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Optimal remanufacturing strategies in name-your-own-price auctions with limited capacity

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ABSTRACT

We study optimal pricing and production strategies faced by a manufacturer in a remanufacturing/manufacturing system. In the reverse channel, returns are collected under a name-your-own-price (NYOP) bidding mechanism. The manufacturer has a limited capacity to produce new and remanufactured products. We characterize the optimal decisions of the consumers and the manufacturer. We find that under the NYOP mechanism, the manufacturer's optimal strategies mainly depend on the bidding cost, the cost saving of remanufacturing, the production capacity, and the market scale. In addition, when remanufacturing needs more capacity than manufacturing , the manufacturer may adopt pure manufacturing strategy without remanufacturing. We also compare this mechanism with the traditional list-price mechanism and find that the manufacturer prefers the NYOP mechanism under the conditions of a low reverse market share, a high manufacturing cost, a sufficient capacity, or a low capacity requirement of remanufacturing. Numerical studies investigate the effect of key parameters on the manufacturer's profit and some managerial insights are obtained.

1. Introduction

Nowadays the environment protection is becoming one of the most pressing issues all around the world. To protect the environment, legislation has been introduced into Europe, North America, Asia and South America to encourage enterprises to enhance the awareness of environmental protection (Zeng et al., 2013; Lagarinhos and Tenório, 2013). In China, the situation seems more urgent. The grievous haze diffusing the whole country in the winter of 2013 has made Chinese people reconsider the huge environmental cost of rapid economic development during the last 35 years.

Besides environmental legislation, more and more companies become interested in remanufacturing operations because of economical benefits (Kaya, 2010). Empirical evidences show that in the process of recycling and remanufacturing, labor, energy as well as materials can be saved, and production lead time is also reduced. In the practice of remanufacturing, the capacity constraint and the mechanism design are two important problems. The former means that the manufacturer may not have enough production capability, which hinders the willingness to collect returns, and the latter means that the manufacturer should design an effective network and mechanism to collect used items. Therefore, it is imperative to simultaneously address these two issues in order to achieve a sustainable remanufacturing strategy.

In the practice, we find that there are two pricing mechanisms used to acquire returns: list-price strategy and name-your-own-price (NYOP) strategy. Traditionally, the OEM offers a list price for all the consumers and then each consumer decides whether he or she likes to do the return. The NYOP mechanism has become popular since the inception of Priceline in 1998. In the NYOP auction, a given price is fixed for every item. This price is called reserve price, and a consumer wins the item only if his or her bid is no less than the reserve price. Now this mechanism has already been widely used in the reverse logistics. In China, a typical example is a famous e-commerce website built by the largest e-commerce company in China, Alibaba Group. This website is specially for collecting second-hand items such as used mobile phones. On this website, used items are listed with a price named by the owners. Some items are clearly labeled with 'no bargaining' while others are not. Even though this website was initially created for other consumers to buy cheaper items, companies such as mobile phone manufacturers can also obtain used items as remanufacturing materials from these channels. Another example is the on-line resource recycling platform named China Resources

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Recycling. On this platform, sellers can name their own prices for the returned products and wait for buyers who can accept these bids. Besides on-line auction, the NYOP strategy has also been applied by many bricks-and-mortar recycling markets in China. In January 2013, Yahoo! News reported that a successful recycling business yielded more than 600 millionaires from Hubei Province in China. All of them have worked as scrap traders. During the scrap trade process, it is a common practice that the trader asks consumers to name their own price to trade recyclables. In these above business practices, if the consumers charge different prices, the payment from manufacturers may be different even if the returns are in similar conditions. This mechanism that consumers name the price is obviously different from the traditional list price mechanism that manufacturers name an identical price. Gönsch (2014) notices consumers' heterogeneity and challenges traditional posted-price(list-price) mechanism. He studies a bargaining process where the manufacturer initially sets an identical price paid for used products and consumers with heterogeneous valuation of used products can then bargain with the manufacturer. Different from the traditional posted price mechanism, the final payment is not identical for different consumers. This important feature is very similar to the NYOP mechanism. For example, the manufacturer's price in the bargaining is very similar to reserve price under the NYOP mechanism.

