

SFE models of Beneficiaries-Pay Transmission Pricing

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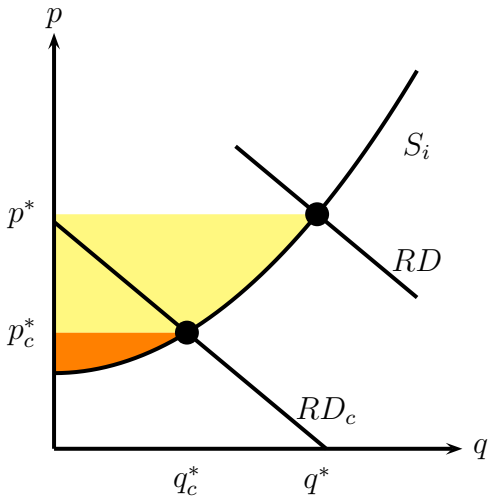
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Outline

- How does the beneficiaries-pay SPD method work?
- How do firms respond to transmission pricing in Cournot models?
- Supply function equilibria with transmission pricing.
- Our conclusions.

How beneficiary-pays charges are calculated

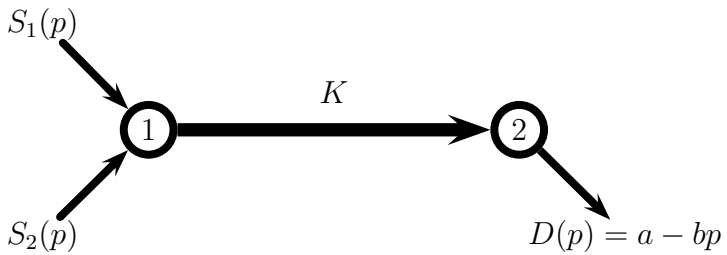


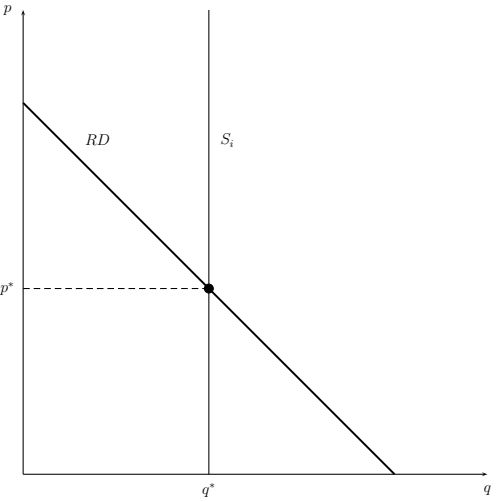
Incentive to conceal perceived benefits

It is plausible that generators may wish to avoid the charges by marking up their offer curves to reduce their perceived surplus:

- with known demand, we will see that generators can avoid charges altogether;
- however, 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. These counteracting forces reduce the firm's incentive to mark up to conceal profits.

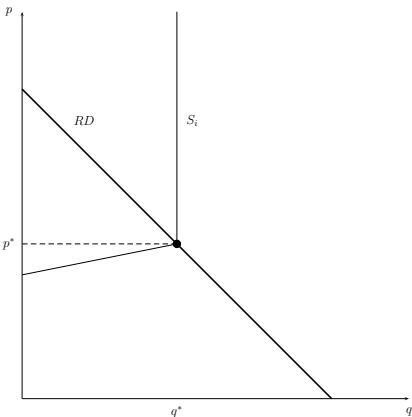
Cournot duopoly model (deterministic demand)





Introduction of a tax

A small portion $\alpha < \frac{1}{2}$ of perceived producer surplus is taxed. Generators respond by marking up below the dispatch quantity (which has no effect of the dispatch point).



Profit maximisation by suppliers

Players try to maximise their profit functional

$$\Pi = \int_c^{\bar{p}} (p - c)q(\psi_p + q'\psi_q) dp.$$

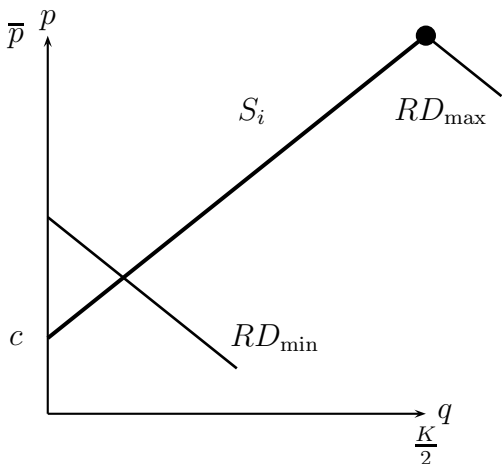
Market distribution function $\psi(q, p)$ is probability that an offer of q MW at price p will not be fully dispatched.

