(\hat{x}(a), c)]$, $F(l) = u(l,a) - (1 - \pi(l)) = u(l,a) - 1 < 0$, $F(\hat{x}(a)) = u(\hat{x}(a), a) - (1 - \pi(\hat{x}(a))) > 0$ and $F(c) = u(c,a) - (1 - \pi(c)) = u(c,a) > 0$. Therefore, $F(x) = u(x,a) - (1 - \pi(x)) = 0$ has a unique solution within $[l, \min(\hat{x}(a), c)]$. Similarly, it is easy to know that $F(x) = u(x,a) - (1 - \pi(x)) = 0$ have a unique solution within $[\max(\hat{x}(a), c), h]$. These two solutions are $x_{pl}(a)$ and $x_{pu}(a)$, respectively. $\forall x \in [l, x_{pl}(a))$, $1 - \pi(x)$ is strictly decreasing so that

$$upper[1 - \pi(x), u(x,a)] \geq [1 - \pi(x), 1 - \pi(x)] > [1 - \pi(x_{pl}(a)), 1 - \pi(x_{pl}(a))]. \tag{2.18}$$

$\forall x \in (x_{pl}(a), \min(\hat{x}(a), c)]$, $u(x,a)$ is a strictly increasing function of x so that

$$upper[1-\pi(x), u(x,a)] \geq [u(x,a), u(x,a)] > [u(x_{pl}(a), a), u(x_{pl}(a), a)]. \tag{2.19}$$

Recalling $1-\pi(x_{pl}(a)) = u(x_{pl}(a), a)$, we have

$$\underset{x\in[l,\min(\hat{x}(a),c)]}{\arg\min}\ upper[1-\pi(x), u(x,a)] = x_{pl}(a). \tag{2.20}$$

Similarly, we have

$$\underset{x\in[\max(\hat{x}(a),c),h]}{\arg\min}\ upper[1-\pi(x), u(x,a)] = x_{pu}(a). \tag{2.21}$$

If $\hat{x}(a) \geq c$, the interval $[\min(\hat{x}(a), c), \max(\hat{x}(a), c)]$ becomes $[c, \hat{x}(a)]$. Since $u(x,a)$ is strictly increasing within $[x_{pl}(a), \hat{x}(a)]$, we have

$$\min_{x\in[c,\hat{x}(a)]} upper[1-\pi(x), u(x,a)] \geq \min_{x\in[c,\hat{x}(a)]} [u(x,a), u(x,a)]$$

$$= [u(c,a), u(c,a)] > [u(x_{pl}(a), a), u(x_{pl}(a), a)]. \tag{2.22}$$

Similarly, if $\hat{x}(a) < c$, the interval $[\min(\hat{x}(a), c), \max(\hat{x}(a), c)]$ becomes $[\hat{x}(a), c]$. Since $u(x,a)$ is strictly decreasing within $[\hat{x}(a), x_{pu}(a)]$, we have

$$\min_{x\in[\hat{x}(a),c]} upper[1-\pi(x), u(x,a)] > [u(x_{pu}(a), a), u(x_{pu}(a), a)]. \tag{2.23}$$

From (2.20) to (2.23), we know

$$x_2(a) = \underset{x\in[l,h]}{\arg\min}\, upper[1-\pi(x), u(x,a)] = \underset{x\in\{x_{pl}(a), x_{pu}(a)\}}{\arg\min}\ u(x,a). \tag{2.24}$$

It is easy to check that (2.24) also holds for the case $u(\hat{x}(a), a) = 1-\pi(\hat{x}(a))$ or $\hat{x}(a) = l$ or $\hat{x}(a) = h$.

Likewise, we can prove Theorem 2.2(2) and 2.2(3). □

Corollary 2.3. Suppose $u(\hat{x}(a), a) \geq 1-\pi(\hat{x}(a))$. The passive focus point $x_2(a)$ is as follows:

(1) if $\hat{x}(a) > c$ and $\exists x_0 \in (c, \hat{x}(a)]$ $u(x_0, a) = 1-\pi(x_0)$ holds, then

$$x_2(a) = \mathop{\arg\min}_{x \in \{x_{pl}(a), x_{pu}(a)\}} u(x,a) = x_{pl}(a);$$

(2) if $\hat{x}(a) < c$ and $\exists x_0 \in [\hat{x}(a), c)$ $u(x_0, a) = 1 - \pi(x_0)$ holds, then

$$x_2(a) = \mathop{\arg\min}_{x \in \{x_{pl}(a), x_{pu}(a)\}} u(x,a) = x_{pu}(a).$$

Proof.

(1) Since $1-\pi(x)$ is strictly increasing within $[c,h]$ and $c < x_0 \le x_{pu}(a) \le h$, $1-\pi(x_{pu}(a)) \ge 1-\pi(x_0)$ holds. Since $u(x,a)$ is strictly increasing within $x \in [l, \hat{x}(a)]$ and $l \le x_{pl}(a) \le c < x_0 \le \hat{x}(a)$, $u(x_0,a) > u(x_{pl}(a),a)$ holds. Therefore, we have

$$u(x_{pu}(a),a) = 1-\pi(x_{pu}(a)) \ge 1-\pi(x_0) = u(x_0,a) > u(x_{pl}(a),a). \tag{2.25}$$

From Theorem 2.2(1), we know $x_2(a) = x_{pl}(a)$.

(2) Likewise, we can prove Corollary 2.3(2). □

Lemma 2.4.

(1) $\forall a_1, a_2 \in A$ $u(x_{pl}(a_1),a_1) < u(x_{pl}(a_2),a_2)$ holds if and only if $x_{pl}(a_1) > x_{pl}(a_2)$ holds; and $u(x_{pl}(a_1),a_1) = u(x_{pl}(a_2),a_2)$ holds if and only if $x_{pl}(a_1) = x_{pl}(a_2)$ holds.

(2) $\forall a_1, a_2 \in A$ $u(x_{pu}(a_1),a_1) < u(x_{pu}(a_2),a_2)$ holds if and only if $x_{pu}(a_1) < x_{pu}(a_2)$ holds; and $u(x_{pu}(a_1),a_1) = u(x_{pu}(a_2),a_2)$ holds if an only if $x_{pu}(a_1) = x_{pu}(a_2)$ holds.

Corollary 2.5.

(1) Assume that $u(\hat{x}(a_i),a_i) \ge 1-\pi(\hat{x}(a_i))$ or $u(\hat{x}(a_i),a_i) \le 1-\pi(\hat{x}(a_i))$ with $\hat{x}(a_i) > c$, $i = 1,2$. If $u(x,a_1) \le u(x,a_2)$ holds for any $x \in [l, \min(\hat{x}(a_1), \hat{x}(a_2))]$, then

$u(x_{pl}(a_1), a_1) \le u(x_{pl}(a_2), a_2)$ holds; and if $u(x, a_1) < u(x, a_2)$ holds for any $x \in [l, \min(\hat{x}(a_1), \hat{x}(a_2))]$, then $u(x_{pl}(a_1), a_1) < u(x_{pl}(a_2), a_2)$ holds.

(2) Assume that $u(\hat{x}(a_i), a_i) \ge 1 - \pi(\hat{x}(a_i))$ or $u(\hat{x}(a_i), a_i) \le 1 - \pi(\hat{x}(a_i))$ with $\hat{x}(a_i) < c$, $i = 1,2$. If $u(x, a_1) \le u(x, a_2)$ holds for any $x \in [\max(\hat{x}(a_1), \hat{x}(a_2)), h]$, then $u(x_{pu}(a_1), a_1) \le u(x_{pu}(a_2), a_2)$ holds; and if $u(x, a_1) < u(x, a_2)$ holds for any $x \in [\max(\hat{x}(a_1), \hat{x}(a_2)), h]$, then $u(x_{pu}(a_1), a_1) < u(x_{pu}(a_2), a_2)$ holds.

Lemma 2.6. The apprehensive focus point of an alternative a, $x_3(a)$, is as follows:

$$x_3(a) = \arg\min_{x \in \{l,h\}} u(x, a) . \tag{2.26}$$

Proof. $u(x,a)$ is a strictly quasi-concave function in x so that

$$\min_{x \in [l,h]} upper[\pi(x), u(x,a)] \ge \min_{x \in [l,h]} [u(x,a), u(x,a)] = [u(l,a), u(l,a)] \wedge [u(h,a), u(h,a)], \tag{2.27}$$

where the equality holds if and only if $x = \arg\min_{x \in \{l,h\}} u(x,a)$ because $\pi(l) = \pi(h) = 0$.

Therefore, (2.26) holds. □

Lemma 2.7. The daring focus point of an alternative a, $x_4(a)$, is as follows:

(1) if $1 - u(\hat{x}(a), a) \ge \pi(\hat{x}(a))$, then $x_4(a) = \hat{x}(a)$;

(2) if $1 - u(\hat{x}(a), a) \le \pi(\hat{x}(a))$, then $x_4(a) = \arg\max_{x \in \{x_{dl}(a), x_{du}(a)\}} u(x, a)$.

$x_{dl}(a)$ and $x_{du}(a)$ are the solutions of $1 - u(x,a) = \pi(x)$ within $[l, \min(\hat{x}(a), c)]$ and $[\max(\hat{x}(a), c), h]$, respectively.

Proof. (1) We have

$$\min_{x\in[l,h]} upper[\pi(x),1-u(x,a)] \geq \min_{x\in[l,h]}[1-u(x,a),1-u(x,a)]$$

$$= [1-u(\hat{x}(a),a),1-u(\hat{x}(a),a)], \tag{2.28}$$

where the equation holds if and only if $x = \hat{x}(a)$. That is, $x_4(a) = \hat{x}(a)$.

(2) Referring to the proof of Theorem 2.2(1), we have

$$x_4(a) = \arg\max_{x\in S} upper[\pi(x),1-u(x,a)] = \arg\min_{x\in\{x_{dl}(a),x_{dl}(a)\}} u(x,a). \tag{2.29}$$

□

Theorem 2.8. If there is an closed interval $G \subseteq [a_l, a_h]$ and $\forall a \in G$ $x_{ol}(a)$ exists, then $x_{ol}(a)$, $\pi(x_{ol}(a))$, $u(x_{ol}(a),a)$ are uniformly continuous within G. $x_{ou}(a)$, $\pi(x_{ou}(a))$, $u(x_{ou}(a),a)$, $x_{pl}(a)$, $\pi(x_{pl}(a))$, $u(x_{pl}(a),a)$, $x_{pu}(a)$, $\pi(x_{pu}(a))$, $u(x_{pu}(a),a)$, $x_{dl}(a)$, $\pi(x_{dl}(a))$, $u(x_{dl}(a),a)$, $x_{du}(a)$, $\pi(x_{du}(a))$ and $u(x_{du}(a),a)$ are also uniformly continuous within their corresponding closed intervals, respectively.

Proof. $\forall a_1, a_2 \in G$, for simplicity we assume $x_{ol}(a_1) \leq x_{ol}(a_2)$. Since $u(x_{ol}(a_2),a)$ is a continuous function of a within $[a_l, a_h]$, $u(x_{ol}(a_2),a)$ is a uniformly continuous function. That is, $\forall \varepsilon > 0$, $\exists \delta > 0$ such that $|a_1 - a_2| < \delta$ implies

$$|u(x_{ol}(a_2),a_1) - u(x_{ol}(a_2),a_2)| < \varepsilon. \tag{2.30}$$

$\hat{x}(a_1) \leq x_{ol}(a_1) \leq x_{ol}(a_2)$ leads to $u(x_{ol}(a_1),a_1) \geq u(x_{ol}(a_2),a_1)$ so that we have

$$u(x_{ol}(a_1),a_1) - u(x_{ol}(a_2),a_2) \geq u(x_{ol}(a_2),a_1) - u(x_{ol}(a_2),a_2). \tag{2.31}$$

Recalling $x_{ol}(a_1) \leq x_{ol}(a_2) \leq c$, we have

$$u(x_{ol}(a_1),a_1) - u(x_{ol}(a_2),a_2) = \pi(x_{ol}(a_1)) - \pi(x_{ol}(a_2)) \leq 0. \tag{2.32}$$

Therefore,

$$|\pi(x_{ol}(a_1))-\pi(x_{ol}(a_2))|=|u(x_{ol}(a_1),a_1)-u(x_{ol}(a_2),a_2)|$$

$$\leq |u(x_{ol}(a_2),a_1)-u(x_{ol}(a_2),a_2)|<\varepsilon . \tag{2.33}$$

We know that $\pi(x_{ol}(a))$, $u(x_{ol}(a),a)$ are uniformly continuous functions within G so that $x_{ol}(a)$ is uniformly continuous within G. Likewise, we have the same conclusions for $x_{ou}(a)$, $\pi(x_{ou}(a))$, $u(x_{ou}(a),a)$, $x_{pl}(a)$, $\pi(x_{pl}(a))$, $u(x_{pl}(a),a)$, $x_{pu}(a)$, $\pi(x_{pu}(a))$, $u(x_{pu}(a),a)$, $x_{dl}(a)$, $\pi(x_{dl}(a))$, $u(x_{dl}(a),a)$, $x_{du}(a)$, $\pi(x_{du}(a))$ and $u(x_{du}(a),a)$. □

Lemma 2.9.

(1) $u(x_1(a),a)=\max\limits_{x\in[l,h]}\min(\pi(x),u(x,a))$,

(2) $u(x_2(a),a)=\min\limits_{x\in[l,h]}\max(1-\pi(x),u(x,a))$,

(3) $u(x_3(a),a)=\min\limits_{x\in[l,h]}\max(\pi(x),u(x,a))$,

(4) $u(x_4(a),a)=\max\limits_{x\in[l,h]}\min(1-\pi(x),u(x,a))$.

Theorem 2.10 (Existence Theorem). If the basic assumptions (1), (2) and (3) hold, then a_1^*, a_2^*, a_3^*, a_4^*, $x_1(a_1^*)$, $x_2(a_2^*)$, $x_3(a_3^*)$ and $x_4(a_4^*)$ always exist and they satisfy the following relations:

(1) $u(x_1(a_1^*),a_1^*)=\max\limits_{a\in[a_l,a_h]}\max\limits_{x\in[l,h]}\min(\pi(x),u(x,a))$,

(2) $u(x_2(a_2^*),a_2^*)=\max\limits_{a\in[a_l,a_h]}\min\limits_{x\in[l,h]}\max(1-\pi(x),u(x,a))$,

(3) $u(x_3(a_3^*),a_3^*)=\max\limits_{a\in[a_l,a_h]}\min\limits_{x\in[l,h]}\max(\pi(x),u(x,a))$,

(4) $u(x_4(a_4^*), a_4^*) = \max_{a\in[a_l,a_h]} \max_{x\in[l,h]} \min(1-\pi(x), u(x,a))$.

Proof. Set $g(x,a) = \min(\pi(x), u(x,a))$. Since $u(x,a)$ is continuous on $[l,h]\times[a_l,a_h]$ and $\pi(x)$ is continuous on $[l,h]$, $g(x,a)$ is continuous on $[l,h]\times[a_l,a_h]$. Using Berge maximum theorem and Lemma 2.9(1), we know $u(x_1(a),a) = \max_{x\in[l,h]} \min(\pi(x), u(x,a))$ is continuous so that a_1^* and $x_1(a_1^*)$ exist and satisfy Theorem 10(1). Likewise, we can prove Theorem 2.10(2), 2.10(3) and 2.10(4). □

Lemma 2.11.

(1) $u(x_1(a_1^*), a_1^*) = \max_{x\in[l,h]} \min(\pi(x), \max_{a\in[a_l,a_h]} u(x,a))$,

(2) $u(x_4(a_4^*), a_4^*) = \max_{x\in[l,h]} \min(1-\pi(x), \max_{a\in[a_l,a_h]} u(x,a))$.

Proof. From Theorem 2.10(1), we have

$$u(x_1(a_1^*), a_1^*) = \max_{a\in[a_l,a_h]} \max_{x\in[l,h]} \min(\pi(x), u(x,a))$$

$$= \max_{x\in[l,h]} \max_{a\in[a_l,a_h]} \min(\pi(x), u(x,a)) = \max_{x\in[l,h]} \min(\pi(x), \max_{a\in[a_l,a_h]} u(x,a)) . \tag{2.34}$$

From Theorem 2.10(4), we have

$$u(x_4(a_4^*), a_4^*) = \max_{a\in[a_l,a_h]} \max_{x\in[l,h]} \min(1-\pi(x), u(x,a))$$

$$= \max_{x\in[l,h]} \min(1-\pi(x), \max_{a\in[a_l,a_h]} u(x,a)) . \tag{2.35}$$

□

Let us consider $v(x,a)$ is quasi-convex continuous in x and quasi-concave continuous in a so that $u(x,a)$ is quasi-convex continuous in x and quasi-concave continuous in a . We have the following theorem.

