Energy Economics

Fachbereich 2 Informatik und Ingenieurwissenschaften

Liberalization of electricity markets

- single provider for electricity generation, transport and distribution
- natural monopoly for electricity transport and distribution
- consumer has no choice

$\Rightarrow$ unbundling electricity grid and generation

$\Rightarrow$ formation of new fields: electricity trading and sales

- Why to avoid monopolies?

Excursus – the monopoly

Perfect competition

Under perfect competition the single company has no influence on prices
$\Rightarrow$ price taker.

Monopoly

In contrast, a monopolist is the only supplier at a market.

- under a monopoly market demand only faces one supplier
- the monopolist can choose its optimal price/quantity pair!
- inverse demand $p(y)$ determines the maximum price p if the monopolist sells quantity y.

Supply of a monopoly

profit maximization by choosing y

$$\max_{y} \Pi(y) = R(y) - C(y) = p(y) \cdot y - C(y)$$

The necessary condition (FOC) yields:

$$\frac{\partial \Pi(y)}{\partial y} = 0 \quad \hookrightarrow \quad \frac{\partial p(y)}{\partial y} y + p(y) - \frac{\partial C(y)}{\partial y} = 0$$

The sufficient condition (SOC) yields:

$$\frac{\partial^2 \Pi(y)}{\partial y^2} < 0 \quad \hookrightarrow \quad \frac{\partial^2 p(y)}{\partial y^2} y + 2 \frac{\partial p(y)}{\partial y} - \frac{\partial^2 C(y)}{\partial y^2} < 0$$

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Profit maximization

profit maximizing condition

$$\frac{\partial p(y)}{\partial y} y + p(y) = \frac{\partial C(y)}{\partial y}$$

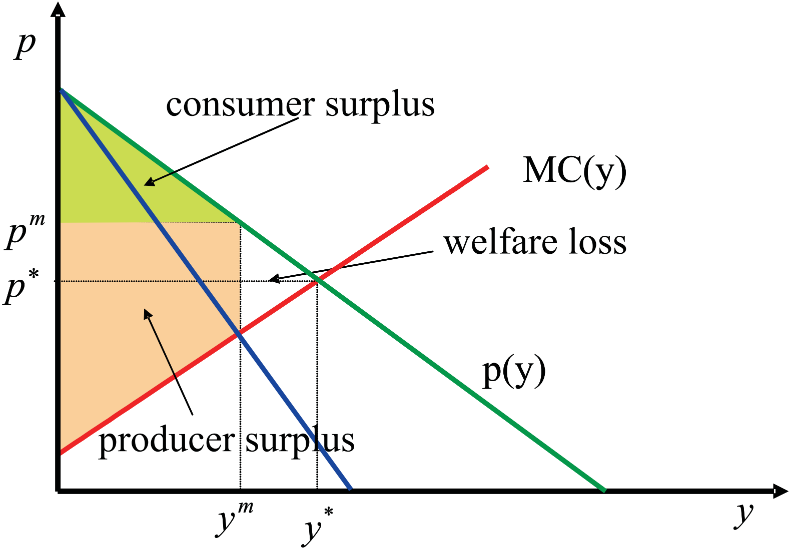
The optimal condition means

marginal revenue = marginal cost: $MR(y) = MC(y)$

$\Rightarrow$ the monopolist does not only ask for compensation of additional cost but also for compensation of the price decrease induced by increased quantity

$$p(y) = \frac{\partial C(y)}{\partial y} \underbrace{- \frac{\partial p(y)}{\partial y} y}_{>0!}$$

Inefficiency of a monopoly



Inefficiency of a monopoly

- the market price under a monopoly is higher when compared to perfect competition
- the output is lower

$\Rightarrow$ lower consumer surplus

- the monopolist still maximizes profit

$\Rightarrow$ higher producer surplus

$\Rightarrow$ nevertheless, welfare loss

$\Rightarrow$ inefficient

Development of monopolies

- exclusive control of an input factor
- natural monopolies by steadily decreasing average cost
- cartels
- state-guaranteed monopolies
  - patents
  - sovereign monopolies

Monopoly – exercise

Our well-known company still produces with the cost curve:

$$C(y) = 10y^2 + 5y + 40$$

and faces a market demand

$$D(p) = 11 - \frac{1}{10}p$$

but now acts as a monopolist

a) Calculate the output of the company and the resulting market price.
b) Calculate MR, MC and demand and illustrate it in one diagram.
c) Calculate and illustrate the differences in consumer rent, producer rent and welfare when compared to perfect competition.

