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Benefits of RFID technology for reducing inventory shrinkage

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ABSTRACT

Inventory shrinkage is prevalent in many industries. Radio Frequency Identification (RFID) technology has been regarded as a promising solution for inventory inaccuracy. Many retailers endeavor to push their suppliers to adopt this technology. This paper considers the situation of a retailer subject to inventory inaccuracies stemming from shrinkage problems. We apply a newsvendor model to analyze how to reduce inventory shrinkage problems by deploying RFID. We study two scenarios for managing an inventory system with shrinkage problems. In the first scenario, the retailer optimizes its operations only by taking into account the inventory shrinkage problems. In the second scenario, the retailer further improves its operations by deploying RFID. We analyze inventory shrinkage problems by optimizing order quantities and expected profits in consideration with the effect of the available rate of ordering quantity, RFID read rate improvement, and the tag price, respectively. The results show that whether the retailer deploys RFID depends on the relative value of the available rate of ordering quantity and RFID read rate improvement. We also present a formulation of the threshold value of tag cost which makes the deployment of RFID cost-effective.

1. Introduction

Inventory inaccuracy is a major operation problem in many supply chains. According to DeHoratius and Raman (2008), inventory inaccuracy occurs when the inventory record does not match the physical inventory that is actually available. An empirical study by DeHoratius et al. (2001) reports that out of close to 370,000 SKUs investigated, more than 65% of the inventory records did not match the physical inventory at the store-SKU level. Moreover, 20% of the inventory records differed from the physical stock by six or more items. Most of the investigations dealing with this issue provide the factors generating errors in inventory systems, and conclude that shrinkage is the main factor generating inventory inaccuracy (Rekik, 2010).

Shrinkage includes inventory theft, spoilage, and damage. Customers can spoil or damage products by tearing a package to try on the contained cloth item, wearing down a shoe by trying it on and walking, erasing software on computers during demonstration, spilling food on clothes, or scratching a car during a test drive (Bensoussan et al., 2007). As a consequence, some products are unavailable for sale. An ECR (Efficient Consumer Response) (2003) Europe project's research shows that the scale of shrinkage in the fast-moving consumer goods sector is 2.41% of the whole turnover value of the sector. Process errors account for 27% of the shrinkage value, 7% is due to deceptions, 28% is due to internal thefts, and 38% is due to external thefts.[1]

Radio frequency identification (RFID) technology has been publicized as a promising solution for inventory shrinkage. Lee and Özer (2007) indicated that RFID can help reduce inventory shrinkage in three ways. First, the ability to accurately monitor inventory can reduce theft and avoid fraud, leading to a direct reduction of inventory shrinkage. Second, depending upon the achieved read accuracy, RFID enhances the accuracy of the information currently obtained through barcode scanning, which is more vulnerable to human error. Third, by providing visibility so that inventory records more closely correspond to actual inventory, replenishment can be more accurate, leading to fewer stock-outs. From an inventory management point of view, Rekik et al. (2009) argued that RFID has two principal values. First, the visibility provided by RFID technology highlights shrinkage problems, ensuring accurate knowledge of actual inventory levels by eliminating the discrepancy between physical and information flows. Second, RFID technology "corrects" shrinkage problems by eliminating them. A study by de Kok et al. (2008) of the effects of RFID technology derived a similar result. Despite the application of RFID mainly at the case level and the pallet level, many researchers have realized its possibility for wider use at the item level as the tag cost descends, and given attention to product application, such as Gaukler et al. (2007), Zhou (2009), and Szmerekovsky and

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[1] http://www.ecr.org/2003

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Zhang (2008). Therefore, we will investigate the effectiveness of RFID technology at the retail level.

1.1. Related literature

Studies related to RFID in inventory management are relatively new. There is some recent work on analysis of inventory inaccuracy. Heese (2007) considered inventory record inaccuracy in a supply chain model, where the Stackelberg manufacturer sets the wholesale price and a retailer determines how much to stock for sale to customers. By contrasting optimal decisions in a decentralized supply chain with those in an integrated supply chain, the results show that inventory record inaccuracy exacerbates the inefficiencies resulting from double marginalization in decentralized supply chains. In two other papers, Sahin (2004) and Sahin and Dallery (2009) analyze the case of a wholesaler that is not aware of inventory errors (or chooses to ignore them) in order to evaluate the efficiency loss due to errors compared with an error-free situation. They assess the effect of various actions for tackling the inventory inaccuracy issue, with a particular focus on actions such as the deployment of a new data capture technology, and finally quantify the economic impact of uncertainty on the inventory level. Contrary to these papers, rather than focusing on inventory inaccuracy in both integrated and decentralized supply chains, we explicitly model profits of the retailer with inventory shrinkage and remove operational inefficiencies by deploying RFID technology.

