Network Expansion to Mitigate Market Power - How Increased Integration Fosters Welfare

Strommarkttreffen
March 31, 2014

Alexander Zerrahn & Daniel Huppmann
Network Expansion Can Increase Welfare

European Commission, 2012

The European Union needs an internal energy market that is competitive, integrated and fluid, providing a solid backbone for electricity and gas flowing where it is needed. [...] Despite major advantages in recent years [...], more must be done to integrate markets, improve competition and respond to new challenges.
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Network expansion from a social welfare perspective
An analysis of the European power exchange EPEX detects
- Without international congestion, welfare would have been higher by 250 million Euro in 2013
→ Pure efficiency gains

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Since mid-1990s, creation of an Internal Energy Market is envisaged as political goal:

- Unbundling of generation, network operation, and retailing
- Increased competition
→ Integration across national borders

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Electricity generation in Europe remains concentrated
Market share of the biggest generator (EU 2012, Eurostat 2012)

- In ten MS above 70%
→ Can further integration mitigate this potential for market power exertion?

European Commission, 2012
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Research Agenda

What we want to answer
Does the expansion of interconnector capacities yield welfare gains through reduced potential to exert market power?

The trade-off
Costs of network expansion vs. benefits of network expansion by reduced market power

To this end, we develop a three-stage model

Stage III
ISO clears market and assigns nodal prices
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Strategic firms in Cournot competition

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*Stage I*
Social planner expands network

*Stage II*
Strategic firms in Cournot competition

*Stage III*
ISO clears market and assigns nodal prices
Actually, Weren’t such Issues Analyzed Before?

→ Yes, basically – our contribution consists in

**Model**

- *Endogenous* tradeoff between costs and welfare-effects of network expansion when strategic firms are present (Neuhoff et al, 2005)

**Methods**

- Application and extension of new method to solve this class of problems
- using properties from duality theory (Ruiz et al, 2012)

**Identification of strategic effects/results**

- Thin-line effect (Borenstein et al, 2000)
- Shift of rents
- Proactive planning (Pozo et al, 2013), overassessment of expansion needs
### The First Stage Selects the Best Equilibrium

<table>
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<th>Stage</th>
<th>Timing</th>
<th>Players and decisions</th>
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|       |               | *Investment in network expansion*                          |
| II    | Spot market   | *Strategic generators*  
|       |               | *Generation at each node*                                  |
| III   |               | *Independent System Operator (ISO)*  
|       |               | *Dispatch of competitive fringe, load, nodal prices, network flows within capacity limits* |

**Spot market:** *Equilibrium Problem under Equilibrium Constraints*

→ **Stage II:** Strategic firms maximize profits (EP)

→ **Stage III:** subject to equilibrium spot market clearing (EC)

**Problem:** Equilibrium constraints do not allow for standard procedures
The First Stage Selects the Best Equilibrium

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**Result**: set of stationary points

- Necessary optimality conditions can explicitly be derived
- However, they describe a multitude of potential equilibria
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**Stage I serves as selection device**

→ Welfare-maximizing planner expands network
→ Selects the best out of all feasible solutions
A Three-Node Network to Illustrate the Model

- Simple network to demonstrate all prevailing strategic effects
- Assumption of nodal prices

**Topology**
- Three nodes
- Three lines

**Generation**
- Two strategic plants
- Zero production costs
- No competitive fringe

**Demand**
- Linear elastic demand
- Only in one node

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P_1 = 10 - q_1
\]
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c_2 = 0
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c_3 = 0
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f_3^{\text{max}} = 3
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f_2^{\text{max}} = 1
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f_1^{\text{max}} = 0.5
\]
Network Expansion Can Increase Welfare

We calculate a benchmark without expansion, and three solution candidates

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→ **Cournot Stable:** Best attainable solution, thin-line effect

**Result 1**

Network expansion can increase welfare
Consequences for the Distribution of Welfare Gains

Who wins? Who loses?
Compare the no expansion benchmark with the...

Asymmetric equilibrium
→ Producers & consumers gain
→ Aggressive firm remains in its position
Consequences for the Distribution of Welfare Gains

Who wins? Who loses?
Compare the no expansion benchmark with the...

**Asymmetric equilibrium**
→ Producers & consumers gain
→ Aggressive firm remains in its position

**Cournot Stable**
→ Producers & consumers gain
→ Previously aggressive firm loses
→ Previously passive firm gains
→ Consumers gains more than producers

Result II
Network expansion can increase welfare, and entails a relative shift of rents from producers to consumers
What Happens if Strategic Behaviour is Neglected...