The first-order optimality condition

$$Z = (p - c)\psi_p - q\psi_q = 0$$

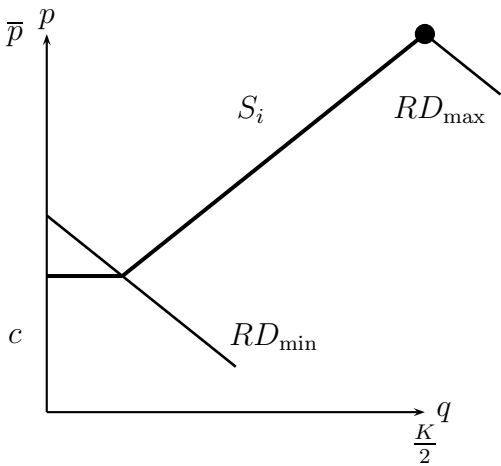
gives rise to a system of differential equations. One can find that the supply function equilibrium is for each firm to offer a linear offer in a duopoly. Moreover, these offers hit the price-cap at the line capacity.

SFE with expanded line



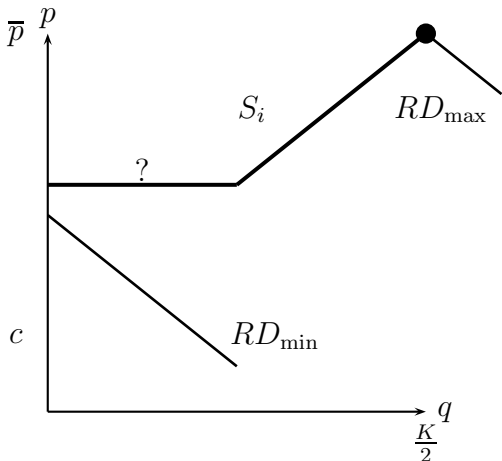
What might happen with a tax? Suppose that $\alpha = 25\%$ of perceived producer surplus is taxed.

Marking up in response to a tax – undispatched segment



Kink in un-dispatched part of curve is fine

Marking up in response to a tax – dispatched region



What about further up the curve, in the part that is sometimes dispatched?

SFE with tax on producer surplus

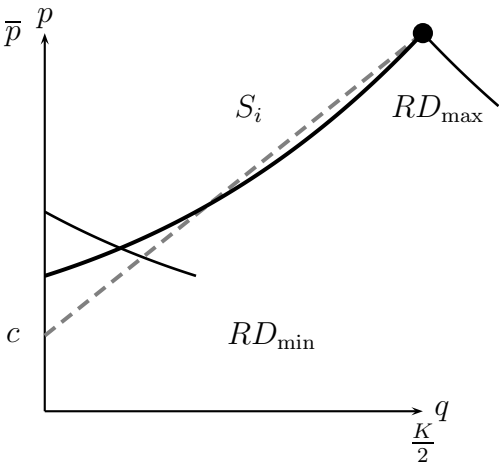
New profit functional

$$\Pi = \int_c^{\bar{p}} (p - c)q(\psi_p + \alpha'\psi_q) - \alpha q(1 - \psi) dp.$$

First-order optimality condition becomes

$$Z = (p - c)\psi_p - (1 - \alpha)q\psi_q - \alpha(1 - \psi) = 0.$$

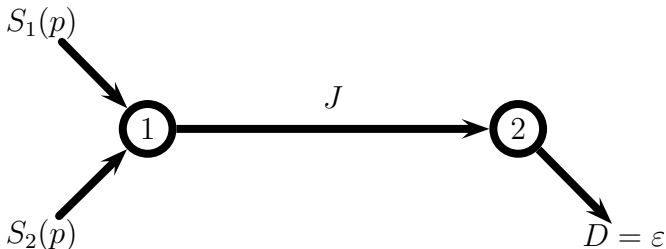
Tax on full producer surplus



In order to avoid the tax, the firms, in equilibrium, mark-up their offer prices for low quantities, but may also mark-down as they approach the line capacity.

