Competitive effects of wind in-feed

Franz Hubert
Olga Spiridonova
Humboldt-Universität zu Berlin

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Motivation

Wind in-feed has zero marginal cost and largely comes from small independent suppliers.

Conventional generation capacities are owned by dominant incumbents with some (local) market power.

Intutition: higher wind infeed increases competition, thereby, lowering prices and increasing consumer surplus.

This intuition may be wrong if transmission constraints are relevant and incumbents behave strategically.

Higher wind infeed may lead to higher prices and lower consumer surplus.

Outline

1. **How can it happen?**
   - We use a variant of Borenstein et al. (2000) (two nodes - one line) to illustrate the possibility.
2. **Is it relevant?**
   - We calibrate the model using German data on demand, transmission capacity and cost.
   - We assume nodel-pricing and the worst possible market structure (two incumbents).
   - We find that it will happen in a relevant range.

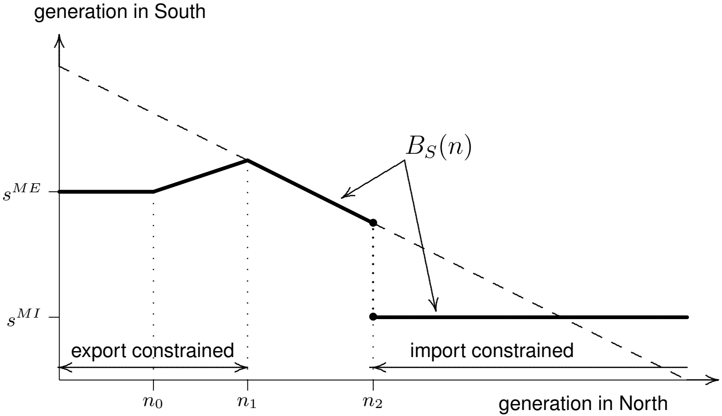
How can it happen: Framework

Based on Borenstein et al. (2000):

- two nodes (North & South) connected by one line of limited transmission capacity
- one strategic generator in each node (the incumbents), competition in quantities.
- nodal pricing

- **competitive wind-infeed only in north**

Best Response Function: South



Features

Under mild assumptions the unconstrained (usual) Cournot best response function (dashed) is continously decreasing with a slope less than one.

With a sufficiently small line capacity, the best response (solid) is non-monotonic and discontinous.

Features Explained

- $n < n^0$: South produces the monopoly quantity for demand in South and exports as much as possible.
- $n \in [n^0, n^1]$: South can increase exports as north increases generation.
- $n \in [n^1, n^2]$: The line is uncongested. We have normal Cournot competition (strategic substitutes). Quantities increase and price declines as generation in North increases, but profits of South will not converge to zero.

Features Explained II

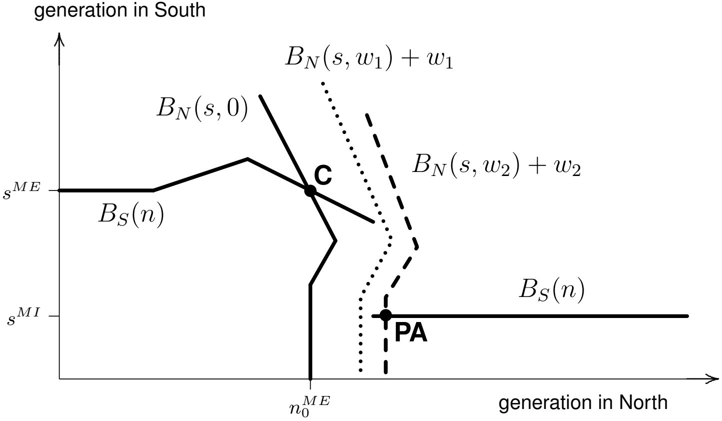
- $n = n^2$: profits from competing in the whole market are equal to profits from accepting maximal imports and acting as a monopolist on residual demand in South.
  At n^2 a small increase of generation in North results in a discontinous drop in generation in South.
- $n > n^2$: any further generation in North reduces prices only in North.