Theorem 2.12. If $u(x,a)$ is quasi-convex continuous in x and quasi-concave continuous in a, then we have

$$\max_{a\in[a_l,a_h]}\min_{x\in[l,h]}\max(1-\pi(x),u(x,a))=\min_{x\in[l,h]}\max(1-\pi(x),\max_{a\in[a_l,a_h]}u(x,a)). \tag{2.36}$$

Proof. Since $\pi(x)$ is strictly quasi-concave, $1-\pi(x)$ is strictly quasi-convex. For any x_1 and x_2, we have

$$1-\pi(\lambda x_1+(1-\lambda)x_2)<\max(1-\pi(x_1),1-\pi(x_2)),\ \ \forall\ \lambda\in(0,1). \tag{2.37}$$

$u(x,a)$ is quasi-convex in x so that for any x_1, x_2 we have

$$u(\lambda x_1+(1-\lambda)x_2,a)\le\max(u(x_1,a),u(x_2,a)),\ \ \forall\ \lambda\in(0,1). \tag{2.38}$$

Setting $f(x,a)=\max(1-\pi(x),u(x,a))$ and considering (2.37) and (2.38), we have

$$f(\lambda x_1+(1-\lambda)x_2,a)=\max(1-\pi(\lambda x_1+(1-\lambda)x_2),u(\lambda x_1+(1-\lambda)x_2,a))$$

$$\le\max(\max(1-\pi(x_1),1-\pi(x_2)),\max(u(x_1,a),u(x_2,a)))$$

$$=\max(\max(1-\pi(x_1),u(x_1,a)),\max(1-\pi(x_2),u(x_2,a)))$$

$$=\max(f(x_1,a),f(x_2,a)), \tag{2.39}$$

which means $f(x,a)$ is quasi-convex in x. $u(x,a)$ is a quasi-concave function of a, that is,

$$u(x,\lambda a_1+(1-\lambda)a_2)\ge\min(u(x,a_1),u(x,a_2)),\ \ \forall\ \lambda\in(0,1). \tag{2.40}$$

Considering (2.40), we have

$$f(x,\lambda a_1+(1-\lambda)a_2)=\max(1-\pi(x),u(x,\lambda a_1+(1-\lambda)a_2))$$

$$\ge\max(1-\pi(x),\min(u(x,a_1),u(x,a_2)))$$

$$=\min(\max(1-\pi(x),u(x,a_1)),\max(1-\pi(x),u(x,a_2)))$$

$$=\min(f(x,a_1),f(x,a_2)), \tag{2.41}$$

which means $f(x,a)$ is quasi-concave in a. Since $u(x,a)$ and $\pi(x)$ are continuous, $f(x,a)$ is a continuous function. According to Sion's minimax theorem (Sion, 1958), we have

$$\max_{a\in[a_l,a_h]}\min_{x\in[l,h]}\max(1-\pi(x),u(x,a)) = \min_{x\in[l,h]}\max_{a\in[a_l,a_h]}\max(1-\pi(x),u(x,a))$$

$$= \min_{x\in[l,h]}\max(1-\pi(x),\max_{a\in[a_l,a_h]}u(x,a)). \tag{2.42}$$

□

Theorem 2.13.

(1) If $\max_{a\in[a_l,a_h]}u(x,a)$ is strictly increasing, then the unique optimal active focus point x_1^* satisfies $\pi(x)=\max_{a\in[a_l,a_h]}u(x,a)$, $x\in(c,h)$ and $a_1^*=\arg\max_{a\in[a_l,a_h]}u(x_1^*,a)$.

(2) If $\max_{a\in[a_l,a_h]}u(x,a)$ is strictly increasing and $\max_{a\in[a_l,a_h]}u(h,a)=1$, then the unique optimal daring focus point is $x_4^*=h$ and $a_4^*=\arg\max_{a\in[a_l,a_h]}u(x_4^*,a)$.

(3) If $\max_{a\in[a_l,a_h]}u(x,a)$ is strictly decreasing, then the unique optimal active focus point x_1^* satisfies $\pi(x)=\max_{a\in[a_l,a_h]}u(x,a)$, $x\in(l,c)$ and $a_1^*=\arg\max_{a\in[a_l,a_h]}u(x_1^*,a)$.

(4) If $\max_a u(x,a)$ is strictly decreasing and $\max_a u(l,a)=1$, then the unique optimal daring focus point is $x_4^*=l$ and $a_4^*=\arg\max_{a\in[a_l,a_h]}u(x_4^*,a)$.

Proof.

(1) It follows from Berge maximum theorem that $\max_{a\in[a_l,a_h]}u(x,a)$ is continuous because $u(x,a)$ is continuous. We have that $F(x)=\max_{a\in[a_l,a_h]}u(x,a)-\pi(x)$ is strictly increasing continuous within $[c,h]$, $F(c)=\max_{a\in[a_l,a_h]}u(c,a)-\pi(c)<0$ and $F(h)=\max_{a\in[a_l,a_h]}u(h,a)-\pi(h)>0$. Therefore, $F(x)=\max_{a\in[a_l,a_h]}u(x,a)-\pi(x)=0$ has a unique solution within (c,h), denoted as x_0. Since $\max_{a\in[a_l,a_h]}u(x,a)$ is strictly increasing within $[l,h]$, $\forall x\in[l,x_0)$, we have

$$\min(\pi(x),\max_{a\in[a_l,a_h]}u(x,a)) \le \max_{a\in[a_l,a_h]}u(x,a) < \max_{a\in[a_l,a_h]}u(x_0,a). \tag{2.43}$$

Meanwhile, $\forall x \in (x_0, h]$, we know

$$\min(\pi(x), \max_{a\in[a_l,a_h]} u(x,a)) \le \pi(x) < \pi(x_0). \quad (2.44)$$

Since $\pi(x_0) = \max_{a\in[a_l,a_h]} u(x_0,a)$, $x = x_0$ satisfies $\max_{x\in[l,h]} \min(\pi(x), \max_{a\in[a_l,a_h]} u(x,a))$. Considering Lemma 2.11(1), we know x_1^* satisfies $\pi(x) = \max_{a\in[a_l,a_h]} u(x,a)$, $x \in (c,h)$ and $a_1^* = \arg\max_{a\in[a_l,a_h]} u(x_1^*, a)$.

(2) Since $\max_{a\in[a_l,a_h]} u(x,a)$ is strictly increasing within $[l,h]$, $\forall x \ne h$ we have $\max_{a\in[a_l,a_h]} u(x,a) < \max_{a\in[a_l,a_h]} u(h,a) = 1$. Meanwhile, $1-\pi(h) = 1$ holds. Considering Lemma 2.11(2), we know $x_4^* = h$ and $a_4^* = \arg\max_{a\in[a_l,a_h]} u(h,a)$.

Likewise, we can prove Theorem 2.13(3) and 2.13(4). □

2.4 Concluding Remarks

In this chapter, with an assumption that the normalized likelihood function and the satisfaction function are quasi-concave, the general solutions of active, passive, apprehensive and daring focus points and optimal alternatives are proposed and the existence theorem is established in the one-shot decision theory.

Chapter 3

Newsvendor Models for Innovative Products

3.1 Introduction

The newsvendor problem is a well-known inventory management problem. It has the following characteristics. Prior to the season, the seller must decide the quantity of the goods to purchase/produce. The procurement lead-time tends to be quite long relative to the selling season. As a result, there's not enough opportunity to replenish inventory once the season has begun. Excess stock can only be salvaged at a loss once the season is over. The classical newsvendor problem is characterized by the fixed selling and wholesale prices and the uncertain demand of goods with a short life cycle, such as perishable items and fashion items. Its optimal order quantity is solved by the critical fractile of the demand distribution. A considerable amount of research (Grubbstrom, 2010; Wang, 2010; Caliskan-Demirag et al., 2011; Chen, 2011; Salinger and Ampudia, 2011; Xu et. al., 2011; Brito and de Almeida, 2012; Seifert et al., 2012; Summerfield and Dror, 2012; Murray et al. , 2012; Wang et al., 2012; Wu et al., 2012; Kwon and Cheong, 2014) and bibliographies have appeared in the newsvendor literature, including those of Petruzzi and Dada (1999), Khouja (1999) and Qin et al. (2011). Many extensions of the classic newsvendor problem, such as different demand functions, different supplier pricing policies to coordinate the supply chain, different retailer risk profits, supplier capacity constraints and multi-product cases have been made. But almost all the extensions have been made in the probabilistic framework where the uncertainty of the demand and the supply is characterized by probability distributions, and the objective function is used to maximize the expected utility or the probability measure of achieving a target profit.

Guo and Ma (2012, 2014) examine the newsvendor problem for the innovative product as defined by Fisher. According to Fisher (1997), products basically belong to either primarily functional category or innovative one. Functional products satisfy basic needs and have stable, predictable demand and long life cycles whereas innovative products have higher profit margins, intrinsically unpredictable demands and short life cycles. In addition, for such an innovative product, the procurement lead-time is usually longer than the selling season so that there is usually only one opportunity to order goods before the season. For example, Sport Obermeyer, a major supplier of fashion skiwear, ships its products in September, but has to commit itself to products well before February (Fisher, 1997). However, the retailer season is only a few months long. Hence, the newsvendor problems for innovative products can be regarded as one-shot decision problems, which are typical for situations where a decision is made only once under uncertainty. Since the life cycle of the innovative product is shorter than the procurement lead-time, determining the optimal order quantity is a typical one-shot decision problem for the retailer.

In this chapter, the one-shot decision theory (OSDT) based newsvendor models are proposed. In the proposed models, for each order quantity, the retailer chooses one demand amongst all possible demands while considering the satisfaction level caused by the occurrence of the demand and the likelihood of the demand occurring. The selected demand is called the focus point of the order quantity. The optimal order quantity corresponds to the maximum satisfaction level of its focus point. We take into account four types of decision makers, i.e. active, passive, apprehensive and daring retailers who focus on the demand with a higher satisfaction and a higher likelihood, the demand with a lower satisfaction and a higher likelihood, the demand with a lower satisfaction and a lower likelihood, the demand with a higher satisfaction and a lower likelihood, respectively.

The optimal order quantities for these four types of retailers are obtained and the theoretical analysis is made.

The contributions of this chapter are as follows: The probabilistic newsvendor models seek the optimal order quantities to maximize the expected values or the probability measures. They take into account all demand values when determining the optimal order quantities. However, there is one and only one demand that will appear when the selling season comes. We build the newsvendor models with the one-shot decision theory which fit the one-shot feature of the retailer's order decision. The managerial insights into the behaviors of different types of retailers are gained by the theoretical analysis. The proposed methods provide a fundamental alternative to analyze the newsvendor problems for innovative products.

The remainder of this chapter is organized as follows: In Section 3.2, newsvendor models for innovative products are developed based on the one-shot decision theory. In Section 3.3, the results of analysis of the proposed newsvendor models are given. In Section 3.4, a numerical example is used to demonstrate the proposed approach. Finally, the research conclusions are given in Section 3.5.

3.2. Newsvendor Models with the One-Shot Decision Theory

Consider a retailer who sells an innovative product. The retailer orders q units before the season at the unit wholesale price W. When the demand x is observed, the retailer sells units (limited by the supply q and the demand x) at the exogenous unit revenue R with $R > W$. Any excess product can be salvaged at the unit salvage price $S_o > 0$ with $W > S_o$. If there is a shortage, the unit opportunity cost is $S_u > 0$. The profit function of the retailer is as follows:

$$r(x,q) = \begin{cases} Rx + (q-x)S_o - Wq; & x < q \\ (R-W)q - S_u(x-q); & x \geq q \end{cases}. \tag{3.1}$$

The demand of the innovative product is a random variable X with the probability density function $f_D(x)$. According to Definition 2.1, the normalized likelihood function of demand is

$$\pi_D(x) = \frac{f_D(x)}{\max f_D(x)}. \tag{3.2}$$

In the following of this chapter, we suppose the following assumption.

Assumption 3.1: The probability density function $f_D(x)$ is a strictly quasi-concave continuous function defined on the interval $[d_l, d_u]$, the mode is $d_c \in (d_l, d_u)$, $f_D(d_l) = 0$ and $f_D(d_u) = 0$.

Following Assumption 3.1, we know that $\pi_D(x)$ satisfies $\pi_D(d_c) = 1$, $\pi_D(d_l) = 0$ and $\pi_D(d_u) = 0$. $\pi_D(x)$ is strictly quasi-concave continuous; d_l and d_u are the lower and upper bounds of the demand, respectively; d_c is the most possible amount of the demand. The smaller the normalized likelihood of a demand *x* is, the more surprising the occurrence of *x* is. Because the demand is inside the interval $[d_l, d_u]$, a reasonable order quantity should also lie in this region. The highest profit of retailer is

$$r_u = (R - W)d_u, \tag{3.3}$$

that is, the retailer orders the most $q = d_u$ and the demand is the largest d_u. The lowest profit is $r_l = \min\{d_l R + (d_u - d_l)S_o - d_u W, d_l R - (d_u - d_l)S_u - d_l W\}$. It is determined by the minimum of two cases: in the first case, the retailer orders the most but the demand is the lowest:

$d_l R + (d_u - d_l) S_o - d_u W$; in the second case, the retailer orders the lowest but the demand is the highest: $d_l R - (d_u - d_l) S_u - d_l W$. We assume $W \geq S_o + S_u$, which leads to

$$r_l = d_l R + (d_u - d_l) S_o - d_u W \ . \tag{3.4}$$

The satisfaction function of the retailer is the following strictly increasing function of the profit r ,

$$u : [r_l, r_u] \to [0,1], \tag{3.5}$$

where $u(r_l) = 0$ and $u(r_u) = 1$.

(3.5) is a general form of the satisfaction function of the retailer where the satisfaction degree of the lowest profit is 0 and the satisfaction degree of the highest profit is 1. The satisfaction function is written as $u(r(x,q))$ in the following parts.

Proposition 3.1.

(1) $u(r(x,q))$ is strictly increasing continuous in x when $q \geq x$ and strictly decreasing continuous in x when $q \leq x$.

(2) $u(r(x,q))$ is strictly increasing continuous in q when $x \geq q$ and strictly decreasing continuous in q when $x \leq q$.

(3) $\max_q u(r(x,q)) = u(r(x,x))$ is strictly increasing continuous.

Since the life cycle of the innovative product is generally shorter than the procurement lead-time, the retailer has only one chance to determine the order quantity and one and only demand will occur. It is reasonable that the retailer needs to contemplate which demand ought to be taken into account before ordering products. The retailer chooses one demand (focus point) amongst all possible ones while considering the normalized likelihood to which the demand will appear in the future and the satisfaction level that the demand can bring about for an order quantity. We consider four types of focus points introduced in Chapter 2 as follows:

Active focus point of an order quantity: The active focus point of an order quantity q, denoted as $x_1^*(q)$, is

$$x_1^*(q) \in \arg\max_{x \in [d_l, d_u]} lower[\pi_D(x), u(r(x,q))]. \tag{3.6}$$

$x_1^*(q)$ is a demand that has a higher likelihood and a higher satisfaction level for an order quantity q.

Passive focus point of an order quantity: The passive focus point of an order quantity q, denoted as $x_2^*(q)$, is

$$x_2^*(q) \in \arg\min_{x \in [d_l, d_u]} upper[1 - \pi_D(x), u(r(x,q))]. \tag{3.7}$$

$x_2^*(q)$ is a demand that has a higher likelihood and a lower satisfaction level for an order quantity q.

Apprehensive focus point of an order quantity: The apprehensive focus point of an order quantity q, denoted as $x_3^*(q)$, is

$$x_3^*(q) \in \arg\min_{x \in [d_l, d_u]} upper[\pi(x), u(r(x,q))]. \tag{3.8}$$

$x_3^*(q)$ is a demand with a lower likelihood and a lower satisfaction level for an order quantity q.

Daring focus point of an order quantity: The daring focus point of an order quantity q, denoted as $x_4^*(q)$, is

$$x_4^*(q) \in \arg\min_{x\in[d_l,d_u]} upper[\pi(x), 1-u(r(x,q))]. \tag{3.9}$$

$x_4^*(q)$ is a demand with a lower likelihood and a higher satisfaction level for an order quantity q.

For one order quantity, more than one demand might exist as one type of focus point. We denote the sets of four types of focus points of an order quantity q as $X_1(q)$, $X_2(q)$, $X_3(q)$ and $X_4(q)$, respectively.

In the newsvendor problem, the retailer contemplates that the focus point is the most appropriate scenarios (demand) for each order quantity and chooses one order quantity which can bring about the best consequence (highest satisfaction level) with the assumption that only focus points come true. The optimal order quantities are obtained as follows:

$$q_1^* \in \arg\max_{q\in[d_l,d_u]} \max_{x_1^*(q)\in X_1(q)} u(r(x_1^*(q),q)), \tag{3.10}$$

$$q_2^* \in \arg\max_{q\in[d_l,d_u]} \min_{x_2^*(q)\in X_2(q)} u(r(x_2^*(q),q)), \tag{3.11}$$

$$q_3^* \in \arg\max_{q\in[d_l,d_u]} \min_{x_3^*(q)\in X_3(q)} u(r(x_3^*(q),q)), \tag{3.12}$$

$$q_4^* \in \arg\max_{q\in[d_l,d_u]} \max_{x_4^*(q)\in X_4(q)} u(r(x_4^*(q),q)). \tag{3.13}$$

q_1^*, q_2^*, q_3^* and q_4^* are called optimal active, passive, apprehensive and daring order quantities, respectively. $x_1^*(q_1^*)$, $x_2^*(q_2^*)$, $x_3^*(q_3^*)$ and $x_4^*(q_4^*)$ are optimal active, passive, apprehensive and daring demands, respectively. The retailer who takes into account the active, passive, apprehensive or daring focus point is called active, passive, apprehensive or daring retailer, respectively.

Comments: The differences between the newsvendor model with the subjective expected utility theory (Newsvendor-SEU) and the newsvendor model with the one-shot decision theory (Newsvendor-OSDT) is shown below.

