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Vertically integrated firms' investments in electricity generating capacities

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ABSTRACT

We compare investments in generating capacities of an integrated monopolist with the aggregate investments of two vertically integrated competing firms. The firms invest in their capacity and fix the retail price while electricity demand is uncertain. The wholesale price is determined in a unit price auction where the firms know the level of demand when they bid their capacities. Total capacities can be larger or smaller with a duopoly than with a monopoly. If the two firms select the Pareto dominant equilibrium, then the retail price is always higher and the social welfare lower in the duopoly case.

1. Introduction

We investigate, whether the incentives to invest in generating capacity can be suboptimal in a duopoly compared to a monopoly market, when firms are vertically integrated. Why should this be the case? The electricity market like many other markets is characterised by an uncertain demand. Electricity can, however, not be stored. Competing firms must use the same distribution network, and the network has to be balanced at each point in time. If the balance cannot be preserved, then the network collapses and none of the firms can sell electricity anymore. This creates externalities that might be better internalised by a monopolist than by competing firms.[2] On the other hand, the monopolist tends to produce less than is socially efficient and would therefore need and build less generating capacities.

von der Fehr and Harbord (1997) as well as Castro-Rodriguez et al. (2001) show that, from a social welfare point of view, firms build suboptimal low levels of generating capacity if prices are set equal to marginal costs in all those cases where the aggregate capacities are sufficient to satisfy demand at marginal cost prices. Otherwise prices are set high enough to balance supply and demand. They also prove that firms invest more in generating capacity, if the spot market price exceeds marginal costs at a fixed margin. In addition von der Fehr and Harbord (1997) endogenise the spot market price of electricity for an inelastic demand that is uncertain in the capacity decision stage, and known, when the firms bid their capacity in the auction. Then the firms under-invest in capacity as long as the distribution of the uncertain inelastic demand is concave. Neither of the two papers compares the market outcome under competition with the one generated by a monopoly.

Contrary to von der Fehr and Harbord (1997), we consider domestic consumers with an ex ante elastic demand for electricity. They can, however, not respond to real-time price signals from the wholesale market. Initially two firms invest in generating capacity. The firms are vertically integrated into the retail sector. Then firms offer retail contracts to the consumers which guarantee a certain retail price at which they can later buy as much electricity as they want to, as long as there is no black-out.[3] The consumers sign the retail contract of the firm with the lowest retail price. Nature chooses the level of the demand

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[2] Joskow and Tirole (2007) also refer to these externalities during uncontrolled black-outs.

[3] Contrary to Joskow and Tirole (2007) we abstract from two-part tariffs for the sake of simplicity and from state contingent rationing rules which the firms fix in advance together with the retail price for their clients. The latter do not play a major role in the retail competition for domestic consumers.

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shock. After observing demand, firms bid prices in the wholesale market in order to get the right to supply their capacity to the network. The wholesale market is modelled as a unit price auction à la von der Fehr and Harbord (1997, 1993).[4] Since the two firms commit to retail prices before the auction takes place, demand is inelastic in the auction as in von der Fehr and Harbord (1997) despite being ex ante elastic.

Consumers cannot instantaneously respond to price signals due to the imperfect metering technology that is used by most residential customers. This technology does not keep track of how much electricity they consume at given points in time, and cannot communicate current market prices.[5]

Before liberalization electricity markets were often characterized by vertically integrated, regulated, regional monopolies. These firms often survived and are now competing in both, the wholesale and the retail market.[6] How vertical integration affects competition on these markets has hardly been analyzed up to now. Studies of the effects of vertical integration on wholesale prices usually consider markets with regulated or predetermined retail prices.[7] Contrary to them, we also endogenize retail prices and explicitly focus on the interaction between the wholesale and the retail market, when vertically integrated firms with market power compete on the two related markets.

It turns out that a vertically integrated monopolist might install a smaller or larger capacity than two vertically integrated competitors if capacity costs are not too high. However, in subgame perfect Nash equilibria that are not Pareto dominated, the duopoly invests more than the monopolist. The social welfare is, nevertheless, always higher in monopoly than in the duopoly case, because the monopoly price is always lower than the duopoly price.

2. The model

Two firms $j = A,B$ generate electricity and are vertically integrated into the retail sector. They face a mass of electricity consumers normalised to one. Consumers suffer from demand shocks. They have a quasi-linear utility function such that their surplus function is given by

$$V(x,\varepsilon,r) = U(x,\varepsilon) - rx = x - \varepsilon - \frac{(x-\varepsilon)^2}{2} - rx, \quad (1)$$

for a representative period where x is electricity consumed, r is the unit retail price, and ε is the demand shock.[8] It hits all the consumers alike and is uniformly distributed on the interval [0,1].[9] The demand for electricity in the representative period can be derived from maximising $V(x;\varepsilon,r)$ with respect to x and results in

$$x(r,\varepsilon) = \max\{1 + \varepsilon - r, 0\}. \quad (2)$$

The single consumer's demand has no weight in total demand. Thus, he cannot influence the balance of supply and demand on the grid and therefore always accepts the lowest retail price offered. If retail prices are identical, he signs each of the two retail contracts with equal probability.

