Environmental Assessment

Fachbereich 2 Informatik und Ingenieurwissenschaften

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Strategic bidding behavior

- Considering single unit bidders, we know from standard auction theory

→ in a pay-as-bid auction there exists an incentive to increase price bids (analogous to bid shading)

→ in a uniform price auction this incentive does not exist

- Does this apply to the suggested auction design with endogenous quantity, too?

→ in contrast to a usual uniform price reverse auction, a manipulated bid may influence endogenous quantity and thus the price

⇒ in the following we compare a situation with true bids and inflated bids

Strategic bidding behavior

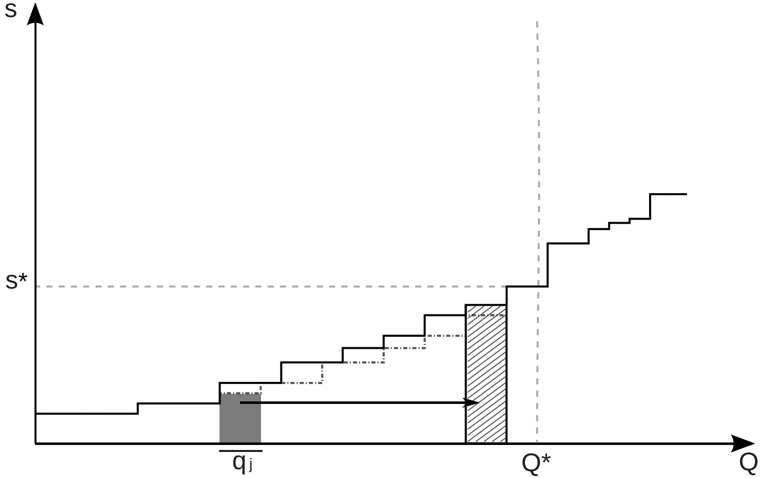


Figure: Exemplary merit order after deception. The deceiver changes from j to k while bidders $j+1$ to former position k all slide down one position.

Impact of an inflated price bid

- According to the illustration of the two preceding slides, we assume the deceiver places an inflated price bid and thus changes from position j to $k \geq j$
- the analysis is carried out from the regulator's point of view who interprets price bids as generators' expected unit costs.

$\Rightarrow$ **for the regulator** an increased price bid **indicates an increase** of expected unit costs although actual **expectations** about unit costs do not change.

Impact of an inflated price bid

- the difference in expected aggregated uncovered costs (from the regulator's view) is

$$\Delta C(l) := \sum_{i=1}^{l} (\hat{s}_i - s_i)\, q_i.$$

- with $\hat{s}_i$ indicating the subsidy rate of bidder i after inflation of the price bid of former bidder j.
- the difference in expected subsidy equals

$$\Delta S(l) := (\hat{s}_l - s_l) \sum_{i=1}^{l} q_i.$$

Impact of an inflated price bid

- using the two preceding equations together with $\varphi(I) := \frac{C(I)}{S(I)}$, yields

$$\begin{aligned}\Delta\varphi(I) :&= \hat{\varphi}(I) - \varphi(I) \\ &= \frac{\Delta C(I)}{S(I) + \Delta S(I)} - \frac{\Delta S(I)}{S(I) + \Delta S(I)} \varphi(I)\end{aligned}$$

- with $\hat{\varphi}(I)$ corresponding to the respective value under an inflated price bid while $\Delta S(I)$ and $\Delta C(I)$ indicate the change of $S(I)$ and $C(I)$ after deception yielding $\hat{C}(I) = C(I) + \Delta C(I)$ and $\hat{S}(I) = S(I) + \Delta S(I)$.
- Demonstrate that the two lines of the equation are equal.

Impact of an inflated price bid

- $\Delta S(l)$ and $\Delta C(l)$ show a distinct behavior depending on the bidders' position in the merit order
- $S(l)$ is the product of the last successful bider's subsidy rate $\hat{s}_l$ and the sum of quantities $\sum_{i=1}^{l} q_i$

⇒ any change induced by deception is propagated from one bidder to the next

⇒ changes increase between position j and k while $\Delta S(l)$ is zero after position k

⇒ We find

$$0 = \Delta S(l < j) \leq \Delta S(l = j) \leq \Delta S(l = j + 1) \leq \cdots \leq \Delta S(l = k)$$
$$\geq \Delta S(l = k + 1) = 0 = \cdots = \Delta S(l = n)$$

Impact of an inflated price bid

- $C(l)$ is the sum of products of the last successful bider's subsidy rate $\hat{s}_l$ and the respective quantity q_i

⇒ any change induced by deception is propagated from one bidder to the next

⇒ changes increase between position j and k while $\Delta C(l)$ is constant after position k

⇒ We find

$$
\begin{aligned}
0 &= \Delta C(l<j) \le \Delta C(l=j) \le \Delta C(l=j+1) \le \cdots \le \Delta C(l=k) \\
&= \Delta C(l=k+1) = \cdots = \Delta C(l=n).
\end{aligned}
$$

Impact of an inflated price bid

- using

$$0 = \Delta S(l < j) \leq \Delta S(l = j) \leq \Delta S(l = j + 1) \leq \cdots \leq \Delta S(l = k)$$
$$\geq \Delta S(l = k + 1) = 0 = \cdots = \Delta S(l = n)$$