Monopoly – exercise

- We can rearrange the demand function to obtain inverse demand which yields

$$
\begin{aligned}
y &= 11 - \frac{1}{10}p \\
\Leftrightarrow p &= 110 - 10y
\end{aligned}
$$

- The output is determined by the maximum profit Π

$$
\begin{aligned}
\Pi &= R(y) - C(y) \\
\Rightarrow \Pi &= p(y)y - C(y) \\
&= (110 - 10y)y - (10y^2 + 5y + 40) \\
&= 110y - 10y^2 - 10y^2 - 5y - 40
\end{aligned}
$$

Monopoly – exercise

- Maximizing the profit eventually yields the output of the monopoly y^m

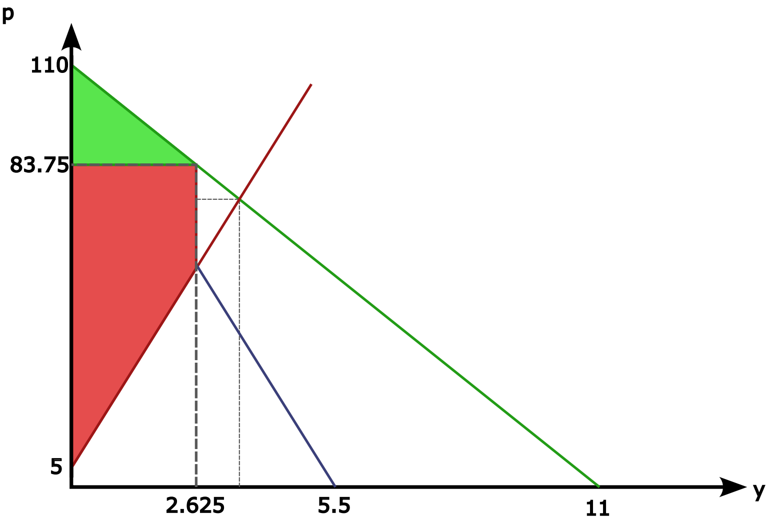
$$
\begin{aligned}
\max_y \Pi(y) &= R(y) - C(y) \\
\Rightarrow 0 &= \underbrace{110 - 20y^m}_{MR} - \underbrace{(20y^m + 5)}_{MC} \\
\Leftrightarrow 105 &= 40y^m \\
\Leftrightarrow y^m &= 2.625
\end{aligned}
$$

Monopoly – exercise

- Profit maximization under perfect competition (reference case) yields the equilibrium output y^*

$$
\begin{aligned}
\max_y \Pi(y) &= R(y) - C(y) \\
\Rightarrow 0 &= \underbrace{110 - 10y^*}_{p(y^*)} - \underbrace{(20y^* + 5)}_{MC} \\
\Leftrightarrow 105 &= 30y^* \\
\Leftrightarrow y^* &= 3.5
\end{aligned}
$$

Monopoly – exercise



Monopoly – exercise

- Calculation of consumer surplus CS, producer surplus CS and welfare W in the reference case yileds

$$
\begin{aligned}
PS &= \frac{(75-5)\cdot 3.5}{2} = 122.5 \\
CS &= \frac{(110-75)\cdot 3.5}{2} = 61.25 \\
W &= PS + CS = 122.5 + 61.25 \\
&= 183.75
\end{aligned}
$$

Monopoly – exercise

- Calculation of the change in consumer surplus CS, producer surplus CS and welfare W with respect to the reference case

$$\Delta PS = (83.75 - 75) \cdot 2.625 - \frac{(75 - MR(2.625)) \cdot (3.5 - 2.625)}{2}$$
$$= 22.96875 - 7.65625 = 15.3125$$

with

$$MR(2.625) = 110 - 20 \cdot 2.625 = 57.5$$

$$\Delta CS = -22.96875 - \frac{(83.75 - 75) \cdot (3.5 - 2.625)}{2} = -26.796875$$
$$\Delta W = \Delta PS + \Delta CS = -11.484375$$

Liberalization dividend

- decreasing wholesale prices
- (increasing electricity generation)

