

Beneficiaries-pay charges for transmission: measurement and incentives

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Electric Power Optimization Centre Workshop

9 September 2015

Energy and Transmission Pricing

Value of Transmission

SPD Charge

Benefits of Transmission

Price-taking SFE

Strategic SFE

SPD Charge on Load

Conclusions

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Outline

- Pricing of energy and transmission
 - The value of a transmission grid
 - Locational marginal pricing of energy
 - Price signals for operation and investment

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 - What benefits does SPD charge measure?
 - Strategic supply function equilibrium.
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What is the value/cost of a transmission grid?

Costs:

- mostly construction – large economies of scale;
- maintenance and repairs, vary little with use;
- losses are a marginal cost, explicitly priced in locational pricing;
- otherwise near zero marginal cost.

What is the value/cost of a transmission grid?

Costs:

- mostly construction – large economies of scale;
- maintenance and repairs, vary little with use;
- losses are a marginal cost, explicitly priced in locational pricing;
- otherwise near zero marginal cost.

The transmission grid provides a number of different benefits:

- reliability;
- short-run efficiency;
- the ability to access electricity when needed;
- competition benefits.

Alternatives to transmission

Example: Large industry on a spur line

Local generation

- Build local supply
- Pay fuel price for energy
- High-risk of non-supply

Connect to grid

- Build large line
- Pay market price for energy
- Shared risk

Alternatives to transmission

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Future scenarios

Local solar or wind supply

- Build local supply
- V. low energy cost
- Need to import when cloudy/calm

Battery storage

- Medium size line
- Energy at off-peak prices
- Shared risk

Alternatives to transmission

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Transmission is an alternative to generation/storage investments

Value of Transmission

- Value of energy transferred
- Value of reserve access (option value)
- Shared cost of reliability and reserve

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Purpose of Transmission Pricing

Hopefully, system value exceeds cost. Fair transmission charges divide cost so that for every participant, value exceeds cost.

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Purpose of Transmission Pricing

Hopefully, system value exceeds cost. Fair transmission charges divide cost so that for every participant, value exceeds cost.

However, these charge should be designed so as to promote both **static** and **dynamic efficiency**.

In particular, once a line is built it is desirable that:

- the line be used, reducing fuel consumption;
- the charging mechanism sends the right (locational) price signals.

The SPD Charge

Proposed SPD charge would apply to large interconnection assets with many users.

Using solutions from Scheduling Pricing and Dispatch (SPD) model with pre- and post-expansion network.

Benefit is difference in surplus between two solutions, a part of which is collected by Transpower as the SPD charge for transmission.

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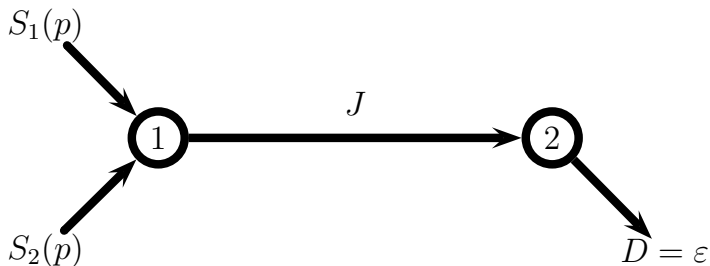
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Charge on benefit from expanded line

The SPD Charge method does not apply a charge based on the entire producer surplus, only based on the difference in producer surplus compared to some counterfactual.

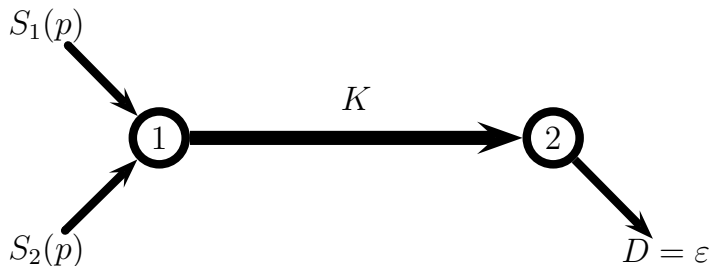


ε random demand shock.

Counter-factual: state of the network prior to any line upgrade.

