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The impact of RFID and EPC network on the bullwhip effect in the Italian FMCG supply chain

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ABSTRACT

This paper provides a quantitative assessment of the potential reduction in the bullwhip effect, and thus in safety stocks, in the supply chain, thanks to real-time visibility of product flows provided by the Radio Frequency Identification (RFID) technology and the EPC Network. The assessment is grounded on a "representative" Italian Fast Moving Consumer Goods (FMCG) supply chain; specifically, the "representative" supply chain is composed of three echelons, namely manufacturers, distributors and retailers of FMCG, whose main features, in terms of both quantitative and qualitative data, were derived through an appropriate survey phase. Reduction of safety stocks is determined based on quantitative methodologies available in the scientific literature. The results of the assessment show that real-time visibility of the supply chain, brought in by RFID and the EPC Network, can dramatically reduce the bullwhip effect, substantially affecting the economical profitability of the whole FMCG supply chain.

1. Introduction

Radio Frequency Identification (RFID) is the use of an object (typically referred to as an RFID tag), applied to or incorporated into a product, for the purpose of identification and tracking, using radio waves. There are several ways of identifying items using RFID, but most systems consist of two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a radio frequency signal; the second is an antenna for receiving and transmitting the signal.

Product data are stored into the tag chip in form of an Electronic Product Code (EPC). EPC standards have been developed by the Auto-ID Center, a partnership founded in 1999 by five leading research universities and nearly 100 leading retailers, consumer products makers and software companies (Niemeyer et al., 2003). EPC data of products are then passed to and shared through the EPC Network, which, according to EPCGlobal (2004), is "a way of leveraging the internet to access a large amount of logistics information that can be shared among authorized partners". Once EPC data are collected by reading RFID tags of cases and pallets, EPC numbers become secure data on companies' middleware.

Today, RFID is widely used in enterprise supply chain management to improve the efficiency of inventory tracking and management. In the logistics pipeline, RFID technology is expected to have a major impact on the efficiency of the whole supply chain. Commonly quoted benefits of RFID encompass increased processes automation, enhanced labour efficiency and better accuracy of logistics processes (Agarwal, 2001; Prater et al., 2005). There are several reasons for this diffusion, such as the capability of RFID tags to provide more information about products than traditional barcodes, as well as to avoid manual operations required to read them (Boxall, 2000; Bylinsky, 2000; Jones, 1999; Moore, 1999), thus improving process automation (Jones et al., 2004; Karkkainen, 2003).

Exploiting the EPC Network for data sharing enables users to find on the internet data related to a specific EPC and to gain access and retrieve those data. Through real-time data sharing, companies have broad and plain visibility over logistic flows and can leverage this information to optimize logistics processes and supply chain management. In the context of grocery retailing, the availability of real-time information throughout the supply chain is regarded as the main benefit of a wide employment of RFID technology EPC Network (Prater et al., 2005). Additional outcomes of RFID deployment can be found in increased inventory visibility, stock-out and safety stocks reduction, real-time access and update of store inventory levels, automated Proof Of Delivery (POD) (Fernie, 1994), availability of accurate Points Of Sale (POS) data and better control of the whole supply chain (Bushnell, 2000).

The earliness of sharing information is recognised to significantly improve supply chain performance (Karaesmen et al., 2002), while delays in information sharing are often identified as one of the major causes of the bullwhip effect (Hong-Minh et al., 2000). RFID technology, coupled with the EPC Network, enables the real-time exchange of necessary information between supply

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chain players, thus solving issues related to lack of communication (Asif and Mandviwalla, 2005; Lin, 2009). This is why RFID technology and the EPC system are also suggested as viable tools to reduce the overall supply chain inventory waste caused by the bullwhip effect (Lapide, 2004; Alinean, 2006). However, although RFID is expected to reduce costs, research indicates that RFID solutions may not be economically profitable (Becker et al., 2009; Fosso Wamba et al., 2008); carrying out a quantitative assessment of RFID impact on supply chain costs can provide valuable findings in this regard.

On the basis of the above premise, the purpose of this paper is to quantify the potential of RFID technology and the EPC Network in reducing the bullwhip effect, and thus safety stocks, in the Italian Fast Moving Consumer Goods (FMCG) supply chain. The paper is organized as follows. In the next section, the bullwhip effect is briefly described, together with available studies that assess the impact of automatic identification technology on the bullwhip effect and inventory management. In Section 3, after an overview of the case being examined and of the methodology followed for data collection, we quantify the impact of RFID technology and the EPC Network for safety stocks reduction for the FMCG supply chain. Concluding remarks and future research directions are finally proposed.

