



Managing product quality risk and visibility in multi-layer supply chain

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ABSTRACT

The Chinese melamine milk recall and a series of product harm scandals ranging from milk powder to chocolate bar indicate that firms and consumers alike are vulnerable to quality risks in a global supply chain. Supply chains are extended by outsourcing and stretched by globalization, which greatly increase the complexity of supply network and decrease the visibility in risk and operation process. It is hard for firms to manage the product quality of such a multi-layer supply chain which has a low traceability of material origin. In this paper, we argue that better visibility of risk in supply chain could minimize the threat of product harm. A supply chain product quality risk management framework, integrating both the incremental calculus and marginal analysis, is proposed. Case study results indicate that the proposed approach has the following benefits: (i) providing evaluation of the product quality risk in supply chain layers; (ii) allowance for firms to have a better 'visibility' of product quality risks in supply chain; and (iii) a traceable justification path for multi-sourcing decision.

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1. Introduction

A wide range of product recall is announced in recent years, ranging from food product to non-food product. Especially, most of these recalled products were made or sourced from China. In 2008, out of the 86 consumer products recalled in the UK, 72% of these recalled products were made in China (RAPEX, 2009). This may be due to the large amount of exports from China, high customer demand, complexity of supply network and large magnitude of global sourcing. Melamine milk incident in 2009 was a classic example of product recall. The recall events were followed by an avalanche of reports in government agency and the press about quality problems with other Chinese-made products. As in all cases both governments and consumers wanted these products promptly to be removed from the marketplace due to the health and safety concerns.

The melamine incident also reveals a fact that there is a domino effect of product recall from bottom of the chain—raw material suppliers to the frontend customers all over the chain. The major cause of this effect is that some of upstream supply chain members add the toxic substance, melamine, to artificially inflate the protein of the milk by increasing the nitrogen level, which is the key test-indicator to influence the protein level in the milk to be acceptable.

This example illustrates that, as supply chains are extended by outsourcing and stretched by globalization, disruption risks and lack of visibility into a supplier's status can both worsen (Yang et al., 2009). It is very hard for firms to manage the visibility of a long or "deep" supply chain which has a low traceability of material origin. Especially, it is a great challenge for a foreign firm to keep track of who did it, what he did and when he did, to the final quality of the products (Lyles et al., 2008). The possible causes of product quality problem in "low visibility" supply chain are myriad, such as, poor material from supplier, non-conformance incoming inspection in manufacturer, product contaminated or damaged during logistics operations.

It is important to make manufacturers aware of anticipation, preparation and managing potential supply quality problem when the supply risks rise. The losses due to product harm crisis can be huge. For example, when China Mengniu Dairy announced the recalls of its tainted product on 17 September 2008, Hong Kong Stock Exchange suspended trading in shares of Mengniu and its stock price dropped almost 60%.

A manufacturer has a number of risk management strategies when managing supply quality risk, including supplier qualification screening, multi-sourcing, flexibility, and penalties levied for supplier non-performance (Yang et al., 2009). Some researches focus on contract designing issue for obtaining the equilibrium outcome that the penalty clauses are adopted as recover damage in non-delivery (Baiman et al., 2000; Yang et al., 2009), or base on the information from the incoming inspection and the external failure (Balachandran and Radhakrishnan, 2005). Intuitively, the effectiveness of supply chain risk management strategies depends on visibility among supply chain members and the manufacturer.

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For instance, if the manufacturer knows that his purchasing order is being outsourced to mainland China by the supplier, the supply risk management strategies would likely be different. Actually, suppliers often have better information about product quality risk than the focal firm does, because of the suppliers' private knowledge of state of operations, quality in production and input sources (i.e. a situation of asymmetric information between buyer and seller).

The majority of recent papers treated the product quality problem as production quality problem (Tannock and Balogun, 2007; Karim et al., 2008; Halesand and Chakravorty, 2006) and supply chain risk management mainly focused on supply chain disruption (Yang et al., 2009; Baiman et al., 2000; Tomlin, 2006). Hwang et al. (2006) examined the arrangement of vendor certification and appraisal in mitigating the problem of supplier quality, but they looked into the problem in inspection strategies and there was nothing much related to the sourcing strategies in supply network. There were only few researches considering the product quality problem in the global supply chain context. Zhu et al. (2007) proposed a quality improvement strategy along the supply chain that both buyer and seller had an incentive to invest in quality investment effort. However, their model did not take into account the supply chain visibility issue between the buyer and seller.

