



Manufacturer's pricing strategy for supply chain with warranty period-dependent demand

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ARTICLE INFO

Article history:

Received 9 March 2011

Accepted 19 December 2011

This manuscript was processed by

Associate Editor Geunes

Available online 13 January 2012

Keywords:

Supply chain management

Pricing

Game theory

Warranty period-dependent demand

ABSTRACT

This article presents a review of the issues associated with a manufacturer's pricing strategies in a two-echelon supply chain that comprises one manufacturer and two competing retailers, with warranty period-dependent demands. The manufacturer, as a Stackelberg leader, specifies wholesale prices to two competing retailers who face warranty period-dependent demand and have different sales costs. The manufacturer considers three pricing options: (1) setting the same price for both retailers, while disregarding their difference with regard to sales cost; (2) setting a different price to each retailer on the basis of their sales cost; and (3) setting the same price to both retailers according to the average sales cost of the industry. In this article, the retailers' optimal warranty periods and their optimal profit, manufacturer's optimal wholesale price, and his/her optimal profit associated with different pricing strategies have been derived using the game theory. Our analysis shows that the results for retailers are the same with Strategy 1 or Strategy 3. In addition, we compared the effects of different pricing strategies of the manufacturer on supply chain decisions and profit. We conclude from the results that the manufacturer should either adopt Strategy 2 with symmetrical sales cost information or Strategy 3 if retailers' sales costs are asymmetrical.

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1. Introduction

Rapid technological advancements have intensified business competition, shortened product life-cycles, increased time-sensitive customer demand, and popularized outsourcing [1]. To deal with these challenges, supply chains have progressively become leaner and more responsive to market needs [2,3]. At the same time however, more and more supply chains have resorted to dependence on services and/or product quality to build brand loyalty to avoid traditional competition which focuses solely on price. For instance, IBM and Dell enjoy a good reputation in terms of their customer service support. Moreover, new product introduction burgeoning at an ever-increasing rate, as products become more complex and government regulation becomes more stringent with regard to product liability [4]. Warranties have become a popular measure for encouraging market demand by reducing risks for consumers. Warranty is a contractual theory of recovery governed by principles of sales [5].

Warranties have received extensive attention in both economics and operations management literature. In economics, three typical theories have been proposed to explain the existence of product warranties: insurance theory, signaling theory, and incentive theory. Insurance theory assumes that consumers are more risk-averse than sellers, and treats warranties as compensation paid to consumers in the event of product failure [6,7]. The signaling theory states that a product warranty is a signal of product quality; a longer and more comprehensive warranty usually indicates better product quality [8]. Incentive theory is an indication of double moral hazards: the terms of the warranty contract describe liabilities for moral hazards of both parties—manufacturers and consumers [9,10].

Published studies on warranty from the viewpoint of operations management are also available. Blischke and Murthy [11] have developed a comprehensive review of the research in this area. Recently, many studies have been carried out by operations researchers to explore various aspects of manufacturer's warranties, such as warranty types [12] and warranty logistics [13]. However, studies on the impact of warranties on supply chains (or in this context) are scarce.

Wee and Law [14] developed a deteriorating inventory model with price-dependent demand, and used heuristics and search methods to derive the optimal number of replenishment and unit