A Second Strategic Producer in the North

With a second strategic player in the North (besides wind) we have four possible outcomes:

1. a unique unconstrained equlibrium in pure strategies (standard case)
2. a unique constrained equlibrium in pure strategies ("passive aggressive")
3. two equlibria: one "standard" the other "passive aggressive"
4. an equlibrium in mixed strategies

Change of Equilibrium as Wind In-feed Increases



Calibration

We calibrate the two-node, two player model using German data for

1. nodes and transmission capacity
2. demand
3. cost of conventional generators

Network

North: federal states of Berlin, Brandenburg, Bremen, Hamburg, Lower Saxony, Mecklenburg-Vorpommern, Saxony, Saxony-Anhalt and Schleswig-Holstein

South: federal states Baden-Wuerttemberg, Bavaria, Hesse, North Rhine-Westphalia, Rhineland-Palatinate, Saarland and Thuringia + Austria and Luxembourg. (similar: Thema (2013) and Egerer et al. (2016)).

Capacity: We report results for 16 GW ATC between North and South (maximum considered in Thema (2013)).

Demand & Cost

- linear demand function; shared 25% (North) : 75% (South).
- two scenarios: mean and peak (top 5% of load hours)
- reference point for each scenario combines EEX price data and ENTSO-E load data
- demand elasticity of -0.25 (-0.5) at the mean (peak) reference point
- quadratic marginal cost: fitted to data from Open Power System Data on conventional power plant capacities and technology costs estimations from Egerer et al. (2014)

Results

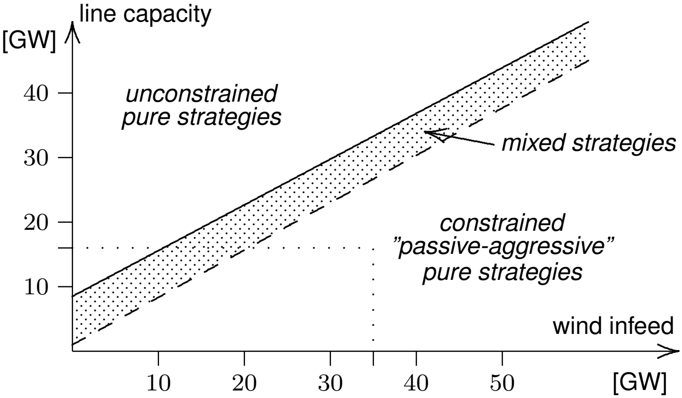
1. Wind in-feed & line capacity $\Longrightarrow$ type of equilibrium.

   In the relevant capacity range we move from unconstrained EQ to mixed EQ and then to passive-aggressive EQ as wind infeed increases.

2. Wind in-feed $\Longrightarrow$ features of the equilibrium (at 16 GW capacity and peak demand).

   As wind infeed increases, total power supply first increases, then decreases, finally increases again. This pattern is repeted for net consumer surplus.

Change of Equilibrium



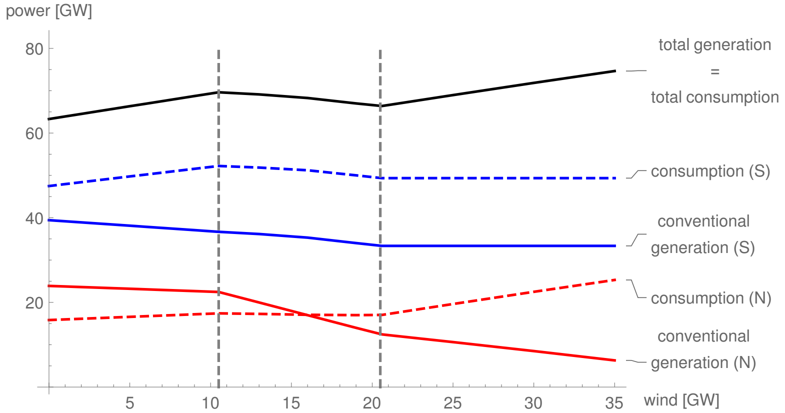
Results

For linear demand and quadratic marginal cost we can explicitly calculate the solution for equilibria in pure strategies.