- and

$$0 = \Delta C(l < j) \leq \Delta C(l = j) \leq \Delta C(l = j + 1) \leq \cdots \leq \Delta C(l = k)$$
$$= \Delta C(l = k + 1) = \cdots = \Delta C(l = n).$$

- directly leads to

$$\Delta \varphi_{max} = \Delta \varphi_{k+1}.$$

Impact of an inflated price bid

- for $l \geq k$ we find $\Delta S = 0$ and constant $\Delta C(l)$ while $S(l)$ is, according to the merit order, continuously increasing which leads to
$$\Delta\varphi(k+1) \geq \Delta\varphi(k+2) \geq \ldots \geq \Delta\varphi(n).$$
- a risk averse deceiver tries to place a bid **below** the formerly pivotal bidder $(k < l^*)$ yielding
$$\Delta\varphi(l^*) \geq \Delta\varphi(l^*+1) \geq \ldots \geq \Delta\varphi(n).$$
- it can be shown that behavior of $\Delta\varphi(l)$ directly translates to behavior of $u(l)$ for $\theta \geq 1$

$\Rightarrow$ there is no rational incentive for a risk averse single unit bidder to inflate the price bid

What about multi-unit bidders?

- multi-unit bidders need not necessarily aim at winning all bids

⇒ no need to place a bid close to but below the pivotal bidder

⇒ in a usual uniform pricing reverse auction with excessive demand one maximum bid already provides a maximum payment for all participating bidders

⇒ we cannot apply our analysis for single-unit bidders to multi-unit bidders

⇒ switch from analytical assessment to simulation

⇒ approximation of the bidding potential

Simulated supply curves

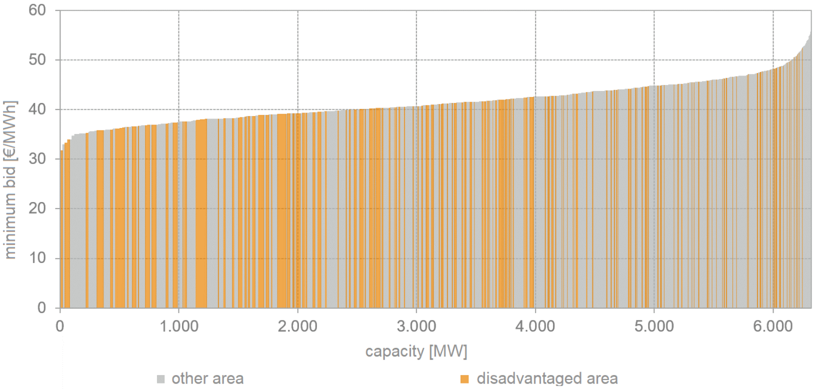


Figure: Supply curve (expected LCOE) of the solar power plant reverse auction which took place on November 1, 2021, modeled by Enervis energy advisors GmbH (2021); illustration made by Enervis energy advisors GmbH (2021) with translated description.

Approximation of the supply curve

- rational assumption: normal distribution of LCOE

⇒ supply curve can be approximated by a probit function

⇒ a probit-function can be well approximated by a logit-function

$$p_l = \sigma \ln\left(\frac{\kappa\chi(l)}{1-\kappa\chi(l)}\right) + p_s \tag{1}$$

- with

$$\kappa := \frac{1}{\chi(n) + \frac{\chi(n)}{n}} = \frac{1}{\chi(n)}\frac{n}{n+1} \tag{2}$$

Approximation of the supply curve

- assuming identical quantities q_i for each project (no loss of generality) yields

$$\chi(l) = \frac{l}{n}\chi(n) \tag{3}$$

and finally

$$p_l = \sigma \ln\left(\frac{l}{n-l+1}\right) + p_s \tag{4}$$

- Eq. 4 allows to control the approximated supply function with only two parameters.
- $\sigma = 0.25$ and $p_s = 4.3$ deliver a good approximation for the supply curve illustrated in Fig. 3.

Exercise

- use the following variant of Eq. 4 to calculate the bids of n=20 bidders

$$s_l = \sigma \ln\left(\frac{l}{n-l+1}\right) + p_s - \overline{p}_{spot} \tag{5}$$

assuming $\sigma = 0.25$, $p_s - \overline{p}_{spot}$=1.7

- Calculate $\chi(l)$, $\varphi(l)$ and the utility u for $\alpha = 0.5$, $\alpha = 0.7$ and $\alpha = 0.8$ using a Cobb-Douglas utility function

$$u_l = \varphi(l)^{\alpha}\chi(l)^{1-\alpha} \tag{6}$$

- assume inflated price bids occur from position 5 onwards. What is the minimum market share for successful deception under these conditions for $\alpha = 0.5$, $\alpha = 0.7$ and $\alpha = 0.8$