1. In Newsvendor-SEU, there are two steps as follows:

Step 1: Evaluating each order quantity by the weighted average of the utilities of all payoffs brought about by all possible demands;

Step2: Selecting the order quantity with the maximum average.

In Newsvendor-OSDT, there are two steps as follows:

Step 1: Seeking an appropriate demand (focus point) for each order quantity;

Step 2: Choosing the order quantity with the maximum satisfaction level of the focus point (selected demand).

2. In Newsvendor-SEU, a utility function is associated with risky situations. If a person is a risk averter, the utility function is concave; if a person is a risk taker, the utility function is convex; if a person is risk neutral, the utility function is linear. In Newsvendor-OSDT, the satisfaction function has no relationship with risk situations. It represents the relative position of the payoff. Which type of focus point is used for making a decision reflects the attitude of a decision maker about uncertainty.

3. Newsvendor-SEU and Newsvendor-OSDT explain why some order quantity is optimal in different ways. In Newsvendor-SEU an order quantity is evaluated based on the average; that is, if the optimal order quantity is chosen every time then the total utility almost surely attains the maximum in the sense of the strong law of large numbers. However, Newsvendor-OSDT gives a clear answer to why some order quantity is optimal when only one decision chance is left to a retailer.

3.3. Analysis Results of OSDT Based Newsvendor Models

Let us first think about how to obtain the optimal active, passive, apprehensive and daring order quantities.

Lemma 3.2. The optimal active order quantity q_1^* is the solution of the following equation:

$$u(r(x,x)) = \pi_D(x), \quad x \in (d_c, d_u). \tag{3.14}$$

The optimal active demand, i.e. $x_1^*(q_1^*)$ is q_1^*.

Proof. The proof follows directly from Theorem 2.13 (1) and Proposition 3.1 (3). □

Interestingly, Lemma 3.2 indicates that the focus point (selected demand) of the active retailer's optimal order quantity is the optimal order quantity itself. It means that the active retailer has confidence that he/she can sell all the products that he/she has optimally ordered.

Lemma 3.3. The optimal passive order quantity q_2^* is the solution of the following equation:

$$u(r(d_{pl}(q),q)) = u(r(d_{pu}(q),q)), \tag{3.15}$$

equivalently,

$$\pi_D(d_{pl}(q)) = \pi_D(d_{pu}(q)), \tag{3.16}$$

where $d_{pl}(q)$ and $d_{pu}(q)$ are the solutions of $u(r(x,q)) = 1-\pi_D(x)$ within $[d_l, \min(q,d_c)]$ and $[\max(q,d_c), d_u]$, respectively. The optimal passive demand, i.e. $x_2^*(q_2^*)$ are $d_{pl}(q_2^*)$ and $d_{pu}(q_2^*)$.

Proof. It follows from Proposition 3.1(3) that $u(r(x,x))$ is strictly increasing continuous within $[d_l, d_u]$. $1-\pi_D(x)$ is strictly decreasing continuous within $[d_l, d_c]$ and strictly increasing continuous within $[d_c, d_u]$. Therefore $F(x) = u(r(x,x)) - (1-\pi_D(x))$ is continuous within

$[d_l, d_u]$ and strictly increasing within $[d_l, d_c]$. Since $F(d_l) = u(r(d_l, d_l)) - (1 - \pi_D(d_l)) < 0$, $F(d_c) = u(r(d_c, d_c)) - (1 - \pi_D(d_c)) > 0$ and $F(d_c) = u(r(d_u, d_u)) - (1 - \pi_D(d_u)) = 0$, there is a unique solution of $F(x) = u(r(x, x)) - (1 - \pi_D(x)) = 0$ within (d_l, d_c), denoted as d^*_{pl}; and there is at least one solution within $(d_c, d_u]$, the minimum solution is denoted as d^*_{pu}. In what follows, we consider q, i.e. $q \in [d_l, d^*_{pl}]$, $q \in [d^*_{pu}, d_u]$ and $q \in [d^*_{pl}, d^*_{pu}]$.

Case 1: $q \in [d_l, d^*_{pl}]$. That is, $u(r(q, q)) \le 1 - \pi_D(q)$ and $q < d_c$. It follows from Theorem 2.2(3) that the passive focus point of $q \in [d_l, d^*_{pl}]$ is $x^*_2(q) = d_{pu}(q)$. From Proposition 3.1(2) and Corollary 2.5(2), we have

$$\max_{q \in [d_l, d^*_{pl}]} u(r(x_2(q), q)) = \max_{q \in [d_l, d^*_{pl}]} u(r(d_{pu}(q), q)) = u(r(d_{pu}(d^*_{pl}), d^*_{pl})). \tag{3.17}$$

Case 2: $q \in [d^*_{pu}, d_u]$. For the case $u(r(q, q)) \le 1 - \pi_D(q)$, Theorem 2.2(2) shows that the passive focus point is $x_2(q) = d_{pl}(q)$. In the case $u(r(q, q)) \ge 1 - \pi_D(q)$, since $u(r(d^*_{pu}, q)) \le u(r(d^*_{pu}, d^*_{pu})) = 1 - \pi_D(d^*_{pu})$ and $F(x) = u(r(x, q)) - (1 - \pi_D(x))$ is a continuous function, $\exists x_0 \in [d^*_{pu}, q]$ $F(x_0) = u(r(x_0, q)) - (1 - \pi_D(x_0)) = 0$ holds. From Corollary 2.3(1), we know that the passive focus point is $x_2(q) = d_{pl}(q)$. Therefore, $\forall q \in [d^*_{pu}, d_u]$, the passive focus point is $x_2(q) = d_{pl}(q)$. From Proposition 3.1(2) and Corollary 2.5(1), we have

$$\max_{q \in [d^*_{pu}, d_u]} u(r(x_2(q), q)) = u(r(d_{pl}(q), q)) = u(r(d_{pl}(d^*_{pu}), d^*_{pu})). \tag{3.18}$$

Case 3: $q \in [d_{pl}^*, d_{pu}^*]$. That is, $u(r(q,q)) \geq 1 - \pi_D(q)$. It follows from Theorem 2.2(1) that

$$u(r(x_2(q),q)) = \min(u(r(d_{pl}(q),q)), u(r(d_{pu}(q),q))). \tag{3.19}$$

From Theorem 2.8, we know that $u(r(d_{pl}(q),q))$ and $u(r(d_{pu}(q),q))$ are uniformly continuous in $q \in [d_{pl}^*, d_{pu}^*]$. Considering $F(q) = u(r(d_{pl}(q),q)) - u(r(d_{pu}(q),q))$, it follows from Proposition 3.1(2) and Corollary 2.5 that $F(q)$ is strictly decreasing within $[d_{pl}^*, d_{pu}^*]$. For $q = d_{pl}^*$ and $q = d_{pu}^*$, we have

$$F(d_{pl}^*) = u(r(d_{pl}(d_{pl}^*), d_{pl}^*)) - u(r(d_{pu}(d_{pl}^*), d_{pl}^*)) > 0, \tag{3.20}$$

$$F(d_{pu}^*) = u(r(d_{pl}(d_{pu}^*), d_{pu}^*)) - u(r(d_{pu}(d_{pu}^*), d_{pu}^*)) < 0. \tag{3.21}$$

Therefore, there is a unique $\tilde{q} \in (d_{pl}^*, d_{pu}^*)$ satisfying $u(r(d_{pl}(\tilde{q}),\tilde{q})) = u(r(d_{pu}(\tilde{q}),\tilde{q}))$. Theorem 2.2(1) shows

$$x_2(\tilde{q}) = \{d_{pl}(\tilde{q}), d_{pu}(\tilde{q})\}. \tag{3.22}$$

Let us consider the case $q > \tilde{q}$. From Proposition 3.1(2), we know $u(r(x,q)) < u(r(x,\tilde{q}))$ for $x \in [d_l, \tilde{q}]$; and $u(r(x,q)) > u(r(x,\tilde{q}))$ for $x \in [q, d_u]$. From Corollary 2.5, we have

$$u(r(d_{pl}(q),q)) < u(r(d_{pl}(\tilde{q}),\tilde{q})), \tag{3.23}$$

$$u(r(d_{pu}(q),q)) > u(r(d_{pu}(\tilde{q}),\tilde{q})). \tag{3.24}$$

From Theorem 2.2(1), we have

$$\max_{q \in [\tilde{q}, d_{pu}^*]} u(r(x_2(q),q)) = u(r(x_2(\tilde{q}),\tilde{q})). \tag{3.25}$$

Likewise, we have

$$\max_{q \in [d_{pl}^*, \tilde{q}]} u(r(x_2(q),q)) = u(r(x_2(\tilde{q}),\tilde{q})). \tag{3.26}$$

From (3.17), (3.18), (3.25) and (3.26), we know $q_2^* = \arg\max_{q \in [d_l, d_u]} u(r(x_2(q),q)) = \tilde{q}$, which means that (3.15) and (3.16) hold. (3.22) means that the optimal passive demand, i.e. $x_2^*(q_2^*)$ are $d_{pl}(q_2^*)$ and $d_{pu}(q_2^*)$. □

Lemma 3.3 implies that the passive retailer chooses the optimal order quantity which makes its two focus points (selected demands) have the same normalized likelihoods and the same satisfaction levels.

Lemma 3.4. The optimal apprehensive order quantity q_3^* is the solution of

$$u(r(d_l, q)) = u(r(d_u, q)), \tag{3.27}$$

that is,

$$q_3^* = \frac{(R - S_o)d_l + S_u d_u}{R - S_o + S_u}. \tag{3.28}$$

The optimal apprehensive demand, i.e. $x_3^*(q_3^*)$ are d_l and d_u.

Proof: It follows from Lemma 2.6 that $\forall q \in [d_l, d_u]$ we have

$$u(r(x_3(q), q)) = \min(u(r(d_l, q)), u(r(d_u, q))), \tag{3.29}$$

which leads to

$$q_3^* = \arg\max_{q \in [d_l, d_u]} u(r(x_3(q), q)) = \arg\max_{q \in [d_l, d_u]} \min(u(r(d_l, q)), u(r(d_u, q))). \tag{3.30}$$

Suppose $\tilde{q}$ is the solution of $u(r(d_l, q)) = u(r(d_u, q))$, that is,

$$u(r(d_l, \tilde{q})) = u(r(d_u, \tilde{q})). \tag{3.31}$$

Proposition 3.1(2) shows if $q < \tilde{q}$ then $u(r(d_l, q)) > u(r(d_u, q))$ and if $q > \tilde{q}$ then $u(r(d_l, q)) < u(r(d_u, q))$ so that we have

$$\max_{q \in [d_l, d_u]} \min(u(r(d_l, q)), u(r(d_u, q)))$$

$$= \max_{q \in [d_l, \tilde{q}]} \min(u(r(d_l, q)), u(r(d_u, q))) \vee \max_{q \in [\tilde{q}, d_u]} \min(u(r(d_l, q)), u(r(d_u, q)))$$

$$= \max_{q \in [d_l, \tilde{q}]} u(r(d_u, q)) \vee \max_{q \in [\tilde{q}, d_u]} u(r(d_l, q)) = u(r(d_u, \tilde{q})) \vee u(r(d_l, \tilde{q})) . \tag{3.32}$$

Therefore, q_3^* is $\tilde{q}$, which is the solution of (3.27). (3.27) leads to (3.28) with considering (3.1). (2.23) implies that $x_3^*(q_3^*)$ are d_l and d_u. □

Lemma 3.4 shows that the apprehensive retailer takes into account two extreme demands (the highest and the lowest demand) and chooses the optimal order quantity which makes the satisfaction levels of the highest demand and the lowest demand equal.

Lemma 3.5. The optimal daring order quantity is

$$q_4^* = d_u . \tag{3.33}$$

The optimal daring demand, i.e. $x_4^*(q_4^*)$ is d_u.

Proof. The proof follows directly from Theorem 2.13(2) and Proposition 3.1(3). □

According to Lemma 3.5, for the daring retailer, the highest demand is his/her optimal order quantity and he/she believes all ordered products can be sold.

It is helpful to discuss the relationships amongst the four types of optimal order quantities and focus points and how the four types of optimal order quantities and focus points change with the parameters. We have the following lemmas.

Lemma 3.6.

(1) The optimal daring order quantity q_4^* is always larger than any other type of optimal order quantity.

(2) Supposing the normalized likelihood function $\pi_D(x)$ is symmetric, we have

$$d_{pl}(q_2^*) + d_{pu}(q_2^*) = d_l + d_u < 2x_1(q_1^*) < 2d_u , \tag{3.34}$$

$$q_1^* > q_2^* > q_3^* . \tag{3.35}$$

Proof.

(1) It is straightforward that q_4^* is always larger than any other type of optimal order quantity.

(2) From Lemma 3.3 and the monotonicity of $u(r(x,q))$, we have

$$r(d_{pl}(q_2^*), q_2^*) = r(d_{pu}(q_2^*), q_2^*) , \tag{3.36}$$

which is equal to

$$Rd_{pl}(q_2^*) + S_o(q_2^* - d_{pl}(q_2^*)) - Wq_2^* = (R-W)q_2^* - S_u(d_{pu}(q_2^*) - q_2^*) . \tag{3.37}$$

From (3.37), we obtain

$$q_2^* = \frac{(R-S_o)d_{pl}(q_2^*) + S_u d_{pu}(q_2^*)}{(R-S_o)+S_u} . \tag{3.38}$$

Hence,

$$q_1^* - q_2^* = d_{ou}^* - \frac{(R-S_o)d_{pl}(q_2^*) + S_u d_{pu}(q_2^*)}{(R-S_o)+S_u} = \frac{(R-S_o)(d_{ou}^* - d_{pl}(q_2^*)) - S_u(d_{pu}(q_2^*) - d_{ou}^*)}{(R-S_o)+S_u} , \tag{3.39}$$

where $q_1^* = d_{ou}^*$ is the solution of $u(r(x,x)) = \pi_D(x)$ within (d_c, d_u) (See Lemma 3.2).

From (3.16), we have

$$\pi(d_{pl}(q_2^*)) = \pi(d_{pu}(q_2^*)) . \tag{3.40}$$

If $\pi_D(x)$ is symmetric, (3.40) implies

$$d_{pl}(q_2^*) - d_l = d_u - d_{pu}(q_2^*) > 0 . \tag{3.41}$$

(3.41) is equal to

$$d_{pl}(q_2^*) + d_{pu}(q_2^*) = d_l + d_u = 2d_c < 2d_{ou}^* < 2d_u , \tag{3.42}$$

which proves (3.34). From (3.42), we have

$$d_{ou}^* - d_{pl}(q_2^*) > d_{pu}(q_2^*) - d_{ou}^* . \tag{3.43}$$

Obviously, $d_{ou}^* - d_{pl}(q_2^*) > 0$ holds. Recalling

$$R - S_o > S_u > 0, \tag{3.44}$$

from (3.39) we know

$$q_1^* - q_2^* > 0. \tag{3.45}$$

By using (3.38) and (3.28), we have

$$q_2^* - q_3^* = \frac{(R-S_o)d_{pl}(q_2^*) + S_u d_{pu}(q_2^*)}{(R-S_o)+S_u} - \frac{(R-S_o)d_l + S_u d_u}{(R-S_o)+S_u}$$

$$= \frac{(R-S_o)(d_{pl}(q_2^*) - d_l) - S_u(d_u - d_{pu}(q_2^*))}{(R-S_o)+S_u}. \tag{3.46}$$

By using (3.41) and (3.44), we know

$$q_2^* - q_3^* > 0. \tag{3.47}$$

(3.46) and (3.47) means (3.35). □

Lemma 3.7. Set the satisfaction function as the following linear function

$$u(r(x,q)) = \frac{r(x,q) - r_l}{r_u - r_l}. \tag{3.48}$$

The optimal active order q_1^* and the optimal active demand $x_1^*(q_1^*)$ are decreasing in the unit wholesale price W, increasing in the unit revenue R and the unit salvage price S_o. The unit opportunity cost S_u has no effect on them.

Proof. Since $r_u(W) = (R-W)d_u$ and $r_l(W) = d_l R + (d_u - d_l)S_o - d_u W$, by using (3.48) we have

$$u(r(W,x,q)) = \frac{r(W,x,q) - r_l(W)}{r_u(W) - r_l(W)} = \begin{cases} \dfrac{(x-d_l)R + (d_u - q)W - (d_u - d_l + x - q)S_o}{(d_u - d_l)(R - S_o)} & ;if\ x < q \\ \dfrac{(q-d_l)R + (d_u - q)W - (d_u - d_l)S_o - (x-q)S_u}{(d_u - d_l)(R - S_o)} & ;if\ x \ge q \end{cases}. \tag{3.49}$$

Therefore,

$$u(r(W,x,x)) = \frac{(x-d_l)R + (d_u - x)W - (d_u - d_l)S_o}{(d_u - d_l)(R - S_o)}. \tag{3.50}$$

Differentiating (3.50) with respect to W, we have

$$\frac{du(r(W,x,x))}{dW} = \frac{(d_u - x)}{(d_u - d_l)(R - S_o)} \geq 0, \tag{3.51}$$

which means $\forall W_1 \leq W_2 \quad u(r(W_1,x,x)) \leq u(r(W_2,x,x))$ holds so that we have

$$u(r(W_1, q_1^*(W_1), q_1^*(W_1))) \leq u(r(W_2, q_1^*(W_1), q_1^*(W_1))), \tag{3.52}$$

where $q_1^*(W_1)$ is the optimal active order quantity with the wholesale price W_1. According to Lemma 3.2, $\pi_D(q_1^*(W_1)) = u(r(W_1, q_1^*(W_1), q_1^*(W_1)))$ holds so that we have

$$\pi_D(q_1^*(W_1)) \leq u(r(W_2, q_1^*(W_1), q_1^*(W_1))). \tag{3.53}$$

Recalling $u(r(W_2, d_c, d_c)) < \pi_D(d_c) = 1$, due to the monotonicity of $\pi_D(x)$ and $u(r(W_2,x,x))$ within $[d_c, q_1^*(W_1)]$, there is a unique solution of $u(r(W_2,x,x)) = \pi_D(x)$ within $[d_c, q_1^*(W_1)]$, that is $q_1^*(W_2)$ and we have $q_1^*(W_1) \geq q_1^*(W_2)$. Therefore, the optimal active order q_1^* and the active focus point $x_1^*(q_1^*)$ are decreasing in W.

