Dynamic quality regulation of the electricity grid

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Overview

The electricity grid has become a major bottle neck for the transition to a low carbon economy. Especially, increasing distances between electricity supply and demand on the one hand and fluctuating energy supply on the other hand require large investments in capacity and quality of the grid infrastructure, respectively. Being subject to regulation the investment decisions of the grid operator crucially depend on the incentives set by regulation policy, that is currently more focused on cost reductions than on quality expansion. However, even though infrastructure quality requires long-term investments, so far the dynamics of regulation have received only little attention.

Here, we introduce a model, that allows us to study the long-term effect of different regulatory regimes on quality investments in natural monopolies. We solve the dynamic decision problem of the regulated monopolist by dynamic optimization and test the stability of long-term steady states.

We find that for linear depreciation rates the common regulatory formulae can always be set to attain optimal quality. However, when the depreciation rate is nonlinear, multiple steady states with different qualities can exist, leading to path dependencies: Under certain assumptions and parameter values regulation can cause multiple saddle point stable equilibria. In this case, depending on the initial quality condition of the electricity grid, the grid operator can access only a single equilibrium, which has not necessarly the socially optimal quality. Our results show that lock in in a subobtimal level of investment may occur within engineered technical systems, as it is observed in ecological systems.

Methods

- dynamic optimization and optimal control theory
- stability analysis
- numerical simulations

Results

We show, that cost-plus, rate-of-return and incentive regulation with an explicit quality element can be set so that the regulated monopolist supplies different levels of quality. For the case of a constant depreciation rate, there is only one saddle point stable equilibrium which is socially optimal. However, for a nonlinear parabolic and quality dependend depreciation rate multiple equilibria with different stability properties occur. Thus, the regulated monopolist cannot reach all of these equilibria, but may be restricted to chose an suboptimal equailibrium. Depeding on the regulation in place, grid operators might face a lock-in on an inferior level of infrastructure investment. Our results suggest, that path dependencies and lock-ins occur not only in ecological systems but also in engineered human systems under regulation.

Conclusions

Our dynamic analysis contributes to the theoretical foundation of the relatively young practise of quality regulation. In particular, we add a further, institutional explanation for the different levels of service quality observed between relative homogenous countries like the EU member states.
Results are relevant for the practice of regulation. In face of high macro-economic cost of power outages on the one hand and the costly provision of quality on the other hand it is crucial for the regulator to enforce the socially most optimal quality. However, depending on the depreciation behaviour at hand the choice of the regulator can set

investment incentives, which lead to socially suboptimal quality levels. Taking this into account, the adjustment of the regulatory formula based on historical data may lead to an unexpected investment behaviour of the regulated monopolist.

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