AN ANALYSIS OF RETURN POLICY CONTRACTS WITH WARRANTY IN A TWO STAGE SUPPLY CHAIN

A THESIS

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CONTENTS

List of Tables

Exponential Distribution

Analysis of Risk

Quality Improvement and Channel Coordination

Uniform Distribution

Normal Distribution

List of Figures

List of Symbols & Notations

γ	First parameter of the warranty dependent demand function
δ	Second parameter of the warranty dependent demand function
φ	Third parameter of the warranty dependent demand function
d	Stochastic part of the demand distribution
s	Lower limit of the uniform distribution followed by d
t	Upper limit of the uniform distribution followed by d
μ	Mean of the normal distribution followed by d
σ	Standard deviation of the normal distribution followed by d
λ	Parameter (poisson arrival rate) of the exponential distribution followed by d
w	Wholesale price per unit
c_m	Manufacturer's production cost per unit
c_r	Retailer's procuring cost per unit
c	Supply chain's total cost of production and distribution per unit
g_m	Manufacturer's cost of lost sales per unit
g_r	Retailer's cost of lost sales per unit
g	Total supply chain's cost of lost sales per unit.
v	Salvage value per unit
p	Retail price per unit
q	Number of units ordered
b	The buyback rate at which the manufacturer buys back the unsold units from the retailer
α	Parameter for quantity flexibility contract such that the manufacturer gives full credit to the retailer up to αq no of unsold units.
θ	Portion of the warranty cost borne by the retailer
k	Length of the warranty period
S(q,k)	Expected sales
I(q,k)	Expected leftover inventory
I_r(q,k)	Expected leftover inventory at the retailer's end after implementation of return policy
I_m(q,k)	Expected leftover inventory at the manufacturer's end after implementation of

	return policy
$L(q,k)$	Expected lost sales
$\mu(k)$	Expected total demand given the warranty length
$X \mid K$	Conditional random variable of demand given the warranty length k
Y	Random variable denoting the time required for the first failure of the product
β	Failure rate of the product
r	Cost of warranty per unit
$x(k,d)$	Total demand
$y(k)$	Warranty dependent demand function
$f(X \mid K)$	Probability density function (Pdf) corresponding to the conditional demand distribution
$F(X \mid K)$	Cumulative distribution function (Cdf) corresponding to the conditional demand distribution
h	Probability density function (Pdf) of d
H	Cumulative distribution function (Cdf) of d
$\pi_m(q,k)$	Expected profit earned by the manufacturer
$\pi_r(q,k)$	Expected profit earned by the retailer
$\pi(q,k)$	Expected profit earned by the entire supply chain.
k_T	Maximum risk borne by total supply chain in case of a risk-averse supply chain
k_M	Maximum risk borne by the manufacturer in case of a risk-averse manufacturer
k_R	Maximum risk borne by the retailer in case of a risk-averse retailer

Abstract

The study investigates the coordination mechanism when return policy contracts are implemented along with a free replacement warranty. The coordination mechanism is explored in case of a two stage supply chain involving one manufacturer and one retailer. It deals with a single product, single selling period model. The problem dealt in the current study is different from the conventional coordination problems in the sense that it considers the warranty period also as one of the decision variables along with other contract parameters in order to achieve supply chain coordination. It is assumed that the product faces a stochastic demand and the demand is also dependent on the length of warranty period offered. The manufacturer offers a free replacement warranty to the customer if the product fails within a specified time interval after sales.

The present research explores the coordination mechanism through warranty period optimization among a possible set of warranty lengths when buyback contract and quantity flexibility contract are implemented. It analyses the relationship among different decision variables and deals with two cases i) when the manufacturer solely bears the warranty cost, ii) when there is a sharing of warranty cost between the manufacturer and the retailer. The study conducts numerical analysis assuming an additive demand distribution one part of which is a nonlinear warranty dependent demand function and the other part of which follows a statistical distribution. The numerical analysis is carried out with respect to a set of values of the exogenous parameters and assuming that the stochastic part of the demand follows a uniform, normal or exponential distribution. Sensitivity analysis is also carried out to investigate the effect of change in the parameter such as mean, standard deviation of the demand distribution on the optimal order quantity, optimal warranty length, supply chain profit and supply chain risk. It also carries out a sensitivity analysis with respect to the exogenous parameters individually to explore the impact of change in cost of production and average warranty cost, retail price, parameters of the warranty dependent demand function on the optimal order quantity, optimal warranty length, supply chain profit and supply chain risk.