Charge on benefit from expanded line

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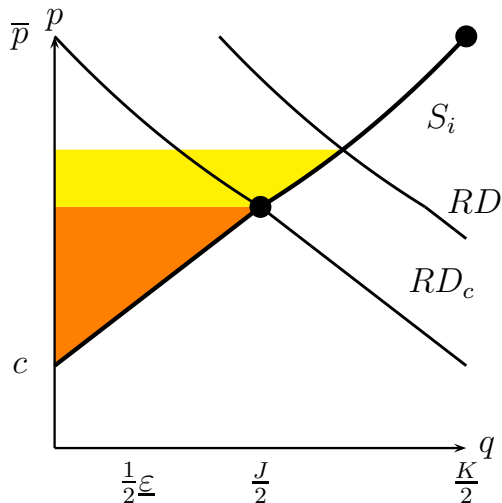
ε random demand shock.

After the line upgrade, line size increased from J to K .

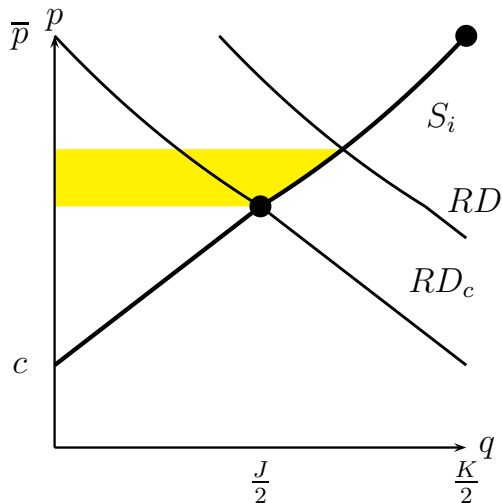
Suppose two firms in node 1 the same cost functions.

Tariff on benefit from expanded line (dispatch $> \frac{J}{2}$)

Transmission charge is a proportion of the benefit accruing due to the increased line capacity.

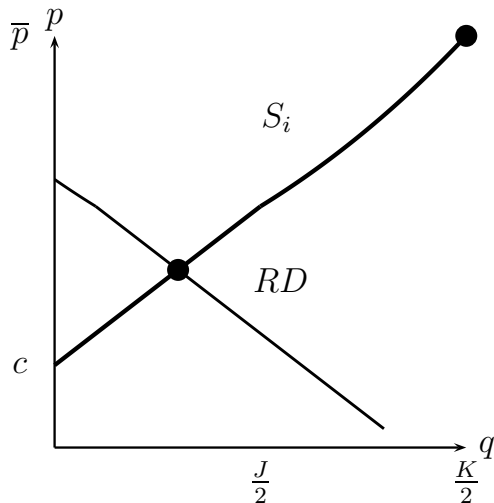


Charge on benefit from expanded line (dispatch $> \frac{J}{2}$)



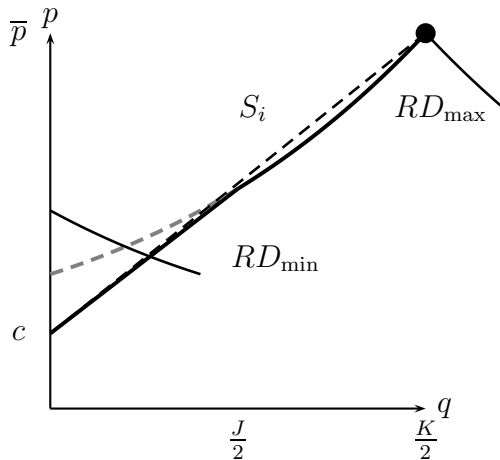
The charge will be based on this area (which depends on the realisation of the demand shock).

Charge on benefit from expanded line (dispatch $\leq \frac{J}{2}$)



For dispatch below $\frac{J}{2}$, the actual and counterfactual dispatch points are the same, so there is no charge.

Maximal offer curve (charge on benefit)



Best curve is maximal for different objectives above and below $J/2$.

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Equilibrium modeling

Generators know their costs with certainty but market conditions are uncertain.

Generators choose supply curves to maximize expected profit.

- Strategic supply function equilibrium - expectation over residual demand curves.
- Price-taking supply function equilibrium - expectation over market prices.

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Incentives for firms that are price-takers

Firms that are **price takers** have no market power — under uniform pricing they offer at marginal cost. However, under pay-as-bid pricing price-taking bidders will mark up above marginal cost (Federico and Rahman 2003).

Under SPD-charge, payoff function is between uniform pricing and pay-as-bid.

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Price-Taking SFE

Equilibrium concept

- Generators take **distribution of prices** to be fixed.
- Generators choose bid curve to maximize profit minus charge
- System operator determines price distribution from bid curves and demand distribution
- Equilibrium is the fixed point where price distribution assumed by generators matches the distribution resulting from their bids.