Simulated supply curves

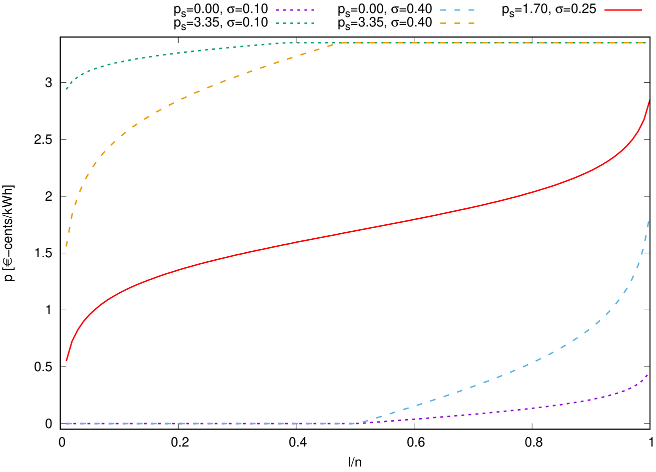


Figure: Supply curves illustrating a variety of parameter combinations (center and the four corners of the following three fugures)

Simulated supply curves

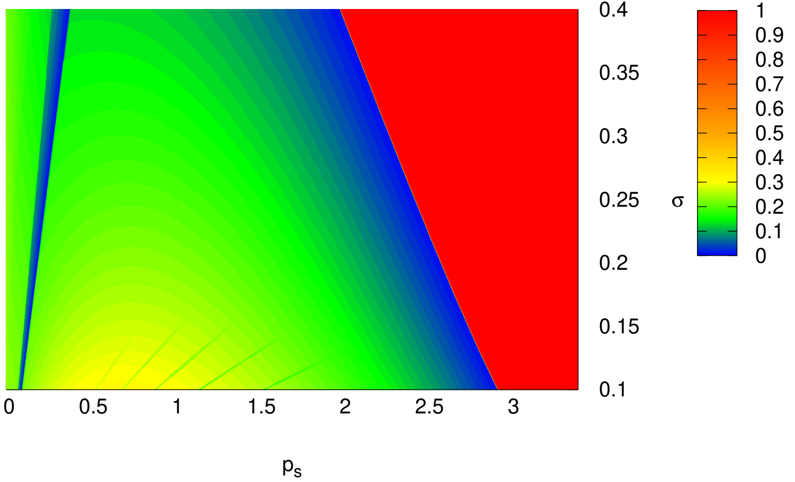


Figure: Minimum market share necessary for successful deception starting from I/n=0.26.

Simulated supply curves

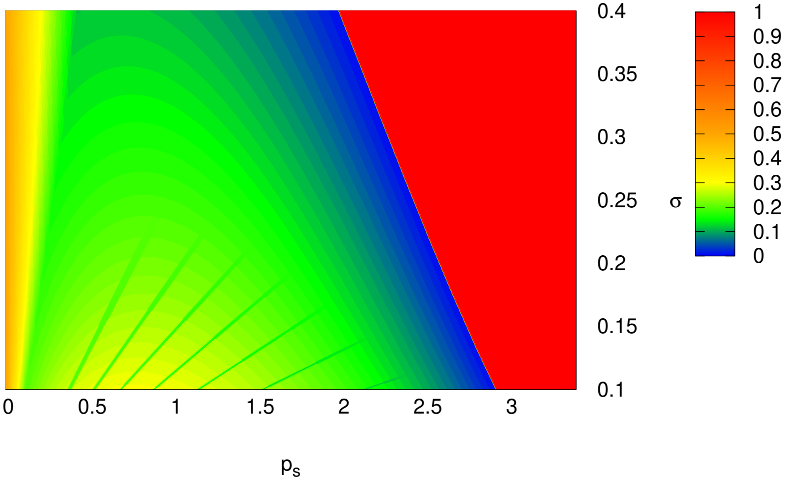


Figure: Minimum market share necessary for successful deception starting from l/n=0.51.

Simulated supply curves

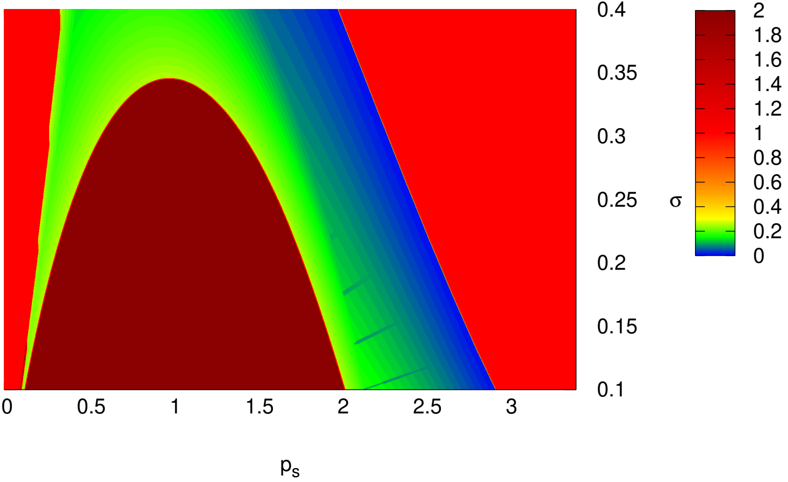


Figure: Minimum market share necessary for successful deception starting from l/n=0.76.