Similarly, we can prove the optimal active order q_1^* and the optimal active demand $x_1^*(q_1^*)$ are increasing in R and S_o. Since there is not S_u in (3.50), S_u has no effect on the optimal active order quantity and the optimal active demand. □

Lemma 3.7 is intuitively obvious if we know that an active retailer believes he/she can sell what he/her optimally orders (shown in Lemma 3.2).

Let us think about the optimal passive order q_2^*. If the unit opportunity cost price S_u increases, $u(r(x,q))$ will remain the same for $x < q$ but decrease for $x \geq q$. Considering Proposition 3.1(2) and Lemma 3.3, we have the following proposition.

Proposition 3.8. The optimal passive order quantity q_2^* increases in the unit opportunity cost S_u.

Proposition 3.8 shows that the passive retailer offsets the loss caused by the increase of the unit opportunity cost by increasing the order quantity.

For the optimal apprehensive order q_3^*, let us consider (3.28). Obviously, we have

$$\frac{dq_3^*}{dS_o} = \frac{(d_u - d_l)S_u}{(R + S_u - S_o)^2} > 0, \tag{3.54}$$

$$\frac{dq_3^*}{dS_u} = \frac{(d_u - d_l)(R - S_o)}{(R + S_u - S_o)^2} > 0, \tag{3.55}$$

$$\frac{dq_3^*}{dR} = -\frac{(d_u - d_l)S_u}{(R + S_u - S_o)^2} < 0, \tag{3.56}$$

$$\frac{dq_3^*}{dW} = 0, \tag{3.57}$$

which can be concluded as the following proposition.

Proposition 3.9. The optimal apprehensive order quantity q_3^* increases in the unit salvage price S_o and the unit opportunity cost S_u, decreases in the unit revenue R. The unit wholesale price W has no effect on q_3^*.

Proposition 3.9 points out that for an apprehensive retailer, he/she orders less at the higher unit revenue and the unit wholesale price has no effect on the optimal order quantity. Interestingly, other researchers (Wang and Webster, 2009; Wang et al., 2009) have arrived at similar results in "risk-averse" and "loss-averse" newsvendor models. However, such results were regarded as the limitations of the expected utility theory (EUT) by themselves. Our model can explain these results as follows:

As shown in Lemma 3.4, the apprehensive retailer worries about two extreme demands, i.e. the smallest demand d_l and the largest demand d_u and seeks an optimal order quantity to make the satisfaction levels of these two demands equal. (3.1) shows that for the same order quantity, the increase of the unit revenue will increase the satisfaction level of d_u more than d_l. To offset this effect, the retailer will decrease the order quantity.

For examining the result related to W, let us begin with the optimal apprehensive order quantity q_3^*. When the unit wholesale price becomes lower and the order quantity remains the same, the payoff at the demand d_u is exactly the same as the one at the demand d_l. On the other hand, from Proposition 3.1(2) we know that if the order quantity increases, the satisfaction level of the demand d_l will become worse; and if the order quantity decreases, the satisfaction level of the demand d_u will become worse. Therefore, the optimal apprehensive order quantity remains q_3^*.

Definition 3.1. $\pi''_D(x)$ is said to be more informed than $\pi'_D(x)$ if and only if $\forall x$ $\pi''_D(x) \le \pi'_D(x)$ holds.

Lemma 3.10. Suppose $\pi''_D(x)$ is more informed than $\pi'_D(x)$. The optimal active order quantities based on normalized likelihood functions $\pi'_D(x)$ and $\pi''_D(x)$ are denoted as q_o^{1*} and q_o^{2*}, respectively; the optimal passive order quantities based on normalized likelihood functions $\pi'_D(x)$ and $\pi''_D(x)$ are denoted as q_p^{1*} and q_p^{2*}, respectively; the optimal apprehensive order quantities based on normalized likelihood functions $\pi'_D(x)$ and $\pi''_D(x)$ are denoted as q_a^{1*} and q_a^{2*}, respectively; the optimal daring order quantities based on normalized likelihood functions $\pi'_D(x)$ and $\pi''_D(x)$ are denoted as q_d^{1*} and q_d^{2*}, respectively. We have

(1) $q_o^{1*} \ge q_o^{2*}$;

(2) $q_a^{1*} = q_a^{2*}$, $q_d^{1*} = q_d^{2*}$;

(3) if normalized likelihood functions $\pi'_D(x)$ and $\pi''_D(x)$ are symmetric, then $q_p^{1*} \le q_p^{2*}$.

Proof.

(1) The solution of $u(r(x,x)) = \pi'_D(x)$ within (d_c, d_u) is denoted as d_{ou}^{*1}. From Lemma 3.2 and Definition 3.1, we know $\pi'_D(d_{ou}^{*1}) = u(r(d_{ou}^{*1}, d_{ou}^{*1})) \ge \pi''_D(d_{ou}^{*1})$. Due to the monotonicity of $\pi''_D(x)$ and $u(r(x,x))$ and $u(r(d_c,d_c)) < \pi''_D(d_c) = 1$, there is a unique solution of $u(r(x,x)) = \pi''_D(x)$ within $(d_c, d_{ou}^{*1}]$, denoted as d_{ou}^{*2}. We have $d_{ou}^{*1} \ge d_{ou}^{*2}$, that is, $q_o^{1*} \ge q_o^{2*}$.

(2) It follows directly from Lemmas 3.4 and 3.5 that $q_a^{1*} = q_a^{2*}$ and $q_d^{1*} = q_d^{2*}$.

(3) The solutions of $u(r(x,q)) = 1 - \pi'_D(x)$ within $[d_l, \min(q, d_c)]$ and $[\max(q, d_c), d_u]$ are denoted as $d'_{pl}(q)$ and $d'_{pu}(q)$, respectively. The solutions of $u(r(x,q)) = 1 - \pi''_D(x)$ within $[d_l, \min(q, d_c)]$ and $[\max(q, d_c), d_u]$ are denoted as $d''_{pl}(q)$ and $d''_{pu}(q)$, respectively. Lemma 3.3 shows

$$u(r(d'_{pl}(q_p^{1*}), q_p^{1*})) = u(r(d'_{pu}(q_p^{1*}), q_p^{1*})), \tag{3.58}$$

$$u(r(d''_{pl}(q_p^{2*}), q_p^{2*})) = u(r(d''_{pu}(q_p^{2*}), q_p^{2*})). \tag{3.59}$$

Due to the symmetry of $\pi''_D(x)$, (3.59) implies

$$d_c - d''_{pl}(q_p^{2*}) = d''_{pu}(q_p^{2*}) - d_c. \tag{3.60}$$

From Lemma 3.3 and Definition 3.1, we know

$$u(r(q_p^{1*}, q_p^{1*})) > 1 - \pi'_D(q_p^{1*}), \tag{3.61}$$

$$u(r(q_p^{2*}, q_p^{2*})) > 1 - \pi''_D(q_p^{2*}) \geq 1 - \pi'_D(q_p^{2*}). \tag{3.62}$$

Suppose $q_p^{1*} > q_p^{2*}$. Considering Proposition 3.1(2), $u(r(x, q_p^{1*})) < u(r(x, q_p^{2*}))$ holds for any $x \in [l, q_p^{2*}]$. Considering (3.61) and using Corollary 2.5(1), we have

$$u(r(d'_{pl}(q_p^{1*}), q_p^{1*})) < u(r(d'_{pl}(q_p^{2*}), q_p^{2*})). \tag{3.63}$$

Likewise, $u(r(x, q_p^{1*})) > u(r(x, q_p^{2*}))$ holds for any $x \in [q_p^{1*}, h]$. Considering (3.62) and using Corollary 2.5(2), we have

$$u(r(d'_{pu}(q_p^{1*}), q_p^{1*})) > u(r(d'_{pu}(q_p^{2*}), q_p^{2*})). \tag{3.64}$$

(3.58), (3.63) and (3.64) imply

$$u(r(d'_{pl}(q_p^{2*}), q_p^{2*})) > u(r(d'_{pu}(q_p^{2*}), q_p^{2*})). \tag{3.65}$$

Due to the symmetry of $\pi'_D(x)$, (3.65) means

$$d_c - d'_{pl}(q_p^{2*}) > d'_{pu}(q_p^{2*}) - d_c. \tag{3.66}$$

(3.60) and (3.66) mean

$$d''_{pl}(q_p^{2*}) - d'_{pl}(q_p^{2*}) > d'_{pu}(q_p^{2*}) - d''_{pu}(q_p^{2*}). \tag{3.67}$$

Since $\pi''_D(x) \leq \pi'_D(x)$, considering Lemma 3.3 it is easy to know

$$d'_{pu}(q_p^{2*}) - d''_{pu}(q_p^{2*}) \geq 0. \tag{3.68}$$

From (3.1), we have

$$\begin{aligned} & r(d'_{pl}(q_p^{2*}), q_p^{2*}) \\ & = r(d''_{pl}(q_p^{2*}) + (d'_{pl}(q_p^{2*}) - d''_{pl}(q_p^{2*})), q_p^{2*}) \\ & = r(d''_{pl}(q_p^{2*}), q_p^{2*}) + (R - S_o)(d'_{pl}(q_p^{2*}) - d''_{pl}(q_p^{2*})). \end{aligned} \tag{3.69}$$

Similarly, we have

$$
\begin{aligned}
& r(d'_{pu}(q_p^{2*}), q_p^{2*}) \\
& = r(d''_{pu}(q_p^{2*}) + (d'_{pu}(q_p^{2*}) - d''_{pu}(q_p^{2*})), q_p^{2*}) \\
& = r(d''_{pu}(q_p^{2*}), q_p^{2*}) + S_u(d''_{pu}(q_p^{2*}) - d'_{pu}(q_p^{2*})) .
\end{aligned}
\tag{3.70}
$$

From (3.5), (3.59), (3.67)-(3.70) and $R > S_o + S_u$, we know $u(r(d'_{pl}(q_p^{2*}), q_p^{2*})) < u(r(d'_{pu}(q_p^{2*}), q_p^{2*}))$, which conflicts with (3.65). As a result, $q_p^{1*} \le q_p^{2*}$.

□

Lemma 3.10 shows that the increase of the uncertainty of the demand can make an active retailer order more and make a passive retailer order less but does not have any effect on the apprehensive and daring retailers.

3.4. Numerical Example

A fashion store, located in Yokohama, Japan, is planning to order a new design fashion sportswear. The unit wholesale price W, the unit revenue R, the unit salvage price S_o and the unit opportunity cost S_u are 7, 10, 1 and 4, respectively. Suppose the probability function of the demand is a triangular function $f_D(x)$, as shown below.

$$
f_D(x) = \begin{cases} 0, & x < 0 \\ 4\times10^{-2} x, & 0 \le x \le 50 \\ 4\times10^{-2}(100-x) & 50 \le x \le 100 \\ 0 & x > 100 \end{cases} .
\tag{3.71}
$$

In the classical newsvendor models, for the risk neutral retailer, the optimal order quantity q^* is set such that

$$F(q^*) = \frac{R - W + S_u}{R - S_o + S_u} = \frac{7}{13}. \tag{3.72}$$

From (3.72), we have the optimal order quantity $q^* = 54.8$. In the following we see the optimal order quantities for Newsvendor-OSDT. The corresponding normalized likelihood function of the demand $\pi_D(x)$ is

$$\pi_D(x) = \begin{cases} 0, & x < 0 \\ 0.02x, & 0 \le x \le 50 \\ 0.02(100 - x) & 50 \le x \le 100 \\ 0 & x > 100 \end{cases}. \tag{3.73}$$

The range of the possible demand is $[0,100]$, that is, $d_l = 0$ and $d_u = 100$. By using (3.1), the profit function is

$$r(x,q) = \begin{cases} 9x - 6q, & x < q \\ 7q - 4x, & x \ge q \end{cases}. \tag{3.74}$$

The highest profit is $r_u = (R - W)d_u = 300$ and the lowest profit is $r_l = d_l R + (d_u - d_l)S_o - d_u W = -600$. The satisfaction function is set as

$$\begin{aligned} u(r(x,q)) &= \frac{r(x,q) - r_l}{r_u - r_l} \\ &= \begin{cases} \frac{1}{100}x - \frac{2}{300}q + \frac{2}{3}, & x < q \\ \frac{7}{900}q - \frac{4}{900}x + \frac{2}{3}, & x \ge q \end{cases}, \end{aligned} \tag{3.75}$$

where $0 \le x, q \le 100$. For illustration of the decision process of Newsvendor-OSDT, we examine the active focus points and their corresponding satisfactions when order quantity $q = 0$, $q = 50$ and $q = 100$. As shown by Fig3.1, Fig 3.2 and Fig 3.3, the active focus points of order quantity $q = 0$, $q = 50$ and $q = 100$ are $x_1^*(0) = 27.3$, $x_1^*(50) = 50$ and $x_1^*(100) = 66.7$, respectively. Their corresponding satisfactions are 0.55, 0.83 and 0.67, respectively. Thus, amongst these three order quantities, $q = 50$ is the best.

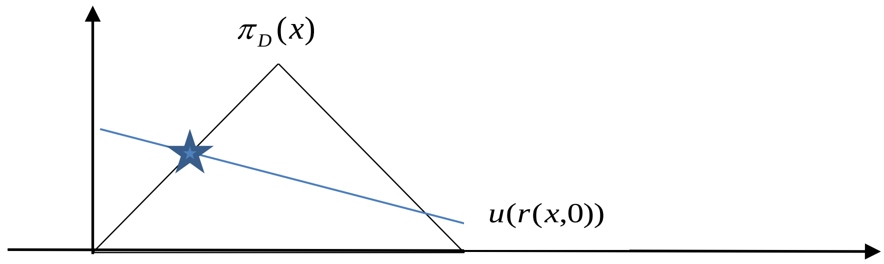

Fig.3.1 The focus point when $q = 0$.

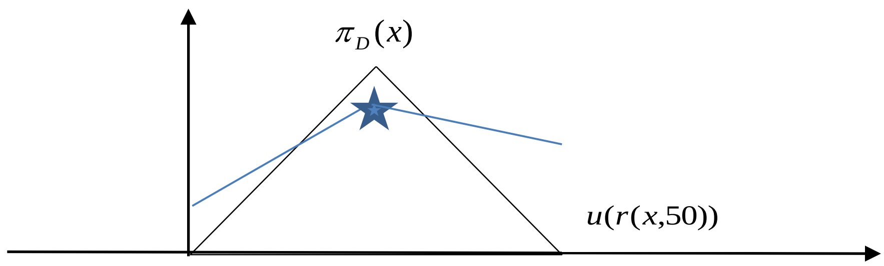

Fig.3.2 The focus point when $q = 50$.

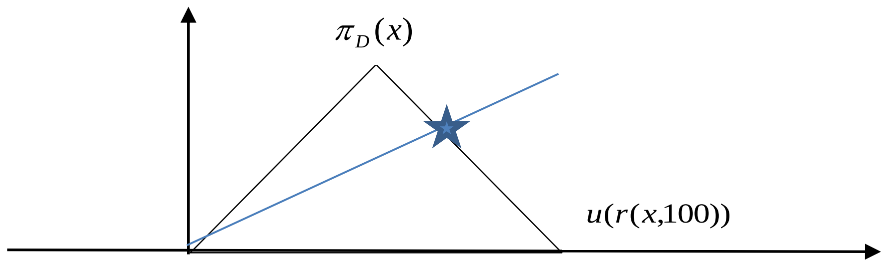

Fig.3.3 The focus point when $q = 100$.

By using (3.14), (3.15), (3.28) and (3.33), we obtain $q_1^* = 57.1$, $q_2^* = 38.3$, $q_3^* = 30.8$ and $q_4^* = 100$. Clearly, we have $q_3^* < q_2^* < q_1^* < q_4^*$ which shows that the order quantity of the apprehensive retailer is less than the one of the passive retailer; the order quantity of the passive retailer is less than the one of the active retailer; the order quantity of the active retailer is less than the one of the daring retailer. Such results are quite in agreement with the situations encountered in the real business world.

In the following we examine how the optimal order quantities change with the parameters. From (3.72), easily we have that the risk neutral optimal order quantity increases in unit revenue *R*, the unit salvage price S_o and the unit opportunity cost S_u; decreases in wholesale price *W*. In Lemma 3.5, Lemma 3.7 and Proposition 3.9, how the optimal active, apprehensive and daring order quantities change with the parameters is shown clearly. From Proposition 3.8, the optimal passive order quantity increases in the unit opportunity cost. In this numerical example, Fig. 3.4, Fig. 3.5 and Fig. 3.6 show how the optimal passive order quantity changes with the unit revenue, unit wholesale price and unit salvage price, respectively.

