Energy Economics 75 (2018) 423–439

Contents lists available at ScienceDirect

Energy Economics

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

A simple regulatory incentive mechanism applied to electricity transmission pricing and investment

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ARTICLE INFO

Article history:
Received 4 October 2017
Received in revised form 27 August 2018
Accepted 30 August 2018
Available online 6 September 2018

JEL classification:
D24
L51
L94
Q40
C61
C63

Keywords:
Incentive regulation
Transmission investment
Bilevel program

ABSTRACT

The informationally simple approach to incentive regulation applies mechanisms that translate the regulator's objective function into the firm's profit-maximizing objective. These mechanisms come in two forms, one based on subsidies/taxes, the other based on constraints/price caps. In spite of a number of improvements and a good empirical track record simple approaches so far remain imperfect. The current paper comes up with a new proposal, called H-R-G-V, which blends the two traditions and is shown in simulations to apply well to electricity transmission pricing and investment. In particular, it induces immediately optimal pricing/investment but is not based on subsidies. In the transmission application, the H-R-G-V approach is based on a bilevel optimization with the transmission company (Transco) at the top and the independent system operator (ISO) at the bottom level. We show that H-R-G-V, while not perfect, marks an improvement over the other simple mechanisms and a convergence of the two traditions. We suggest ways to deal with remaining practical issues of demand and cost functions changing over time.

1. Introduction and motivation

The purpose of regulatory incentive mechanisms is to influence the profit function of the regulated firm in such a way that profit maximization leads to goal fulfillment of the regulator, where the objective is usually assumed to be the maximization of welfare in the form of social surplus. Such mechanisms are desirable, because the regulator typically is less informed about costs and demands facing the firm and because the regulator can only do limited monitoring and enforcement. The mechanisms should therefore be easily enforceable. In particular, such mechanisms can induce socially optimal electricity transmission investments.

Two basic types of approaches have been developed in the academic literature. The informationally sophisticated or Bayesian approach has dominated the theoretical literature, starting with Baron and Myerson (1982) and Laffont and Tirole (1986). Informationally demanding mechanisms capture uncertainty and asymmetric information by a subjective probability distribution of types of firms, where the regulator only knows the distribution, while the firm also knows its own type. The mechanisms are called Bayesian, because regulators start with a subjective *a priori* type distribution of firms and they use Bayesian updating to reach posterior distributions.

The main drawbacks of the Bayesian approach are (1) that regulators cannot be monitored well by the public, because the distribution

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https://doi.org/10.1016/j.eneco.2018.08.033
0140-9883/

of firm types is based on subjective probabilities, which makes it somewhat arbitrary (Koray and Saglam, 2005), and (2) because real-world functional forms for type distributions, costs and demands are largely unknown it is hard to get realistic quantitative results, which would make it highly complex for an application.

However, the sophisticated approach provides strong insights into the incentive properties of regulation. For example, (1) firms have to receive an information rent in order to be induced to reveal their type, or (2) it is impossible to reach a first-best outcome, or (3) the less the regulator can commit to future policies the weaker incentives should be. In sum, this approach is not very practical but highly insightful.

In contrast, the informationally simple or non-Bayesian approach does not use a formal probabilistic model but applies mechanisms that translate the regulator's objective function into the firm's profit-maximizing objective. These mechanisms are typically quite practical, easy to understand and are at least partially based on observable or even verifiable data. They come in two forms, one based on subsidies/taxes the other based on constraints/price caps. The subsidy approach goes back to Loeb and Magat (L-M) (Loeb and Magat, 1979), while the constraint/price cap approach goes back to Vogelsang and Finsinger (V-F) (Vogelsang and Finsinger, 1979). In spite of a number of improvements and a good empirical track record, simple approaches so far remain imperfect relative to well-defined social welfare maximization. In particular, regulators generally do not have the power to grant subsidies or to impose taxes, while constraint-based mechanisms are unable to reach optimal outcomes in an environment with demand and cost functions changing over time.

The current paper comes up with a new proposal, the H-R-G-V mechanism, which blends the mechanisms in the L-M tradition with those in the V-F tradition and is shown in simulations to be effective in electricity transmission pricing and investment. In particular, it is not based on subsidies and it gets rid of the issue of slow or no convergence that has plagued the constraint-based mechanisms. The H-R-G-V mechanism requires the regulator to have only local information of demand but no information on costs. While local demand information may be hard to come by in other industries, Gans and King (2000) point out that such information is readily available for electricity transmission networks based on nodal pricing. At the same time electricity transmission pricing and investment are very timely issues because of the restructuring of electricity from traditional fossil fuel-based generation to renewables. We therefore provide a detailed application of the H-R-G-V mechanism to electricity transmission pricing and investment, using simulations to show optimality properties of the H-R-G-V mechanism.