Outline

Life time of CO_2 in the atmosphere

"Carbon dioxide cycles between the atmosphere, oceans and land biosphere. Its removal from the atmosphere involves a range of processes with different time scales. About 50% of a CO_2 increase will be removed from the atmosphere within 30 years, and a further 30% will be removed within a few centuries. The remaining 20% may stay in the atmosphere for many thousands of years" (Denman *et al.*, 2007).

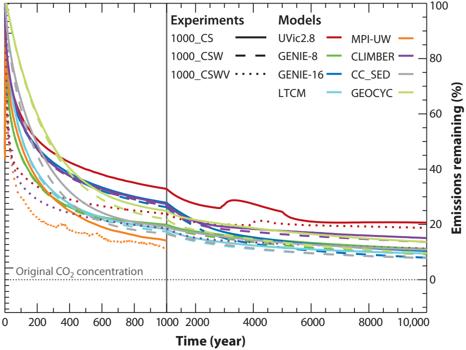


Figure: Atmospheric CO_2 trajectories for the 10,000-year duration of certain climate model simulations (Archer *et al.*, 2009)

Changes in global surface temperatures according to scenarios

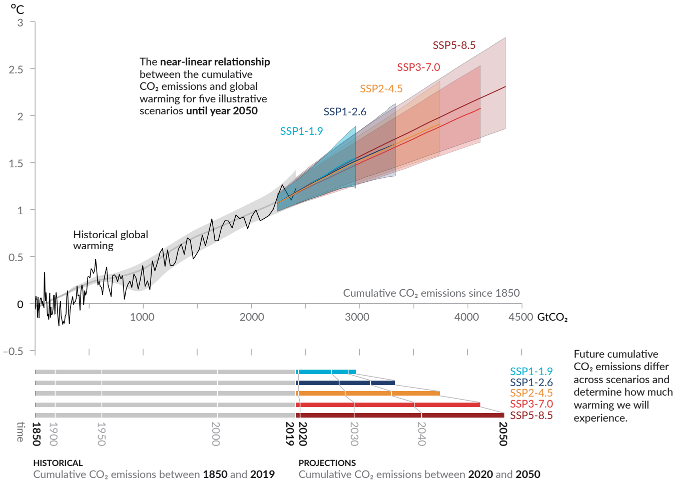


Figure: Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$; source: IPCC (2021).

Development of CO_2 emissions

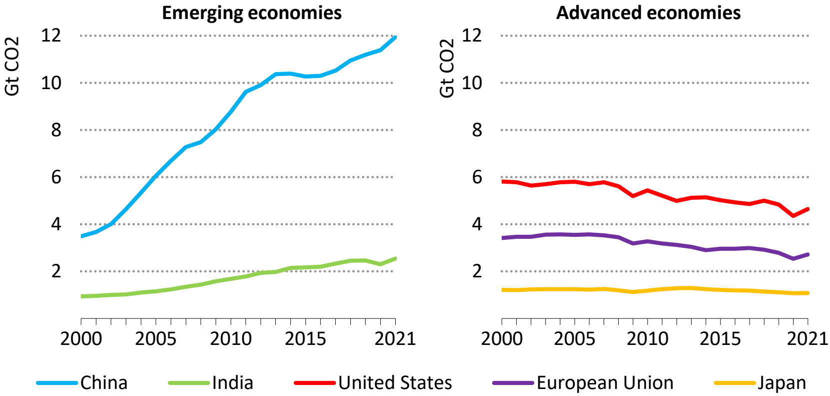


Figure: CO_2 emissions in selected emerging and advanced economies, 2000-2021; source: IEA (2022).

Cumulative CO_2 emissions worldwide

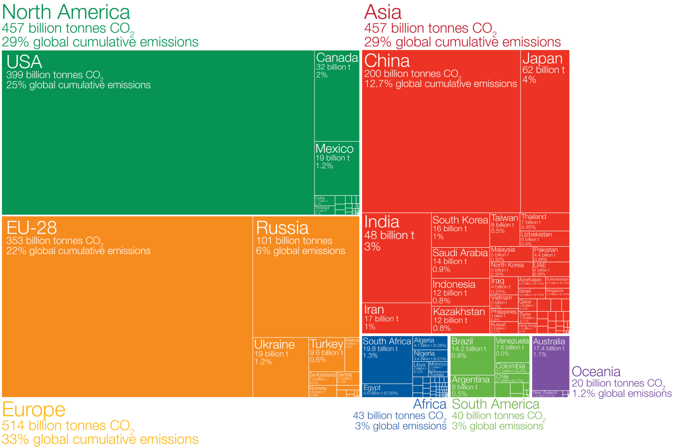
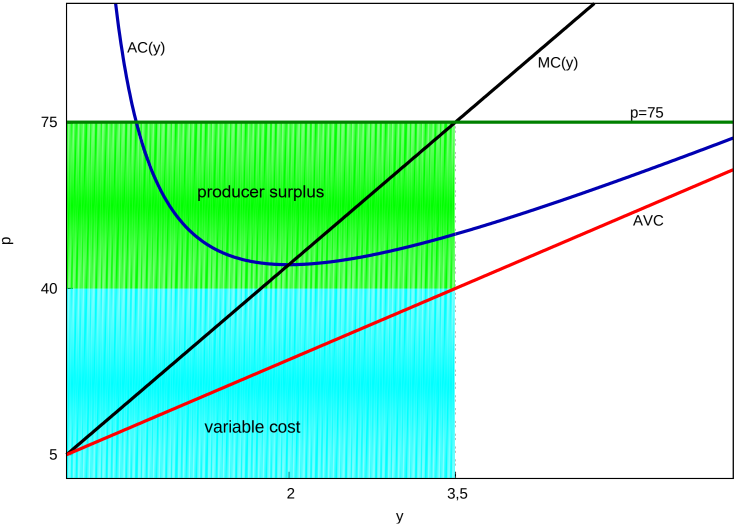