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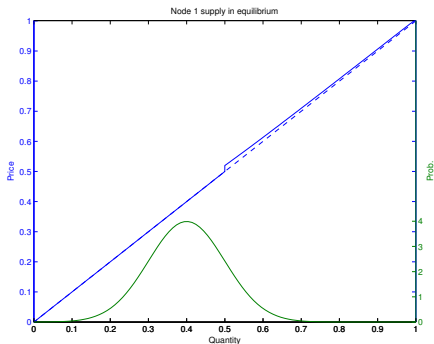
Equilibrium concept

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- System operator determines price distribution from bid curves and demand distribution
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We can show that

- Industry offer curve is independent of the number of price-taking generators;
- Last unit is offered at cost;
- Price-taking offer-stacks are a lower-bound (in price) for strategic SFE.

Equilibrium offer curve



For quantities below J , the equilibrium offer curve is at marginal cost, since there is no charge payable in this region (and it does not affect the perceived benefit).

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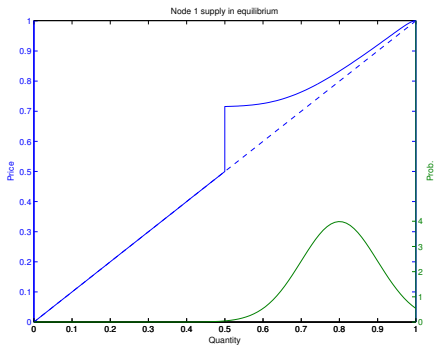
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Equilibrium offer curve



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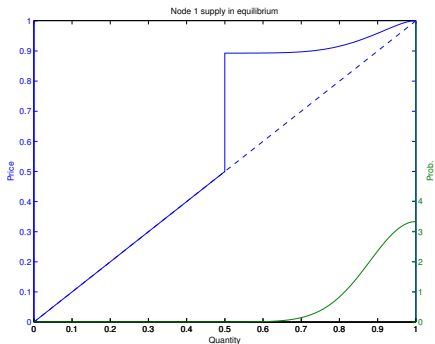
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Equilibrium offer curve



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What if firms can influence market price?

The previous example shows how price-taking firms will alter their bids in response to the SPD charge.

But what happens when firms have market power?

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Equilibrium concept

- Generators take **distribution of residual demand curves** to be fixed.
- Generators choose bid curve to maximize profit minus charge.
- Nash equilibrium — all players bid optimally given others' bids.

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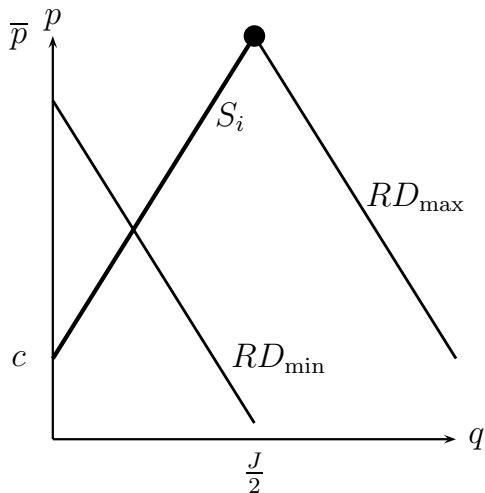
Equilibrium concept

- Generators take **distribution of residual demand curves** to be fixed.
- Generators choose bid curve to maximize profit minus charge.
- Nash equilibrium — all players bid optimally given others' bids.

We can show that

- Last unit is offered at boundary price that depends on excess production capacity, demand elasticity and increase in marginal costs.
- More firms means more competitive offers, closer to cost.

Duopoly SFE with low-capacity line (no charge)



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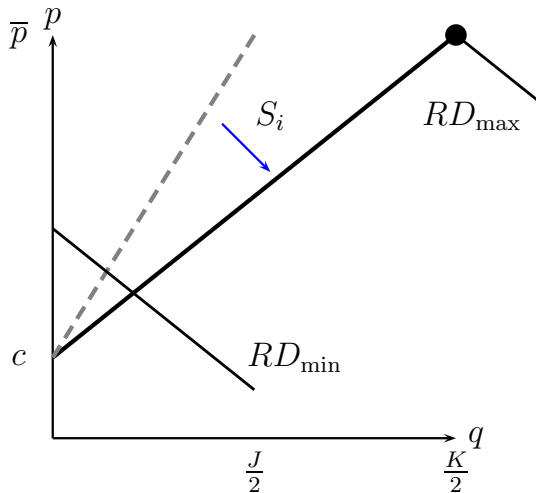
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Duopoly SFE with expanded line (no charge)



Larger capacity gives a flatter curve (more competitive). Change in network shifts SFE already.

