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The effects of concession period structures on BOT road contracts

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ABSTRACT

Under the build-operate-transfer (BOT) approach, the private firm builds and operates a road within the concession period and transfers the project at no cost to the government at the end of the concession period. Based on whether the construction period and the private operation period are defined together or separately, there are two concession period structures: single-period concession structure (SPCS) and two-period concession structure (TPCS). This paper simultaneously compares socially optimal toll prices in both private and public operation periods, road quality, and concession period under SPCS and TPCS, respectively. We find that if the marginal social welfare with respect to toll price in private operation period is sufficiently more responsive than to road quality, then the optimal road capacity and toll prices under SPCS are higher than those under TPCS. Otherwise if marginal social welfare in public operation period is sufficiently more responsive to road quality, then the optimal toll prices under SPCS are lower while the optimal road quality under SPCS is higher. We also find that the optimal concession periods are independent of concession period structures. This paper has made three extensions to further investigate the effects of concession period structures (1) when the toll price is determined by the private firm; (2) when renegotiation takes place; and (3) when government support policies are present. Based on our model results, this paper derives several policy implications regarding BOT road contract design under different concession period structures.

1. Introduction

In the last two decades, build-operate-transfer (BOT) has emerged as one of major approaches for delivering public roads (Tan and Yang, 2012a; Xiong and Zhang, 2014, 2016). Under the BOT approach, the private firm builds and operates the road within the concession period and transfers the project at no cost to the government at the end of the concession period. Therefore, a typical BOT road project includes two periods: the concession period, which can be divided into the construction period and the private operation period, and the public operation period. In the construction period, the private firm builds the road to meet the government's requirements on road capacity and road quality. In the private operation period, the private firm begins to recoup the investment by toll revenue. In the public operation period, the government replaces the private firm to continue operating the road.

Since the BOT road is owned by the private firm and the government respectively in and after the concession period, its length affects the private firm's profit and also social welfare. In practice, the concession period can be defined in two ways: (1) the single-period concession structure (SPCS), which defines the construction period and the private operation period together and (2) the two-period concession structure (TPCS), which defines the construction period and the private operation period separately (Ye and Tiong, 2003). Intuitively, the two concession period structures are equivalent if the private firm completes the construction task on the

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planned schedule. Otherwise, SPCS allows the private firm to enjoy a longer (shorter) operation period if he[1] completes the construction task ahead of schedule (behind schedule). It is worth pointing out that TPCS does not mean that the government offers separate construction and operation contracts to different private firms. Rather, similar to SPCS, the government still contracts with a single private firm to build and operate the road. TPCS just represents a way to define concession period, under which the length of the private operation period stays the same no matter construction is ahead of schedule or is behind the schedule. Some previous literature has stressed the importance of concession period structures in designing BOT contracts (Zhang, 2009; Yu and Lam, 2013).

For the BOT road, the private firm makes the investment in the construction period and begins to see a positive cash flow in his operation period. Therefore, the private firm is motivated to complete the project early to obtain more discounted profit, which is a recognized advantage of the BOT approach (Niu and Zhang, 2013).

By taking into account the private firm's investment in expediting construction, this paper argues that socially optimal BOT contracts should be different under SPCS and TPCS. This paper simultaneously compares the government's optimal toll prices in both private and public operation periods, road capacity, road quality, and concession period, respectively, under SPCS and TPCS. Our model results show that if the marginal social welfare with respect to toll price in private operation period is sufficiently more responsive to road capacity than to road quality, the optimal road capacity and toll prices under SPCS are higher than those under TPCS. Otherwise if marginal social welfare in public operation period is sufficiently more responsive to road quality, then the optimal road quality under SPCS is higher while the optimal toll prices under SPCS are lower. Moreover, we find that the government's optimal concession periods equal the road life, which are independent of the concession period structures. To obtain more results, this paper has made several extensions to further compare the optimal BOT contracts under SPCS and TPCS (1) when the toll price is determined by the private firm; (2) when renegotiation takes place; and (3) when government support policies are present.

This paper is closely related to the literature on optimal BOT road contract design. Studies in this area examine different combinations of road capacity, road quality, toll price, and concession period by considering different influencing factors. Yang and Meng (2000) examined the BOT network design problem in a general road network and developed mathematical models to characterize the optimal selection of capacity-toll combination under monopolistic and competitive markets. They further examined the selection of the capacity-toll combination in the presence of heterogenous users (Yang et al., 2002). Chen and Subprasom (2007) developed various road pricing models under demand uncertainty to analyze the trade-offs among objectives of the government, the private firms, and the road users. Ubbels and Verhoef (2008) analyzed private firms' choice of capacity and toll price in a competitive bidding framework. Guo and Yang (2009) simultaneously determined road capacity, concession period, and toll price to maximize social welfare while satisfying the private firm's participation constraints. To incorporate different interests of the government and the private firm, Tan et al. (2010) considered a bi-objective optimization problem in determining concession period, road capacity and toll price. They have examined the properties of the Pareto-efficient BOT contract. They further investigated the impact of user heterogeneity on the optimal Pareto-efficient contract (Tan and Yang, 2012b). Niu and Zhang (2013) examined the impact of demand uncertainty on road capacity, concession period, and toll price by simultaneously considering both the government's and the private firm's objectives. Feng et al. (2015) investigated the impact of different government guarantees on the private firm's optimal toll price, road capacity, and road quality.

Since concession period is important for BOT projects, many researchers have particularly investigated the decision on the length of concession period. However, these studies ignored the effects of concession period structures. For instance, Zhang (2009) and Carbonara et al. (2014) proposed a win-win model to determine the optimal length of concession period under SPCS. Yu and Lam (2013) separately examined the optimal construction and operation periods by Net Present Value method under TPCS. Qiu and Wang (2011) investigated the extension of concession period under TPCS to incentivize the private firm to improve project quality.

A number of other studies have examined flexible-term BOT contracts. Tan and Yang (2012a) considered a flexible contract that involved selection of concession period, road capacity, and toll price by assuming that the contract variables can be *ex post* adjusted after the demand uncertainty is resolved in the operation period. To reduce the frequency of renegotiations in BOT contracts, Engel et al. (1997, 2001) proposed a flexible-term mechanism under which the concession period ends once the private firm's present value of revenue achieves a predetermined level. Nombela and De Rus (2004) improved this mechanism by proposing an alternative mechanism under which the concession period depends not only on the toll revenue but also on the maintenance costs. Albalate and Bel (2009) used data from the oldest Spanish toll motorways and performed a simulation to compare the performance of the fixed-term and flexible-term concession contracts. It is worth noting that under Engel flexible-term concession period, the concession period ends at the same time under SPCS and TPCS. As a result, concession period structures have no effects on BOT contract design. To justify the differences between SPCS and TPCS, we take the assumption that the concession period will be fixed under both SPCS and TPCS if the private firm completes construction on time. In fact, many researchers have argued that fixed concession period is common in international BOT practice (Zhang, 2009; Carbonara et al., 2014). Vassallo (2010) even suggested that although a flexible-term contract mitigated traffic risk, it was rarely adopted in practice. One reason might be that the mechanism limited the upside profitability of the private firm.

This paper makes three contributions to the literature. First, we compare the optimal BOT road contracts under different concession period structures. To this end, we simultaneously investigate the government's optimal toll prices, road capacity, road quality, and concession period under each concession period structure. We then compare these decision variables respectively. To our knowledge, this paper is the first to consider the effects of the concession period structure on BOT road contract design. Second, this paper investigates the effects of uncertainty in completion of the construction task on the government's optimal BOT road contracts.

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

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