Figure: Cumulative CO_2 emissions over the period from 1751 to 2017. Figures are based on production-based emissions which measure CO_2 produced domestically from fossil fuel combustion and cement and do not correct for embedded in trade (i.e. consumption-based). Emissions from international travel are not included; source: OurWorldinData.org `https://ourworldindata.org/contributed-most-global-co2`.

Cost, profit, producer surplus



Supply of a company

profit maximization by quantity management

For a company acting as price taker we find the following objective function

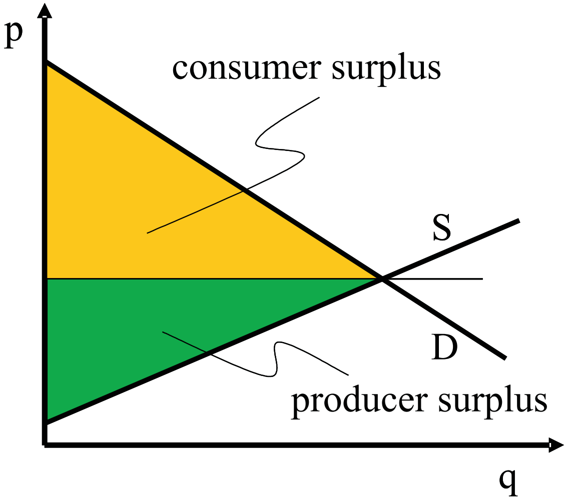
$$\max_{y} \Pi = p\,y - C(y)$$

the decisive variable is the output
The solution of this maximization problem requires the fulfillment of first order conditions (FOC) and second order conditions (SOC)

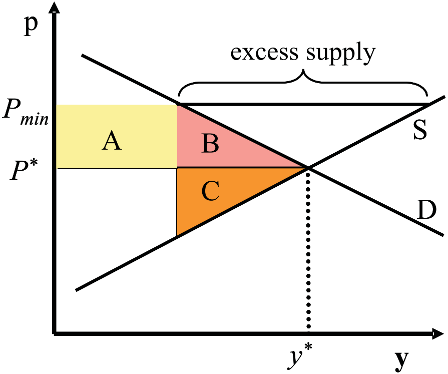
- FOC

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

Welfare

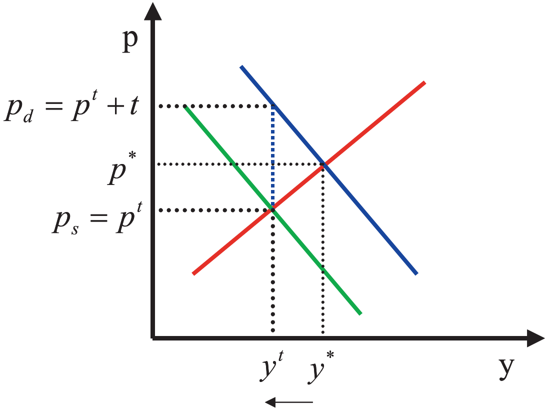


Minimum prices



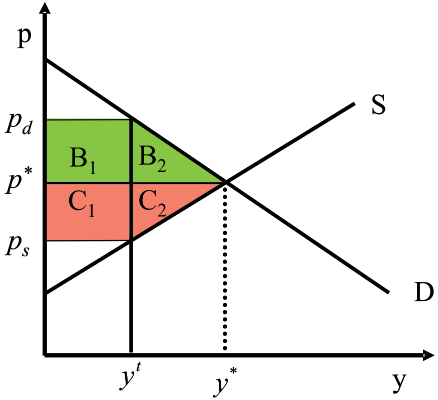
An administered minimum price p_{min} leads to excess supply. Former consumer surplus A is redistributed to producers. Consumers lose B, producers lose C summing up to the welfare loss $B + C$.

Consumption tax



A consumption tax lowers the demand curve
⇒ demand and thus the price decrease.

Welfare effect of taxes



The loss of consumer surplus is $B_1 + B_2$, the loss of producer surplus is $C_1 + C_2$.

External effects

The market mechanism so far is based on

- individual preferences
- income
- prices
- production technology
- market organization (e.g. perfect competition)
- rational behavior (utility and profit maximization)

Still, the impact of the market outcome on a third parties' (outside the market) utility or profit is not considered.
$\Rightarrow$ external effects

Market failure

Example

Assume a river with a factory upstream and a fisher downstream.

- waste water of the factory
- shrinking fish population

⇒ market failure

What does a reduction of the factory output cost (society)?
→ welfare reduction (approximation)
→ MAC = D - S

What does the emission of the factory cost?