2. Literature analysis

2.1. The bullwhip effect: overview and quantitative models

Lee et al. (2004a), define the bullwhip effect as a phenomenon where orders to the supplier tend to have a larger variance than sales to the buyer, and the distortion propagates upstream in an amplified form. The bullwhip effect involves both demand distortion and variance amplification moving upstream the supply chain. Such effects were first demonstrated by Forrester (1961) and are currently observed in several supply chains (see Lee et al., 2004b; Geary et al., 2006, for several examples). Demand distortion causes excessive inventory, poor forecasts, loss of revenue, excessive/insufficient production capacity, and inaccurate production plans throughout supply chain systems (Lee et al., 2004a).

The bullwhip effect can be ascribed to four major causes (Lee et al., 2004a): (i) demand signal processing; (ii) order batching; (iii) price fluctuations; and (iv) rationing and shortage gaming. In this paper, we focus on the first cause. This refers to variance amplification generated by imperfect information on product demand. Demand forecasts rarely match data related to real consumption, since each supply chain echelon estimates future demand based on orders received from the previous echelon. Hence, adopting only forecast data to predict the final demand of products leads to distorted information. Such distortion is amplified upstream the supply chain, if, at each echelon, only information on orders received is used to predict demand. Long lead times are also recognised as further amplifying this phenomenon.

Several works that develop analytical models to quantify demand amplification due to the bullwhip effect by separately investigating the different causes are available. Our literature review was focused on statistical inventory control models for bullwhip effect assessment, as they are used in this study. One of the first attempts to quantify the bullwhip effect was performed by Chen et al. (2000). These authors investigated the impact of demand forecasting, lead time and information sharing on demand variability in a three-echelon supply chain, quantifying the increase in the bullwhip effect due to those factors. The variance ratio (i.e., the ratio between the demand variance at the downstream and at the upstream stages of the supply chain) was analytically derived by the authors as a viable measure of the bullwhip effect for each cause previously mentioned. Following a similar approach, Lee et al. (2004a) have analytically computed the increased variability of demand as a consequence of three out of the four causes of bullwhip effect, namely demand signal processing, rationing and shortage gaming and order batching. Through a simulation model, Chatfield et al. (2004) have examined the effect of stochastic lead time, information sharing and the level of information quality on demand variance amplification in a multi-echelon supply chain. A simulative approach was also exploited by Holland and Sodhi (2004), who strived to quantify the impact of order batching on the bullwhip effect of a simple supply chain. As a result of the simulations, regression models for variance amplification were derived for manufacturer's and retailer's orders.

2.2. RFID as a tool for reducing the BE

The scientific literature has indicated real-time information sharing between supply chain partners as the main benefit that can be achieved when EPC data on products and pallets/cases become available to all players through the EPC Network. This involves improved supply chain visibility and availability of updated point-of-sale data, which, in turn, are recognised as viable tool to reduce the bullwhip effect caused by imperfect demand signal processing (Asif and Mandviwalla, 2005).

In light of the above, several studies have appeared that discuss the benefit of information sharing to reduce the bullwhip effect (e.g., Cachon and Fisher, 2000) or to improve inventory management (e.g., Kelepouris et al., 2008). Similarly, it is recognised that RFID is a suitable technology to manage the bullwhip effect (Wilck, 2006; Pålsson, 2008). Among recent works, Wang et al. (2008) simulated the impact of RFID on the inventory replenishment of the Taiwanese thin-film transistor liquid-crystal display supply chain. They found that the RFID-enabled supply chain benefits from a 6.19% decrease in total inventory cost, and that the degree of improvement of stock level is less appreciable at the retailer's tier. Sarac et al. (2008) analyzed the economical impact of RFID technologies on supply chain performance. They compared the effects of RFID technologies with different tagging levels for different product types and investigated the corresponding impact on the resulting ROI. The results indicate that different technologies can improve the supply chain performance at different ratios, and that the economical outcomes depend on the chosen technology, the tagging level and the product investigated. Fleisch and Tellkamp (2005) simulate a one-product, three-level, supply chain. They detail shrinkage errors as low process quality, theft, and items becoming unavailable for sale. They compare two models with and without an inventory-level alignment. Their results show that the elimination of inventory inaccuracy, even as small as 2%, can reduce out of stock and supply chain costs. Moreover, Bagchi et al. (2007) suggest that RFID technology can be successfully used for improving the flow of information, which, in turn, reduces the variance of an inventory system, and thus its costs.

However, most of the existing studies do not precisely focus on providing a quantitative analysis of how (and to what extent) RFID affects inventory management by reducing the bullwhip effect and the amount of safety stock in the supply chain. Wilck (2006) argues that this is due to the fact that RFID introduction for supply chain management is relatively new and its benefits are still being researched. Hence, we aim at extending the previous studies by providing a quantitative assessment of the impact of RFID in reducing the bullwhip effect in a real supply chain.