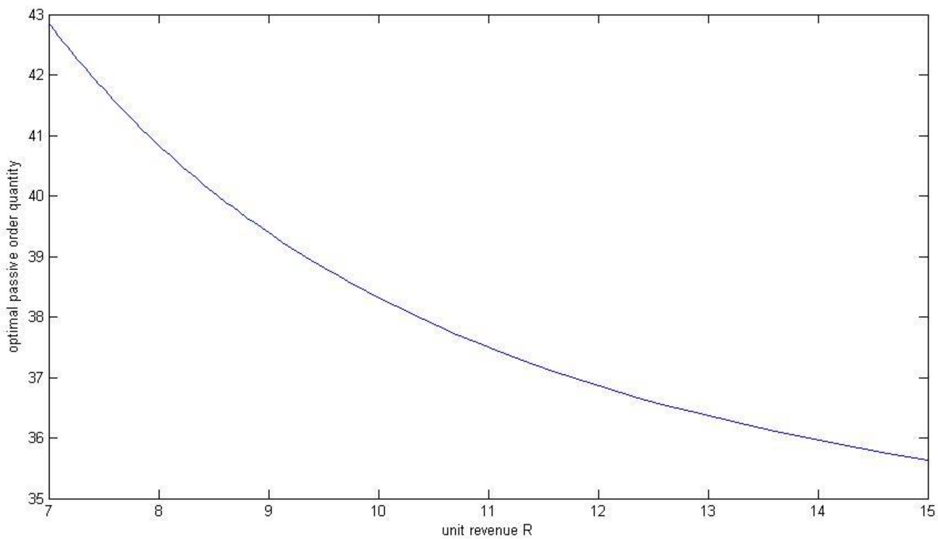

Fig. 3.4 Relationships between the unit revenue and the optimal passive order quantity

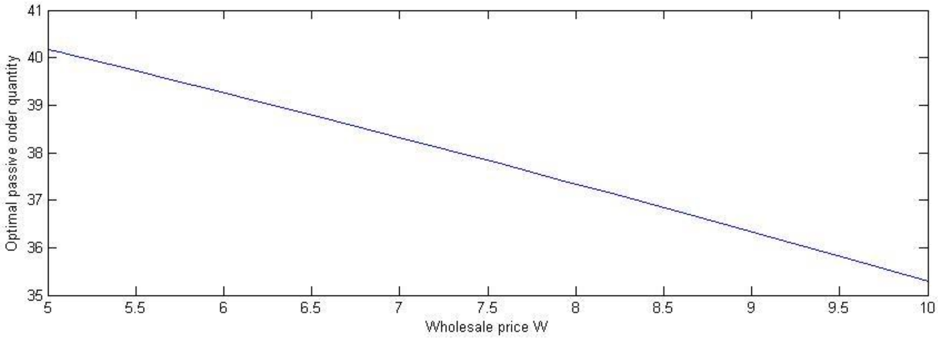

Fig. 3.5 Relationships between the wholesale price and the optimal passive order quantity

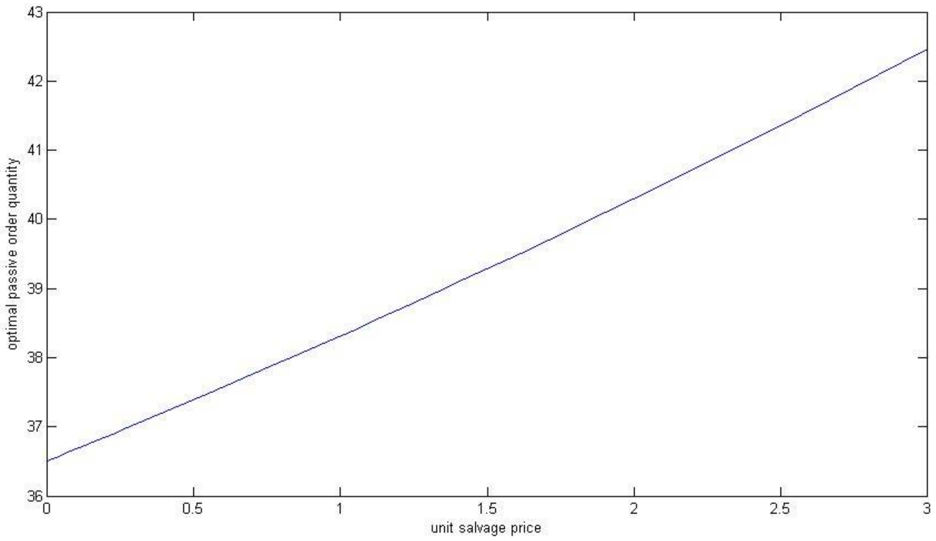

Fig. 3.6 Relationships between the unit salvage price and the optimal passive order quantity

3.5. Concluding Remarks

This research analyzes the newsvendor problems for innovative products. Following the same idea of Fisher (1997), the innovative products are featured by the unpredictable demand and short life cycles. Due to the shorter life cycle than the procurement lead-time, determining the order quantity is a typical one-shot decision problem. Instead of using the subjective expected utility theory (SEU), we utilize the one-shot decision theory (OSDT) to analyze the newsvendor problems. The proposed models are scenario-based decision models; they are fundamentally different from the newsvendor models with SEU which are lottery-based models.

Newsvendor models with four types of focus points are developed for four types of retailers; i.e., the active retailer, the passive retailer, the apprehensive retailer and the daring retailer. The active retailer takes into account a demand with a higher satisfaction and a higher likelihood; the passive retailer focuses on a demand with a lower satisfaction and a higher likelihood; the apprehensive retailer thinks over a demand with a lower satisfaction and a lower likelihood; the daring retailer considers a demand with a higher satisfaction and a lower likelihood. The optimal order quantities for these four types of retailers are obtained and we have the following conclusions:

(1) The focus point of the active retailer's optimal order quantity is the optimal order quantity itself. It means that the active retailer has confidence that he/she can sell all the products that he/she has optimally ordered.

(2) The passive retailer chooses the optimal order quantity which makes its two focus points have the same normalized likelihoods and the same satisfaction levels.

(3) The apprehensive retailer takes into account two extreme demands (the highest and the lowest demand) and chooses the optimal order quantity which makes the satisfaction levels of the highest demand and the lowest demand equal.

(4) For the daring retailer, the highest demand is his/her optimal order quantity and he/she believes all ordered products can be sold.

(5) The optimal daring order quantity is always larger than any other type of optimal order quantity. If the normalized likelihood function is symmetric, the optimal active order quantity is larger than the optimal passive one; the optimal passive order quantity is larger than the optimal apprehensive

one.

(6) Setting the satisfaction function as a linear function, the optimal active order quantity and its focus point are decreasing in the unit wholesale price, increasing in the unit revenue and the unit salvage price. The unit opportunity cost has no effect on them.

(7) The passive retailer offsets the loss caused by the increase of the unit opportunity cost by increasing the order quantity.

(8) The optimal apprehensive order quantity increases in the unit salvage price and the unit opportunity cost, decreases in the unit revenue. The unit wholesale price has no effect on it.

(9) The increase of the uncertainty of the demand can make an active retailer order more and make a passive retailer order less but does not have any effect on the apprehensive and daring retailers.

The above results provide managerial insights into the behaviors of different types of retailers.

Chapter 4

Price-Setting Newsvendor Models for Innovative Products

4.1 Introduction

The newsvendor models have been extensively reviewed (Cachon, 2003; Petruzzi and Dada, 1999; Petruzzi and Dada, 2010; Qin et al, 2011). In the classic newsvendor problem, the retail price is considered as an exogenous value. It is only for a perfect competitive market where the retailers are price-takers. There are many papers related to price-setting newsvendor models (Chen and Simchi-Levi, 2004; Raz and Porteus, 2006; Lau et al, 2007; Arcelus et al, 2007; Xu et al, 2011; Kocabiyikoglu and Popescu, 2011; Wang et al, 2012; Xu and Lu, 2013; Chen et al, 2014). Until now, almost all price-setting newsvendor models are built to maximize the subjective expected utilities or the probability measures of achieving target profits.

In this chapter, the price-setting newsvendor problem for the innovative product is considered. As introduced in Chapter 3, this dissertation highlights that for a retailer who sells an innovative product, how to determine the optimal order quantity can be regarded as a one-shot decision problem, which is typical for a situation where a decision is made only once under uncertainty. In a one-shot decision problem, there is one and only one chance for only one state of nature (scenario) occurring. Guo (2011) initially proposed the one-shot decision theory (OSDT) for dealing with such one-shot decision problems. The one-shot decision making problems have been researched in the papers (Guo, 2010a; Guo, 2010b; Guo et al, 2010; Guo, 2011; Guo, 2014; Guo and Li, 2014). Guo and Ma (2014) proposed a newsvendor model for innovative products based on the one-shot decision theory where the retailer was in a perfect competitive market so that the selling price was given. Ma and Guo (2013) and Ma (2014) examined the price-setting newsvendor models in the supply chain for innovative products.

This chapter takes into account the retailer who sells an innovative product in a monopoly market. In this case, the retailer has only one chance to decision the order quantity and the retail price with the uncertain demand. The one-shot decision theory (OSDT) based price-setting newsvendor models are proposed for this situation. In the proposed models, the procedure for determining the optimal order quantity and the optimal retail price is divided into three steps. In the first step, the retail price is fixed. For each order quantity, the retailer will contemplate one state (scenario) from all possible states with considering the satisfaction level when this state occurs and its occurrence likelihood. The selected state (scenario) is called the focus point of the order quantity. The retailers who take into account the state (scenario) with a higher satisfaction and a higher likelihood, a lower satisfaction and a higher likelihood, a higher satisfaction and a lower likelihood, a lower satisfaction and a lower likelihood are called active, passive, daring and apprehensive retailers, respectively. In the second step, the order quantity whose focus point corresponds to the highest satisfaction level is determined as the optimal order quantity for this fixed retail price. The profit which corresponds to the highest satisfaction level is used to evaluate this given retail price. In the third step, we determine the optimal retail price which leads to the highest profit. In this research, the optimal order quantities and retail prices for the four types of retailers are obtained and the theoretical analysis is made.

The contributions of this chapter are as follows: The existing price-setting newsvendor models are the subjective expected utility based or the probability measure based. They seek the optimal order quantity and the optimal retail price to maximize the expected utility or the probability measure of achieving a target profit. They take into account all demand values when determining the optimal order quantity and the optimal retail price. However, one and only one demand will occur when selling an innovative product due to its short life cycle. This chapter analyzes the price-setting newsvendor models with the one-shot decision theory (OSDT) which fit the one-time feature of the retailer's joint price/quantity decision. Different from the subjective expected utility based models in which the retailer's risk attitude is reflected by different utility functions, in OSDT based models the retailer chooses which type of focus point (scenario) for making a decision characterizes the attitude of this retailer about uncertainty. The theoretical analysis provides the managerial insights into the behaviors of different types of retailers. The proposed methods provide a fundamentally different vehicle for analyzing the newsvendor problems in a monopoly market of an innovative product.

The reminder of this chapter is organized as follows. In Section 4.2, price-setting newsvendor models for innovative products are proposed. In Section 4.3, the theoretical analysis results are given. In Section 4.4, a numerical example is used to demonstrate the proposed models. Some concluding remarks are provided in Section 4.5.

4.2 Price-Setting Newsvendor Models Based on One-Shot Decision Theory

As shown in Chapter 3, we built the Newsvendor-OSDT which is only for a perfect competitive market where the retailers are price-takers. However, it provided an alternative way to analyze newsvendor problems for innovative products. In the following we consider a retailer who sells an innovative product in the monopoly market. The retailer orders q units before the season at the unit wholesale price W. The following linear inverse demand function is considered:

$$x = b - aR, \tag{4.1}$$

where x>0 is the demand and R is the retail price. b>0 is the x-intercept of (4.1) representing the limit demand of the innovative product when the retail price approaches to zero. $a > 0$ is the slope of (4.1) showing the demand decreases when the retail price increases by one unit. We call a as the price sensitivity of the market demand. The uncertainty of the demand is represented by the parameter b with a normalized likelihood function $\pi(b)$. The profit function for the retailer is a function with the retail price and the order quantity as the decision variables. With considering (3.1), it can be expressed as:

$$r(R,b,q) = \begin{cases} (R-W)(b-aR) - (W-S_o)(q-b+aR); & b-aR < q \\ (R-W)q - S_u(b-aR-q); & b-aR \geq q \end{cases}. \tag{4.2}$$

Recall Definition 2.2, we have the the satisfaction function, i.e. $u(R,b,q)$. Four types of focus points which have been introduced in Chapter 2 and Chapter 3 are considered as follows.

Active focus point: For a fixed retail price R, the active focus point of the order quantity q, denoted as $b_1(R,q)$, is

$$b_1(R,q) \in \arg\max_b lower[\pi(b), u(R,b,q)]. \tag{4.3}$$

For a fixed retail price R, $b_1(R,q) - aR$ is the focused demand value that has a higher likelihood and a higher satisfaction level for an order quantity q.

Passive focus point: For a fixed retail price R, the passive focus point of the order quantity q, denoted as $b_2(R,q)$, is

$$b_2(R,q) \in \arg\min_b upper[1-\pi(b), u(R,b,q)]. \tag{4.4}$$

For a fixed retail price *R*, $b_2(R,q)-aR$ is the focused demand value that has a higher likelihood and a lower satisfaction level for an order quantity *q*.

Apprehensive focus point: For a fixed retail price *R*, the apprehensive focus point of the order quantity q, denoted as $b_3(R,q)$, is

$$b_3(R,q) \in \arg\min_b upper[\pi(b), u(R,b,q)]. \tag{4.5}$$

For a fixed retail price *R*, $b_3(R,q)-aR$ is the focused demand value that has a lower likelihood and a lower satisfaction level for an order quantity *q*.

Daring focus point: For a retail price *R*, the daring focus point of the order quantity q, denoted as $b_4(R,q)$, is

$$b_4(R,q) \in \arg\min_b upper[\pi(b), 1-u(R,b,q)]. \tag{4.6}$$

For a fixed retail price *R*, $b_4(R,q)-aR$ is the focused demand value that has a lower likelihood and a higher satisfaction level for an order quantity *q*.

For a fixed retail price *R*, we denote the sets of four types of focus points of the order quantity q as $B_1(R,q)$, $B_2(R,q)$, $B_3(R,q)$ and $B_4(R,q)$, respectively. The optimal order quantities for four types of the retailers are

$$q_1(R) \in \arg\max_q \max_{b_1^*(R,q)\in B_1(R,q)} u(R, b_1(R,q), q), \tag{4.7}$$

$$q_2(R) \in \arg\max_q \min_{b_2^*(R,q)\in B_2(R,q)} u(R, b_2(R,q), q), \tag{4.8}$$

$$q_3(R) \in \arg\max_q \min_{b_3^*(R,q)\in B_3(R,q)} u(R, b_3(R,q), q), \tag{4.9}$$

$$q_4(R) \in \arg\max_q \max_{b_4^*(R,q)\in B_4(R,q)} u(R, b_4(R,q), q). \tag{4.10}$$

From (4.3)-(4.10), we can see that for a fixed *R*, the profit functions of the active, passive, apprehensive and daring retailers are $r(R, b_1(R, q_1(R)), q_1(R))$, $r(R, b_2(R, q_2(R)), q_2(R))$, $r(R, b_3(R, q_3(R)), q_3(R))$ and $r(R, b_4(R, q_4(R)), q_4(R))$, respectively, which are called active, passive, apprehensive and daring profit functions, respectively. Because they are the functions of single variable *R*, for simplicity, we use $r_1(R)$, $r_2(R)$, $r_3(R)$ and $r_4(R)$ in the following. For each type of retailer, the optimal retail price is which to maximize his/her profit function.

$$R_1^* \in \arg\max_R r_1(R), \quad q_1^* \in q_1(R_2^*); \tag{4.11}$$

$$R_2^* \in \arg\max_R r_2(R), \quad q_2^* \in q_2(R_2^*); \tag{4.12}$$

$$R_3^* \in \arg\max_R r_3(R), \quad q_3^* \in q_3(R_3^*); \tag{4.13}$$

$$R_4^* \in \arg\max_R r_4(R), \quad q_4^* \in q_4(R_4^*). \tag{4.14}$$

R_1^*, R_2^*, R_3^* and R_4^* are called optimal active, passive, apprehensive and daring retail prices, respectively.

4.3. Analysis Results

In this section, we suppose the following assumption.

Assumption: The normalized likelihood function $f(b)$ is a unimodal function defined on the interval $[b_l, b_u]$, the mode is $b_c \in (b_l, b_u)$, $f(b_l) = 0$ and $f(b_u) = 0$.

From (4.1), we know $b_l - aR$ and $b_u - aR$ are the lower and upper bounds of the demand respectively; $b_c - aR$ is the most possible amount of demand. Because the demand is inside the interval $[b_l - aR, b_u - aR]$, a reasonable supply also should lie in this region. The highest profit of retailer is

$$r_u(R) = (R - W)(b_u - aR), \tag{4.15}$$

that is, the retailer orders the most $q = b_u - aR$ and the demand is the largest $b_u - aR$. The lowest profit is determined by the minimum of two cases, one is that the retailer orders the most but the demand is the lowest: $(b_l - aR)R + (b_u - b_l)S_o - (b_u - aR)W$; the other is that the retailer orders the lowest but the demand is the highest: $(b_l - aR)(R - W) - (b_u - b_l)S_u$. For the sake of simplification, the assumption $W \geq S_o + S_u$ is made, which leads to

$$r_l(R) = (b_l - aR)R + (b_u - b_l)S_o - (b_u - aR)W. \tag{4.16}$$

For a fixed retail price *R*, the satisfaction level of a retailer is the following continuous strictly increasing function of the profit r,

$$u : [r_l(R), r_u(R)] \to [0,1], \tag{4.17}$$

where $u(r_l(R)) = 0$, $u(r_u(R)) = 1$.