Tariff on benefit from expanded line

But the SPD method doesn't tax all the producer surplus, only the difference in producer surplus compared to some counterfactual.

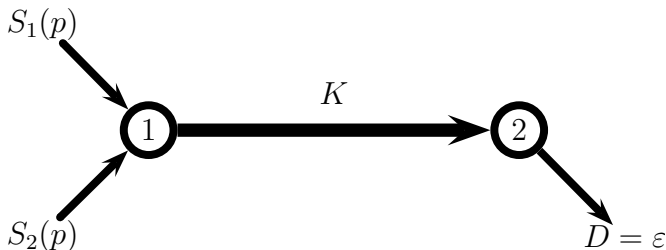


$$\varepsilon \sim U[\underline{\varepsilon}, \bar{\varepsilon}]$$

This counterfactual is the state of the network prior to any line upgrade.

Tariff on benefit from expanded line

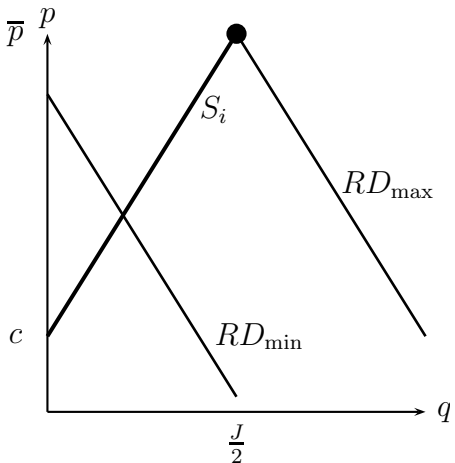
But the SPD method doesn't tax all the producer surplus, only the difference in producer surplus compared to some counterfactual.



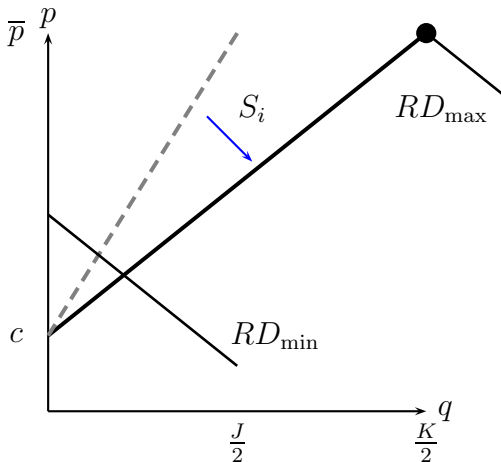
$$\varepsilon \sim U[\underline{\varepsilon}, \bar{\varepsilon}]$$

After the line upgrade we have the following network; the size of the line has increased from J to K .

SFE with low-capacity line (no charge)



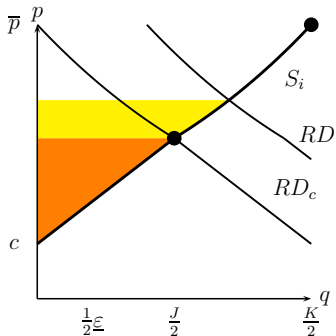
SFE with expanded line (no charge)



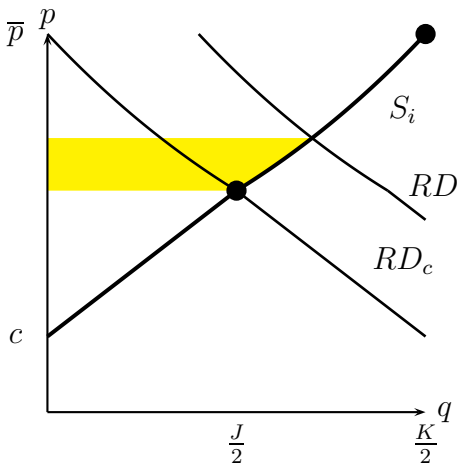
Larger capacity gives a flatter curve (more competitive). The SPD-based TPM methods, all assume the offer stays the same – this would not be a valid assumption in this case.