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price to maximize the total present-value net profit. Hu et al. [15] evaluated the wholesale and revenue-sharing contract between one supplier and one retailer, where the supplier offers free replacement warranty to satisfy the warranty-length elastic demand. They showed that supply chain coordination only occurs if the supplier and retailer share both revenue and warranty costs, with the share of the warranty cost set to be equal to the share of the profit. Hu [16] further investigated a fair and equitable profit allocation as the sharing of profit according to each party's relevant cost. These models are based on a monopolistic setting, and competition has not been taken into consideration. Chung et al. [17] investigated an integrated production-inventory-deteriorating model by taking into consideration the pricing policy, imperfect production, inspection planning, warranty period, and the stock-level-dependent demand with the Weibull deterioration, partial backorder, and inflation. They showed that the pricing policy, market demand, inspection planning, and the effect of the warranty policy are significant factors in this model. Wee et al. [18] developed optimal pricing and replenishment policies in a lean and agile supply chain system for a single vendor and multiple buyers, and derived that the pricing strategy with price reduction is a mutually beneficial strategic partnership between the vendor and the buyers. Hartman and Laksana [19] used dynamic programming to model a number of extended warranty contracts that differ in design, including restrictions on deferrals and renewals. They derived the optimal strategy for a consumer with perfect information and determined the optimal pricing policy for the provider, when given the consumer's risk characterization. Recently, Jiang and Zhang [20] considered a single manufacturer who markets a product through a retailer to consumers and modeled the interaction between the manufacturer and the retailer as a two-stage game. They examined the effects of a service plan on the role played by a manufacturer's base warranty and showed that (1) when consumers can assess product quality, the manufacturer's warranty is negatively affected by the presence of a service plan and (2) when consumers cannot assess product quality, a high-quality manufacturer is motivated to offer a base warranty to indicate its quality. Gao et al. [21] developed two bi-level pricing models for pricing problems with the buyer and the vendor in a supply chain designated as the leader and the follower, respectively. To solve problems defined by these two models, a PSO based algorithm is used. Kim and Bell [22] investigated the impact of demand substitution on the optimal pricing and production quantity levels for the cases of symmetrical and asymmetrical demand substitution. They show that revenue managers and supply chain coordinators should adapt product prices in each market segment and order quantities to take into account substitution by customers and the costs of supplying product to each market. Yang et al. [23] studied pricing and target oriented decision making together in the newsvendor model, and showed that the probability of a newsvendor achieving both targets depends critically on the relative magnitudes of the profit margin and the ratio between the profit target and the revenue target. Arcelus et al. [24] evaluated the pricing and ordering policies of a retailer in a newsvendor framework, and showed some analytical properties and numerical examples to illustrate the main features of the models. Li et al. [25] studied the design of extended warranties using a supply chain framework consisting of a manufacturer and an independent retailer. They developed a game-theoretical model to compare different schemes for extended warranties and showed that, depending on the repair-cost relationship, either party could provide better extended warranty policies and generate more system profit.

In China, the competition between two leading home appliance retailers, SUNING and GOME (with total sales of 156.2 billion

Yuan and 154.9 billion Yuan, respectively, in 2010), has come to a point where price difference (or differentiation) for the same or similar products has been so slight or insignificant to their customers that the competition becomes intensified by offering additional warranty (beyond the manufacturers' warranty) to customers. For instance, by promising customers additional warranty for up to 3 years, GOME has made its flat TV products more attractive than that of its competitors. A similar phenomenon can be observed among many businesses/industries around the world. In the present study, the primary interest is focused on the competitive behavior of a manufacturer and retailers when the mode of competition shifts from strategies that consider price differentiation to strategies that emphasize service differentiation. In this context, the scope is delineated on the demands that are influenced primarily by the warranty period offered by retailers. This is not implying that the impact of price has been ignored. Price remains fundamental as a basis for market competition. However, it may not always be the only means determining competition: when everyone offers the same price, one would win definitely by adopting a more comprehensive strategy—in this case, a more attractive service contract in the form of additional/extended warranty by the retailer.

This article presents an investigation of the manufacturer's pricing strategy for a supply chain consisting of one manufacturer and two competing retailers. The manufacturer, as a Stackelberg leader, specifies wholesale prices to two competing retailers who face warranty period-dependent demands. For the manufacturer, there are three normal pricing strategies:

- (1) Strategy 1: Manufacturer negotiates with both retailers simultaneously according to their sales cost and specifies a single wholesale price for both retailers.
- (2) Strategy 2: Manufacturer negotiates with retailers separately on the basis of their sales cost and sets different wholesale prices to the two retailers.
- (3) Strategy 3: Manufacturer negotiates with retailers simultaneously according to their average sales cost $c_1 + c_2/2$ and sets a wholesale price to both retailers.

However, several questions of interests emerge:

- (1) What are retailers' optimal warranty periods and the manufacturer's optimal wholesale price for manufacturer's different pricing strategies?
- (2) What is the effect of manufacturer's different pricing strategy on supply chain, such as retailers' decisions and their profits, manufacturer's decisions and profit, and the profit of the entire supply chain?
- (3) Which pricing strategy proposed by the manufacturer should be adopted in response to the different sales cost scenarios?

This study aims to address these issues and provide insights with regard to the influence of manufacturer's pricing strategy on supply chain decisions and performance. Note that a warranty period assurance provided by manufacturer, though common in practice, is not a focus of our current work. The focus of this study is on manufacturer's pricing strategies with the consideration of warranty period-dependent demands. Compared with the previous research, our study concentrates on the evaluation of manufacturer's pricing strategies in conjunction with retailers gaming interaction, and related impact on supply chain's decisions and performance when all channel members are affected by warranty period-dependent demands. This is a unique contribution because few analyses of similar studies have made such a connection. In addition, the results of the study can also provide

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