Among the few studies that analytically deal with the value of RFID in inventory control, Dutta et al. (2007) examine three dimensions of the value proposition of RFID and attempt to identify areas for further investigation. Lee and Özer (2007) argue that there is a huge credibility gap of the value of RFID, and that a void exists in showing how to arrive at the proclaimed values and how those values can be realized. Lee and Lee (2010) present the supply chain RFID investment evaluation model and provide a basis for enhancing our understanding of RFID value creation, measurement, and ways to maximize the value of RFID technology. Rather than analyzing the value of RFID at the pallet level in a supply chain, we study item-level RFID for coping with inventory shrinkage in a retail store. Our work is also distinguished from their model in that we consider RFID cost issues in inventory decisions. Additionally, rather than searching for retailer or manufacturer benefits from the technology in addition to those where the incentives are aligned, we are particularly interested in analytically identifying the threshold.

Camdereli and Swaminathan (2010) consider a supply chain under the misplacement of inventory and study both centralized and decentralized cases, identifying the conditions to coordinate the supply chain under the implementation of RFID. The results show that the incentives of the parties to invest in the technology are not perfectly aligned in the existence of the fixed cost of investment. Based on the relative payments of the parties for the fixed cost of investment, the incentives to adopt RFID can be characterized into regions, where they observe only one or two parties benefiting from the technology when the tag price falls into a specified region. In this paper, we research the effects of RFID adoption on the retail store rather than the whole supply chain. Instead of analyzing both the RFID tag costs and the fixed costs of technology investment, we consider only the RFID tag cost investment, since the fixed costs of technology investment account for only a relatively small part of the total cost of item-level RFID investment.

Rekik et al. (2009) is a closely related paper to our work. The focus of the authors is to analyze the problem of theft in a store by optimizing the holding cost under a service level constraint. They also analyze the value of RFID technology in the inventory system, and propose an analytical critical tag cost which makes the deployment of RFID technology cost-effective. Rather than considering perfect RFID technology which could eliminate theft errors completely, we suppose that only a part of shrinkage errors can be eliminated because RFID is imperfect, which is closer to the actual situation in retail stores. In their work, they do not consider the cost for stock-out and the incentive issues as a result of implementation of RFID. In our work, we incorporate the penalty cost for stock-out using RFID in the model and focus on the incentive of retail stores to deploy such a technology. Additionally, we further analyze the effect of available rate of ordering, RFID read rate improvement, and the tag price, respectively.

1.2. Our paper and contributions

This paper studies how to reduce the effects of inventory shrinkage problems by deploying RFID. We consider two different scenarios. In the first scenario, the retailer optimizes its operations only by taking into account the inventory shrinkage problems. In the second scenario, the retailer further improves the inventory system by deploying RFID. We analyze the effect of available rate of ordering, RFID read rate improvement, and the tag price, respectively; the results show that the decision to deploy RFID depends on the available rates of ordering and RFID read rate improvement. When the available rates of ordering fall below the critical value, the retailer gains a higher profit by deploying RFID. We also propose an analytical critical tag cost which makes the deployment of RFID cost-effective.

The remainder of the paper is organized as follows. In Section 2, we describe the issue of shrinkage and discuss the two different scenarios that can be used to model the issue. We also analyze the lemmas of our model in two scenarios. Finally, assuming that demand is subject to the uniform distribution, we derive the optimal order quantity and expected profits. In Section 3, we develop the parameters of the sensitivity analysis through a numerical example. We analyze the effect of available rates of ordering, RFID read rate improvement, and the tag price, respectively, and we also provide an analytical expression of the cost of the RFID tag, which makes the deployment cost-effective. In Section 4, we conclude our paper and point out the direction for further research.

2. A general inventory framework for inventory shrinkage

We consider that a retailer's products are provided by the supplier at a unit cost c, and the retailer sells a single seasonal product to end customers at a unit price p. The inventory decision of the retailer is made within a one-period newsvendor framework, the aim of which is to find the optimal order quantity and expected profit under uncertain demand. One of the underlying assumptions in the formulation of the newsvendor problem is that there is no misalignment between the physical and information flows, meaning that the retailer operates without execution errors (Rekik et al., 2008). Considering the shrinkage problem, the newsvendor model should be revisited.

In order to model the impact of the shrinkage problem, we define α as the random variable which reflects the effect of shrinkage on the real quantity which is available to end customers during the selling season: α is the ratio between the real quantity which is available to end customers and the total physical quantity available in the store. Under our modeling assumptions, the two situations are equivalent since knowledge of the available rate of ordering quantity and point-of-sale data will directly provide information on the realization of demand for shrinkage.