Computers & Industrial Engineering 125 (2018) 309–318

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Quality contracts with the supplier's private product manufacturability information

Bin Cao, Jie Gao*

School of Management, Xi'an Jiaotong University, Xi'an 710049, China
State Key Laboratory for Manufacturing System Engineering, Xi'an 710049, China

ARTICLE INFO

Keywords:
Outsourcing
Moral hazard
Product manufacturability
Screening
Tournament

ABSTRACT

In the production outsourcing environment, the manufacturer may also outsource the product design to the supplier. In this case, the supplier determines not only the quality effort during the manufacturing process but also the ease degree of production, which comes into being during the product design process and is referred to as product manufacturability. Both the manufacturing effort and the product manufacturability (either low- or high-type) may be the supplier's private information. In this paper, we examine the manufacturer's separating equilibrium piece rate quality contract (the quality penalty is based on the supplier's absolute quality performance) and tournament quality contract (the quality penalty is based on relative performance) under asymmetric product manufacturability information. With the piece rate quality contract, the supplier with low-type product manufacturability exerts a lower manufacturing effort than the first-best level and obtains the reservation payoff, while the high-type supplier spends the first-best effort and earns a positive information rent. By contrast, with the tournament quality contract, the low-type supplier obtains an information rent, while the high-type supplier only gets the reservation payoff. Finally, we find that the manufacturer prefers the piece rate (tournament) quality contract when the manufacturer believes the supplier is high-type with a low (high) probability by a numerical example.

1. Introduction

The product quality plays an important role in improving the firm's competitive advantage (Zhu, Zhang, & Tsung, 2007). It is dependent not only on the quality effort spent in the manufacturing process (i.e., manufacturing effort) but also on the ease degree with which the product can be produced (i.e., product manufacturability) (Swink, 1999). A higher quality can be achieved for a given manufacturing effort when the product manufacturability is high. The product manufacturability is determined by the product design, which generally includes concept development, system design, detail design (e.g., parameter and tolerance design), process design, prototype and testing (Jeang, 2001; Rangan, Rohde, Peak, Chadha, & Bliznakov, 2005). Therefore, the product design has a significant impact on the product quality and accounts for about 80% of quality performance (Ahire & Dreyfus, 2000; Huthwaite,1988; Li & Ni, 2018; Moradinaftchali, Song, & Wang, 2016). To improve the product manufacturability, many firms adopt design for manufacturability (DFM) approach by integrating the manufacturing considerations into the various product design processes (Banerjee, Li, Fowler, & Gupta, 2007; Hoque, Halder, Parvez, & Szecsi, 2013; Kuo, Huang, & Zhang, 2001).

Nowadays, many firms outsource the production to upstream suppliers (Contract Manufacturer, CM) to reduce the production cost (Cachon & Harker, 2002; Gilbert, Xia, & Yu, 2006). Some firms even outsource both the product design and production to the suppliers (Original Design Manufacturer, ODM) to access their skills and technologies (Ciravegna, Romano, & Pilkington, 2013; Shen, Li, Dong, & Quan, 2016). ODM strategy is commonly used in the auto industry, electron industry, aircraft industry and fashion industry (Shen et al., 2016; Shy & Stenbacka, 2003). In this study, we firstly consider a two-echelon supply chain consisting of one manufacturer (he) and one supplier (she), both of whom are risk-neutral and operate in the ODM regime. The supplier's manufacturing effort is generally unobservable, and thus is non-contractible. Hence, the manufacturer should design an effective incentive contract to cope with the moral hazard problem so that the desired product quality level can be achieved (Reyniers & Tapiero, 1995a, 1995b). To do this, the manufacturer needs to know the product manufacturability as the manufacturing effort spent to achieve a specific quality level also depends on the product manufacturability.

In the ODM regime, the supplier can learn about the product

* Corresponding author at: School of Management, Xi'an Jiaotong University, Xi'an 710049, China.
E-mail address: gaoj@mail.xjtu.edu.cn (J. Gao).

https://doi.org/10.1016/j.cie.2018.08.033

Available online 30 August 2018
0360-8352/

manufacturability during the product design process, especially when the DFM approach is adopted. However, the manufacturer may not be informed about the product manufacturability because he may not completely involve in the product design processes for confidential or technological reasons. Therefore, the manufacturer has to screen the product manufacturability information when he proposes the quality incentive contract. The existing literature on supply chain quality management mainly examines the impacts of non-contractible effort or asymmetric quality information (e.g., component quality) but does not take product manufacturability into consideration (Baiman, Fischer, & Rajan, 2000, 2001; Balachandran & Radhakrishnan, 2005; Lim, 2001; Reyniers & Tapiero, 1995a, 1995b). In this study, we examine the manufacturer's quality incentive contracts by considering both the non-contractible manufacturing effort and asymmetric product manufacturability information to fill this gap.

In general, a quality incentive contract specifies the per-unit penalty charged on the supplier for each defective product and the procurement price paid to compensate her cost. This contract is a kind of piece rate quality contract as the quality penalty is based on the supplier's absolute quality performance, such as internal failures (defective products are identified by the manufacturer's incoming inspection) and external failures (defective products are identified by external consumers). The low-type supplier obtains a lower quality level and thus pays a greater penalty than the high-type one if both of them spend the same manufacturing effort. Otherwise, the low-type supplier has to spend more manufacturing effort to achieve the same quality level of the high-type supplier. Hence, the low-type supplier bears a larger cost and would claim for a higher procurement price. Due to the asymmetric product manufacturability information, both the low- and high-type suppliers may claim for the high procurement price, which incurs the adverse selection problem. We firstly examine the uninformed manufacturer's separating equilibrium piece rate quality contracts that address both the adverse selection and moral hazard problems.

