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INCENTIVE REGULATION FOR EFFICIENT TRANSMISSION EXPANSION

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Overview

In competitive electricity markets, the power transmission sector remains a monopoly business, and therefore is still subject to regulation. However, the regulation of the transmission network remains a challenging task due to the complex nature of the power system. For example, transmission regulation should take account of technological externalities among transmission lines as governed by physical laws (e.g., Kirchhoff's laws).

The incentive regulation approach relies on regulatory incentive mechanisms that induce the transmission company to efficiently expand the network. Although this is generally considered as an alternative or complement to the merchant transmission approach, the limited numbers of such incentive schemes specifically for transmission regulation have been explored in the literature. See, for example, Joskow and Tirole (2005) for details.

Vogelsang (2001) introduced a two-part price cap mechanism that attempts to induce the transmission company to raise enough revenue for transmission investment, and at the same time, receive correct signals for efficient network expansion. However, since Vogelsang's (2001) mechanism does not take account of the technological externalities among transmission lines, it is difficult to see how the optimal network expansion is achieved. It therefore remains an unresolved question as to how appropriate price cap mechanisms are designed in the presence of technological externalities. Specifically, the externalities must be internalized in such a way that both short-run and long-run efficiency are promoted.

Methods

We develop regulatory incentive mechanisms for efficient investment in the transmission network, taking into account both technological externalities among transmission lines and information asymmetry between the regulator and the Gridco. Special attention is focused on developing the incentive mechanisms that attempt to internalize technological externalities governed by physical laws. Moreover, we focus on asymmetric information about the Gridco's cost structure, supposing that the regulator does not know the capacity cost function of transmission lines.

Extended Price Cap Regulation for Gridco. In general, a price cap mechanism sets some ceiling for prices to be charged by the regulated firm. The firm is allowed to choose any prices as long as some average price index is below the ceiling, i.e., the price cap.

We need to modify and extend the original price cap mechanism in order to internalize technological externalities and assure the convergence of the process. By introducing an additional constraint on the capacity, we develop the extended price cap mechanism for Gridco. We can further develop an extended form of the two-part price cap mechanism originated by Vogelsang (1989).

The extended price cap mechanism for Gridco: In each period t, the regulator allows the Gridco to choose the transmission capacity $\mathbf{k}^t$ that satisfies the following constraint:

$$\boldsymbol{\eta}(\mathbf{k}^t)' \cdot \mathbf{k}^{t-1} + \boldsymbol{\eta}(\mathbf{k}^{t-1})' \cdot \mathbf{F}(\mathbf{q}^{t-1}, \mathbf{k}^t) \le 2r(\mathbf{k}^{t-1}),$$

$$cs(\mathbf{k}^t) \ge cs(\mathbf{k}^{t-1}).$$

The extended two-part price cap mechanism for Gridco: In each period t, the regulator allows the Gridco to choose the transmission capacity $\mathbf{k}^t$ that satisfies the following constraint:

$$\boldsymbol{\eta}(\mathbf{k}^t)'\cdot\mathbf{k}^{t-1} + \boldsymbol{\eta}(\mathbf{k}^{t-1})'\cdot\mathbf{F}(\mathbf{q}^{t-1},\mathbf{k}^t) + \mathbf{a}^{t}{}'\cdot\mathbf{x} \le 2r(\mathbf{k}^{t-1}) + \mathbf{a}^{t-1}{}'\cdot\mathbf{x},$$

$$cs(\mathbf{k}^t) - \mathbf{a}^{t}{}'\cdot\mathbf{x} \ge cs(\mathbf{k}^{t-1}) - \mathbf{a}^{t-1}{}'\cdot\mathbf{x}.$$

Incremental Surplus Subsidy Scheme for Gridco. If the regulator can subsidize the Gridco, surplus-based schemes can be used in order to induce the Gridco to choose the optimal transmission capacity without its budget constraint. One such scheme is the dynamic regulatory mechanism proposed by Sappington and Sibley (1988). Their mechanism, called the incremental surplus subsidy (ISS) scheme, provides a monopoly firm with a subsidy based on a period-to-period changes in the consumers' surplus (subtracted by the firm's operating profit).

The ISS scheme for Gridco: In each period t, the regulator allows the Gridco to choose the transmission capacity $\mathbf{k}^t$, and provides the following subsidy s^t to the Gridco:

$$s^t \equiv \left\{cs(\mathbf{k}^t) - cs(\mathbf{k}^{t-1})\right\} - \pi(\mathbf{k}^{t-1}).$$

Results

We show that both linear and two-part tariff-based price cap mechanisms can achieve, in the long run, the optimal capacity expansion in the presence of technological externalities, while short-run efficiency can be maintained under nodal pricing.

Proposition 1: *For any given* $\pi(\mathbf{k}^0) \ge 0$, ***the extended price cap mechanism*** *induces the Gridco to choose the optimal transmission capacity under a budget constraint, i.e.,* $\mathbf{k}^*$, *in a dynamic process. That is, there exists* $\mathbf{k}^*$ *such that:*

(i) $\lim_{t\to\infty} v(\mathbf{k}^t) = v(\mathbf{k}^*)$. (ii) $\boldsymbol{\eta}(\mathbf{k}^*) - \boldsymbol{\tau}(\mathbf{k}^*) = R\left\{\boldsymbol{\psi}(\mathbf{k}^*) - \boldsymbol{\varphi}(\mathbf{k}^*)\right\}$.

Proposition 2: *For any given* $\pi(\mathbf{k}^0) + \mathbf{a}^{0}{}'\cdot\mathbf{x} \ge 0$, ***the extended two-part price cap mechanism*** *induces the Gridco to choose the optimal transmission capacity without a budget constraint, i.e.,* $\mathbf{k}^f$, *in a dynamic process. That is, there exists* $\mathbf{k}^f$ *such that:*

(i) $\lim_{t\to\infty} v(\mathbf{k}^t) = v(\mathbf{k}^f)$. (ii) $\boldsymbol{\eta}(\mathbf{k}^f) = \boldsymbol{\tau}(\mathbf{k}^f)$.

We also provide a formal analysis of the ISS scheme specifically for efficient network expansion.

Proposition 3: *Under* ***the ISS scheme for Gridco****, the following holds for any given* s^0, $\mathbf{k}^0$:

(i) *The Gridco chooses the optimal transmission capacity without a budget constraint, i.e.,* $\mathbf{k}^f$ *in every period*: $\eta^l(\mathbf{k}^f) = \tau^l(\mathbf{k}^f), \quad t = 1,\ldots,\infty$.

(ii) *The Gridco gains no profit from the second period onward (i.e., the Gridco can gain strictly positive profit only in the first period)*: $\pi(\mathbf{k}^t) + s^t = 0, \quad t = 2,\ldots,\infty$.

Conclusions

This paper has examined regulatory incentive mechanisms for efficient investment in the transmission network, taking into account both technological externalities among transmission lines and information asymmetry between the regulator and the Gridco. By adding extra constraints associated with power flow, we have developed extended price cap mechanisms that can internalize technological externalities among transmission lines. We have shown that the new mechanisms can achieve, in the long run, the optimal capacity expansion in the presence of technological externalities, while short-run efficiency can be maintained under nodal pricing. We have also examined the surplus-based scheme with government transfers. We have provided a formal analysis of the incremental surplus subsidy (ISS) scheme specifically for efficient network expansion.