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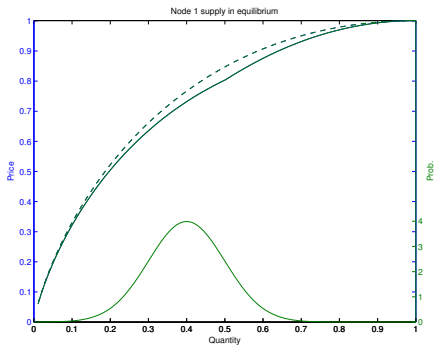
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Strategic equilibrium supply functions



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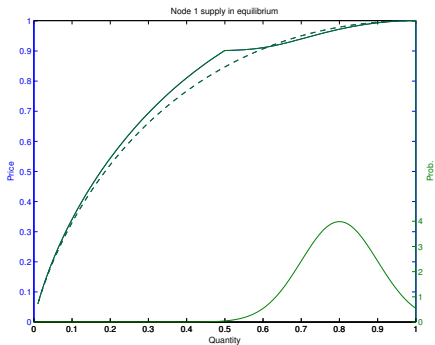
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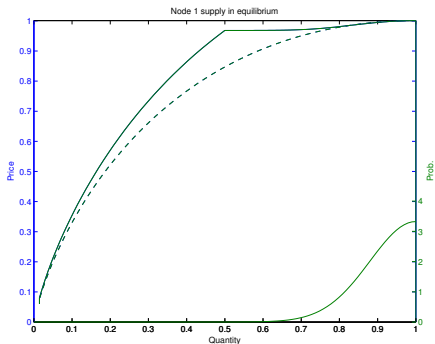
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Incentive to conceal perceived benefits

In both models, generators are able to **conceal their perceived benefits** by changing their offer.

This could lead to inefficiency in the dispatch model as well as **shifting the burden of paying for the transmission asset** onto those market participants who cannot or do not behave strategically.

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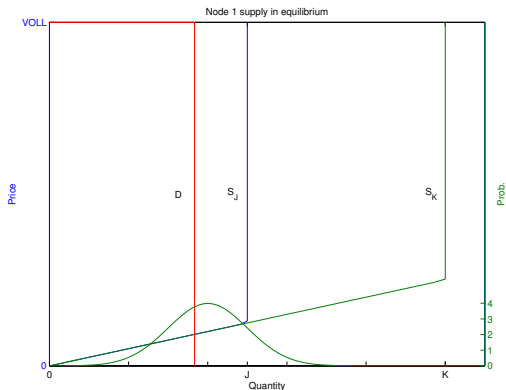
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- With uncertain demand, a firm must balance its incentive to minimize the transmission charge against the incentive to maximize its profit in the current period.
- Producers can still 'hide' most of their benefits.
- The more certain they are of demand levels, the more benefits they can hide.
- Measuring benefits using spot-market bids gives incentives to alter those bids.

SPD Charge on Load



Early years, low demand.

Small probability of a large charge.

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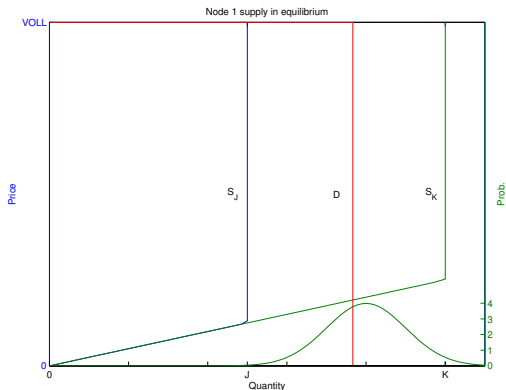
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SPD Charge on Load



Demand rises.

All nodal load charged for transmission in peak period.

Becomes a peak surcharge

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- When generators are price-takers, they raise offer prices in response to the SPD charge.
- If generators can control prices, incentives more mixed.
- Demand uncertainty limits producers' ability to avoid SPD charge.
- As demand rises, more of SPD charge is passed to load.

