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Electricity Markets
5. Exercise Sheet
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Exercise 1: Support Schemes for Renewables

1. Describe the concept of a Feed-In Tariff (FIT) for renewables.
2. How might a FIT distort efficient market signals?
3. Describe how an auction process to determine the FIT rate can be more efficient than an administratively-set tariff.
4. With reference to the German Renewable Energies Law, describe how Direct Marketing is implemented.
5. Describe another subsidy scheme for renewables of your choice and contrast its benefits and drawbacks compared to a FIT.

Exercise 2: Hedging with a cap (call option)

Suppose a price-taking generator has a linear cost function with a marginal cost of $c = \$10/\text{MWh}$ and a capacity of K. The price in the market is uniformly distributed between \$0/MWh and \$50/MWh.

1. Write down an expression for the net profit the generator makes as a function of the price P.
2. In order to eliminate completely its price risk, the generator sells a cap (call option) with a strike price of its marginal cost c. At what price of the cap P_{Cap} does the generator on average make the same profit as without the cap?

Exercise 3: Cournot duopoly

Consider a market with two generators who can influence the market price. They compete through their output levels x_1 and x_2, which are unrestricted. Their marginal costs are c_1 and c_2. The market price is set by the inverse demand function, which is a linear function of the total production, $\pi = a - b(x_1 + x_2)$ with $a \geq c_i$ and $b > 0$.

1. Write down the function for the net profit which each generator maximises.

2. Derive a pair of simultaneous equations that the x_i satisfy based on the stationarity of their objective functions.

3. Show that the equilibrium solution is given by

$$x_i = \frac{a - 2c_i + c_{3-i}}{3b}$$

and derive the equilibrium price.

4. Show that, depending on a, the price can be higher than either of the c_i.

Exercise 4: Market power with nodal pricing

Reconsider the solution to Exercise 2 “Negative Nodal Prices” from the 4. Exercise Sheet.
There was a load of $\ell = 100$ MW at node 3, a generator with marginal cost $c_1 = 1$ €/MWh at node 1 and a generator with marginal cost $c_3 = 10$ €/MWh at node 3, each with unlimited capacities. Line $2 \to 3$ has capacity 10 MW.

1. Using the solution from last time, show that for the generic situation that $c_1 < c_3$ we have generator dispatches $P_1 = 25$ MW and $P_3 = 75$ MW and nodal prices $\lambda_1 = c_1$, $\lambda_2 = 2c_1 - c_3$, $\lambda_3 = c_3$ and flows

$$\begin{matrix} 1 \to 2 \\ 1 \to 3 \\ 2 \to 3 \end{matrix} \begin{pmatrix} 10 \\ 15 \\ 10 \end{pmatrix}$$

2. Given that commodities typically flow from cheaper areas to more expensive ones, so that transporters can make a profit, what is unusual about the flow on $2 \to 3$?

3. If the generators no longer bid at their marginal cost but decide to act strategically, what freedom do they have to modify their prices? How is their ability to exercise market power affected by the line constraints, compared to an unconstrained market?

Exercise 5: Optimal behaviour of generators with storage

Suppose we have a market with three generators A, B and C which have variable costs of \$0/MWh, \$10/MWh and \$50/MWh respectively and capacities of 500 MW each.

Consider three consecutive demand hours with inelastic demands of 800 MW, 1200 MW and 700 MW. The generators are dispatched to minimise total costs.

1. If there were no other constraints, how would the generators dispatch in each hour? What would be the total cost of generation?

2. Suppose Generator A is a hydroelectric plant with storage whose energy is limited by river inflow to 200 MWh over the three hours. What is the cost minimising dispatch and total cost now?

3. Suppose Generator A is a hydroelectric plant with storage whose energy is limited by river inflow to 1200 MWh over the three hours. What is the cost minimising dispatch and total cost now?

4. Suppose we replace Generator A with a battery with perfect efficiency, a power output and input limit of 200 MW and an energy capacity of 200 MWh. At the beginning of the period it is uncharged. What is the cost minimising dispatch and total cost now?