Marginal abatement cost and marginal damage

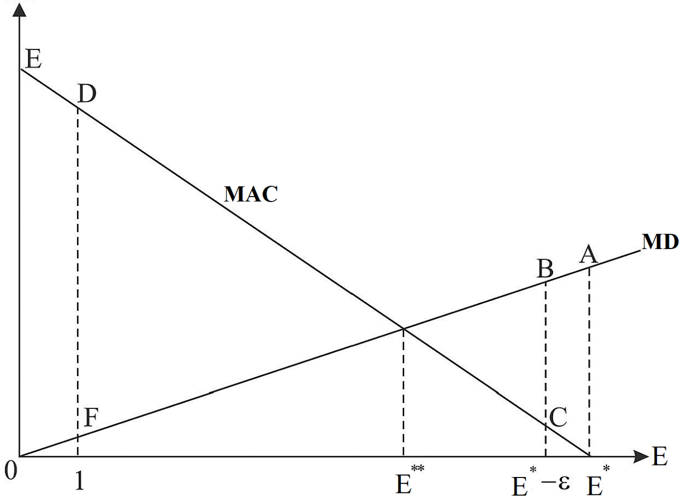


Figure: With adjustments taken from Endres (2022)

The Coase theorem and its problems

Summary

*"Let **exclusive property titles** to the environment be defined, and let them be **transferable**. Let there be **no transaction costs**. Let individuals maximize their utilities, and let them be nonaltruistic. Then a bargaining solution among different users of the environment will result in a Pareto-optimal allocation of the environment. The resulting allocation is **independent of the initial distribution of property titles**."* (Siebert, 2008).

- impact of property rights assignment
- transaction cost
- free rider problem

Income effect

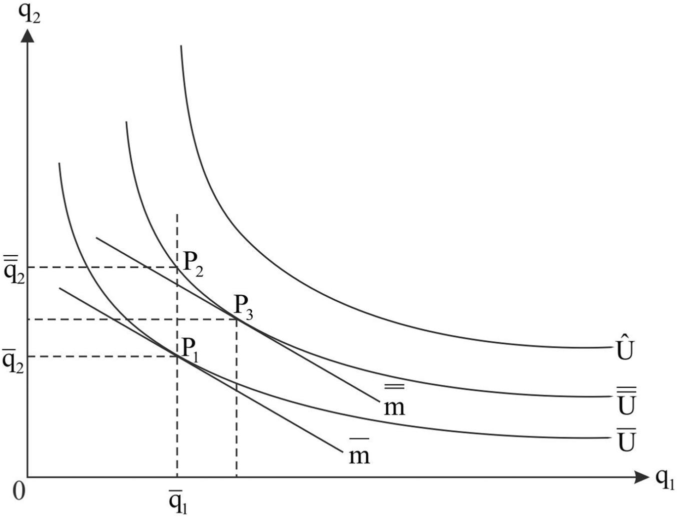


Figure: With adjustments taken from Endres (2022)

Impact of property rights assignment

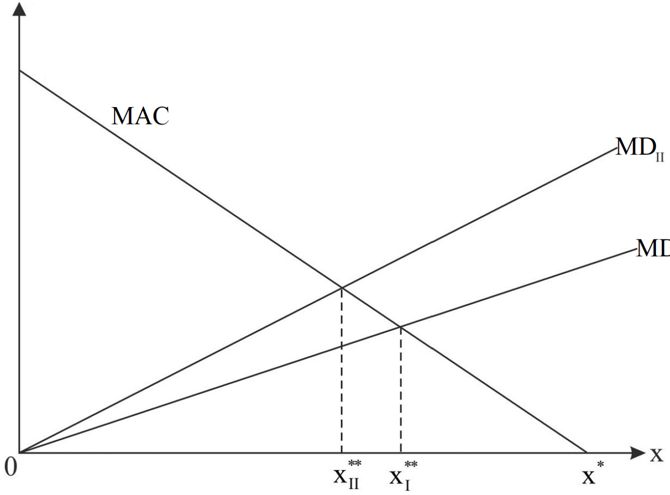


Figure: Marginal damage MD "nominally" increases when property rights are assigned to the pollutee (MD_I) instead of the polluter (MD_{II});source: with adjustments taken from Endres (2022)

Coase and transaction cost

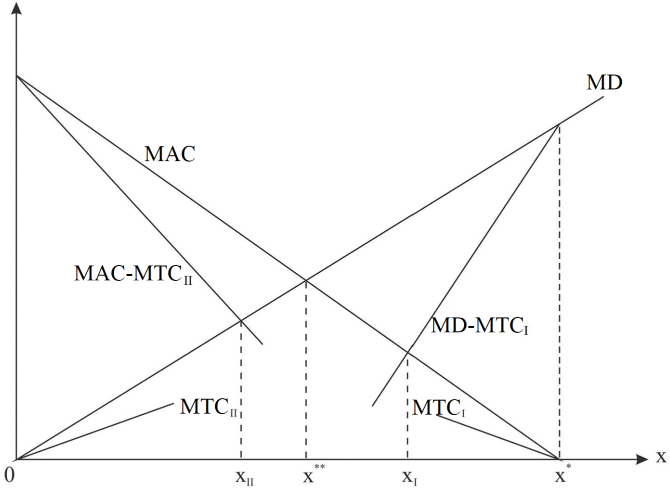


Figure: With adjustments taken from Endres (2022)

