


An Item-Level RFID Investment Decision in Green Supply Chain Considering Information Leakage

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ABSTRACT

The entry of potential competitors disrupts the original market equilibrium, which in turn hinders the adoption of RFID technology. This paper focuses on a supply chain consisting of one supplier and two retailers in a master-slave relationship. It develops a decision model for RFID investment, employing a simultaneous game to analyze how RFID technology influences the revenue and strategic behavior of supply chain members. Based on numerical analysis, the key findings of this study are as follows: (1) The adoption of RFID technology increases the revenue of both retailers to some extent. (2) The incumbent retailer demonstrates a stronger ability to withstand risks. (3) The maximum label cost and revenue-sharing rate that suppliers can bear are influenced by the market equilibrium in the absence of RFID. This study offers both theoretical and practical insights for promoting RFID technology in competitive markets.

KEYWORDS

Green Supply Chain, RFID, Information Leakage, Signal Game

INTRODUCTION

Green supply chain management (GSCM) is a supply chain model that integrates environmental protection principles, focusing on addressing environmental issues at each stage of the supply chain. This approach promotes the coordinated development of economic growth and environmental sustainability, helping enterprises reduce resource consumption, minimize pollution, and enhance operational efficiency.

Radio-frequency identification (RFID) technology—a non-contact and remote automatic identification tool—has become essential in supply chain management and logistics, enabling effective tracking and data collection (Unhelkar et al., 2022). Compared to traditional barcodes, the advantage

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of RFID technology is achieved by the reusability of its tags (Shin & Eksioglu, 2015). In addition, RFID tags can be repurposed by uploading new information into the tags, which results in significant cost savings and environmental benefits (Nayak et al., 2015). By connecting manufacturers, suppliers, retailers, and consumers, RFID enhances the efficiency, cost-effectiveness, and environmental responsibility of GSCM operations.

In China, Cainiao has extensively used RFID technology to monitor and manage green logistics, particularly for reusable logistics boxes and cross-border parcels. According to the 2021 Double 11 Cainiao (2021) Green Logistics Report, during the 2021 Double 11 shopping event, Cainiao's green logistics initiatives, supported by widespread RFID use, reduced carbon emissions by 53,000 tons.

RFID technology in green product production enables real-time, accurate inventory tracking, reducing misplacement and commodity loss (Li et al., 2021). During the recycling of waste products, RFID records product information to increase recycling efficiency and recovery rates (Conдеми et al., 2019). Implementing RFID throughout the green supply chain can significantly enhance overall operational performance, improve economic returns, reduce environmental impact from waste, fulfill corporate social responsibilities, and establish a positive corporate image (Luo et al., 2022).

Despite its advantages, RFID adoption faces several challenges. First, in green supply chains, high implementation costs (Amarpreet & Cheng, 2017) and concerns over potential information leakage (Li et al., 2024) present significant barriers. Second, while RFID enhances efficiency, it also raises important ethical and privacy concerns.

The impact of RFID on GSCM practices and environmental performance has garnered increasing attention from researchers. RFID technology functions by encoding information onto a tag, which transmits data to a reader via radio waves, ultimately updating a computer database (Ouadou et al., 2024). This rapid data transmission allows for near real-time information processing, which is highly beneficial for supply chain operations. Over the past decade, the use of RFID in manufacturing has expanded steadily across various stages of the supply chain, maximizing operational efficiency and boosting the in-store customer experience (Swedberg, 2024).

Recently, the implementation of RFID in green supply chains has attracted growing interest, though research in this area is still in its early stages. Researchers are actively exploring the positive correlation between RFID utilization (Nayak et al., 2022) and green supply chain effectiveness, highlighting both the economic and environmental benefits of supply chain collaboration. Rajaraman et al. (2020) proposed that a multi-hypothesis tracking approach with RFID technology can significantly reduce the effort required to search for missing workpieces—by up to 80% in the number of workpieces visited and 60% in distance traveled. This finding emerged from a strategic study involving information and capacity sharing.

Previous research indicates a positive association between RFID technology utilization and improvements in GSCM practices and environmental performance. The current study advances this understanding by examining the specific impact of item-level RFID technology on the sustainability of green supply chains. The authors establish that integrating RFID at the item level can play a crucial role in supporting the environmental sustainability strategies of retail supply chain organizations.

Previous research on RFID technology in GSCM has largely overlooked the risk of information leakage. This study addresses this gap by examining a two-tier supply chain comprising one supplier and two retailers in a master-slave relationship, both selling a single product. The authors analyze how RFID technology impacts the revenues of the master retailer, the supplier, and the entrant retailer, focusing on the simultaneous RFID investment decisions made by the two retailers. Using a Stackelberg game approach, the authors establish a threshold range for the incumbent retailer's revenue-sharing rate with the supplier. The study's analysis provides valuable insights and practical guidance for incumbent retailers considering RFID technology implementation amidst peer competition.

Based on a review of studies on RFID implementation in green supply chains, this research addresses the following key questions:

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