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

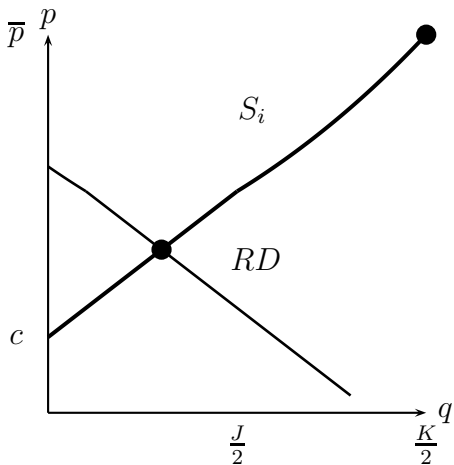
Rather than paying a tax on the full producer surplus, the transmission charge is a proportion of the benefit accruing due to the increased line capacity.



Thus if, in equilibrium, the dispatched quantity is greater than $\frac{J}{2}$ (the counter-factual's maximum dispatch due to the smaller line), then the benefit would be perceived profit less the orange triangle.

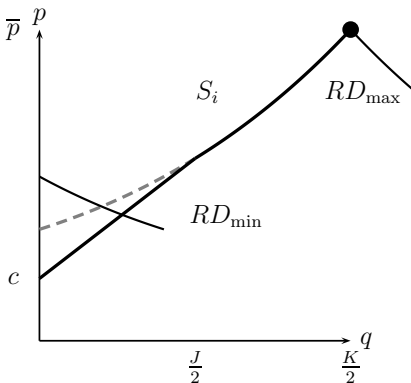
Tariff on benefit from expanded line (dispatch $> \frac{J}{2}$)

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

Tariff 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.

Equilibrium offer curve (tariff on benefit)



For quantities below $\frac{J}{2}$, the equilibrium offer curve is straight, since there is no tax payable in this region (and it does not affect the perceived benefit).

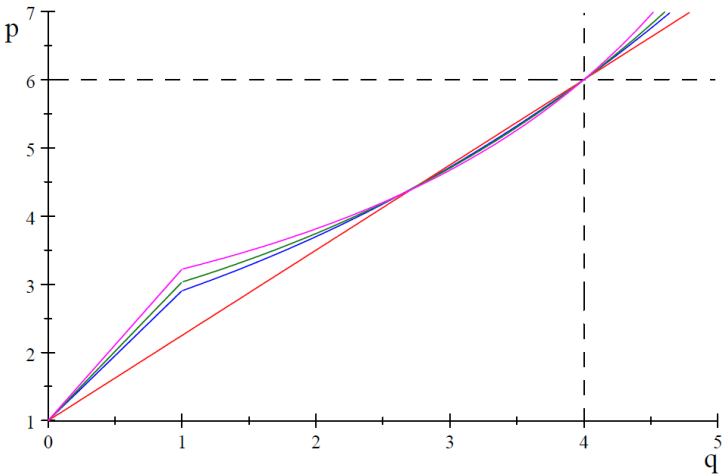
For quantities greater than $\frac{J}{2}$, the equilibrium curve matches the curve where the charge was applied to total perceived surplus.

Illustrative Example

Consider a duopoly, over a network as shown earlier.

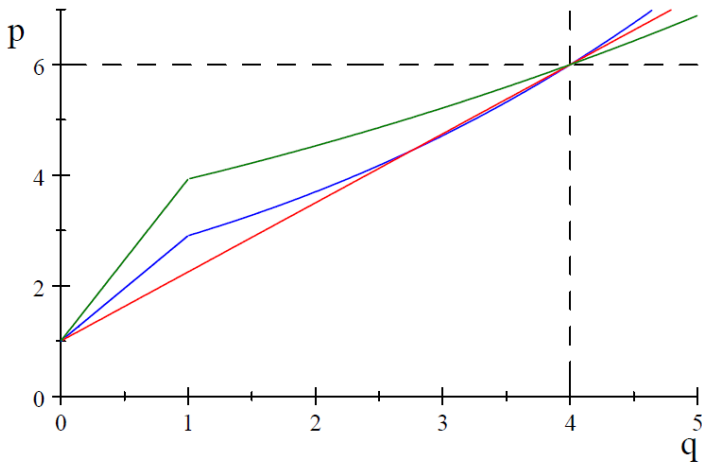
- The initial capacity of the transmission line is $J = 2$, and the line is expanded to $K = 8$.
- The marginal cost of both generators is $c = 1$, and there is a price-cap in the market of 6.
- The demand at node 2 is random, and uniformly distributed between $\underline{\epsilon} = 0$ and $\bar{\epsilon} = 10$.
- Firms are charged $\alpha = 25\%$ of their benefits.