$\Rightarrow$ increasing consumer surplus

$\Rightarrow$ decreasing producer surplus

$\Rightarrow$ increasing welfare

Equilibrium price and quantity

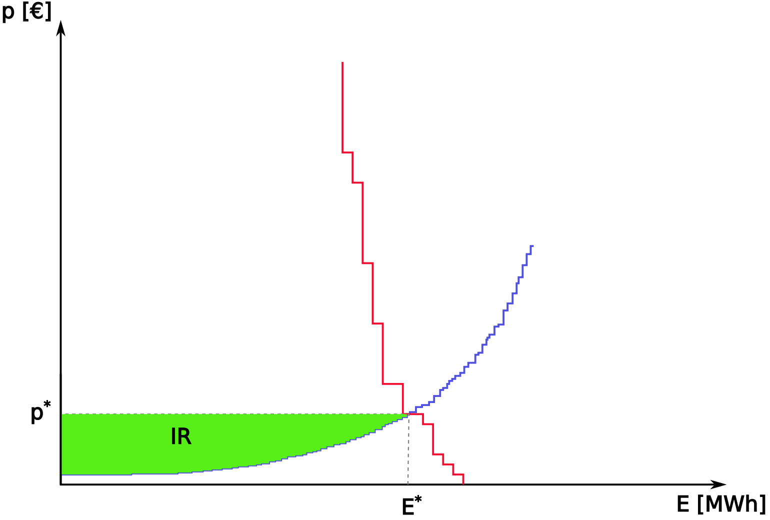


Figure: Schematic illustration of the merit order with inframarginal rent (IR).

Merit order with increased demand

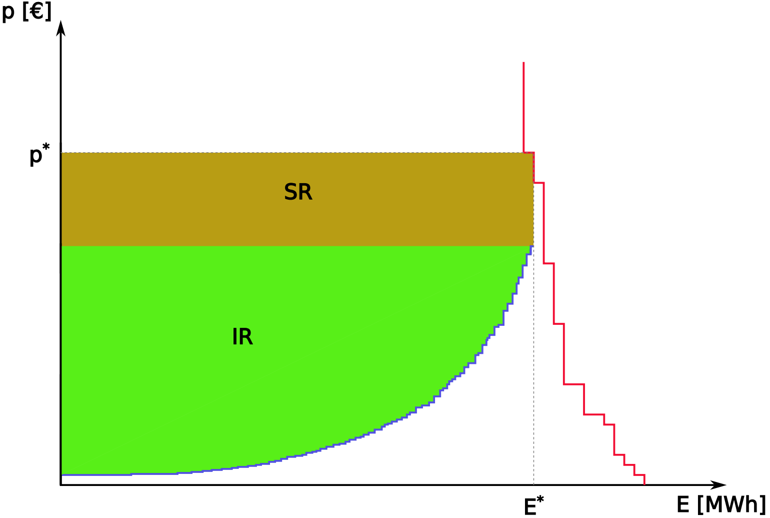


Figure: Schematic illustration of the merit order with increased demand.

Merit order with a further increase in demand

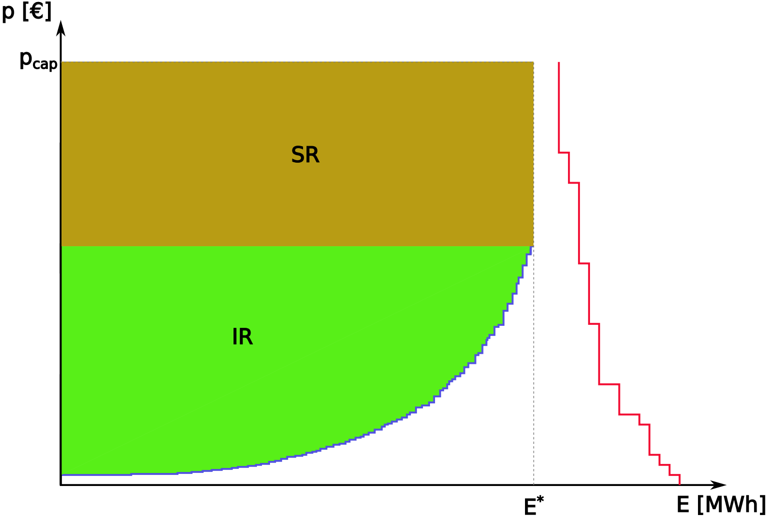


Figure: Schematic illustration of the merit order with a further increase in demand.

