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Transmission capacities and competition in Western European electricity market

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HIGHLIGHTS

- The ability of integration to reduce market power depends on transmission capacities.
- In the model firms compete in quantities, know their impact on prices and congestion.
- In Western Europe integration will not diminish market power.
- Line extension stimulates competition but is not a substitute for the regulation.

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ABSTRACT

The integration of national electricity markets into a single European one is expected to reduce the ability of dominant players to exercise market power. This paper investigates whether or not existing transmission capacities of cross-border interconnectors are sufficient to achieve this result and create vigorous competition in the market. A model with two decision levels is used. On the first level profit maximizing generators play Cournot game against each other. On the last level the system operator clears the market and determines flows in the network to maximize social welfare subject to a set of physical constraints. As each strategic generator anticipates her impact on equilibrium prices and congestion in the system, her optimization problem is subject to equilibrium constraints from the system operator's problem.

The analysis demonstrates that interconnector capacities in Western Europe are insufficient for integration alone to reduce the exercise of market power. I compare several possible competition-enhancing policies: expansion of interconnectors and different scenarios of national markets' restructuring. I show that although increase of line capacity is a useful tool to stimulate competition in an integrated market, it is not a substitute for the restructuring of large players.

1. Introduction

Energy goals of European Union include affordable and competitive prices, environmental sustainability and security. An integrated energy market is considered a fundamental prerequisite to achieve these objectives in a cost-effective way.[1] In its turn, integration heavily depends on the physical infrastructure used to deliver electric power. The European transmission system, however, was developed in times when regulated regional monopolists dominated the market and cross-border transmission capacities were required only for system reliability. Therefore the adequacy of existing transmission capacities comes into question.

In this paper I focus on the effect the transmission capacities in the network have on competition in the market for electric power. It is expected that an integrated market would have a positive effect on competition. Dozens of generators would compete with each other with no single firm having a significant market share. Since no single generator would be dominant, the ability of firms to exercise market power would be curtailed. Currently the threat of market power abuse cannot be dismissed, as regional market concentration in Europe remains high. Out of 28 member countries of European Union, in 2012 in 23 the market share of the largest generation company was at least 25%, and in nine countries it was above 75%.[2] Such concentration is not likely to disappear any time soon, but it might be mitigated through the integration of regions into a larger market. Although recent developments towards a common market in electric power generation yielded some convergence in wholesale prices, substantial differences remain,[3] pointing at insufficient transmission capacities. If the

[1] See European Commission (2014c).

[2] See European Commission (2014a, 2014b).

[3] See Zachmann (2008).

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capacities of interconnectors are indeed inadequate to allow for vigorous competition, market power of regional dominant players may not be diminished in an integrated market. This, in turn, would mean that integration without regulation or without restructuring of large companies may not produce the desired competitive market outcome.

To analyze the effect the transmission capacities in the network have on competition in the market for electric power one has to make several modeling assumptions. First, that generating companies are not price-takers. It's impossible to study the potential for market power abuse without considering it. Second, that generating companies take into account the influence they have on flows and congestion. I discuss the models that employ those two assumptions in greater detail in the next section. For the purposes of an introduction it is important to note that due to computational difficulties such models were rarely used to analyze real life power markets with large networks. Therefore this paper, with an analysis of an aggregated representation of Western European countries' network, presents a contribution to the energy policy literature. I show potential drawbacks of an integration combined with a complete deregulation, and compare the effects of several possible changes in the market structure that can lead to a more competitive outcome in the integrated market.

The rest of this paper is organized as follows. The second section provides the literature review. The third section describes the mathematical model, the solution approach employed to find Nash equilibrium and the data on the Western European market. The fourth section presents market equilibria in case of oligopoly and, as a benchmark, in case of perfect competition. The analysis shows that existing interconnector capacities are insufficient to reduce market power of dominant players in an integrated market. The fifth section compares two possible competition-enhancing policies: an increase of interconnector capacities and an increase in the number of generation companies. The paper concludes with a discussion of results and their implications for market policy.