The present study determines the risk expressions for the retailer, manufacturer and the entire supply chain in case of buyback contract, quantity flexibility contract in conjunction with warranty. Risk is measured by calculating the variances in absolute profits of the respective parties in the supply chain. It also investigates the effect of change in order quantity on the risks borne by the manufacturer, the retailer and the total supply chain while the warranty length is kept optimal. Similar investigation is performed to examine the impact of change in warranty length upon the risks borne by the manufacturer, the retailer and the total supply chain keeping the order quantity optimal. The study also examines how the solution of the centralised system is affected when the supply chain is risk-averse in nature. It also provides an example and guideline for the coordinator of the supply chain to design the contract parameters and set the decision variables in a manner such that the channel coordination is achieved by satisfying the risk constraints of both the parties as well as of the entire supply chain.

The study examines the necessity of aligning the quality decision, warranty policy and production level of a supply chain by investigating the impact of quality improvement of the product on the optimal order quantity, optimal warranty length, optimal supply chain profit and

profits of both the parties of the supply chain. The study also provides a guideline to recoordinate the supply chain by redesigning the contract parameters after the quality development of the product in case of buyback contract and quantity flexibility contract.

The study shows that with increase in buyback rate the wholesale price increases linearly in order to achieve coordination. It also shows that with increase in the buyback rate the retailer's profit decreases and the manufacturer's profit increases linearly. The risks borne by the retailer and the manufacturer are found to be convex decreasing and convex increasing respectively in nature with increase in buyback rate. The study shows that in case of quantity flexibility contract, with increase in α values the wholesale price increases both in case of uniform and exponential distribution, where the nature of the curve is convex for the former whereas it is nonlinear (neither concave nor convex) in case of the latter. However, for the normal distribution the curve is initially concave increasing and later on becomes parallel to horizontal axis i.e. the wholesale price becomes constant. These findings conform to the finding that the coordination in case of quantity flexibility contract differs depending on the demand distribution faced by the retailer. It is found that in case of exponential demand distribution with higher variance, the manufacturer is required to offer a higher flexibility to the retailer in terms of quantity ordered compared to those of uniform and normal demand distribution with equal mean but lower variance. This is required to ensure that both the parties in the supply chain have a positive profit. The study also finds that with increase in mean of the distribution, the standard deviation remaining unchanged, there is an increase in the optimal order quantity and supply chain profit. The optimal warranty length either remains unchanged or decreases. This gives an insight to the managerial practice by establishing that when there is a positive impact in the demand due to increase in the mean of the demand distribution, the supply chain earns more profit by reducing the warranty length or by keeping it unchanged.

The study shows that with increase in the order quantity the risks borne by the retailer, manufacturer and the total supply chain increase linearly when the warranty length is kept optimal. It is also found that with increase in the warranty length the risks borne by the retailer, manufacturer and the entire supply chain initially increase and then gradually decrease while the order quantity is kept optimal. This analysis provides interesting managerial insight by suggesting necessary methods of designing contract parameters and formulating decision variables to achieve mean-variance coordination of the supply chain when the supply chain and its parties are risk-averse in nature. The study finds that due to recoordination of the supply chain because of quality development initiative, there is a continuous increase in the profit of the entire supply chain as well as both the parties in the supply chain within the same optimal warranty length. It is also found that with decrease in the failure rate of the product, the optimal warranty length either increases or remains unaltered.

Keywords: Supply Chain Coordination, Free Replacement Warranty, Buyback Contract, Quantity Flexibility Contract, Return Policies.