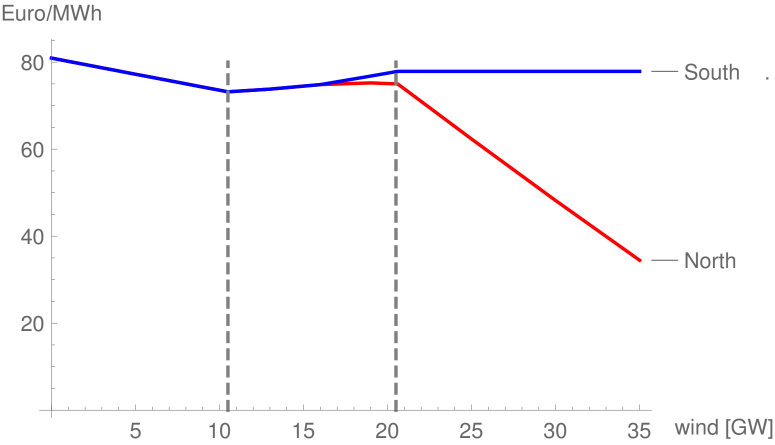
For combinations of wind infeed and transmission capacities which result in mixed equilibria, we numerically approximate the probability distribution and calclate the expected values for the variables of interest.

In the following we display results for a transmission capacity of 16GW and peak demand, for which we have a mixed strategy equilibrium for 10.5 GW $<$ wind infeed $<$ 20.5 GW.

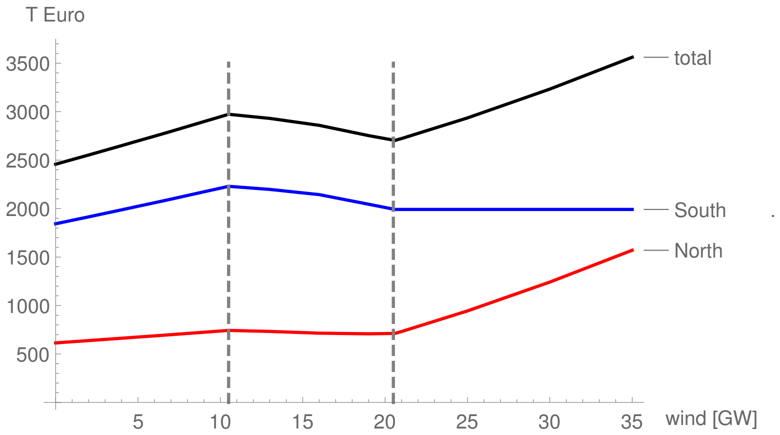
Generation and Consumption



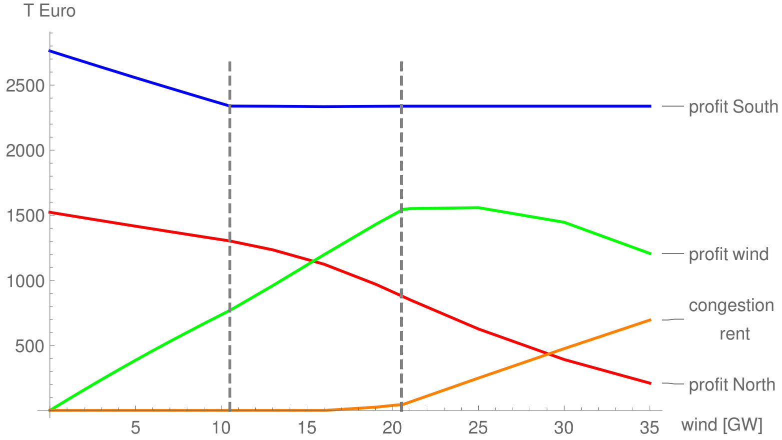
Nodal Prices



Net Consumer Surplus



Profits and Congestion Rent



Limitations

- We have zonal pricing with redispatch rather than nodal pricing. (Although zonal pricing is likely to exacerbate market power (Harvey and Hogan (2000)).
- The German/Austrian region has more than two large conventional suppliers, so the scope for the abuse of market power is smaller.
- The network is linked to European neigbours, which will increase competition.

References I

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