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

Strommarkttreffen
March 31, 2014

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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*

Network Expansion Can Increase Welfare

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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Network expansion from a political perspective

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?*

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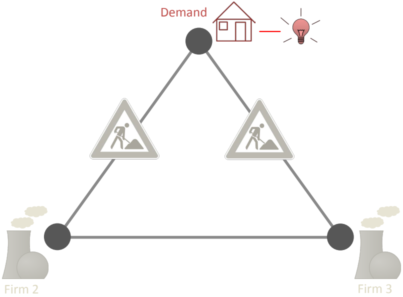
Research Agenda

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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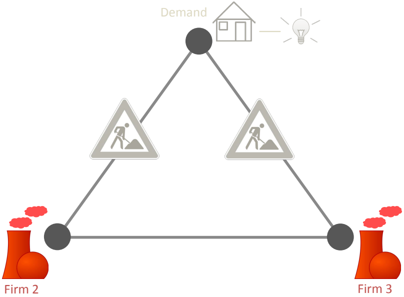

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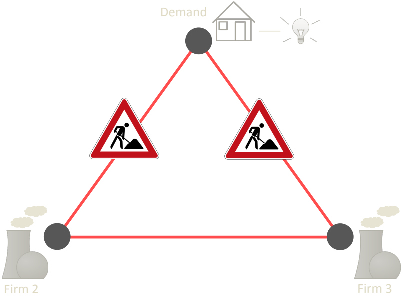
Stage I
Social planner expands network

Stage II
Strategic firms in Cournot competition

Stage III
ISO clears market and assigns nodal prices



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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

Stage	Timing	*Players* and decisions
I	Network expansion	*Benevolent social planner* 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

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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

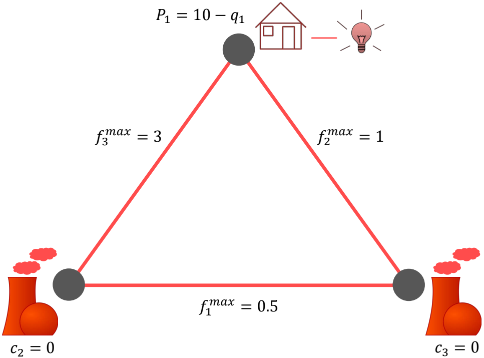
A Three-Node Network to Illustrate the Model

- 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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Network Expansion Can Increase Welfare

We calculate a benchmark without expansion, and three solution candidates

		Benchmark No Expansion	*Asymmetric*	*Cournot Instable*	*Cournot Stable*
Generation	firm 2	0	0	3.33	3.33
	firm 3	1.5	5	3.33	3.33
Network capacity (initial + **expansion**)	line 1	0.5 (0.5 + **0**)	1.67 (0.5 + **1.17**)	0.5 (0.5 + **0**)	0.8 (0.5 + **0.3**)
	line 2	1 (1 + **0**)	3.33 (1 + **2.33**)	3.33 (1 + **2.33**)	3.33 (1 + **2.33**)
	line 3	3 (3 + **0**)	3 (3 + **0**)	3.33 (3 + **0.33**)	3.33 (3 + **0.33**)
Total expansion		**0**	**3.5**	**2.67**	**2.97**
Network flows	line 1	−0.5	−1.67	0	0
	line 2	1	3.33	3.33	3.33
	line 3	−0.5	−1.67	−3.33	−3.33
Welfare	total	13.88	34	41.78	41.48

→ **Benchmark:** Passive-aggressive equilibrium (Borenstein et al, 2000)

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→ **Benchmark:** Passive-aggressive equilibrium (Borenstein et al, 2000)
→ **Asymmetric:** Passive-aggressive equilibrium
→ **Cournot Instable:** Optimistic and pessimistic solutions
→ **Cournot Stable:** Best attainable solution, thin-line effect