Equilibrium offer as a function of the tax



No charge – red; $\alpha = 0.25$ – blue; $\alpha = 0.33$ – green; $\alpha = 0.5$ – magenta.

Equilibrium offer as a function of the max demand shock



No charge – red; $\bar{\epsilon} = 10$ – blue; $\bar{\epsilon} = 20$ – green.

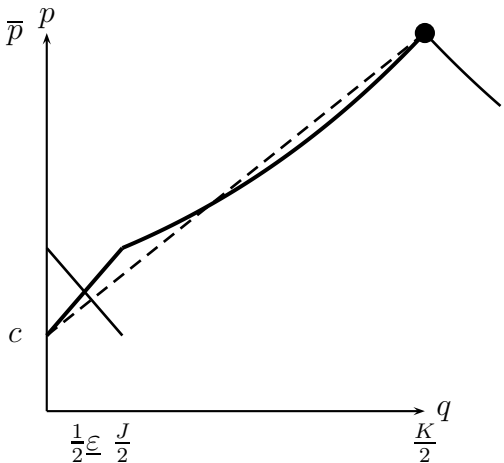
Welfare Calculations

Curve	α	CS	Π^U	Π^T	Tax per firm	Social Surplus
S	0	0.6666	0.6666	0.6666	0	2
S	0.25	0.6666	0.6666	0.5833	0.0833	2
S^T	0.25	0.6947	0.6527	0.5869	0.0658	2

S is the linear SFE that results when there are no transmission charges; S^T is the modified SFE accounting for the tax.

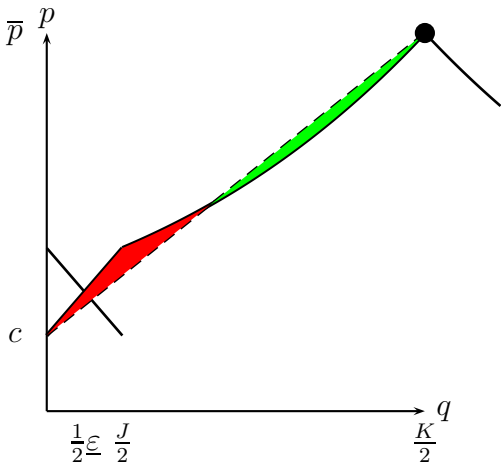
CS is the consumer surplus, and Π^U and Π^T are the per-firm profits (untaxed and taxed).

