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## Quality improvement incentive strategies in a supply chain

Seung Ho Yoo<sup>a</sup>, Taesu Cheong<sup>b,\*</sup><sup>a</sup> Division of Interdisciplinary Industrial Studies, Hanyang University, Seoul 04763, South Korea<sup>b</sup> School of Industrial Management Engineering, Korea University, Seoul 02841, South Korea

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### ABSTRACT

This paper investigates several incentive mechanisms for collaborative product quality improvement in a buyer-driven supply chain, and the impacts of those mechanisms on supply chain performance. The buyer, the Stackelberg leader, determines the sales price of a product while the supplier is responsible for production and product quality determination. We develop analytical models incorporating two reward schemes to better understand how the buyer can facilitate the supplier's quality improvement efforts. We offer managerial insights and practical guidelines for implementing quality management in the supply chain, derived from both an analytical comparison and numerical experiments.

### 1. Introduction

Nowadays, firms commonly focus on their core competencies while outsourcing other functions to the suppliers that possess particular technical and cost advantages. This outsourcing trend has yielded various forms of supply chain. In a typical buyer-supplier relationship such as an OEM (original equipment manufacturer)-CM (contract manufacturer) supply chain or a final assembler-supplier supply chain, the buyer determines the design specification of the product and delegates the production to a supplier. Therefore, the supplier should ensure compliance with the design specification of the product while the design quality of the product is specified by the buyer. However, the more sophisticated the competition among supply chains becomes, the more the buyers need to rely on their suppliers to keep up with the changing needs of consumers by improving time-to-market and operational efficiency. Therefore, the recent outsourcing trend does not allow suppliers to only focus on the quality compliance of their production process but requires them to also engage in product design, which entails investing in their own R&D capabilities (Kaya and Özer, 2009; Xie et al., 2011, 2014). For example, Nike cooperates with its suppliers in product design while almost 100% of shoe production is outsourced (Johnsen and Ford, 2007). Similarly Boeing delegated complete control of the design and production of their parts to approximately fifty suppliers in order to reduce the development time and cost of its 787 Dreamliners (Tang et al., 2009). Apple has also involved many suppliers including Foxconn, LG and Samsung at the product design and development stages (Back et al., 2010). Likewise, many of the store-brands or private-label products of retail and grocery chains are designed and made by agricultural and food manufacturers. Under these circumstances, a buying firm needs to find effective and efficient ways to control the supplier's quality decisions, which affect customer demand and subsequently the performance of the overall supply chain.

In this paper, we investigate such a buyer-supplier supply chain in which a buyer delegates the design of a product as well as its production to a supplier, reflecting the recent outsourcing trend we mentioned above, while the buyer determines its sales price. In this situation, the buyer is well aware that, excluding its sale price decision, the supplier's quality decision is the main determinant of its own performance, and furthermore that of the overall supply chain. Hence, the buyer needs to find a way to facilitate the supplier's

\* Corresponding author.

E-mail addresses: [shoyoo@hanyang.ac.kr](mailto:shoyoo@hanyang.ac.kr) (S.H. Yoo), [tcheong@korea.ac.kr](mailto:tcheong@korea.ac.kr) (T. Cheong).<https://doi.org/10.1016/j.tre.2018.01.005>

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quality investment. Therefore, we here investigate reward (or incentive) strategies that differ from the subjects of most previous studies addressing supply chain quality management. Previous studies have mainly dealt with a penalty contract based on inspection results or external failures, an approach which imposes a kind of financial punishment for a supplier's quality failures, in the traditional buyer-supplier relationship. We again remark that in the traditional supply chain a buyer is responsible for product design and maintains a transactional relationship with a supplier while a supplier is responsible for meeting the buyer's design specification. Thus, in traditional supply chain quality management, the buyer typically uses a penalty scheme to control the conformance to design specifications in production. However, if we consider the recent supply chain trend in which the supplier is responsible for not only production but also collaboration with the buyer on product design, it is difficult for the buyer to maintain a short-term transactional relationship and furthermore difficult to impose a penalty scheme that is based on quality of conformance to the design specifications. In this situation, the more appropriate control mechanism may be a reward scheme that proactively facilitates the supplier's quality investment and long-term creative efforts in design activities, rather than reactively punishing according to a penalty scheme.