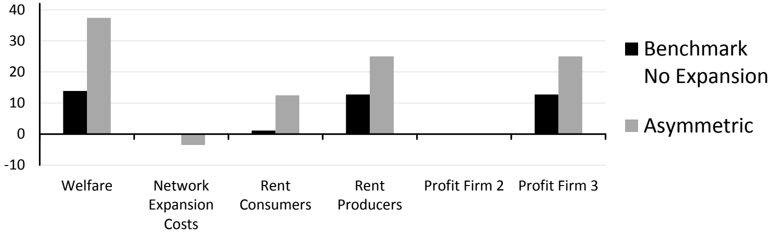
Result I

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

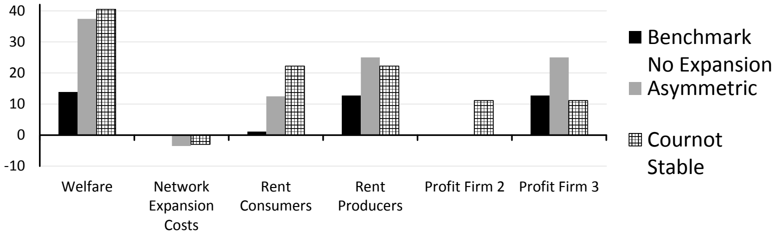


Consequences for the Distribution of Welfare Gains

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

			Competitive market	*Strategic firms (C)*
No expansion	Welfare		21.88	13.88
Expansion	Welfare		44.5	41.48
	Network capacity (initial + **expansion**)	line 1	0.5 (0.5 + **0**)	0.8 (0.5 + **0.3**)
		line 2	4.75 (1 + **3.75**)	3.33 (1 + **2.33**)
		line 3	4.25 (3 + **1.25**)	3.33 (3 + **0.33**)
	Total expansion		**5**	**2.97**

In the optimum

→ More expansion, less welfare gain

What Happens if Strategic Behaviour is Neglected...

Assume all firms competitive and determine optimal network expansion

			Competitive market	*Strategic firms (C)*
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		line 3	4.25 (3 + **1.25**)	3.33 (3 + **0.33**)
	Total expansion		**5**	**2.97**

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

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Backup - Solution of the EPEC

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

$$\forall i,\ \max_{g_i} \Pi\left(g_i, g_{-i}\right) \qquad \text{s.t. } 0 \leq g_i \leq g_i^{max} \quad (\kappa)$$

subject to market clearing by the ISO

Stage III; Equilibrium Constraints

$$\begin{aligned} \max \ \mathit{Welfare}\left(g, d, \delta\right) \text{ s.t. } \ \mathit{Nodal\ Balance}\left(g, d, \delta\right) = 0 \quad (p_n) \quad \forall n \\ \mathit{Feasible\ Flows}\left(\delta\right) \leq 0 \quad (\mu_l) \quad \forall l \end{aligned}$$

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

$$\begin{aligned} \frac{\partial \mathit{Welfare}}{\partial g} + p_n \frac{\partial \mathit{Nodal\ Balance}}{\partial g} &\geq 0 \perp g \geq 0 \\ \frac{\partial \mathit{Welfare}}{\partial d} + p_n \frac{\partial \mathit{Nodal\ Balance}}{\partial d} &\geq 0 \perp d \geq 0 \\ \frac{\partial \mathit{Welfare}}{\partial \delta} + p_n \frac{\partial \mathit{Nodal\ Balance}}{\partial \delta} + \mu \frac{\partial \mathit{Feasible\ Flows}}{\partial \delta} &= 0 \perp \delta \\ \mathit{Nodal\ Balance}\left(g, d, \delta\right) &= 0 \perp p_n \quad \forall n \\ -\mathit{Feasible\ Flows}\left(\delta\right) &\geq 0 \perp \mu \geq 0 \end{aligned}$$

Backup - Solution of the EPEC

Spot market: EPEC

$$\forall i,\ \max_{g_i} \Pi\left(g_i, g_{-i}\right) \qquad \text{s.t. } 0 \leq g_i \leq g_i^{max} \quad (\kappa),$$

$$\frac{\partial Welfare}{\partial g} + p_n \frac{\partial Nodal\ Balance}{\partial g} \geq 0 \perp g \geq 0$$

$$\frac{\partial Welfare}{\partial d} + p_n \frac{\partial Nodal\ Balance}{\partial d} \geq 0 \perp d \geq 0$$

$$\frac{\partial Welfare}{\partial \delta} + p_n \frac{\partial Nodal\ Balance}{\partial \delta} + \mu \frac{\partial Feasible\ Flows}{\partial \delta} = 0 \perp \delta$$

$$Nodal\ Balance\left(g, d, \delta\right) = 0 \perp p_n \quad \forall n$$

$$-Feasible\ Flows\left(\delta\right) \geq 0 \perp \mu \geq 0$$

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 vansih

- 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

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

describe the **stage III equilibrium constraints without bilinearities**

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

→ Solution space for the strategic firms' optimization problem