Overall markup depends on magnitude of expansion



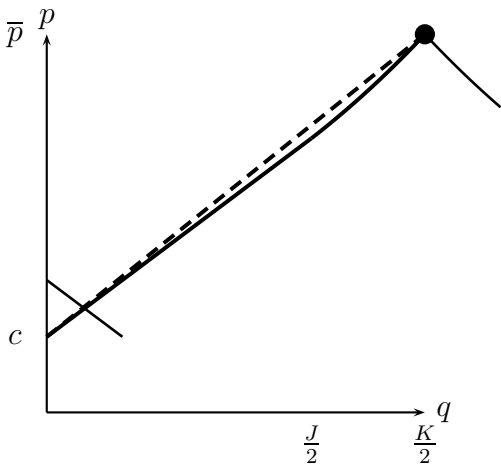
$J \ll K$ – some mark-up at lower end

Overall markup depends on magnitude of expansion



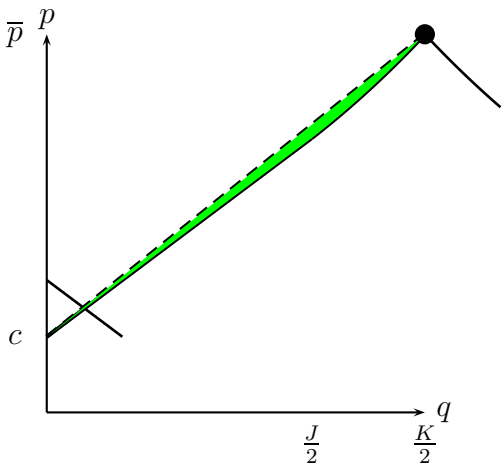
$J \ll K$ – some mark-up at lower end

Overall markup depends on magnitude of expansion



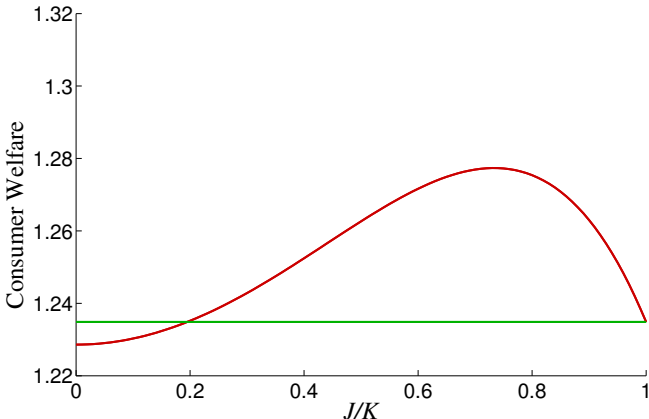
$J \approx K$ – mark-down from untaxed SFE

Overall markup depends on magnitude of expansion



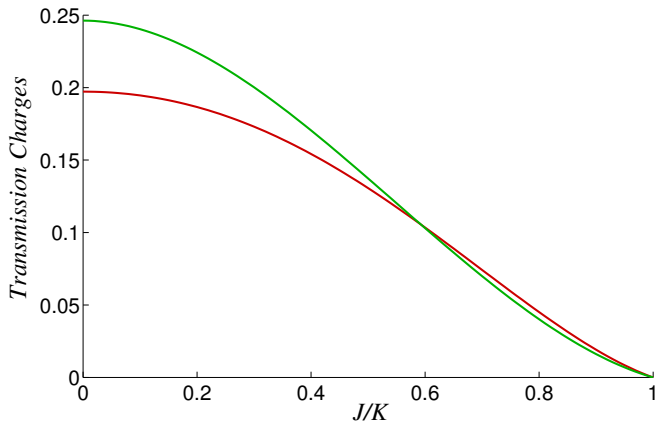
$J \approx K$ – mark-down from untaxed SFE

Consumer welfare comparison



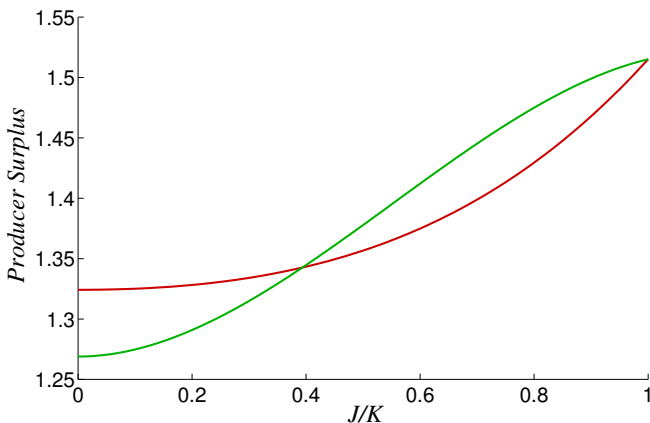
When $\frac{J}{K} < 0.2$ the expected consumer welfare drops as the firms try to avoid the charge; otherwise the consumers are better off.

Generator transmission charges comparison



When $\frac{J}{K} < 0.6$ the expected charge drops as the firms change their behaviour; interestingly, the firms end up paying a slightly higher charge for small increases in line size.

Producer surplus comparison



When $\frac{J}{K} < 0.4$ the expected producer surplus increases as the firms try to reduce the charge paid. For smaller line upgrades the producers are worse off.

Summary

- If the charge is a small % of the benefits, the equilibrium is close to the uniform price SFE.
- There is a greater incentive to mark up lower part of curve; exacerbated when the probability of lost load increases.
- Competitiveness depends on size of transmission capacity expansion.
- These equilibria are valid so long as $\alpha < \frac{1}{2}$.

Future Work

- Asymmetric firms (e.g. firms at either end of a potentially constrained line). Here upstream firms receive benefits and downstream firms, disbenefits.
- Examining the behaviour of firms when compensation is offered for disbenefits.
- Using a fixed-point methodology to find the proportion of benefits that must be charged to fund the investment.