(4.17) gives a general form of a satisfaction function of a retailer where the satisfaction level of the lowest profit is 0 and the satisfaction level of the highest profit is 1.

We have the following lemmas and propositions. Lemma 4.1-4.4 are similar to Lemma 3.2-3.5.

Lemma 4.1. For a fixed retail price *R*, the optimal active focus point $b_1(R, q_1(R))$ is the solution of the following equation:

$$u(R,b,b-aR)=\pi(b), \quad b\in[b_c,b_u]. \tag{4.18}$$

Its corresponding focused demand value is $b_1(R,q_1(R))-aR$, the optimal active order quantity is $q_1(R)=b_1(R,q_1(R))-aR$ and the active profit function is

$$r_1(R)=(R-W)q_1(R). \tag{4.19}$$

The Lemma 4.1 indicates that the focused demand value of the active retailer's optimal order quantity is the optimal order quantity itself. It means that the active retailer has confidence that he/she can sell all the products that he/she has optimally ordered.

Lemma 4.2. The optimal passive order quantity $q_2(R)$ is the solution of the following equation:

$$u(b_{pl}(q),q)=u(b_{pu}(q),q), \tag{4.20}$$

where $b_{pl}(R,q)$ and $b_{pu}(R,q)$ are the solutions of $u(R,b,q)=1-\pi(b)$ within $[b_l,\min(q+aR,b_c)]$ and $[\max(q+aR,b_c),b_u]$, respectively. The optimal passive focus points, i.e. $b_2(R,q_2(R))$ are $b_{pl}(R,q_2(R))$ and $b_{pu}(R,q_2(R))$. Their corresponding focused demand values are $b_{pl}(R,q_2(R))-aR$ and $b_{pu}(R,q_2(R))-aR$, respectively. The passive profit function is

$$r_2(R)=(R-S_o)(b_{pl}(R,q_2(R))-aR)-(W-S_o)q_2(R). \tag{4.21}$$

Lemma 4.2 implies that the passive retailer chooses the optimal order quantity which makes its two focus points have the same relative satisfaction level.

Lemma 4.3. The optimal apprehensive order quantity $q_3(R)$ is the solution of

$$u(R,b_l,q) = u(R,b_u,q)\,, \tag{4.22}$$

that is,

$$q_3(R) = \frac{(R-S_o)(b_l-aR)+S_u(b_u-aR)}{R-S_o+S_u}\,. \tag{4.23}$$

The optimal apprehensive focus points, i.e. $b_3(R,q_3(R))$ are b_l and b_u. Their corresponding focused demand values are $b_l - aR$ and $b_u - aR$, respectively. The apprehensive profit function is

$$r_3(R) = (R-S_o)(b_l-aR)-(W-S_o)q_3(R)\,. \tag{4.24}$$

Lemma 4.3 shows that the apprehensive retailer always takes into account two extreme values of the parameter *b* (the higher and lower bounds of *b*) and chooses the optimal order quantity which makes the satisfaction levels of the higher and lower bounds of *b* equal.

Lemma 4.4. The optimal daring order quantity is

$$q_4(R) = b_u - aR\,. \tag{4.25}$$

The optimal daring focus point, i.e. $b_4(R,q_4(R))$ is b_u. Its corresponding focused demand value is $b_u - aR$. The daring profit function is

$$r_4(R) = (R-W)(b_u-aR)\,. \tag{4.26}$$

According to Lemma 4.4, the daring retailer always thinks the higher bound of the parameter *b*. The corresponding focused demand value (the highest possible demand) is his/her optimal order quantity and he/she believes all ordered products can be sold.

The following proposition indicates the relationships amongst the four types of retailers' focused profits.

Proposition 4.5. For any $R > W$, we have the following relationships amongst the four types of retailers' focused profits.

$$r_4(R) > r_1(R) > r_2(R) > r_3(R). \tag{4.27}$$

Proof.

First, we prove $r_4(R) > r_1(R)$. From Lemma 4.1 and 4.4, we have $r_1(R) = (R-W)q_1(R)$, $r_4(R) = (R-W)(b_u - aR)$ and $q_1(R) < b_u - aR$ so that we know $r_4(R) > r_1(R)$. Then, we prove $r_1(R) > r_2(R)$. From Lemma 4.2, we have

$$r_2(R) < (R-W)(b_{pl}(R, q_2(R)) - aR) \le (R-W)q_1(R) = r_1(R). \tag{4.28}$$

Finally, we prove $r_2(R) > r_3(R)$. From (4.21) and (4.24), we know

$$r_2(R) - r_3(R) = (R - S_o)(b_{pl}(R, q_2(R)) - b_l) - (W - S_o)(q_2(R) - q_3(R)). \tag{4.29}$$

Considering $R - S_o > W - S_o > S_u > 0$ and $b_{pl}(R, q_2(R)) - b_l > q_2(R) - q_3(R) > 0$, we have $r_2(R) - r_3(R) > 0$. □

Since the demand is not less than zero, it is reasonable that $R \in [W, \frac{b_l}{a}]$ and $b_l > aW$. Suppose $u(R,b,q) = \dfrac{r(R,b,q) - r_l(R)}{r_u(R) - r_l(R)}$, we analyze the concavity of the active profit function and the solution of the optimal active retail price, as shown below.

Proposition 4.6. If $\forall b \in (b_c, b_u)$, $\pi(b)$ and $u(R,b,b-aR)$ are of class C^1, and

$\pi'(b)-\dfrac{\partial u(R,b,b-aR)}{\partial b}\neq 0$ and $a>\dfrac{b_u-b_c}{(b_u-b_l)(S_o-W)\pi'(b)}$ hold, then the active profit function $r_1(R)$ is concave. Furthermore, if $b_l-aW>b_u-b_l$, then the unique solution of $r_1'(R)=0$ lies on the interval $R\in(W,\dfrac{b_l}{a})$, which is the optimal active retail price R_1^*.

Proof.

First, we prove the concavity of $r_1(R)$. Using Lemma 1 and the implicit function theorem, we know $b_1(R,q_1(R))$ is a continuously differentiable function of *R*, and

$$b_1''(R,q_1(R))=\frac{\frac{\partial^2 u(R,b,b-aR)}{\partial R^2}(\pi'(b)-\frac{\partial u(R,b,b-aR)}{\partial b})+\frac{\partial^2 u(R,b,b-aR)}{\partial b\partial R}\cdot\frac{\partial u(R,b,b-aR)}{\partial R}}{(\pi'(b)-\frac{\partial u(R,b,b-aR)}{\partial b})^2}. \quad (4.30)$$

Since $b_c\le b\le b_u$, with considering (4.18), we have $\pi'(b)<0$, $\dfrac{\partial u(R,b,b-aR)}{\partial b}>0$, $\dfrac{\partial u(R,b,b-aR)}{\partial R}<0$, $\dfrac{\partial^2 u(R,b,b-aR)}{\partial R^2}>0$, $\dfrac{\partial^2 u(R,b,b-aR)}{\partial b\partial R}>0$, that is $b_1''(R,q_1(R))<0$. Meanwhile,

$$b_1'(R,q_1(R))=\frac{(b_u-b)(W-S_o)}{(R-S_o)(R-W-(b_u-b_l)(R-S_o)\pi'(b))}<a. \quad (4.31)$$

Considering Lemma 4.1, we have

$$\frac{d^2 r_1(R)}{dR^2}=2q_1'(R)+(R-W)q_1''(R)=2(b_1'(R)-a)+(R-W)b_1''(R)<0. \quad (4.32)$$

(4.32) implies the active profit function $r_1(R)$ is concave.

Next we prove if $b_l-aW>b_u-b_l$, then the mode of $r_1(R)$ lies on the interval $R\in(W,\dfrac{b_l}{a})$.

The first derivative of the active profit function is

$$r_1'(R)=q_1(R)+(R-W)q_1'(R)=q_1(R)+(R-W)(b_1'(R,q_1(R))-a). \quad (4.33)$$

Easily we know $r_1'(W)=q_1(W)>0$. Considering $b_l-aW>b_u-b_l$ and $b_1'(R,q_1(R))\Big|_{R=\frac{b_l}{a}}<a$, we have $r_1'(R)\Big|_{R=\frac{b_l}{a}}<0$.

Since $r_1(R)$ is concave, $r_1'(R)\big|_{R=W} > 0$ and $r_1'(R)\Big|_{R=\frac{b_l}{a}} < 0$, the unique solution of $r_1'(R) = 0$ lies on the interval $R \in (W, \frac{b_l}{a})$. □

Proposition 4.6 shows that the concavity of the active profit function is related to the price sensitivity of the market demand. Propositions 4.7, 4.8 and 4.9 examine the concavities of passive, apprehensive and daring profit functions, respectively; and provide the solutions of optimal passive, apprehensive and daring retail prices. Proofs of Proposition 4.7, 4.8 and 4.9 are similar to Proof of Proposition 4.6.

Proposition 4.7. If $\pi(b)$ is of class C^1 for $b \in (b_l, b_c)$ and $b \in (b_c, b_u)$ and $u(R,b,q)$ is of class C^1 for $q \in (b_l - aR, b_u - aR)$, $b \in (b_l, b_c)$ and $b \in (b_c, b_u)$ and $q_2''(R) > \dfrac{2(b_{pl}'(R, q_2(R)) - a) + (R - S_o)b_{pl}''(R, q_2(R))}{W - S_o}$ holds, then the passive profit function $r_2(R)$ is concave. Furthermore, if for any $R \in [W, \frac{b_l}{a}]$, $q_2'(R) > \dfrac{R - S_o}{W - S_o} \cdot b_{pl}'(R, q_2(R)) + \dfrac{b_{pl}(R, q_2(R))}{W - S_o}$ holds, then the optimal passive retail price is $R_2^* = \dfrac{b_l}{a}$; if $q_2'(R)\big|_{R=W} < \dfrac{b_{pl}(W, q_2(W)) - aW}{W - S_o} + b_{pl}'(R, q_2(R))\big|_{R=W} - a$ and

$$q_2'(R)\Big|_{R=\frac{b_l}{a}} > \frac{b_{pl}(\frac{b_l}{a}, q_2(\frac{b_l}{a})) + (\frac{b_l}{a} - S_o)b_{pl}'(R, q_2(R))\Big|_{R=\frac{b_l}{a}} - 2b_l - aS_o}{W - S_o}$$

hold, then the unique solution of $r_2'(R) = 0$ lies on the interval $R \in (W, \frac{b_l}{a})$, which is the optimal passive retail price R_2^*.

Proposition 4.7 points out that the concavity of the passive profit function depends on the relationship between the changes in retail price R of the optimal passive order quantity and of its corresponding focused demand value.

Proposition 4.8. The apprehensive profit function $r_3(R)$ is concave. Furthermore, if $b_l - aW > b_u - b_l$, then the optimal apprehensive retail price is the unique solution of $r_3'(R) = 0$ within $R \in (W, \frac{b_l}{a})$.

Proposition 4.9. The daring profit function $r_4(R)$ is concave. If $b_l - aW > b_u - b_l$, then the optimal daring retail price is $R_4^* = \frac{b_u + aW}{2a}$, and lies on the interval $R \in (W, \frac{b_l}{a})$; otherwise, $R_4^* = \frac{b_l}{a}$.

Propositions 4.8 and 4.9 show that the apprehensive and daring profit functions are always concave. Suppose the four types of retailers have concave focused profit functions, we have Proposition 4.10 and 4.11 as follows.

Proposition 4.10. We have the following relationships amongst the four types of retailers' optimal retail prices.

$$R_4^* > R_1^* > R_2^* > R_3^* . \tag{4.34}$$

Proof.

First we prove $R_4^* > R_1^*$. From Lemma 4.1 and Proposition 4.6, we know the optimal active retail price R_1^* is the solution of $r_1'(R) = q_1(R) + (R - W)q_1'(R) = 0$, that is $R_1^* = W - \frac{q_1(R)}{q_1'(R)}$.

From Lemma 4.1 and Proposition 4.5, we have $b_c - aR \le q_1(R) \le b_u - aR$ and $-a < q_1'(R) < -\frac{1}{2}a$, which lead to $R_1^* < \frac{b_u}{a} - R_1^* + W$. That is, $R_1^* < \frac{b_u + aW}{2a} = R_4^*$. Next we prove $R_1^* > R_2^*$. From Lemma 4.1 and Lemma 4.2, we have $r_1'(R) - r_2'(R) > b_l(R) - b_{pl}(R, q_2(R)) > 0$. With considering the concavities of $r_1(R)$ and $r_2(R)$, we have $R_1^* > R_2^*$. Similarly, we can prove $R_2^* > R_3^*$. □

Proposition 4.11. The optimal active, passive, apprehensive and daring retail prices are decreasing in a.

Proof.

It is trivial to prove that the optimal daring retail price $R_4^* = \frac{b_u + aW}{2a}$ is decreasing in a. In the following, we show the optimal active retail price is decreasing in a. For $a_1 < a_2$, from Lemma 4.1, we know $q_1(a_1, R) - q_1(a_2, R) = (a_2 - a_1)R$ and $q_1'(a_1, R) - q_1'(a_2, R) = a_1 - a_2$, which lead to

$$\begin{aligned}
&r_1'(a_1, R) - r_1'(a_2, R) \\
&= q_1(a_1, R) - q_1(a_2, R) + (R - W)(q_1'(a_1, R) - q_1'(a_2, R)). \\
&= W(a_2 - a_1) > 0.
\end{aligned} \tag{4.35}$$

With considering the concavity of $r_1(R)$, we know the optimal active price R_1^* is decreasing in a. Similarly, we can prove the optimal passive and apprehensive retail price is decreasing in the parameter a. □

Proposition 4.11 shows that the increase of the price sensitivity of the market demand can make four types of retailers charge lower retail prices.

4.4 Numerical Example

A fashion store, located in Yokohama, Japan, is planning to order a new design fashion clothes from France. The fashion store is monopoly in the east Japan market. The unit wholesale price *W*, the unit salvage price S_o and the unit opportunity cost S_u are 7000, 1000 and 4000 (JPY), respectively. The market demand depends on the retail price and $b_u = 1500$, $b_l = 1000$. Let us consider the retailer's pricing policies when $a = 0.02$, $a = 0.05$ and $a = 0.10$. As an example, let us see the details when $a = 0.05$.

Suppose the normalized likelihood function of the parameter *b* is $\pi(b) = 0.004 - \left|\frac{b-1250}{62500}\right|$. By using (4.2), the profit function is

$$r(R,b,q) = \begin{cases} (R-7000)(b-0.05R) - 6000(q-b+0.05R); & b-0.05R < q \\ (R-7000)q - 4000(b-0.05R-q); & b-0.05R \geq q \end{cases}. \tag{4.36}$$

We obtain $R_1^* = 16767$, $R_2^* = 14328$, $R_3^* = 13919$ and $R_4^* = 18500$; $r_1^* = 4598000$, $r_2^* = 2792900$, $r_3^* = 1394500$ and $r_4^* = 6612500$. Similarly, we can obtain that when $a = 0.02$, $R_1^* = 36804$, $R_2^* = 29384$, $R_3^* = 28797$, $R_4^* = 41000$, $r_1^* = 17507000$, $r_2^* = 10766000$, $r_3^* = 8865800$ and $r_4^* = 23120000$; when $a = 0.10$, $R_1^* = 10000$, $R_2^* = 9033$, $R_3^* = 8922$, $R_4^* = 10000$, $r_1^* = 857140$, $r_2^* = 400110$, $r_3^* = -799350$ and $r_4^* = 1500000$. The relationships between retail prices and profits when $a = 0.02$, $a = 0.05$ and $a = 0.10$ are shown in Fig. 4.1, Fig. 4.2 and Fig. 4.3, respectively.