Pigouvian tax

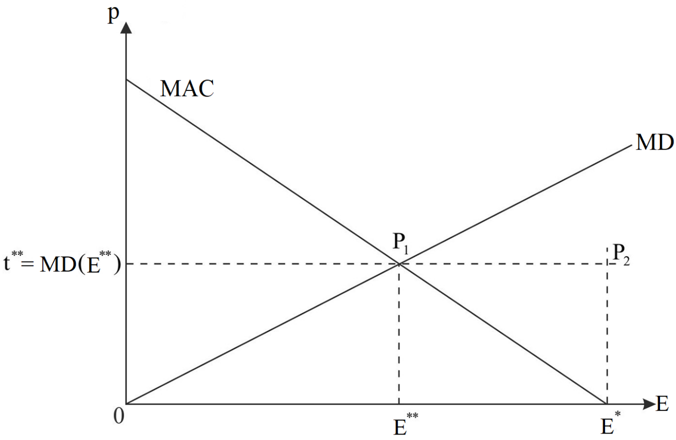


Figure: With adjustments taken from Endres (2022)

Pigouvian tax

- tax rate t>MAC

→ emission reduction advantageous

- tax rate t<MAC

→ emission (production) increase advantageous

⇒ for t =MD(E^{**}) emissions will reduce to the social optimum

Pigouvian tax and subsidy

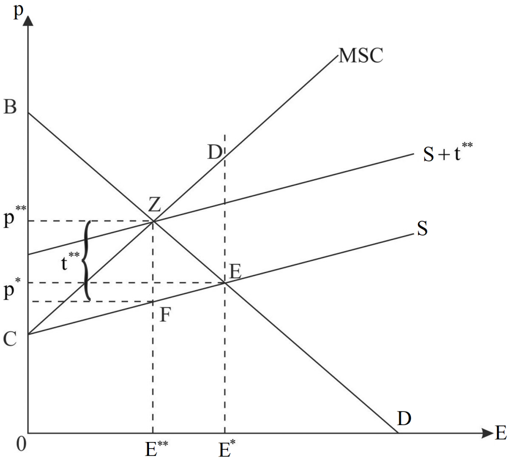


Figure: With adjustments taken from Endres (2022)

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Policy instruments for emission reduction

- obligations
- taxes
- allowances

→ efficiency

→ innovation incentives

→ accuracy

Policy instruments for emission reduction

- obligations

→ define a threshold value or intensity for **every emitter**

- taxes/subsidies

→ defining a tax/subsidy rate t/s which results in a certain emission level $E^{'}$

⇒ partial internalization if $t < \mathrm{MD}(E^{**})$

- allowances or emission certificates

→ define a threshold value $E^{'}$ or intensity for **a sector, countries, the world** allowing trade between emitters

⇒ partial internalization if $E^{'} > E^{**})$

Choice of policy instruments

- Which policy instrument to choose with respect to

→ efficiency

→ innovation incentives

→ accuracy

- What about a combination of policy instruments?

Policy instruments – efficiency

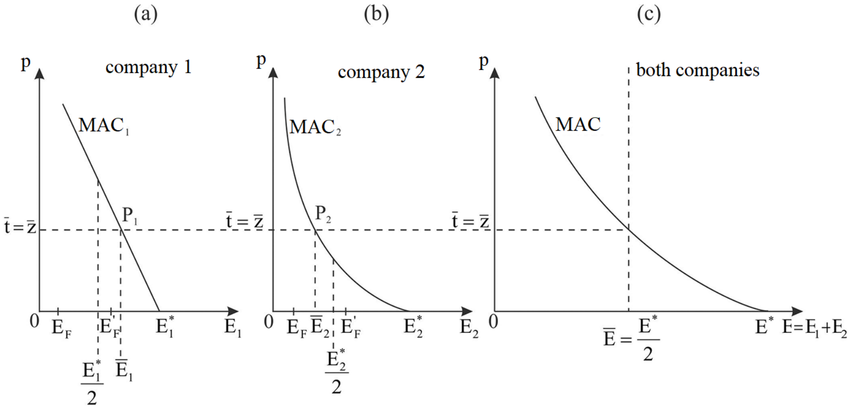

Figure: With adjustments taken from Endres (2022)

Policy instruments – innovation incentives

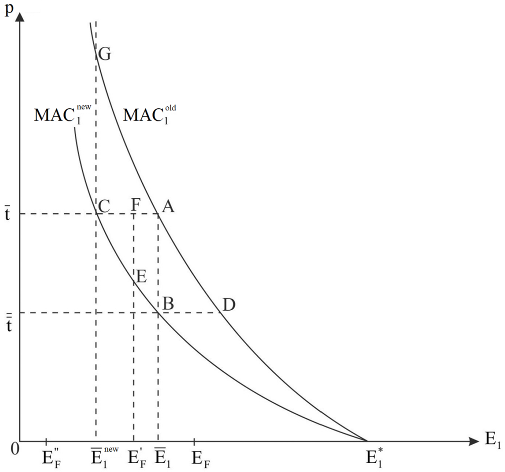

Figure: With adjustments taken from Endres (2022)