Assume all firms competitive and determine optimal network expansion

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<tr>
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<th>Welfare</th>
<th>Competitive market</th>
<th>Strategic firms (C)</th>
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<tr>
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<td>Network capacity (initial + expansion)</td>
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In the optimum
→ More expansion, less welfare gain
What Happens if Strategic Behaviour is Neglected...

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In the optimum
→ More expansion, less welfare gain

The counterfactual
→ Network does not admit equilibrium solution
→ ... interpretation?

Result III
Neglecting strategic firms yields overassessment and undervaluation of expansion needs
Thank you very much for the attention
Network Expansion, Market Power, and Welfare

The Three-Stage Model

Results for a Three-Node Network

Literature

- ACER/CEER. Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2012, 2013

All pictograms under public domain free licence (Wikimedia Commons)
Backup - Solution of the EPEC

Stage II: Equilibrium Problem
Strategic firms maximize profits in Cournot competition

\[ \forall i, \max_{g_i} \Pi (g_i, g_{-i}) \quad \text{s.t.} \quad 0 \leq g_i \leq g_i^{\text{max}} \quad (\kappa) \]

subject to market clearing by the ISO

Stage III; Equilibrium Constraints

\[ \max \text{ Welfare} (g, d, \delta) \quad \text{s.t.} \quad \text{Nodal Balance} (g, d, \delta) = 0 \quad (p_n) \quad \forall n \]

\[ \text{Feasible Flows} (\delta) \leq 0 \quad (\mu_l) \quad \forall l \]

Procedure:
Transform stage III problem into equilibrium constraints we can work with

\[ \frac{\partial \text{Welfare}}{\partial g} + p_n \frac{\partial \text{Nodal Balance}}{\partial g} \geq 0 \quad g \geq 0 \]

\[ \frac{\partial \text{Welfare}}{\partial d} + p_n \frac{\partial \text{Nodal Balance}}{\partial d} \geq 0 \quad d \geq 0 \]

\[ \frac{\partial \text{Welfare}}{\partial \delta} + p_n \frac{\partial \text{Nodal Balance}}{\partial \delta} + \mu \frac{\partial \text{Feasible Flows}}{\partial \delta} = 0 \quad \delta \geq 0 \]

\[ \text{Nodal Balance} (g, d, \delta) = 0 \quad p_n \quad \forall n \]

\[ -\text{Feasible Flows} (\delta) \geq 0 \quad \mu \geq 0 \]
Backup - Solution of the EPEC

Spot market: EPEC

\[ \forall i, \max_{g_i} \Pi(g_i, g_{-i}) \quad \text{s.t.} \quad 0 \leq g_i \leq g_i^{\text{max}} \quad (\kappa), \]

\[ \frac{\partial \text{Welfare}}{\partial g} + p_n \frac{\partial \text{Nodal Balance}}{\partial g} \geq 0 \quad \perp \quad g \geq 0 \]

\[ \frac{\partial \text{Welfare}}{\partial d} + p_n \frac{\partial \text{Nodal Balance}}{\partial d} \geq 0 \quad \perp \quad d \geq 0 \]

\[ \frac{\partial \text{Welfare}}{\partial \delta} + p_n \frac{\partial \text{Nodal Balance}}{\partial \delta} + \mu \frac{\partial \text{Feasible Flows}}{\partial \delta} = 0 \quad \perp \delta \]

\[ \text{Nodal Balance} (g, d, \delta) = 0 \quad \perp p_n \quad \forall n \]

\[ -\text{Feasible Flows} (\delta) \geq 0 \quad \perp \mu \geq 0 \]

Here’s the problem:

- Stage II equilibrium problem subject to an MCP
- i.e. to nonconvex equilibrium constraints
- Necessary conditions cannot be derived explicitly
Backup - Solution of the EPEC

Reformulate Equilibrium Constraints such that bilinearities vanish

- Set up dual problem for stage III
- By definition, solution of the dual problem is no larger than solution of the primal
- The reverse inequality must hold as constraint

→ All vectors fulfilling the following constraints

\[
\begin{align*}
\text{Nodal Balance} & \quad (g, d, \delta) = 0 \quad (p_n) \quad \forall n \\
\text{Feasible Flows} & \quad (\delta) \leq 0 \quad (\mu_l) \quad \forall l \\
\text{Dual Constraints} & \quad \leq 0 \quad (\nu) \\
\text{Primal} & \quad (g, d, \delta) - \text{Dual}(p, \mu) \leq 0 \quad (\xi)
\end{align*}
\]

describe the stage III equilibrium constraints without bilinearities

- The first two (in)equalities comprise all feasible vectors for the primal problem
- The third inequality comprises all feasible vectors for the dual problem
- The primal-dual inequality ensures optimality

→ Solution space for the strategic firms' optimization problem