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Inframarginal rent (IR) and scarcity rent (SR)

Let us assume sufficient competition $\rightarrow$ power plant operators bid with their variable cost:

- If demand can be satisfied, all operators, except the one with highest variable cost, receive an **inframarginal rent (IR)**
- If demand can only be partially satisfied, a price peak for electricity above variable cost of all power plants occurs

$\Rightarrow$ power plant operators receive a **scarcity rent (SR)**

- for a price above highest variable cost all power plants are assumed to run

$\Rightarrow$ SR is equal for all power plant operators

The missing money problem

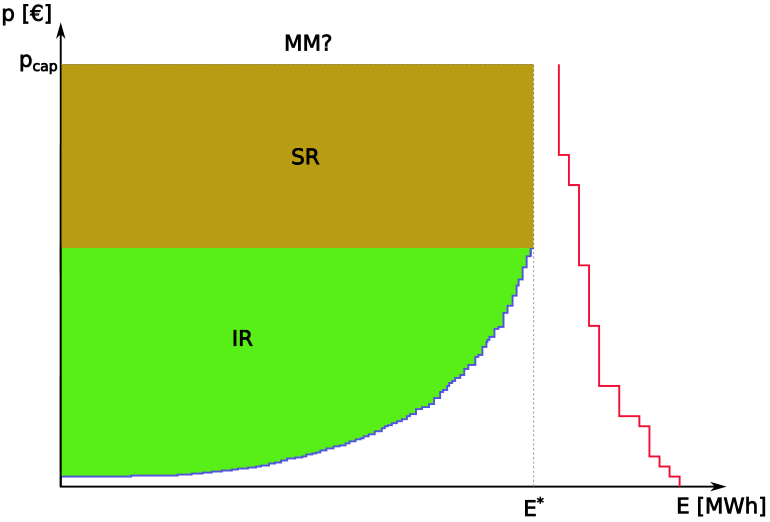

Figure: Schematic illustration of the merit with price cap and potential missing money (MM).

Market power and missing money (MM)

- Scarcity rents are necessary to refinance and incentivize investments
- Market power can be abused to inflate prices and reduce supply

$\Rightarrow$ price caps are used to limit market power abuse

- a price cap cuts scarcity rents

$\Rightarrow$ MM occurs if the price cap is too low

$\Rightarrow$ revenues at the electricity market are not sufficient to refinance and incentivize investments

Hedging load against high prices

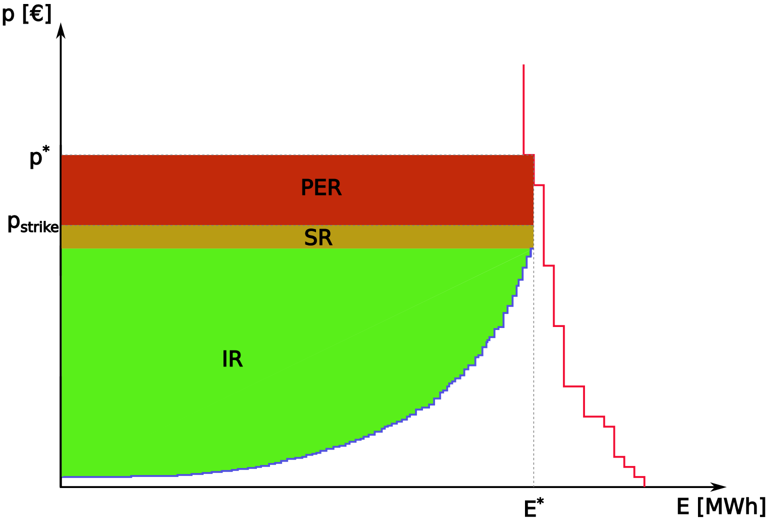

Figure: Schematic illustration of the merit order with increased demand.