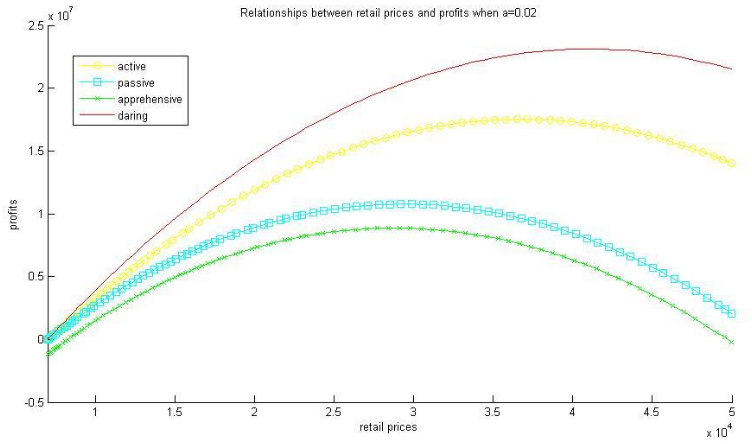

Fig.4.1. Relationships between retail prices and profits when $a = 0.02$

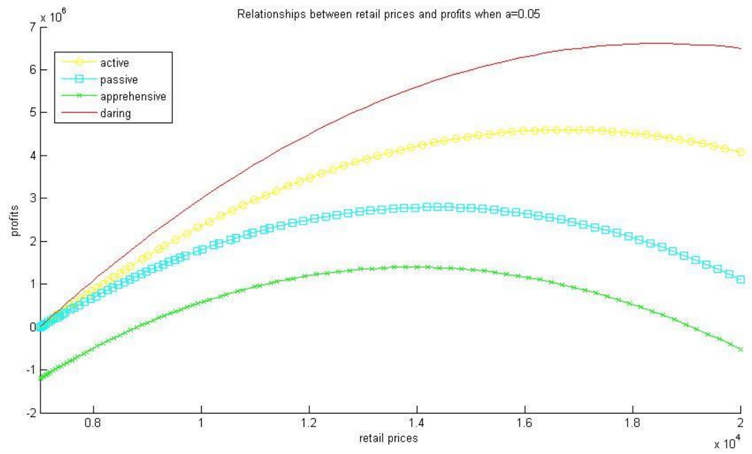

Fig.4.2. Relationships between retail prices and profits when $a = 0.05$

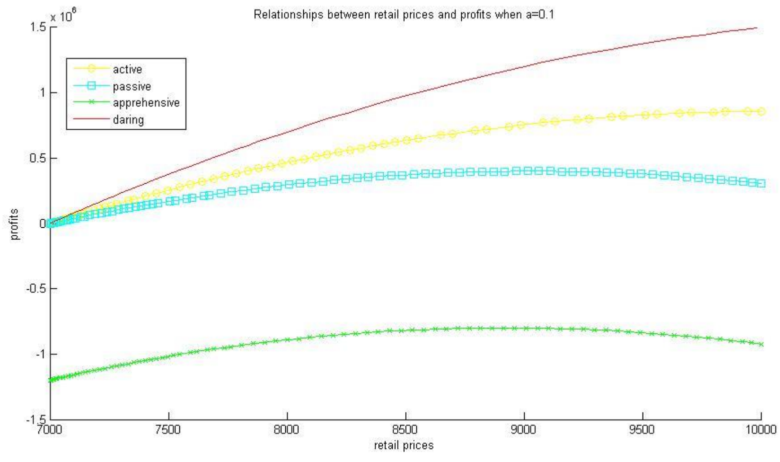

Fig.4.3. Relationships between retail prices and profits when $a = 0.10$

The numerical example shows three interesting phenomena. First, the numerical example indicates that for any $R > W$, $r_4(R) > r_1(R) > r_2(R) > r_3(R)$. That is the focused profits of the daring retailer are higher than the ones of active retailer; the focused profits of the active retailer are higher than the ones of passive retailer; the focused profits of the passive retailer are higher than the ones of apprehensive retailer. Second, we have $R_4^* > R_1^* > R_2^* > R_3^*$ which shows that the optimal retail prices of the daring retailer is higher than the ones of active retailer; the optimal retail prices of the active retailer is higher than the ones of passive retailer; the optimal retail prices of the passive retailer is higher than the ones of apprehensive retailer. Third, we observe that with the increase of the price sensitivity of market demand (the increase of parameter a), all of the four types of retailers charge the lower retail prices. Such phenomena are quite in agreement with the situations encountered in the real business world.

4.5 Concluding Remarks

This chapter examines the price-setting newsvendor problems for the innovative product. As mentioned by Fisher (1997), the innovative products are featured by the unpredictable demand and short life cycles. Considering the one-time feature of the retailer's decision making problem for ordering the innovative product, the price-setting newsvendor model with the one-shot decision theory is proposed. Different from the price-setting newsvendor model with the subjective expected utility theory where the optimal order quantity and the optimal retail price are obtained based on the weighted average of the utilities of all payoffs, the price-setting newsvendor model with the one-shot decision theory determines the optimal order quantity and the optimal retail price only based on the satisfaction level of its focus point (one selected demand). Hence, the proposed model is scenario-based which is fundamentally different from the existing models which are probability distribution based (lottery-based).

Four types of retailers are considered. They are the active retailer who considers the focus point with a higher satisfaction and a higher likelihood; the passive retailer who thinks the focus point with a lower satisfaction and a higher likelihood; the apprehensive retailer who identifies the focus point with a lower satisfaction and a lower likelihood and the daring retailer who takes into account the focus point with a higher satisfaction and a lower likelihood. Suppose the four types of retailers have concave profit functions, there are following conclusions:

For any retail price larger than unit wholesale price, the daring retailer will imagine the higher profit than the active retailer; the active retailer will imagine the higher one than the passive retailer; the passive retailer will imagine the higher one than the apprehensive retailer.

The optimal daring retail price is higher than the optimal active one; the optimal active retail price is higher than the optimal passive one; the optimal passive retail price is higher than the optimal apprehensive one.

With the increase of the price sensitivity of the market demand, every type of the retailer charges a lower retail price.

The above results provide managerial insights into the behaviors of different types of retailers in the monopoly market of the innovative product.

Chapter 5

Wholesale Price Contract in the Supply Chain for Innovative Products

5.1 Introduction

As a fundamental research of the supply chain management, a single manufacturer selling a product to a retailer who faces a newsvendor problem has been extensively researched. Due to its simplicity, the wholesale price contract is wildly used in practice and it has been studied in various aspects (Cachon, 2003). However, most of models for the wholesale price contract have been developed within the expected utility (EU) framework which is not characterize the one-time feature of innovative products (Lariviere and Porteus, 2001; Sarmah et al., 2006; Pasternack, 2008). Furthermore, the value of information sharing in the supply chain has attracted much attention from both practitioners and researchers in the past decades. But most of the works are focusing on the value of demand information sharing (Cachon and Fisher, 2000; Lee et al., 1997a; Lee et al., 1997b; Lee et al., 2000; Zhou and Benton Jr, 2007). Until now, the information sharing of participants' personalities in the supply chain is still on 'virgin territory'.

This chapter is focusing on the two-echelon supply chain for the innovative product. The supply chain consists a single manufacturer and a single retailer. The manufacturer produces a kind of innovative product and sells it to the retailer. With conjecturing the retailer's order quantity, the manufacturer charges a wholesale price of the product. After observing the wholesale price, the retailer who is facing uncertain demand need to decide his/her order quantity. It is a typical Stackelberg game in the supply chain where the manufacturer acts as a Stackelberg leader and the retailer acts as follower. Due to the one-time feature of innovative products, how to determine the optimal order amount can be regarded as a one-shot decision problem for the retailer, which are typical for situations where a decision is made only once under uncertainty. Ma et al. (2013), Ma and Guo (2013) and Ma (2014) studied the supply chain of innovative products.

In the proposed models of this charpter, after observing the wholesale price, for each order quantity, the retailer chooses one demand amongst all possible demands while considering the satisfaction level caused by the occurrence of the demand and the likelihood of the demand occurring. The selected demand is called the focus point of the order quantity. The optimal order quantity corresponds to the maximum satisfaction level of its focus point. The different retailers who focus on different demands are regarded as retailers with different personalities. The optimal wholesale price contracts for the manufacturer when he/she is facing different types of retailers are obtained and some further theoretical analysis is made.

The key contributions to the literature are as follows. This chapter presents a first formal analysis of the information sharing of the participants' personalities in the supply chain. The analysis shows the differences of the wholesale price contracts for the retailers with different personalities and the importance of personality information sharing both in the make-to-order and make-to-stock supply chain. This chapter also provides the managerial insights into the different behaviors of the supply chain participants for innovative products.

The reminder of this chapter is organized as follows. In Section 5.2, the Stackelberg game in the supply chain of innovative products is introduced. In Section 5.3, the analysis results are obtained. Some summary of concluding remarks are provided in section 5.4.

5.2 The Stackelberg Game in the Supply Chain of Innovative Products

A manufacturer produces a kind of innovative product and sells it to a retailer. For simplicity, the manufacturer's production cost is assumed to be zero. The retailer faces a newsvendor problem as described in the Chapter 3. The manufacturer acts as a Stackelberg leader, offering the wholesale price *W*. With conjecturing the retailer's order quantity *q*, the manufacturer charges an optimal wholesale price, which maximize his/her profit, that is

$$f(W,q) = Wq, \tag{5.1}$$

After observing *W*, the retailer places an optimal order quantity, which maximizes his/her own satisfaction level, and then the market demand is realized. The market demand is characterized by a normalized likelihood function $\pi(x)$ as defined by Definition 2.1.

5.2.1 The lower level problem: the retailer's model

For the retailer, the wholesale price *W* is provided by the manufacturer. Following (3.1), the profit function of the retailer is

$$r(W,x,q) = \begin{cases} Rx + (q-x)S_o - Wq; & x < q \\ (R-W)q - S_u(x-q); & x \geq q \end{cases}. \tag{5.2}$$

The satisfaction function of retailer, as defined by Definition 2.2, can be written as $u(W,x,q)$. We consider four types of retailers introduced in previous chapters.

Active retailer

Based on the above analysis, the active retailer takes into account a demand with a higher satisfaction and a higher likelihood. His/her decision-making procedure within the one-shot decision framework is described as follows:

Step 1: After observing the wholesale price W, determine the active focus point $x_1(W,q)$ for each order quantity q:

$$x_1(W,q) \in \arg\max_x lower[\pi(x), u(r(W,x,q))]. \tag{5.3}$$

Step 2: obtain the optimal active order quantity $q_1(W)$ for the fixed wholesale price *W*:

$$q_1(W) \in \arg\max_q \max_{x_1(W,q) \in X_1(W,q)} u(r(W, x_1(W,q), q)), \tag{5.4}$$

where $X_1(W,q)$ is the set of active focus points $x_1(W,q)$.

Passive retailer

If the retailer is of passive type, he/she focuses on a demand with a lower satisfaction and a higher likelihood. His/her decision-making procedure within the one-shot decision framework is described as follows:

Step 1: After observing the wholesale price W, determine the passive focus point $x_2(W,q)$ for each order quantity q:

$$x_2(W,q) \in \arg\min_x upper[1-\pi(x), u(r(W,x,q))]. \tag{5.5}$$

Step 2: obtain the optimal passive order quantity $q_2(W)$ for the fixed wholesale price *W*:

$$q_2(W) \in \arg\max_q \max_{x_2(W,q) \in X_2(W,q)} u(r(W, x_2(W,q), q)), \tag{5.6}$$

where $X_2(W,q)$ is the set of passive focus points $x_2(W,q)$.

Apprehensive retailer

The apprehensive retailer thinks over a demand with a lower satisfaction and a lower likelihood and he/she makes an order decision as follows:

Step 1: After observing the wholesale price W, determine the apprehensive focus point $x_3(W,q)$ for each order quantity q:

$$x_3(W,q) \in \arg\min_x upper[\pi(x), u(r(W,x,q))]. \tag{5.7}$$

Step 2: obtain the optimal apprehensive order quantity $q_1(W)$ for the fixed wholesale price *W*:

$$q_3(W) \in \arg\max_q \max_{x_3(W,q)\in X_3(W,q)} u(r(W, x_3(W,q), q)), \tag{5.8}$$

where $X_3(W,q)$ is the set of apprehensive focus points $x_3(W,q)$.

Daring retailer

The daring retailer's considers a demand with a higher satisfaction and a lower likelihood and his/her decision-making procedure is as follows:

Step 1: After observing the wholesale price W, determine the daring focus point $x_4(W,q)$ for each order quantity q:

$$x_4(W,q) \in \arg\min_x upper[\pi(x), 1-u(r(W,x,q))]. \tag{5.9}$$

Step 2: obtain the optimal daring order quantity $q_4(W)$ for the fixed wholesale price *W*:

$$q_4(W) \in \arg\max_q \max_{x_4(W,q)\in X_4(W,q)} u(r(W, x_4(W,q), q)), \tag{5.10}$$

where $X_4(W,q)$ is the set of daring focus points $x_4(W,q)$.

5.2.2 The upper level problem: the manufacturer's model

Two types of supply chain are examined in this section: make-to-order and make-to-stock. In the make-to-order supply chain, the manufacturer performs production after the retailer's ordering decision. Therefore, there are no demand uncertain for the manufacturer. On the other hand, in the make-to-stock supply chain, the manufacturer performs production before the retailer's ordering decision. If the manufacturer produces too much innovative products, the unsold products will be salvaged; if the manufacturer's production quantity is less than the demand, he/she will suffer an opportunity cost. We consider the make-to-order supply chain firstly.

5.2.2.1 Make-to-order supply chain

The retailer's optimal response $q_1(W)$, $q_2(W)$, $q_3(W)$ or $q_4(W)$ is obtained in the lower level problem. With consideration of (5.1), the imagined profit functions of the manufacturer who is facing active, passive, apprehensive or daring retailer are as follows:

$$f(W, q_1(W)) = Wq_1(W); \tag{5.11}$$

$$f(W, q_2(W)) = Wq_2(W). \tag{5.12}$$

$$f(W, q_3(W)) = Wq_3(W); \tag{5.13}$$

$$f(W, q_4(W)) = Wq_4(W). \tag{5.14}$$

The manufacturer's optimal wholesale prices when he/she is facing different retailers are as follows:

$$W_i^* \in \arg\max_W f(W, q_i(W)), \ i=1,2,3 \text{ or } 4. \tag{5.15}$$

W_1^*, W_2^*, W_3^* and W_4^* are the optimal wholesale prices of the manufacturer when he/she is facing active, passive, apprehensive and daring retailers, respectively.

The imagined profit of the whole supply chain when the manufacturer is facing active, passive, apprehensive or daring retailer is as follows

$$\Omega_1^* = (R - W_1^*)q_1(W_1^*); \tag{5.16}$$

$$\Omega_2^* = (R - W_2^*)q_2(W_2^*). \tag{5.17}$$

$$\Omega_3^* = (R - W_3^*)q_3(W_3^*); \tag{5.18}$$

$$\Omega_4^* = (R - W_4^*) q_2(W_4^*) . \tag{5.19}$$

Ω_1^*, Ω_2^*, Ω_3^* and Ω_4^* are called optimal active, passive, apprehensive and daring profits, respectively.

5.2.2.1 Make-to-stock supply chain

Due to the short life cycle of innovative products (usually shorter than the lead-time), shortening the lead-time becomes an important topic of the supply chain management of such products. Knowing the personalities of the retailers, the manufacturer is able to perform the production in advance. Facing the retailers with different personalities, the manufacturer selects a strategy and its corresponding optimal wholesale price contract to coordinate the supply chain (production quantity equals to order quantity).

In this make-to-stock supply chain, the manufacturer imagine that he/she performs as an integrated manufacturer and decides a production quantity in advance, which is a typical newsvendor problem. The profit function of the integrated manufacturer is shown as below.

$$f(x,P) = \begin{cases} Rx + (P-x)S_o - c_p P; & x < P \\ (R-c_p)P - S_u^M (x-P); & x \geq P \end{cases}, \tag{5.20}$$

where x is the market demand, P is the production quantity, S_o is the unit salvage price, S_u^M is the integrated manufacturer's unit opportunity cost, c_p is the production cost and $c_p > S_o$. The satisfaction level of the integrated manufacturer is written as $u_f(x,q)$.

Similar as Chapter 3, there are active, passive, apprehensive and daring focus points lead to active, passive, apprehensive and daring production quantity, i.e., P_1 , P_2 , P_3 and P_4 , which represent active, passive, apprehensive and daring strategies, respectively.

5.3 Analysis Results

In this section we suppose the probability density function of demand satisfies the Assumption 3.1. After observing the wholesale price *W* represented by the manufacturer, following (3.3) and (3.4), the retailer's highest profit $r_u(W)$ and lowest profit $r_l(W)$ are obtained as follows.

$$r_u(W) = (R - W)d_u. \tag{5.21}$$

$$r_l(W) = d_l R + (d_u - d_l)S_o - d_u W, \text{ (supposing } W \geq S_o + S_u\text{)}. \tag{5.22}$$

5.3.1 The analysis results of make-to-order supply chain

We suppose the satisfaction function of the retailer is $u(W,x,q) = \dfrac{r(W,x,q) - r_l(W)}{r_u(W) - r_l(W)}$. If $\forall x \in (d_c, d_u)$, $\pi(x)$ is of class C^1, then we have Theorem 5.1.

Theorem 5.1. When the manufacturer faces active retailer, the manufacturer's imagined profit function $f(W, q_1(W)) = Wq_1(W)$ is a concave function of wholesale price *W*.

Proof.

From (5.11), we have

$$f''(W, q_1(W)) = 2q_1'(W) + Wq_1''(W). \tag{5.23}$$

From (3.20), we have

$$q_1'(W) = \frac{\dfrac{\partial u(W,x,x)}{\partial W}}{\pi'(x) - \dfrac{\partial u(W,x,x)}{\partial x}}, \tag{5.24}$$

which lead to

$$q_1''(W) = \frac{\frac{\partial^2 u(W,x,x)}{\partial W^2}(\pi'(x) - \frac{\partial u(W,x,x)}{\partial x}) + \frac{\partial^2 u(W,x,x)}{\partial x \partial W} \cdot \frac{\partial u(W,x,x)}{\partial W}}{(\pi'(x) - \frac{\partial u(W,x,x)}{\partial x})^2}. \tag{5.25}$$

Since $x \in (d_c, d_u)$, with considering (3.2), (5.2) and Definition 2.2, we have

$$\pi'(x) < 0, \tag{5.26}$$

$$\frac{\partial u(W,x,x)}{\partial x} = \frac{R-W}{(d_u - d_l)(R - S_o)} > 0, \tag{5.27}$$

$$\frac{\partial u(W,x,x)}{\partial W} = \frac{d_u - x}{(d_u - d_l)(R - S_o)} > 0, \tag{5.28}$$

$$\frac{\partial^2 u(W,x,x)}{\partial W^2} = 0, \tag{5.29}$$

$$\frac{\partial^2 u(W,x,x)}{\partial x \partial W} = \frac{-1}{(d_u - d_l)(R - S_o)} < 0. \tag{5.30}$$

From (5.23) to (5.30), we know $f''(W, q_1(W)) < 0$. □

If $\pi(x)$ is symmetric, and it is of class C^1 for $x \in (d_l, d_c)$ and $x \in (d_c, d_u)$, then we have Theorem 5.2.