Therefore, we introduce two reward strategies to facilitate the supplier's quality investment and reveal their different characteristics. The two strategies are differentiated by how they incentivize the supplier's effort based on a target or not. Specifically, one reward contract lacks a target quality level and provides a reward proportional to the supplier's resulting quality level, and the other provides a reward based on a predetermined target quality level, which is determined according to consumers' expectations of product quality. Note that the latter strategy can also penalize the supplier, as in previous studies, if the resulting quality level is below the target level. Through a comparison of the two reward strategies along with a no-incentive strategy, we intend to address the following questions.

- (a) Under what conditions should the buyer consider a reward (or incentive) strategy to facilitate the supplier's quality effort and investment?
- (b) Is it a rational and reasonable decision for the buyer to offer a financial reward to the supplier? Is a reward strategy beneficial to not only the supplier but also both the supply chain and the buyer?
- (c) Which reward strategy guarantees outperformance, specifically, in terms of quality, market, and profit performance of the entire supply chain and of each player?

By answering the above questions, we aim to contribute to the literature by bridging the gap between practice and academia. We will clarify the important implications for supply chain practices by offering practical guidelines to supply chain managers, including how to better facilitate the supplier's quality effort and enhance the overall performance of a supply chain.

The remainder of the paper is as follows. Section 2 provides a literature review and discusses our contributions to the existing literature. Section 3 presents the basic model used to address the problem dealt with by this paper and its centralized version is discussed in Section 4. In Section 5, we specifically examine two reward contract schemes along with the conventional wholesale price contract under the decentralized supply chain configuration, and in Section 6 compare them. In Section 7, we perform numerical experiments and discuss their managerial implications. Finally, we summarize our main results and conclude in Section 8.

## 2. Literature review

There have been many previous studies dealing with issues and problems in supply chain quality management, including Reyniers and Tapiero (1995), Baiman et al. (2000, 2001), Lim (2001), Balachandran and Radhakrishnan (2005), Hwang et al. (2006), Chao et al. (2009), Hsieh and Liu (2010), Volodymyr and Christopher (2012), Wan et al. (2014), Dong et al. (2016) and Gao et al. (2016). They investigated a traditional situation in which a buyer delegates only the production process to a supplier, focusing on how the buyer can minimize total cost by controlling the supplier's quality failures and subsequent defect problems. Most studies adopted a penalty contract as a control mechanism, based on the information from incoming inspections or external failures, since they examined a traditional relationship between players, in which the supplier is only responsible for the product quality conformance to the design specification set by the buyer. Therefore, it is rational and effective to impose a penalty to control the supplier's failure to conform with the specification.

However, we need to note that imposing a penalty can make the relationship adversarial and thus only proper when the buyer just maintains a short-term, transactional relationship with the supplier. On the other hand, if a buyer needs to build a long-term, mutually-beneficial relationship with a supplier as a strategic partner, not only a penalty but also a reward for the supplier's high quality performance should be also taken into consideration. This also holds true when considering the recent business environment where the buyer needs to rely more on the complimentary capabilities of its various critical suppliers (with respect to production as well as product design) to cope with consumers' changing preferences and needs. Thus, our study has more in common with previous studies investigating reward contracts than those investigating penalties only. Starbird (2001) examined the performances of two different quality control schemes, i.e., reward and penalty schemes. This study, like ours, considered the financial incentives for the supplier's quality performance given a target quality level. However, unlike ours, Starbird (2001) did not consider the effect of quality on consumers' buying behavior, and the reward for quality performance was not a decision variable. Schmitz (2005) examined a principal-agent model in which the agent determines quality and the principal is the user of an innovation. It considered an incentive contract that differentiated payments depending on cases of failure and success. Differently from Schmitz (2005), our paper considers a more specific supply chain situation and investigates the effect of a target performance level on overall supply chain performance. Kaya and Özer (2009) also considered a recent outsourcing trend in which a supplier is principally responsible for overall product quality, and a per-unit payment incentivizes the supplier to attain a high level of quality. On the other hand, in this

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