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Subsidizing and pricing private toll roads with noncontractible service quality: A relational contract approach

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ABSTRACT

In private toll roads, some elements of the private operator's performance are noncontractible. As a result, the government cannot motivate the private operator to improve them through a formal contract but through a self-enforcing contract that both parties are unwilling to deviate unilaterally. In this paper, we use noncontractible service quality to capture these performance elements. By employing a relational contract approach, we aim to investigate the optimal subsidy plan to provide incentives for quality improvement. We show that government subsidy is feasible in quality improvement when the discount factor is sufficiently high and marginal cost of public funds is sufficiently small. Under feasible government subsidy, we have demonstrated the optimal subsidy plans in different scenarios. Moreover, some comparative statics are presented. Based on the derived subsidy plans, we further investigate the optimal toll price. We find that the optimal toll price generates zero surplus for the private operator and positive surplus for consumers. We then make two extensions of our model to re-investigate the government's optimal decisions on subsidy plan and toll price when her decision sequence is changed and when government compensation is present upon termination of the relationship. Some implications for practice have been derived from our model results.

1. Introduction

During the last few decades, public roads are being increasingly operated by the private sector. This trend is driven by multiple merits of private participation. For instance, it has been widely acknowledged that the involvement of private operators relieves budgetary burden of the government (Engel et al., 2013; Niu and Zhang, 2013; Qiu and Wang, 2011). Moreover, due to accessibility to advanced technology, the private operator can provide operation service more innovatively (Nombela and de Rus, 2004; Tan and Yang, 2012). However, some studies have also recognized the downside of private participation. They argue that to maximize the profit, the private operator determines his[1] performance level based on his own profit function, which is lower than the socially optimal performance level (Verhoef, 2007). Therefore, it is necessary for the government to offer incentives for performance improvement so that higher performance level can be achieved and thus social welfare can be improved.

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[1] In this paper,we use "he" to identify the private operator and "she" the government.

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A natural way to provide such incentives is by government subsidy. Based on previous literature, government subsidy can serve two functions in private toll roads. First, government subsidy increases attractiveness of private toll roads. For many toll roads, toll revenue is insufficient to recover the private operator's investment especially in the presence of price restrictions. Therefore, to guarantee private profit, government subsidy[2] is introduced. A number of studies focus on this function of government subsidy in private toll roads. Chen and Subprasom (2007) analyzed a build-operate-transfer (BOT) road and suggested that government subsidy was necessary to achieve financial viability in the presence of price regulations. They also quantified the minimum subsidy level to make the private investor attain the minimum financial performance. Ubbels and Verhoef (2008) studied performance of government subsidy in a competitive bidding setting. They showed that government subsidy was necessary to achieve the second-best social welfare. Moreover, they found that if the award criteria associated with government subsidy were properly designed, the resulting social welfare could approach the second-best solution. Tan and Yang (2012) studied the optimal subsidy size for flexible BOT contract to maximize social welfare under the constraint of private participation. In their benchmark case where both parties have perfect information on traffic demand, they found a unique threshold with respect to the private operator's required minimum rate of return. They pointed out that positive government subsidy improved social welfare only when the private operator required a higher rate than the threshold. By partitioning traffic demand into different domains in the presence of demand uncertainty, they also demonstrated the optimal subsidy plan in each domain.

Second, government subsidy creates incentives for the private operator to improve his performance. This subsidy type is named as performance-based subsidy, which ties the private operator's performance with the subsidy size (Irwin, 2003; Mumssen et al., 2010). Tan (2011) suggests that government subsidy can align goals of the private operator and the government and drive the private operator to improve performance. There are also some studies examining this function of government subsidy. For instance, Fearnley et al. (2004) took an example of Norwegian intercity rail transport and stressed the importance of performance-based subsidy in inducing the private operator to provide a socially optimal performance level. They recommended three performance-based subsidy types: passenger-related subsidy, kilometer-related subsidy, and seat-related subsidy. They argued that these subsidy types combined social goal with the private operator's commercial goal. More importantly, these subsidies made the private operator improve his performance level that brought extra benefits for users. Some other studies focused on performance-based government subsidy in motivating the private operator to deliver high service level in the bus sector (Hensher and Houghton, 2004; Hensher and Stanley, 2003).

An implicit assumption underlying these two streams of literature is that the private operator's performance can be perfectly measured ex post. Therefore, their analysis is built upon formal contract that can be enforced by the court. However, in practice, some elements of the private operator's performance are noncontractible. As a result, the government cannot employ subsidy to motivate the private operator to improve these noncontractible performance elements through a formal contract. Rather, the government needs a self-enforcing subsidy plan to provide incentives in which both the government and the private operator are unwilling to deviate unilaterally. This closely relates to the notion of "relational contract" that emphasizes the role of trust in creating incentives on noncontractible performance (Gibbons, 2005; Levin, 2003). Relational contract is characterized by self-enforcement: Both parties adhere to the agreement in each period since deviation can lead to destruction of trust and hence the value of future cooperation. By noting prevalence of relational contracts in practice, there are a number of applications of relational contract approach in operations management (Taylor and Plambeck, 2007; Tunca and Zenios, 2006), labor market (Li and Matouschek, 2013) and local public service (Desrieux et al., 2013). However, as far as we are aware, there are still no studies on relational contract in the context of private toll roads. To fill this gap, by adopting a relational contract approach, we will investigate the optimal subsidy plan in the presence of the private operator's noncontractible performance. In our case, a relational contract specifies for every period the government's promised subsidy plan, the private operator's effort on performance improvement, and whether they will adhere to the promised terms.

In this paper, we use noncontractible service quality to capture the private operator's performance elements that cannot be perfectly measured ex post.[3] Therefore, noncontractible service quality may include characteristics of the road (pavement smoothness, etc.), characteristics of travel corridor (scenery and landscaping, etc.), on-road or roadside service, and impact on the environment. Based on this definition, noncontractible service quality can only be well-perceived by the government, that is, it is observable but is not verifiable.[4] We will show how to design government subsidy (including subsidy structure and subsidy size) to motivate the private operator to improve noncontractible service quality and thus social welfare.[5] Moreover, we go further by considering the optimal toll price under this optimal subsidy design.

Specifically, we characterize the government's decisions into a two-stage optimization problem, which is solved by backward induction. In the second stage, the government designs the subsidy under a given toll price. In this stage, we view government subsidy as an incentive mechanism to change the private operator's quality-improvement effort. We will present the optimal subsidy plans in different scenarios. In the first stage, we investigate the optimal toll price based on the derived

[2] In some countries of Asia, government subsidy covers nearly one-quarter of operation costs for road projects (Asian Development Bank, 2000).

[3] Note that we use service quality in a different way. In previous literature, service quality is defined as the volume/capacity ratio.

[4] If the private operator's performance can only be perceived by consumers, then the government can use questionnaire, survey, or interview to solicit their evaluation.

[5] Some portion of government subsidy may depend on some objective indicators rather than noncontractible service quality. However, due to ex post verifiability, this portion can be assumed to be fixed, which does not affect our analysis. Therefore, we have excluded its effects from our model.