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The NZ market



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Assumptions, caveats

- No vertical integration (gen-tailers)
- No forward or hedge contracts
- Uniformly distributed demand shock from 0 to 6000 MWh
- SPD charge capped at $1/3$ of benefits
- Boundary price of \$500

Could relax some or most of these

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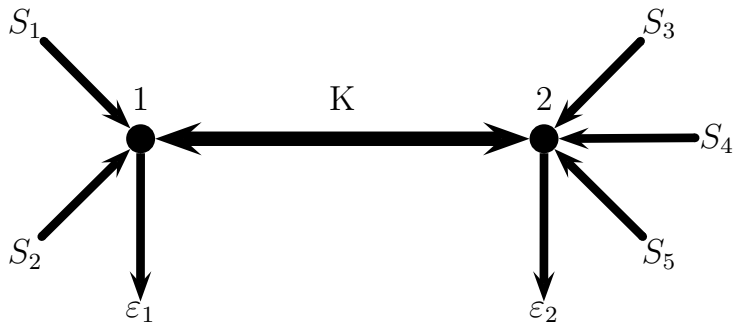
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Model with 5 generators



Line capacity increases from 750 to 1400 MW

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Marginal cost and plant capacity

Producer	Node	Intercept	Slope	Capacity	Technology
1	1	10	0	3000	Hydro
2	1	10	0	1000	Hydro
3	2	10	0.025	900	Hydro/Gas
4	2	10	0	1500	Hydro
5	2	50	0	800	Coal

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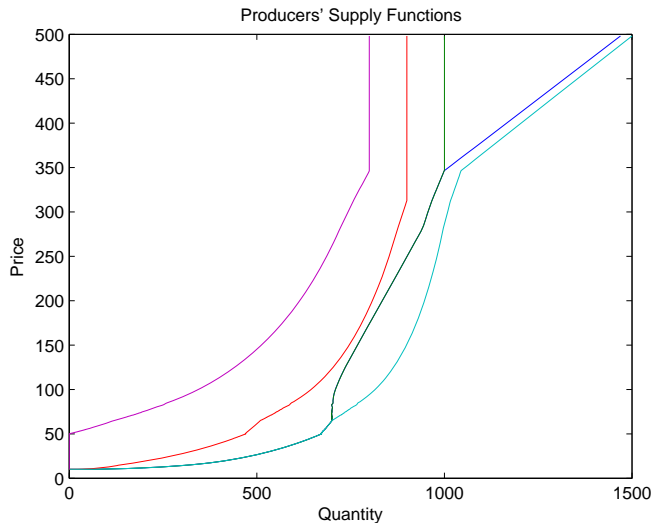
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Strategic Equilibrium



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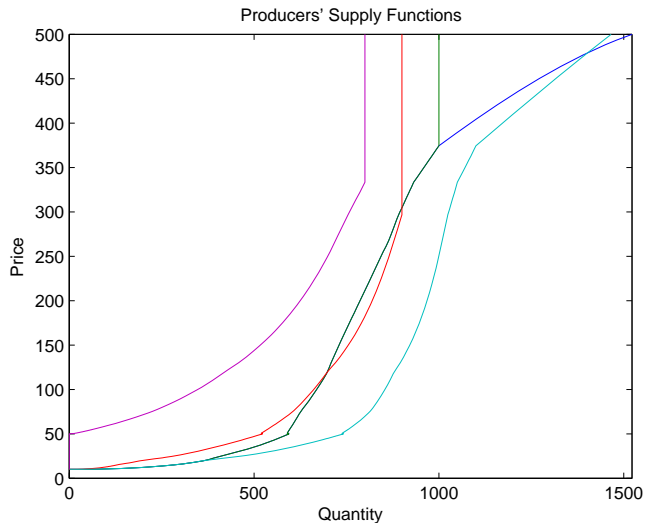
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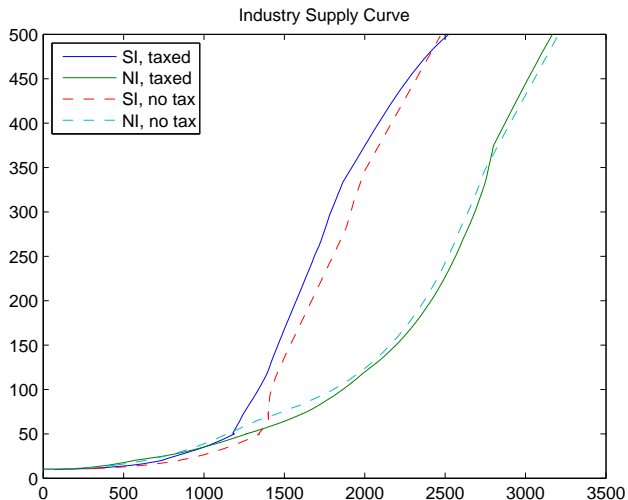
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Effects of SPD charge

Raises offer prices of generators in exporting nodes

Similar spot-market distortions to a MWh charge

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