



# Quality control game model in logistics service supply chain based on different combinations of risk attitude

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## ABSTRACT

The existing quality control studies of supply chain mostly only consider one member's risk attitude, and ignore the combination of two members' risk attitudes. Therefore, a discussion about different risk attitudes affect quality control game of supply chain especially in logistics service supply chain (LSSC) is required. A basic quality control game model (Model I) was established in a LSSC composed of a logistics service integrator (LSI) and a functional logistics service provider (FLSP). In this model, LSI can choose to provide quality supervision or not, and FLSP can choose to accomplish a task according to the quality contract or cheat. The mixed-strategy Nash equilibrium of Model I was presented. A new model (Model II) with different combinations of risk attitudes was then built based on Model I, and the new mixed-strategy Nash equilibrium was provided. The influences of various combinations of risk attitudes on LSI's supervision probability and FLSP's compliance probability were also discussed. Results show that the level of risk attitude of LSI and FLSP should not be unlimited, and an interval is existed respectively. LSI prefers risk-seeking FLSP in order to obtain smaller supervision possibility and larger compliance possibility.

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## 1. Introduction

Many studies reveal that companies have not benefited from production or service outsources, but rather are suffering the penalty cost caused by suppliers' changes in the quality level (Earl, 1996). Moreover, because of the uncertainty in the external environment and the interaction between members of the supply chain, the loss and gain are determined not only by a company's own risk attitude but also suppliers' risk attitude (Gray and Boehlje, 2005). Therefore, logistics service integrators (LSIs) have to consider both the quality level and operational risk of functional logistics service providers (FLSPs) in order to obtain high quality logistics services, when choosing FLSPs in the operation of logistics service supply chain (LSSC), see Liu et al., 2011. Also according to a survey by the Bureau of Economic Operations Adjustment of China National Development and Reform Commission (Liu et al., 2013), service quality ranks 2nd in 2008 and 1st in 2009 in the selection standards of FLSP. This reveals the increasingly significance of service quality in China. In order to obtain better service, many LSIs not only take risk-aversion attitude and select FLSPs with high quality, but also attempt to strengthen supervision on the service operations of FLSPs. In short, in the studies of quality management of logistics services outsourcing, it

is necessary to investigate the interaction of the quality effort level and risk attitude of the supply chain members.

From the perspective of theoretical research, supply chains including LSSC are the typical systems that require coordination. Strengthening the quality supervision by the LSI is the key factors for achieving successful cooperation within a service supply chain (Liu et al., 2013). Considering that the members of LSSC have different risk attitudes, LSI must fully investigate the influence of risk attitude on quality control game for quality coordination in LSSC (Xie et al., 2011). Most of the existing studies on supply chain quality focus on the manufacturing supply chain. Research on quality control game within the service supply chain is relatively inadequate. Moreover, existing studies consider the risk attitude of the selected member of supply chain (such as LSI or FLSP), whereas the interaction of risk attitude of all members is often ignored (Schweitzer and Cachon, 2000; Rabin, 2000; Tapiero, 2005; Wu et al., 2010). Therefore, investigating quality control game based on the characteristics of logistics service products is very necessary.

From the perspective of practice, many industrial instances have demonstrated the necessity of research on the supply chain quality control game with different combinations of risk attitudes. Sichuan East Logistics Company in China, for example, is one of the Chinese AAAA-level logistics companies, with the main business services of undertaking large boilers transportation from the production site to the customers. Such a transport of large products is typically high-risk and high-yield logistics service that generates enormous profits. In practice, Sichuan East Logistics Company incorporates many FLSPs'

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transport capacities, and transports the customer's boiler from Sichuan to other provinces. In the management of the FLSPs, FLSPs are expected to have a certain sense of risk seeking, dare to undertake customers' demand for large products transport services. However Sichuan East Logistics Company does not want its FLSP's risk attitude level too high, as a high risk seeking attitude level (Smidts, 1997) may result in fail of meeting customer's requirements for service quality. Therefore, Sichuan East Logistics Company prefers to select FLSPs whose risk attitude levels are in a good range. In order to ensure high-quality transportation services, the combination of Sichuan East Logistics Company and its FLSP's risk attitude level is limited a certain degree.

With the above motivations, current study aims to investigate the influence of risk attitude combinations on quality control game in LSSC. In order to ensure the cooperation of LSI and FLSP, we try to find the answers about the following questions.

- What kind of risk attitude combination is reasonable?
- Whether there exists a feasible range for the risk attitude combination?
- What kind of risk attitude combination can lead to the best coordination efficiency (i.e. the smallest supervision probability of LSI and the largest compliance probability of FLSP) in LSSC?
- In the case of risk attitude combination, is there an equilibrium in the quality control game?