2. Modeling of electricity markets: literature review

Capacity constraints strengthen market power, as they limit the ability of outside competitors to enter the market. The importance of transmission capacities for competitions in coupled markets has been highlighted in a seminal paper of Borenstein et al. (2000). With insufficient line capacity a strategic generator may find it profitable to restrict her output. This will congest the line into her area of dominance and allow her to exploit market power over the residual demand. But not only a restriction in output can be a profitable way to avoid competition. Cardell et al. (1997) show that a strategic generator can increase her production to congest the line from her area of dominance, prevent competitors from entering her market and therefore be free to exercise market power. As pointed out by Cardell et al. (1997) for a three node example in such a case the total generation in the market will be less compared to the foreclosed competitive outcome.[4] With sufficiently large lines such strategies of congesting lines to avoid competition may no longer be a part of equilibrium. Cardell et al. (1997) emphasize the need for market analysis with realistic models as the profitability of a congesting strategy depends on the exact properties of the network. In general, a sufficiently large increase of transmission capacity merges nodes into one market and strengthens competition between previously monopolistic players. Moreover, one does not necessarily need a lot of transmission capacity to increase competition. As Borenstein et al. (2000) demonstrate, even a relatively small line has a potential to induce Cournot equilibrium between two former monopolists. Surprisingly, this effect does not depend on how much power will actually flow via the line.

In the above mentioned examples profit-maximizing firms take their impact on network operation into account. Another numerical approach to model strategic firms in constrained networks is to assume that generating firms can't correctly anticipate the effect of their output on flows and congestion. Such models are sometimes referred as portraying "naive" generators and are used, for example, in Hobbs (2001) and Tanaka (2009). Compared to models with "non-naive" generators they have an advantage of being formulated as mixed complementarity problems with unique solutions. This significantly simplifies calculations for large networks. A disadvantage of such approach is that it can produce lower price estimates as shown in Neuhoff et al. (2005), thus leading to overly optimistic conclusions. Therefore I assume in this paper that generating companies understand how to manipulate congestion, as, for example in Borenstein et al. (2000).

A power market with strategic generators that can correctly anticipate the effect of their output on flows and congestion and use this knowledge to their advantage can be represented as a two-level game. In terms of timing, first action is taken by strategic generators, who choose their level of output to maximize their profits. Next the system operator maximizes social welfare subject to a set of physical constraints while taking generators' output as given. As each strategic generator correctly anticipates how her choices will influence equilibrium prices and congestion in the system, her optimization problem is subject to equilibrium constraints from the system operator's problem. That is strategic generator's problem of profit maximization includes in itself first order necessary optimality conditions from the system operator's problem as a part of the constraints set. This type of problem, solved by each strategic generator, is known as a mathematical program with equilibrium constraints (MPEC).[5] As there are several strategic producers on the market, finding an equilibrium requires solving a system of MPECs, or an equilibrium problem with equilibrium constraints (EPEC).

Examples of two-level modeling of energy markets can be found, among others, in Cardell et al. (1997), Cunningham et al. (2002), Hu et al. (2004), Ehrenmann (2004), Ralph and Smeers (2006) and Hu and Ralph (2007). As MPECs are, in general, nonconvex,[6] an EPEC might have many or none pure strategy Nash equilibria. Borenstein et al. (2000) demonstrate this problem in the simplest two node network. A number of papers, for example, Fortuny-Amat and McCarl (1981), Gabriel and Leuthold (2010), Ruiz et al. (2012) and Siddiqui and Gabriel (2013) address the challenges of solving an MPEC. As a result of those computational difficulties the two-level approach was rarely used to analyze real life power markets with large networks. For example, Ehrenmann and Neuhoff (2009) and Neuhoff et al. (2005) both use EPECs to analyze the power markets of Northwestern Europe. Ehrenmann and Neuhoff (2009) compare outcome under market coupling and under a coordinated auction of interconnectors, and conclude that market coupling performs better. They point out an important issue: market coupling can produce ambiguous incentives. On the one hand, it can reduce the ability of generators to exercise market power by importing demand elasticity. On the other hand, if companies own generating capacities at several nodes, integration can provide an incentive to increase the exercise of market power.

[4] A similar two node result can be found in the Appendix of Borenstein et al. (2000), with the examples of asymmetric market equilibria.

[5] For a comparison with other approaches in modeling electricity markets see Ventosa et al. (2005).

[6] See, for example, Gabriel et al. (2013) and Hu and Ralph (2007).