Firms are risk neutral and maximize their (expected) profits. Variable costs of generating electricity are assumed constant and, for the sake of simplicity, equal to zero. The costs of firm j consist only of the costs of capacity which are

$$C(k_j) = zk_j, \quad (3)$$

where z is a constant unit cost of capacity, and k_j the generation capacity installed by firm j. Firms decide on their capacity k_j and on their retail price offer r_j before they know the level of demand in the representative period.[10] When they bid their capacity in the electricity wholesale market, the demand shock is realised and the retail price is fixed. Therefore the market demand is known for sure and does not respond to changes in the wholesale price.

The wholesale market price of electricity is determined in a unit price auction of the type introduced by von der Fehr and Harbord (1997, 1993).[11] For simplicity firms have to bid a price p_j at which they are willing to supply their whole generating capacity.[12] The auctioneer must secure the balance of supply and demand on the grid if possible.[13] He orders the bids according to their prices and determines the marginal bid that is just necessary to equal supply and demand. The price of the marginal bid is the spot market price paid to all generators for each unit of capacity that is actually dispatched on the grid.[14] The capacity of the supplier that has bid below the marginal price is dispatched completely, whereas the marginal supplier is only allowed to deliver electricity necessary to balance supply and demand.[15]

Since in our framework demand does not respond to changes in the wholesale price and since the total amount of installed capacities can also not be influenced by the wholesale price, the auctioneer may also fail to find a price that balances supply and demand in the market. Then a black-out occurs in the representative period.

In reality firms compete not only once in a representative period but repeatedly on the wholesale and on the retail market. We abstract from the repeated nature of both retail and wholesale markets in order to simplify the analysis and to avoid running into issues of collusion.[16]

A black-out in our representative period can be interpreted as an inadequate supply of electricity. No firm can sell and deliver electricity, and all the firms realise zero profits. Thus, we abstract from any rationing by the auctioneer or the generators of electricity.[17]

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4 Green and Newbery (1992) based on Klemperer and Meyer (1989) suggested an alternative approach where firms bid differentiable supply functions instead of step functions as in von der Fehr and Harbord (1997, 1993).

5 Borenstein (2002), Faruqui et al. (2001) as well as Borenstein and Holland (2005) show under which circumstances increasing the number of price-responsive consumers improves social welfare in a perfectly competitive electricity market. Their approach has been further extended by Joskow and Tirole (2006).

6 A high degree of vertical integration of electricity generating firms into the retail sector can for example be observed in France, Spain and Germany. See e.g. Bergman et al. (1999) and European Commission (2001).

7 See e.g. Kühn and Machado (2004), Bushnell et al. (2008), Mansur (2007) and Baldursson and von der Fehr (2007).

8 With the concept of a representative period we abstract quite a bit from reality in electricity markets where consumers demand electricity over lots of periods which are all subject to demand shocks.

9 These shocks should not be mistaken for the volatility of demand during a single day which is somehow foreseeable. They refer to events like a hot summer in California or a cold winter in the north of Europe.

10 Our model only reflects uncertainty from really unforeseeable events during a period in which the retail price cannot be adapted. Extreme weather conditions are good examples whereas longer lasting economic booms or downturns might not qualify since they are after a while anticipated.

11 Such an auction was at the heart of the Electricity Pool in England and Wales before the reform in 2001, and still is in place in other liberalised markets like, e.g., the Nord Pool in Scandinavia or the Spanish wholesale market. See Bergman et al. (1999).

12 Thus, we do not consider the problem of strategic capacity withholding in order to raise the auction price. See Crampes and Creti (2005) and Le Coq (2002) for such analyses.

13 Transmission constraints are not considered here, although they might interact with constraints in the generating capacity. See Wilson (2002) for insights into this problem and for the analysis of isolated transmission constraints Borenstein et al. (2000), Joskow and Tirole (2000) and Léautier (2001).

14 The analysis here differs from simple Bertrand competition with capacity constraints as in Kreps and Scheinkman (1983) where the undercutting firm receives only its own price per unit sold even if its capacity is too low to serve all customers.

15 According to Wilson (2002) we assume an integrated system because participation in the auction is compulsory if a generating firm wants to sell electricity.

16 This has been analysed by Fabra (2003) and by Dechenaux and Kovenock (2007) for the wholesale market.

17 See Joskow and Tirole (2007) for an analysis of a market where retailers propose not only prices to consumers but also rationing rules which they want to apply. Although in reality residential consumers are sometimes rationed, the rationing rules are usually not spelled out in any sort of contract with their retailers.