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CAPACITY CHOICE IN DECENTRALIZED ELECTRICITY MARKETS – WILL IT BE OPTIMAL?

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OVERVIEW

In basic economic theory, markets with an atomistic supply structure perform best in terms of welfare-maximizing production capacity and output quantity. That holds true, unless there are market failures that lead to suboptimal market results. In this contribution, we analyze the electric power industry where investment in production capacity constitutes delivery insurance for all market participants and thus incorporates a positive external effect. This externality has been identified by [1] and others and investigated by various authors (e.g. [2-8]). However, these investigations are either based on regulated markets or on perfectly competitive markets. What is still missing in the literature, is a thorough analysis in deregulated but oligopolistic market settings like they are predominant in most electricity markets at present.
For this purpose, we develop a static Cournot-model with stochastic supply availability where symmetric firms maximize expected profits through simultaneously deciding on capacity investment and production quantity given a deterministic demand. Moreover, we derive the welfare-maximizing equilibrium when a social planner decides on the optimal number of firms in the market. Subsequently, we calibrate numerical model outcomes by exemplarily applying data from the German electricity market.

METHODS

We develop a Cournot-model with an exogenous and deterministic demand function $P(X)$ as well as exogenous and constant variable production cost q and capital unit cost r. Furthermore, there is a time gap between the latest trading opportunity and actual physical production and consumption (= gate closure time gap), as it is technically required for power grid planning and controlling purposes. This, however, leads to a stochastic availability of installed production capacity at the time of production and, thus, to a positive probability of blackouts which occur if the available capacity $\tilde{k}$ is insufficient to cover demand. Following, every firm $i = 1,\ldots,n$ maximizes its expected profit $E(\pi_i)$ deciding on production capacity k_i and production quantity x_i:

$$\max_{x_i,k_i} E(\pi_i) = \left(\Pi_{j=1}^{n}\int_{\frac{x_j}{k_j}}^{1} g\left(\frac{\tilde{k}_j}{k_j}\right) d\,\frac{\tilde{k}_j}{k_j}\right)\left(P(X)\,x_i - qx_i\right) - rk_i, \qquad (1)$$

where $g(\cdot)$ is the density function of the capacity availability. Thus, individual decisions do impact the profits of other firms not only through variations in prices, but also through lower or higher probabilities of blackouts.
In order to derive a closed-form solution for the Nash equilibrium, we use some simplifying assumptions, such as an uniformly distributed supply shock or an iso-elastic demand function.
For a numeric application, we exemplarily apply data of the German electricity market (partly OLS- and MLE-estimated from power exchange data) and solve the system of equations using appropriate MATLAB algorithms (solver: fsolve).

RESULTS

The algebraic results show that there are two countervailing welfare effects of an increase in the number of firms. First, there is the ordinary competition effect that results in an increase in total output and welfare. Second, the network externality leads to a higher probability of blackouts as new firms enter the market and, thus, to lower outputs and a lower welfare. Consequently, there is an optimal number of firms where both effects neutralize each other.

The numeric computations visualize these findings. Figure 1 illustrates the decision calculus of a firm in a market setting with five players assuming all other players to behave accordingly to Nash. Obviously, a too small individual insurance margin (i.e. the gap between output x_i and investment k_i) results in losses due to the probability of blackouts, while too much capacity leads to losses because of capital costs. Thus, there is an individually optimal choice, which is subsequently compared to choices in market settings with more and less firms.

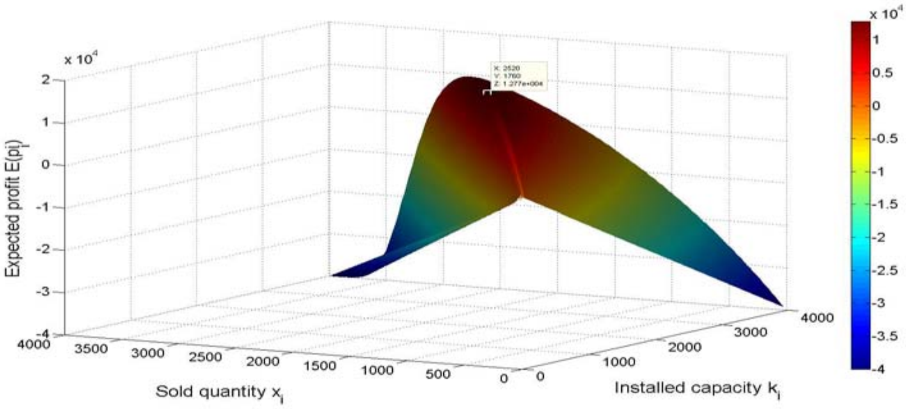

Figure 1: Expected profits of firm i, $i = 1, \ldots, 5$.

The results are depicted in Figure 2. Focusing on welfare, the network externality effect begins to dominate the competition effect when a new firm enters a duopolistic market.

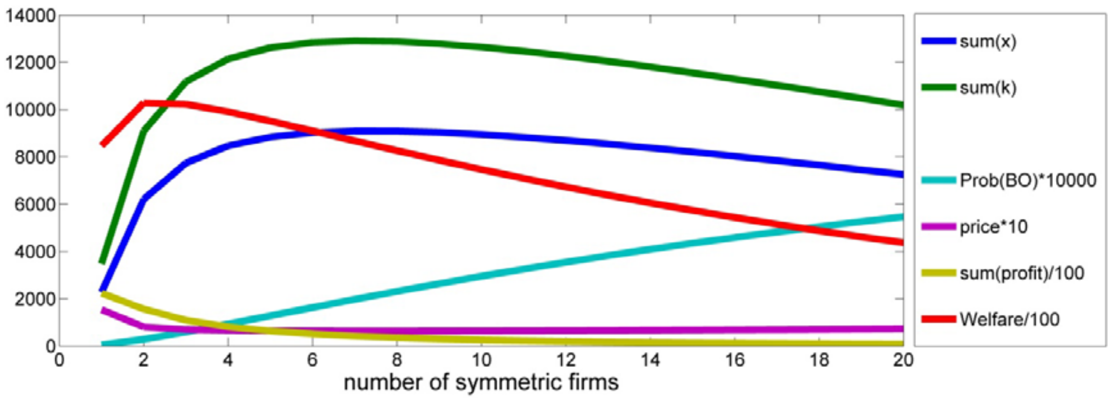

Figure 2: Market equilibrium values in dependence of the number of firms.

CONCLUSIONS

Our results reveal that the standard welfare-enhancing competition effect of an increasing number of firms, induced by lower prices and higher output quantities, is countervailed by a decrease in delivery insurance and thus by a growing probability of delivery disruptions (blackouts). Beyond a certain number of firms, the latter effect dominates. As a consequence, the socially optimal number of firms is limited. Thus, an increasing competition intensity, i.e. a rising number of firms in the market, might lead to a suboptimal level of supply security. In the consequence, measures such as capacity mechanisms (payments, subscriptions,…) might be necessary.

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