Although most papers on supply chain quality contracts consider the supply chain consisting of one supplier and one manufacturer, many companies outsource to multiple suppliers to alleviate the supply chain risks, and use relative quality performance to evaluate the suppliers (Chen & Wu, 2013; Shu & Wu, 2009). When the principal outsources to multiple agents, the tournament contract, with which the penalty or prize is based on the agents' relative performance, can also be used to incentivize the agents' effort (Lazear & Rosen, 1981; Tsoulouhas, 1999). It has been widely used to alleviate the two-sided moral hazard problems, in which both the principal and the agents take hidden actions (Carmichael, 1983). This is because the relative performance can help to filter the impact of the principal's hidden action, which acts as a common shock over the performance of all the agents. In this study, the product manufacturability also plays the role of common shock over the product quality of the multiple suppliers. Hence, the impact of the product manufacturability may be filtered by using relative performance, which helps to alleviate the adverse selection problem arising from asymmetric product manufacturability information. We further consider that the manufacturer outsources to multiple homogeneous suppliers and examine the separating equilibrium tournament quality contracts. To the best of our knowledge, our paper is the first one that uses relative performance to address adverse selection problems in quality incentive contracts.

The rest of this paper is organized as follows. We review the related literature in the next section. Section 3 describes the model setup. The piece rate and tournament quality contracts are examined in Sections 4 and 5, respectively. Section 6 provides the numerical analysis. The conclusions are given in Section 7.

2. Literature review

This paper is related to literature on piece rate quality contracts and tournament contracts.

Some early papers on piece rate quality contracts examine the effect of the contracts in alleviating moral hazard problems caused by non-contractible actions, such as the supplier's quality improvement effort and the manufacturer's inspection effort (Baiman et al., 2000; Reyniers & Tapiero, 1995a, 1995b). Besides the supplier's non-contractible quality improvement effort, the manufacturer can also exert effort to improve product quality. Therefore, a few studies further consider that the product quality is jointly determined by the supplier's and the manufacturer's effort (Balachandran & Radhakrishnan, 2005; Chao, Iravani, & Savaskan, 2009; Dong, Xu, Xu, & Wang, 2016; Hsieh & Liu, 2010; Zhu et al., 2007). Besides incoming inspection, the buyer may use vendor certification to evaluate the supplier's quality performance as the high-quality supplier can pass the certification with a greater probability. Some papers examine the impact of certification regime, under which the buyer accepts the product as long as it passes the certification (Chen & Deng, 2013; Hwang, Radhakrishnan, & Su, 2006).

In addition to moral hazard problems, a group of studies on piece rate quality contracts address the adverse selection problem caused by hidden information. Some papers focus on the uninformed player's piece rate quality contracts when the other player owns private information, such as quality level (Lan, Zhao, & Tang, 2015; Lim, 2001), quality improvement cost (Kaya and Özer, 2009; Yan, Zhao, & Tang, 2015; Yang, Lu, & Xu, 2016), or both of them (Chen & Hu, 2015). Kaya and Özer (2009) examine the buyer's incentive-compatible contract when the supplier's quality effort and product quality level are non-contractible and the quality improvement cost is the supplier's private information. In the separating equilibrium, the buyer reduces the per-unit payment of the high-cost supplier to screen the cost information. Different from the above papers, in which the uninformed player acts as the Stackelberg leader and offers the contracts, a few papers examine the piece rate quality contract when the informed player offers the contract (Baiman, Fischer, & Rajan, 2001). Furthermore, Yang, Zhang, and Zhu (2017) examine the incentive-compatible piece rate quality contract when both the two players have private bargaining power information. Different from the above papers that only consider the piece rate contract, we further examine the tournament quality contract that employs relative quality performance to address the adverse selection problem.

Our paper is also related to studies on tournament contracts. Early papers on tournament contracts mainly examine their roles in alleviating the moral hazard problem caused by the agents' non-contractible effort (Green & Stokey, 1983; Lazear & Rosen, 1981; Nalebuff & Stiglitz, 1983). Besides the agents' effort, the principal may also exert non-contractible effort, which leads to two-sided moral hazard problems. The principal's effort acts as a common shock over the outcomes of all the agents, and thus may be filtered by using relative performance with a tournament contract. Some papers examine the roles of tournament contracts in alleviating the two-sided moral hazard problem (Carmichael, 1983; Marinakis & Tsoulouhas, 2012, 2013; Tsoulouhas, 1999). A few papers further consider that the agents are heterogeneous in abilities, which may lead to distinct impacts of the principal's effort on the agents' performance (Konrad & Kovenock, 2010; Tsoulouhas & Marinakis, 2007). It is shown that the heterogeneous abilities reduce the effect of tournament contract on filtering the impact of the principal's effort. Thus, the piece rate contract is preferred when the agents are highly heterogeneous.

In addition to moral hazard problems, a few studies on tournament contracts address the adverse selection problem caused by asymmetric information. Lazear and Rosen (1981) consider that the heterogeneous abilities of the agents are asymmetric information when the contracts are agreed on and find that the low-ability agents will lie. Tsoulouhas (2017) further examines the pooling contract (only one contract is offered for all the agents) and screening contracts (each agent chooses its corresponding contract) when the abilities are the agents' private information. It is shown that the pooling contract outperforms the screening contracts under some situations. Different from the