Based on the model developed by Liu et al. (2013), we initially establish a model for quality control game in LSSC without risk attitude. Then, LSI's optimal supervision probability and FLSP's optimal compliance probability are provided. Finally, we add risk attitudes of both LSI and FLSP into model and develop the model for quality control game in LSSC. Some important findings are established in this paper. For example, the levels of risk attitude of LSI and FLSP should not be unlimited, and an interval should exist between each side's risk attitude to maintain supply chain cooperation. This study also found that LSI prefers risk-seeking FLSP when LSI attempts achieve high supply chain coordination efficiency.

This paper is organized as follows. Section 2 provides the literature review and Section 3 presents the basic game model (Model I) for quality control game in LSSC. With the extension from the basic model, Section 4 primary focuses on discussing the model for quality control game with risk attitude (Model II). The probability changes of quality decision-making of LSI and FLSP at different combinations of risk attitude are also discussed in this section. Matlab 8.0 software is utilized for numerical analysis in Section 5 to verify the main conclusions. The conclusions of this paper are presented in Section 6. The last section outlines the limitations of this study and proposes suggestions for future research.

## 2. Literature review

Researches on quality control games with risk attitude mainly focus on the manufacturing supply chain. While researches on the service supply chain, especially LSSC, are relatively inadequate. This section of literature review includes two aspects: 1) summary of research development on supply chain coordination with risk attitude and 2) review of literature on quality control games in the supply chain.

### 2.1. Supply chain coordination with risk attitude

Given that a supply chain is multi-agent, multi-link, and cross-region, it is vulnerable to the impact of unfavorable factors from the external and internal of the supply chain. These factors create risks in the supply chain. Thus, risk attitudes of the members will have a

significant influence on supply chain performance. Many researchers recently discussed the coordination within manufacturing supply chains based on the risk attitudes of the supply chain members. Some typical methods to measure supply chain risk and optimize supply chain decisions were often utilized. In these studies, risk is measured by different methods such as mean-variance model (Choi et al., 2008; Lin et al., 2010), risk sharing (risk pooling) (Xiao and Yang, 2008), utility theory (Agrawal and Seshadri, 2000a,2000b; Hensher et al., 2007; Kumbhakar, 2002; Wu and Olson, 2008), prospect theory (Schweitzer and Cachon, 2000; Rabin, 2000), value at risk (Tapiero, 2005), conditional value at risk (Wu et al., 2010; Chen et al., 2007), and downside-risk (Grootveld and Hallerbach, 1999). Among these methods, utility theory is the most common one for describing risk attitude behavior. Researchers utilize utility theory to analyze supply chain decisions. Agrawal and Seshadri (2000a,2000b) established the distributor and retailer's expected utility model and proved that risk neutral distributor can optimize classical single-period inventory (newsboy model) by providing a menu contract to the risk-averse retailer. The producers' expected utility function for expected profit was presented by Kumbhakar (2002), who reported that fisheries are averse to risks based on panel data of a Norwegian salmon farm. With the aim to analyze distribution services in the distribution chain, Hensher et al. (2007) studied the influence of shippers' preferences on distribution services by establishing the carriers' utility model. Wu and Olson (2008) developed a utility model for the principal and analyzed the trade-off among expected costs, quality acceptance levels, and on-time delivery distributions by comparing and analyzing the results from the models of chance constrained programming, data envelopment analysis, multi-objective programming as well as simulation.

Analysis of existing researches on supply chain decision-makers' risk attitude indicates that most studies only considered the risk attitude of a single supply chain decision maker (Schweitzer and Cachon, 2000; Rabin, 2000; Tapiero, 2005; Wu et al., 2010) or considered only the influence of the decision-maker with risk-averse attitude on supply chain coordination (Chen et al., 2007; Grootveld and Hallerbach, 1999; Agrawal and Seshadri, 2000a,2000b). However, not all members of the supply chain are risk-averse. Some of them are intended to be risk-seekers (Kocabasoglu et al., 2007). The different risk attitudes of participants may have an impact on supply chain coordination. Therefore, analyzing the different combinations of risk attitudes and their impact on supply chain coordination has become very necessary.

### 2.2. Supply chain quality control game

Quality issues in the supply chain, mostly those with regard to the significance and importance of quality in the manufacturing supply chain (Balachandran and Radhakrishnan, 2005; Seth et al., 2006), and the contract design of quality control have been discussed extensively in literature. The *International Journal of Production Economics* used to publish a special issue for supply chain quality management in which eight papers focus on theoretical models and empirical studies (Cheng et al., 2005). The risk involved in quality control game was also discussed in recent years. For example, Baiman et al. (2000) discussed quality control game in supply chain cooperation based on the moral hazard principle. Lim (2001) established a quality control model with asymmetric information. Kaya and Ozer (2009) investigated the quality risk of outsourcing. Chao et al. (2009) discussed two contractual agreements according to which product recall costs are shared between the manufacturer and supplier to induce quality improvement, for cases where information on the quality of the supplier's product is not accessible to the manufacturer. The results showed that the menu of contracts not only significantly decreased cost caused by information asymmetry but also improved product quality.

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