To address these gaps in the current literature, we investigate the interaction between product quality risk, supply chain visibility, quality related costs and multi-sourcing decision. In this context, we seek to address the following questions:

- Research Question 1: How to evaluate the product quality risk and its visibility in multi-layer supply chain environment?
- Research Question 2: How does a manufacturer select the appropriate sourcing suppliers with consideration of supply reliability and visibility?

In answering these questions, we develop a decision support framework for product quality risk management, which incorporates various supply risk management strategies, including supplier qualification screening, multi-sourcing, penalties levied for supplier's defects. We also propose a marginal incremental analysis-based approach as the basis of mitigating quality risk in their multi-tier supply chain so that an integrated multi-criteria decision path is developed. The proposed marginal incremental analysis approach is a sequence of transparent steps to provide clarity of thought into the evaluation and selection process that decision makers undertake.

In the following sections, the development of the proposed approach is explained. Section 2 discusses the recent literatures and Section 3 describes the background and motivation to adopt a marginal incremental analysis-based approach in the product quality risk management framework. Section 4 describes Model of product quality risk, product quality related cost, and visibility. In Section 5, a case is used to illustrate the application of the proposed approach. Finally, the results are described and implications of this research for industrialists and academics are discussed.

2. Literature reviews

2.1. Supply chain quality management

Most of the extant research on supply chain quality management assumes that the product quality risk is a poor quality control in production of manufacturer. Also, they consider quality management and supply chain management as two separate

entities (for example, Kannan and Tan, 2002; Tan et al., 1998). A few studies attempted to advance the understanding of Supply Chain Quality Management (SCQM) with supplier evaluation (Lin et al., 2005; Lo and Yeung, 2006), but their models were not comprehensive. For instance, Lin et al. (2005) included QM practices, supplier participation and supplier selection while Lo and Yeung (2006) put supplier selection, supplier development and supplier integration as the components of SCQM. However, these models neglected the evaluation of supply risk embedded in the multi-layer supply chain. Also, they neglected the need for evaluating the suppliers with actions such as information sharing, process audits and inspection analysis.

2.2. Supply chain risk management

The attention of supply chain risk management is raised after "The Albuquerque Incident" happened in March 2000. It shocked all industrial areas as Ericsson got a major loss of about US\$400 million indicated in 2001 just primarily due to gaps in supply of radio chips from these suppliers (Norrman and Jansson, 2004). Current risk management options for protecting the consumer are precautionary and are aimed at risk reduction. It should be noted that risk can never be completely eliminated and a "zero risk" cannot be proved (Bradley, 2003). Modern business management incorporates risk and risk taking (Smallman, 1996); however, there is a perspective that traditional perceptions of risk management view human risk taking as the root cause of accidents (Adams, 1995). Despite this view, businesses firms usually strive ways to trade-off risks, benefit and perform some form of balancing of risk and reward (Adams, 1995). The way that they make these trade-offs depends on what are deemed to be acceptable level of risk, the size of the benefit and the attitude of the organization to risk taking (Smallman, 1996; Adams, 1995). Some organizations and individuals are highly risk-averse while others are risk-takers (Harland et al., 2003).

Supply chain risk management has attracted interest from both researchers and industrialists. Yang et al. (2009) had grouped the tools for managing supply chain risk into four main themes: multi-sourcing (e.g., Anupindi and Akella, 1993; Babich et al., 2005, 2007), alternative supply sources and backup production (e.g., Serel et al., 2001; Kouvelis and Milner, 2002), flexibility (e.g., Van Mieghem, 2003; Tomlin and Wang, 2005) and supplier selection (e.g., Deng and Elmaghraby, 2005). On the other hand, Microsoft and Arthur Anderson developed a supply risk assessment process—Comprehensive Outsource Risk Evaluation (CORE) system in which Risk is analyzed "objectively". It analyzes supply risk through measures such as financial data or through a combination of objective and subjective measures (Zsidisin et al., 2004). All suppliers are assessed due to key areas: performance, schedule, and cost. A risk rating is assigned by an operation team or functional specialist based on data such as product audits, system evaluations, or/and performance. Furthermore, Ericsson has developed a proactive risk management framework, which involves an in-depth analysis in suppliers and sub-tiers suppliers of critical components in their production lines (Norrman and Jansson, 2004). However, the effectiveness of these frameworks mainly relies on the expert experience and neglects the importance of supply chain visibility in affecting the supply chain risk.

2.3. Supply chain visibility

Most companies now include global sourcing as part of their procurement strategy. It results in a longer supply chain crossing landscape. For instance, there is about half of Mattel Toy production outsourced to the overseas vendor plants. The product quality

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