Theorem 5.2. When the manufacturer faces passive retailer, the manufacturer's imagined profit function $f(W, q_2(W)) = Wq_2(W)$ is a concave function of wholesale price *W*.

Proof.

From (5.12), we have

$$f''(W, q_2(W)) = 2q_1'(W) + Wq_2''(W). \tag{5.31}$$

From (3.22), we have

$$q_2'(W) = \frac{\frac{\partial \pi(d_{pl}(W,q))}{\partial W} - \frac{\partial \pi(d_{pu}(W,q))}{\partial W}}{\frac{\partial \pi(d_{pu}(W,q))}{\partial q} - \frac{\partial \pi(d_{pl}(W,q))}{\partial q}}, \tag{5.32}$$

which lead to

$$q_2''(W) = \frac{-(\frac{\partial \pi(d_{pl}(W,q))}{\partial W} - \frac{\partial \pi(d_{pu}(W,q))}{\partial W})(\frac{\partial^2 \pi(d_{pu}(W,q))}{\partial q \partial W} - \frac{\partial^2 \pi(d_{pl}(W,q))}{\partial q \partial W})}{(\frac{\partial \pi(d_{pu}(W,q))}{\partial q} - \frac{\partial \pi(d_{pl}(W,q))}{\partial q})^2} . \quad (5.33)$$

With considering (3.2), (5.2) and Definition 2.2, we know $q_2'(W) < 0$ and $q_2''(W) < 0$, which lead to $f''(W, q_2(W)) < 0$. □

Proposition 5.3. When the manufacturer is facing the apprehensive or daring retailer, he/she always sets the wholesale price equal to retail price and obtains the whole profit in the supply chain.

Proposition 5.4. The imagined profits of the supply chain when the manufacturer is facing different types of retailers have the relationships:

$$\Omega_3^* < \Omega_2^* < \Omega_1^* < \Omega_4^* \quad (5.34)$$

In the following we examine the behaviors of supply chain participants when the market changes. Suppose the market demand is a triangular distribution with range $[d_l, d_u]$. The normalized likelihood function $\pi(x)$ can expressed as

$$\pi(x) = \begin{cases} \dfrac{x - d_l}{\lambda(d_u - d_l)} & d_l \le x \le d_l + \lambda(d_u - d_l) \\ \dfrac{d_u - x}{(1-\lambda)(d_u - d_l)} & d_l + \lambda(d_u - d_l) \le x \le d_u \end{cases} , \quad (5.35)$$

where $0 < \lambda < 1$.

$d_l + \lambda(d_u - d_l) \in (d_l, d_u)$ is the peak of the normalized likelihood function and it is the most possible demand. The most possible demand $d_l + \lambda(d_u - d_l)$ is increasing in parameter λ.

We examine the situation that the manufacturer is facing active retailer. Suppose the manufacturer's optimal wholesale price $W_1^* \in (d_l, d_u)$, that is $f'(W, q_1(W)) = 0$ has a solution in (d_l, d_u). We have the following theorem.

Proposition 5.5. When the manufacturer is facing the active retailer, his/her optimal wholesale price increases while the most possible demand increases.

Proof.

From (5.11), we have

$$\frac{\partial^2 f(W, q_1(W), \lambda)}{\partial\lambda\partial W} = \frac{\partial q_1(W, \lambda)}{\partial\lambda} + W \frac{\partial^2 q_1(W, \lambda)}{\partial\lambda\partial W}. \tag{5.36}$$

From (3.20), we have

$$q_1(W) = \frac{d_u(R - S_o) + (1-\lambda)(d_l R - d_u W + (d_u - d_l)S_o)}{R - S_o + (1-\lambda)(R - W)}, \tag{5.37}$$

which lead to

$$\frac{\partial^2 q_1(W, \lambda)}{\partial\lambda\partial W} = \frac{2(1-\lambda)(d_u - d_l)(R - S_o)^2}{(R - S_o + (1-\lambda)(R - W))^3} > 0. \tag{5.38}$$

Since $x \in (d_c, d_u)$, with considering (3.20) and (5.35), we have

$$\frac{\partial q_1(W, \lambda)}{\partial\lambda} > 0. \tag{5.39}$$

From (5.36), (5.38) and (5.39), we know $\frac{\partial^2 f(W, q_1(W), \lambda)}{\partial\lambda\partial W} > 0$. Referring the concavity of $f(W, q_1(W))$, we know that the manufacturer's optimal wholesale price is increasing in λ. □

Theorem 5.5 provide the managerial insights into the changes of supply chain performance and behaviors of manufacturer and retailer when market grows.

5.3.1 The analysis results of make-to-stock supply chain

Proposition 5.6. If $\forall x \in (d_c, d_u)$, $\pi(x)$ and $u_f(x, p)$ are of class C^1, there is a unique $W_2 \in (c_p, R)$ which satisfies $q_1(W_2) = P_2$.

Proof.

From (3.14), we know that $q_1(W)$ is the solution of

$$u(W, x, x) = \pi(x). \tag{5.40}$$

Using the implicit function theorem, we know that $q_1(W)$ is a continuously differentiable function of *W*, and $q_1'(W) < 0$. With considering Lemma 3.6, we know that there is a unique $W_2 \in (c_p, R)$ which satisfies $q_1(W_2) = P_2$. □

W_2 in Proposition 5.6 is called passive wholesale price contract, which is corresponded to the passive strategy of the manufacturer. From Proposition 5.6 we can see that when the manufacturer faces active retailer, the passive strategy can coordinate (production quantity equals to order quantity) the supply chain. From Proposition 3.8, with the changing of wholesale price, the changes of passive order quantity is depending on the setting of parameters, we have the following Proposition.

Proposition 5.7. When the manufacturer is facing the passive retailer, no strategy can surely coordinate the supply chain.

From Lemma 3.5 and Proposition 3.9, the wholesale price has no effect on apprehensive and daring order quantities, we obtain Proposition 5.8.

Proposition 5.8. When the manufacturer is facing the apprehensive/daring retailer, the apprehensive/daring strategy can coordinate the supply chain.

5.4 Concluding Remarks

This chapter examines the wholesale price contract in a simple supply chain of the innovative product. We use the one-shot decision theory to analyze the behaviors of supply chain participants. The one-time feature of innovative products is considered. Different from the existing models, we introduce the personalities of the supply chain participants into our models, and we show the importance of personality information sharing. Stackelberg equilibriums are proposed to analyze the optimal wholesale pricing of manufacturer and the optimal order quantity of retailer both in the make-to-order and make-to-stock supply chains. To the best of my knowledge, it is the first time that the contracts in the make-to-stock supply chain is studied. Different types of retailers, called active, passive, apprehensive and daring retailers, lead to different Stackelberg equilibriums. The managerial insights into the changes of supply chain performance and behaviors of manufacturer and retailer when market grows are also discussed.

Chapter 6

Conclusions

In this dissertation, three supply chain management models which fit the one-shot feature of innovative products are studied based on the one-shot decision theory. The general solutions and existence theorem are proposed in one-shot decision theory so that the mathematical basics in analyzing the supply chain management models are given. The main achievements obtained in this dissertation are summarized as follows.

In Chapter 2, the general solutions of active, passive, apprehensive and daring focus points and optimal alternatives are proposed and the existence theorem is established in the one-shot decision theory.

In Chapter 3, newsvendor models for innovative products are proposed based on the one-shot decision theory. Four types of retailers who choose four different types of focus points, i.e. active, passive, apprehensive and daring retailers are examined by one-shot decision theory. The proposed models are scenario-based decision models which provide a fundamental alternative to analyze the newsvendor problems of innovative products.

In Chapter 4, price-setting newsvendor models for innovative products are proposed. In the classic newsvendor problem, the retail price is considered as an exogenous value. It is only for a perfect competitive market where the retailers are price-takers. When the retailer is selling an innovative product in a monopoly market, he/she has only one chance to determine not only the order quantity but also the retail price the retail price to maximize his/her profit. The one-shot decision theory based price-setting newsvendor models are proposed for this situation.

In Chapter 5, the wholesale price contracts in the supply chain for innovative products are discussed. In this supply chain, a single manufacturer sells innovative products to a retailer who is facing a newsvendor problem. Based on one-shot decision theory, the Stackelberg equilibriums are obtained for the optimal wholesale price of manufacturer and the optimal order quantity of retailer both in the make-to-order and make-to-stock supply chain. Different types of retailers lead to different Stackelberg equilibriums. In the proposed models, the one-time feature of innovative products and the information sharing of personalities are considered. The managerial insights into the changes of supply chain performance and behaviors of manufacturer and retailer when market grows are also discussed.

References

Arcelus, F. J., Kumar, S. and Srinivasan, G., 2007. Manufacturer's pricing strategies in a single-period framework under price-dependent stochastic demand with asymmetric risk-preference information. Journal of the Operational Research Society, 58(11), 1449-1458.

Brito, A.J. and de Almeida, A.T., 2012. Modeling a multi-attribute utility newsvendor with partial backlogging. European Journal of Operational Research, 220(3), 820-830.

Cachon, G. P. and Fisher, M.L., 2000. Supply chain inventory management and the value of shared information. Management science, 46(8), 1032-1048.

Cachon, G. P., 2003. Supply chain coordination with contracts. In: Graves, S.C. and Kok, A.G. de (eds.), Handbooks in Operations Research and Management Science: Supply Chain Management, Vol. 11. Elsevier, North-Holland, 229-339.

Caliskan-Demirag, O, Chen, Y. and Li, J., 2011. Customer and retailer rebates under risk aversion. International Journal of Production Economics, 133(2), 736-750.

Chen, J., 2011. Returns with wholesale-price-discount contract in a newsvendor problem. International Journal of Production Economics, 130(1), 104-111.

Chen, X., Pang, Z. and Pan, L., 2014. Coordinating inventory control and pricing strategies for perishable products. Operations Research, 62(2), 284-300.

Chen, X. and Simchi-Levi, D., 2004. Coordinating inventory control and pricing strategies with random demand and fixed ordering cost: The finite horizon case. Operations Research, 52(6), 887-896.

Fisher, M.L., 1997. What is the right supply chain for your product? Harvard Business Review (March-April), 105-116.

Grubbstrom, R.W., 2010. The newsboy problem when customer demand is a compound renewal process. European Journal of Operational Research, 203(1), 134-142.

Guo, P., 2010a. One-shot decision approach and its application to duopoly market. International Journal of Information and Decision Sciences, 2(3), 213-232.

Guo, P., 2010b. Private real estate investment analysis within a one-shot decision framework. International Real Estate Review, 13(3), 238-260.

Guo, P., Yan, R. and Wang, J., 2010. Duopoly market analysis within one-shot decision framework with asymmetric possibilistic information. International Journal of Computational Intelligence System, 3(6), 786-796.

Guo, P., 2011. One-shot decision theory. IEEE Transactions on SMC, Part A: Systems and Humans, 41(5), 917-926.

Guo, P., 2014. One-shot decision theory: A fundamental alternative for decision under uncertainty. In P. Guo and W. Pedrycz (Eds.), Human-Centric Decision-Making Models for Social Sciences. Studies in Computational Intelligence (Vol. 502, pp. 33-55). Berlin Heidelberg: Springer-Verlag.

Guo, P. and Li, Y., 2014. Approaches to multistage one-shot decision making. European Journal of Operational Research, 236(2), 612–623.

Guo, P. and Ma, X., 2012. Newsvendor problem with one-shot decision theory. In Proceedings of the 10th International FLINS Conference on Uncertainty Modeling in Knowledge Engineering and Decision Making, 507-512.

Guo, P. and Ma, X., 2014. Newsvendor models for innovative products with one-shot decision theory. European Journal of Operational Research, 239(2), 523–536.

Khouja, M., 1999. The single-period (news-vendor) problem: Literature review and suggestions for future research. Omega, 27(5), 537-553.

Kocabiyikoglu, A. and Popescu, I., 2011. An elasticity approach to the newsvendor with price-sensitive demand. Operations Research, 59(2), 301-312.

Kwon, K. and Cheong, T., 2014. A minimax distribution-free procedure for a newsvendor problem with free shipping. European Journal of Operational Research, 232(1), 234-240.

Lariviere, M.A. and Porteus, E.L., 2001. Selling to the newsvendor: an analysis of price-only contracts. Manufacture & Service Operation Management, 3(4), 293-305.

Lau, A. H. L., Lau, H. S. and Wang, J. C., 2007. Some properties of buyback and other related schemes in a newsvendor-product supply chain with price-sensitive demand. Journal of the Operational Research Society, 58(4), 491-504.

Lee, H. L., Padmanabhan, V. and Whang, S., 1997a. Information distortion in a supply chain: The bullwhip effect. Management Science, 43(4), 546–558.

Lee, H. L., Padmanabhan, V. and Whang, S., 1997b. Bullwhip effect in a supply chain. Sloan Management Review, 38(Spring), 93–102.

Lee, H. L., So, K. C. and Tang, C. S., 2000. The value of information sharing in a two-level supply chain. Management science, 46(5), 626-643.

Ma, X., 2014. Price-setting newsvendor models for innovative products and its extension to the two-echelon supply chain. In Proceedings of APDSI-ICOSCM-ISOMS 2014, Yokohama.

Ma, X. and Guo, P., 2013. Optimal pricing and returns policies for innovative products with the one-shot decision theory. In Proceedings of the 2013 IEEE IEEM, Bangkok.

Ma, X., Wang, C. and Guo, P., 2013. Channel coordination in the supply chain with the one-shot decision theory. In Proceedings of the 2013 Joint IFSA World Congress, NAFIPS Annual Meeting (IFSA/NAFIPS), 146-150.

Madden, P., 1986. Concavity and optimization in microeconomics. Oxford: Blackwell.

Murray, C.C., Gosavi, A. and Talukdar, D., 2012. The multi-product price-setting newsvendor with resource capacity constraints. International Journal of Production Economics, 138(1), 148-158.

Pasternack, B. A., 2008. Optimal pricing and return policies for perishable commodities. Marketing science, 27(1), 133-140.

Petruzzi, N.C. and Dada, M., 1999. Pricing and the newsvendor problem: A review with extensions. Operations Research, 47(2), 183-194.

Petruzzi, N. C. and Dada, M., 2010. Newsvendor models, in Wiley Encyclopedia of Operations Research and Management Science, Cochran, J.J., Cox Jr., L.A., Keskinocak, P., Kharoufeh, J. P. and Smith, J.C., Eds., John Wiley & Sons, Hoboken, NJ.

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

Raz, G. and Porteus, E. L., 2006. A fractiles perspective to the joint price/quantity newsvendor model. Management Science, 52(11), 1764-1777.

Salinger, M. and Ampudia, M., 2011. Simple economics of the price-setting newsvendor problem. Management Science, 57(11), 1996-1998.

Sarmah, S.P., Acharya, D. and Goyal, S.K., 2006. Buyer vendor coordination models in supply chain management. European Journal of Operational Research, 175(1), 1-15.

Seifert, R.W., Zequeira, R.I. and Liao, S., 2012. A three-echelon supply chain with price-only contracts and sub-supply chain coordination. International Journal of Production Economics, 138(2), 345-353.

Sion, M., 1958. On general minimax theorems. Pacific Journal of Mathematics, 8(1), 171-176.

Summerfield, N.S. and Dror, M., 2012. Stochastic programming for decentralized newsvendor with transshipment. International Journal of Production Economics, 137(2), 292-303.

Wang, C.X., Webster, S. and Suresh, N.C., 2009. Would a risk-averse newsvendor order less at a higher selling price? European Journal of Operation Research, 196(2), 544-553.

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

Wang, C.X., 2010. The loss-averse newsvendor game. International Journal of Production Economics, 124(2), 448-452.

Wang, J.C., Lau, A.H.L. and Lau, H.S., 2012. Practical and effective contracts for the dominant retailer of a newsvendor product with price-sensitive demand. International Journal of Production Economics, 138(1), 46-54.

Wu, Z., Crama, P. and Zhu, W., 2012. The newsvendor's optimal incentive contracts for multiple advertisers. European Journal of Operational Research, 220(1), 171-181.

Xu, M. and Lu, Y., 2013. The effect of supply uncertainty in price-setting newsvendor models.

European Journal of Operational Research, 227(3), 423-433.

Xu, X., Cai, X. and Chen, Y., 2011. Unimodality of price-setting newsvendor's objective function with multiplicative demand and its applications. International Journal of Production Economics, 133(2), 653-661.

Zhou, H. and Benton Jr, W. C., 2007. Supply chain practice and information sharing. Journal of Operations Management, 25(6), 1348-1365.