In this paper, we mainly investigate two important issues: (1) What are the optimal strategies of consumers and the manufacturer under this new NYOP mechanism? (2) How does the manufacturer make a choice between the NYOP mechanism and the traditional list-price mechanism? To address the above issues, we study optimal pricing and production strategies faced by a manufacturer in a remanufacturing/manufacturing system. In the reverse channel, returns are collected under a name-your-own-price (NYOP) bidding mechanism. The manufacturer has a limited capacity to produce new and remanufactured products. We characterize the optimal decisions of the consumers and the manufacturer. Numerical studies investigate the effect of key parameters on the manufacturer's profit and some managerial insights are obtained. We believe that our findings can help the manufacturer make the optimal choice about the pricing mechanism for return collection. Specifically, our paper contributes to the existing literature in threefold. First, we creatively introduce the NYOP mechanism for return acquisition into remanufacturing system. As many scholars argued (Gönsch, 2014; He, 2015; Zhou and Yu, 2011), return acquisition from consumers is one of the most important issues in remanufacturing. Therefore, the consumers' behavior plays an important role in the reverse logistics. We model the consumers' objective function and decision variable under this new NYOP mechanism. Our work enriches the studies of consumers' behavior in the reverse logistics. Second, we compare the NYOP mechanism with the traditional list-price mechanism, and find the conditions under which the manufacturer prefers the NYOP mechanism or the list-price mechanism, which explains why both NYOP mechanism and list-price mechanism are used in practice. In addition, it helps the manufacturer make the optimal choice about pricing mechanism. Third, we also consider the capacity constraint of production which makes this paper more realistic and complex.

The remainder of this paper is organized as follows. In Section 2, we make a brief literature review and state the innovation of this paper. In Section 3, the model and assumptions are presented. We first investigate the case that remanufacturing consumes less capacity than manufacturing and then the case that remanufacturing consumes more capacity. In Section 4, the effect of parameters associated with the NYOP mechanism is investigated through numerical experiments. We also compare these two mechanisms in this section. Section 5 summarizes the main results and points out some directions for future research. All the proofs are given in the appendix.

2. Literature review

The most related stream of research focuses on the pricing mechanism for return collection. Under the list-price strategy, Savaskan et al. (2004) address the problem of choosing the appropriate reverse channel structure for the collection of used products from consumers. They find that among these three recycling models, the retailer is the most effective undertaker of product collection activity for the manufacturer. Sun et al. (2013) study a multi-period acquisition pricing and remanufacturing decision problem under random price-sensitive returns, and they analyze characteristics of the optimal acquisition price and derive a monotonic pricing policy depending on the starting level of the whole inventory in each period. Atamer et al. (2013) focus on pricing and production decisions in utilizing reusable containers with stochastic customer demand. In their model, the return quantity depends on both demand and the acquisition fee determined by the manufacturer. Bulmus et al. (2014b) consider acquisition prices offered for returns with different quality types and on selling prices of new and remanufactured products. He (2015) models a closed-loop supply chain (CLSC)with a manufacturer and its supply channels-recycle channel and reliable supply channel, and he finds the effect similar to double marginalization often occurred in the normal forward supply chain. To the best of our knowledge, only very few researchers investigate the NYOP mechanism in recycling. Most research about NYOP pricing mechanism which focus on the forward flow provides us some managerial insights and hints. As argued by many researchers, the NYOP channel provides a niche market where consumers are sensitive to price or psychologically prefer this kind of auction (see Segan, 2005). Terwiesch et al. (2005) provide dynamic programming models to identify the optimal bidding strategy for consumers, and their results show that a haggling model may be better than a list-price model if the consumers are rather heterogeneous. Ding et al. (2005) and Cai et al. (2009) study the case where there exist both NYOP channel and list-price channel. Furthermore, Wang et al. (2010) examine the NYOP retailer's information revelation strategy when competing with list-price channel. Their results suggest that the NYOP mechanism can increase the expected profit for supply chain participants. Mostly related to our work in reverse logistics, Gönsch (2014) and Agrawal et al. (2015) notice the consumers' heterogeneity and adopt a generalized Nash bargaining solution to model the negotiation outcome. Gönsch (2014) studies a bargaining process where the manufacturer sets an identical price paid for used products and consumers with heterogeneous valuation of used products can bargain with the manufacturer. Agrawal et al. (2015) investigate when and how an original equipment manufacturer should offer a trade-in rebate to recover used products in order to achieve better price discrimination and weaken competition from third-party remanufacturers. Slightly different from our work, they use exogenous parameters to model negotiation outcome in equilibrium, therefore, the consumers' objective function and decisions are not well investigated.

The other related research is on capacity constraint problem, Bayındır et al. (2007) investigate the effect of finite production capacity and initial inventory levels on the optimal policy as well as the effect of substitution policy on the optimal order-up-to levels and the expected profit. However, they assume that the market demand is independent of retail price and ignore the pricing decision. Georgiadis et al. (2006) study how the lifecycles and

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