Capacity market fundamentals

- regulator determines the total capacity necessary $\underline{C}$
- regulator defines a strike price p_{strike}
- regulator buys call options amounting to the necessary capacity
- call option of the regulator set an incentive to deliver electricity in an scarcity event

$\rightarrow$ Reliability Option (RO)

The power plant operator's view

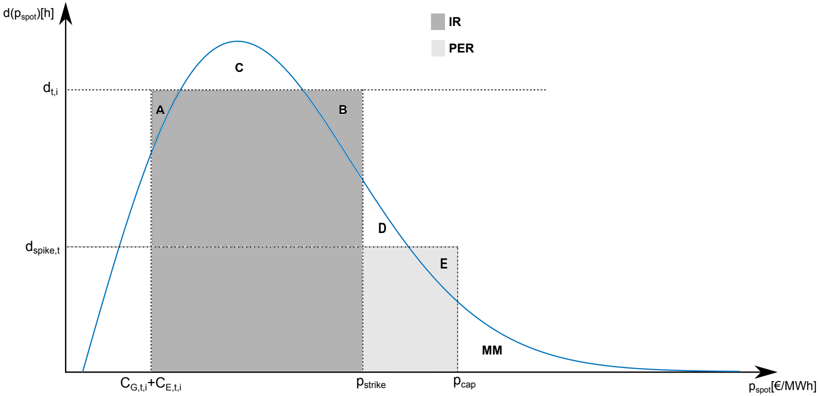

Figure: Schematic illustration of the distribution of electricity spot market prices for one year in €/MWh. The duration of power plant i's production in hours is a function of the spot price; source: Schäfer and Altvater (2019).

The power plant operator's view

- We can calculate IR and PER of power plant operator i as follows

$$
\begin{aligned}
IR_{t,i} &= \int_{C_{G,t,i}+C_{E,t,i}}^{p_{strike}} d(p_{spot,t})\ \mathrm{d}p_{spot,t} \\
&= d_{t,i}\left(p_{strike} - C_{G,t,i} - C_{E,t,i}\right)
\end{aligned}
$$

$$
\begin{aligned}
PER_{t} &= \int_{p_{strike}}^{p_{cap}} d(p_{spot,t})\ \mathrm{d}p_{spot,t} \\
&= d_{spike,t}\left(p_{cap} - p_{strike}\right)
\end{aligned}
$$

The power plant operator's view

- We introduce the failure rate $X_{IR,t,i}$ and $X_{PER,t,i}$

$\rightarrow$ share of total time the power plant is not running although prices are above variable cost

$\rightarrow$ failure rates are individual for each power plant

$\rightarrow$ $X_{IR,t,i} \geq X_{PER,t,i}$ since incentives to keep the power plant running are higher

$\Rightarrow$ for a power plant operator who simply sells electricity at the **energy-only market** revenue R in year t equals

$$R_t = (1 - X_{IR,t,i})IR_{t,i} + (1 - X_{PER,t,i})PER_t$$

Investment decision and capital

- How does the capital stock of a power plant change over its lifetime?
- We assume that the change of capital K of power plant i with respect to time t in years can be described by the following equation

$$K_{t,i} = K_{0,i}(1-\delta_i)^t - K_{0,i}\tilde{\delta}_i t \qquad \forall 1 > \delta_i, \tilde{\delta}_i \geq 0$$

- δ_i corresponds to the depreciation rate, a risk premium and the interest rate (profit margin) of the power plant
- $\tilde{\delta}_i$ corresponds to a linear depreciation rate if necessary
- An incentive to invest in new power plants only exists if there is a realistic chance to get back the investment (with an appropriate profit) during the lifetime T of the power plant

Investment decision and capital

- We assume p_{strike} equal to variable (and emission) cost of the last power plant in the merit order

$\Rightarrow$ scarcity rent vanishes

- lifetime depreciation of the power plant yields

$$
\begin{aligned}
K_{0,i} - K_{T,i} &= K_{0,i}(1 - (1-\delta_i)^T + \tilde{\delta}_i T) \\
&= \sum_{t=1}^{T} (K_{t-1,i} - K_{t,i}) := \sum_{t=1}^{T} k_{t,i} \\
&= K_{0,i} \sum_{t=1}^{T} \left((1-\delta_i)^t \frac{\delta_i}{1-\delta_i} + \tilde{\delta}_i \right) \\
&= \sum_{t=1}^{T} \left((1 - X^e_{IR,t,i}) IR^e_{t,i} + (1 - X^e_{PER,t,i}) PER^e_t + (1 - X^e_{PER,t,i}) MM^e_t \right)
\end{aligned} \tag{1}
$$

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