This paper is structured as follows. In Section 2 we provide a short history of simple regulatory incentive mechanisms. Section 3 then motivates two-part tariffs as a bridge between subsidy-based and constraint-based mechanisms. Section 4 shows the main theoretical properties of the H-R-G-V mechanism, contrasting it in particular to a two-part tariff version of Sappington's and Sibley's ISS mechanism. While Sections 2 to 4 assume a very simplified context of a monopoly firm facing only end-users as customers and without specifically modeling investments, Section 5 is a detailed application of H-R-G-V to electricity network investment, where transmission is an intermediate input placed in the electricity value chain between generation and distribution companies, while the sale of electricity to end-users is not explicitly modeled. A more general application of H-R-G-V to electricity network investment is presented in Section 6. Section 7 provides numerical results. Section 8 concludes the paper and discusses some further thoughts. The last section is an appendix for the reader interested in the conversion of the model for the detailed mathematical derivation of a numerical simulation of the H-R-G-V mechanism in the setting of a multi-node electricity transmission network.

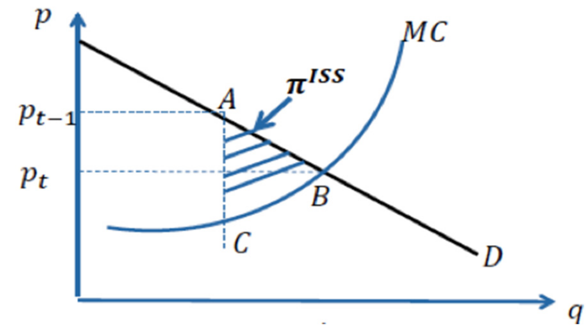

Fig. 1. The firm's profit under ISS in period t.

2. A short history of simple regulatory incentive mechanisms[1]

In 1979, Loeb and Magat (1979) published their famous mechanism, which offered marginal cost pricing and cost-minimizing incentives under a subsidy scheme that handed over consumer surplus as a subsidy to the firm. In the same year Vogelsang and Finsinger (1979) published their V-F mechanism, which was a discrete dynamic adjustment process that did not require subsidies and led to Ramsey pricing with zero profits without requiring the regulator to have demand and service-specific cost information.[2] While being simple and while dealing well with asymmetric information between the regulator and the regulated firm, both mechanisms had severe drawbacks limiting their practical application. The L-M mechanism required the regulator to know the demand function for the firm's services and required potentially huge subsidies, represented by the area between the price line and the inverse demand curve. Since the demand function is not easily observable, there can be severe disputes about the size of the subsidy. In contrast to L-M, the V-F mechanism required no demand information but provided poor cost-minimizing incentives and took time to converge to Ramsey prices, meaning that it could be subject to strategic manipulation (Sappington, 1980) and would perform badly under changing cost and demand conditions (Neu, 1993; Fraser, 1995). Subsequent mechanisms were partially able to deal with these problems.

The main new development starting from L-M as the basis was the incremental surplus subsidy (ISS) scheme by Sappington and Sibley (1988). It gave the firm a subsidy (or charged a tax) amounting to the change in consumer surplus over last period minus last period's accounting profit based on market revenues and expenses, while the firm collected current period market revenues and had to pay current period expenses.[3]

$$ISS_t = V(p_t) - V(p_{t-1}) - \pi_{t-1} \tag{1}$$

Here V(p) stands for consumer surplus and π for the firm's market profit under linear pricing.[4] As a result, in each period the firm's after-subsidy profits Π_t^{ISS} would equal the change in total surplus ΔW_t over last period. It is represented by area ACB in Fig. 1.

$$\Pi_t^{ISS} = ISS_t + \pi_t = \Delta V_t + \Delta \pi_t = \Delta W_t \tag{2}$$

[1] For an exhaustive history of both Bayesian and non-Bayesian mechanisms see Armstrong and Sappington (2007).

[2] Ramsey prices maximize social welfare subject to the constraint that the regulated firm at least breaks even. Such prices vary inversely with the price elasticities of the services provided by the firm.

[3] For simplicity we assume at this point that there is only a single output, but, as can be seen below, all our arguments extend to the multi-product case.

[4] Because of their better observability Sappington and Sibley (1988) use current expenses instead of partially unobservable economic costs. Thus, π may not be strictly interpreted as profit.