

ABSTRACT

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Title: Modeling, Optimizing, and Impact Analysis of Incentive and Regulation Mechanisms in Infrastructure Privatization.

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Many governments have implemented privatization programs in infrastructure sectors to close the infrastructure investment gap. Incentive and regulation mechanisms are critical for fostering an investment-enabling and performance-ensuring environment for infrastructure privatizations. However, the optimal configurations and impacts of incentives and regulations remain ambiguous, which prevents governments from designing and implementing effective mechanisms to induce private investments and improve social welfares. This dissertation addresses this significant problem by closing five main knowledge gaps in modeling, optimizing, and impact analysis of incentive and regulation mechanisms in infrastructure privatization.

The first knowledge gap is the unclear impacts of various government incentives on the private investment behaviors including the choices of investment timing, capacity, and price under demand uncertainty. The real option theory and optimization technique are employed to characterize the private sector's decisions under demand uncertainty, when various government incentives are offered. The results suggest that revenue guarantee, concession period extension, lump-sum subsidy, and unit subsidy can induce early investment. Revenue guarantee and concession period extension have limited impacts on the choices of capacity and price. Lump-sum subsidy leads to a smaller capacity and a higher price, while unit subsidy leads to a larger capacity and a lower price, when comparing to the choices by a monopoly without government incentives.

The second knowledge gap is the absence of a mechanism to shield the government from assuming excessive contingent liability when providing an incentive such as debt guarantee. This dissertation elaborates the use of project bonds and a credit default swap (CDS), in which the government charges the private sector for providing a debt guarantee. A financial model is calibrated by market data to predict the default probability, and a pricing mechanism is suggested to determine the CDS premium. The impacts of project parameters including capital structure, asset rate of return and volatility, bankruptcy loss rate, and tax rate on the default probability and CDS premium are assessed. It is concluded that the CDS can provide funds for the government to cover excessive contingent liability, and the insurance premium is also affordable for the private sector.

The third knowledge gap is the lack of an optimization model and algorithm for incentive allocation when the evolution of project benefits is ambiguous and the incentive cost is uncertain. The ambiguity of project benefit evolution, the decision-maker's attitude to the ambiguity, and the uncertainty in incentive cost are incorporated into the real option analysis for project evaluation, upon which a knapsack problem is formulated with a probabilistic budget constraint. The optimization problem is then solved and the optimality gap is obtained in a case study, which demonstrates the efficacy of the proposed method.

The fourth knowledge gap is that the impacts of privatization arrangement such as capacity allocation and royalty payment on the price and quality decisions by both the public and private sectors, as well as the social welfare and private profits are not clear. This dissertation elaborates a public-private duopoly game to close this knowledge gap by answering three questions. First, how will the privatization shape the quality and pricing decisions by both the public and private sectors? Second, to what extent should the infrastructure or service be privatized and how much should the royalty payment be? Third, how will the efficiency of private sector affect the privatization arrangement? The results suggest that with increasing capacity allocated

to the private sector, the private sector charges a higher price and maintains a higher level of quality, while the public sector chooses a higher price but a lower level of quality. The optimal capacity released to the private sector is a function of its efficiency, and the royalty payment increases sharply as the private sector gains more capacity. The analyses reveal the coupled effects of capacity allocation and private efficiency on the price and quality decisions, as well as the social welfare and private profit.

The fifth knowledge gap is that the optimal decisions for infrastructure provision are not characterized under different regimes, resulting in the government's dilemma of selecting the best regime for infrastructure provision. This dissertation characterizes the optimal choices of investment timing, price, quality, and subsidy/tax or franchise fee in both the regulation and deregulation regimes, and compares the two regimes in terms of social welfare under demand uncertainty and information asymmetry. The results suggest that with perfect information, as the shadow cost of public funds and demand volatility increase, the regulatory investment timing, price, and quality increase and approach the decisions by a private monopoly. However, with imperfect information, the regulated firm is recommended to delay its investment, provide a higher quality, and overcharge consumers. In terms of social welfare, the regulation regime under information symmetry dominates the regulation regime under information asymmetry and the deregulation regime. Whether deregulation dominates regulation under information asymmetry depends on the interplay of a variety of factors including the shadow cost of public funds, the demand volatility, the government's imperfect information on the firm's cost structure, and the franchise fee.

This dissertation offers rich insights for the design and analysis of incentive and regulation mechanisms in infrastructure privatization. It not only explains the underlying working principles of incentives and regulations with much enhanced consideration of endogenous stakeholders' interactions and exogenous market

conditions, but also optimizes their designs and implementations. The insights yielded from this dissertation will help to improve social welfare and save taxpayer's money.