Policy instruments – accuracy

- obligations and allowances allow an accurate determination of the emission level

→ difficulties may occur if they aim at intensities instead of total emissions

→ different treatment of old and new utilities can be problematic

- tax rates need an adjustment if a constant emission objective shall be established (inflation, technological progress)
- accuracy is less important close to E^* while it becomes more important close to E^{**}

Policy instruments – time sequence

- ETS and emission tax have advantages with respect to efficiency when compared to obligations
- without adjustments innovation incentives are highest for the emission tax
- accuracy is highest for obligations and the ETS
- investment incentives are best for an emission tax (planning security)

⇒ close to E^* the emission tax is superior to the other policy instruments while later the ETS is superior

Intermediate objectives and uncertainty

- emissions abatement with an absolute cap

$$E[A^A] = E[E^*] - E^{'} \tag{7}$$

→ $E[]$ indicates an expectation value

- emissions abatement with an intensity-based cap

$$E[A^I] = E[E^*] - e^{'} E[Y] \tag{8}$$

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Deviation from optimal objectives

- variance for emissions abatement with an absolute cap

$$var[A^A] = var[E^*] \tag{9}$$

- emissions abatement with an intensity-based cap

$$var[A^I] = var[E^*] - 2e' cov[E^*, Y] + e'^2 var[Y] \tag{10}$$

⇒ Is the variance lower with an absolute emission cap or an intensity-based emission cap?

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Minimizing deviations

- If the variance for an intensity-based emission cap is lower than for an absolute emission cap, we receive

$$
\begin{aligned}
& var[A^I] < var[A^A] \\
\Rightarrow & e'^2 var[Y] < 2e' cov[Y, E^*] \qquad (11) \\
\Leftrightarrow & \frac{\nu[Y]}{\nu[E^*]\rho[Y, E^*]} \frac{E'}{E[E^*]} < 2 \qquad (12) \\
\Rightarrow & \xi \frac{E'}{E[E^*]} < 2 \qquad (13)
\end{aligned}
$$

⇒ approach follows Sue Wing *et al.* (2009)

Regression of emission intensities

$$\ln(e_i) = b + a_t \cdot (i - 2000) + a_p \cdot p_{i,ratio} + \epsilon \tag{14}$$

- b as axis intercept
- ϵ as error term
- $p_{i,ratio}$ corresponds to the price ratio between hard coal and gas ($p_{i,coal}/p_{i,gas}$)
- $p_{i,coal}$ and $p_{i,gas}$ consist of pure fuel prices $\tilde{p}_{i,coal}$ and $\tilde{p}_{i,gas}$ plus a respective surcharge $\Delta p_{i,coal}^{ets}$ and $\Delta p_{i,gas}^{ets}$ stemming from the EU ETS

Development of emission intensities

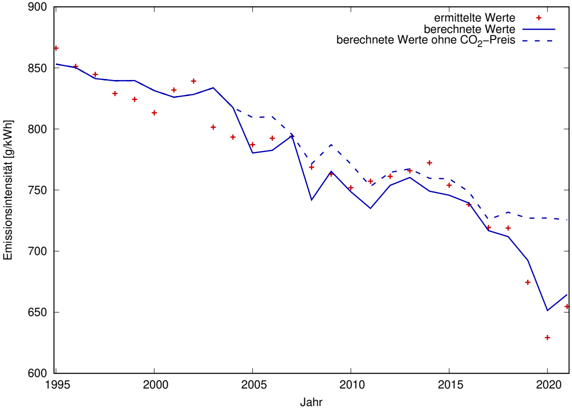

Figure: Development of real and calculated emission intensities in the German electricity sector between 1995 – 2021 together with counterfactual scenario without ETS; own illustration.

Comparison of CO_2 reductions

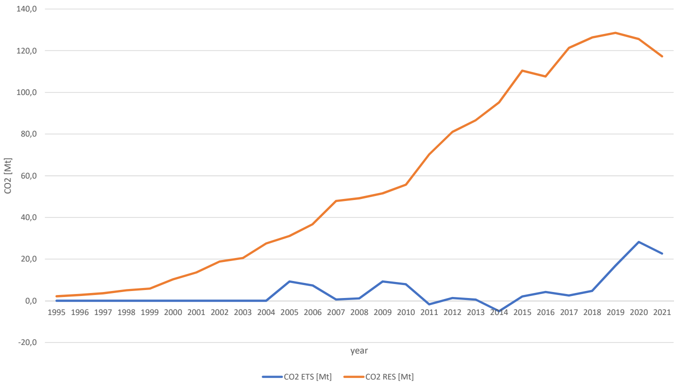

Figure: Development of CO_2 reduction assigned to the ETS and subsidies for RES from 1995 – 2021. The reduction assigned to the ETS is based on the counterfactual scenario developed above. The reduction assigned to subsidized RES is based on the product of emission intensity and electricity generated by RES with a discount of 10 % for fossil power plants on standby.

Promotion of RES

- **feed in tariff (FIT)**

  fixed price paid for electricity from RES connected with an **acceptance obligation** for generated electricity

- **feed in premium (FIP)**

  electricity from promoted RES is regularly sold at the market but the seller in addition receives a **premium**

⇒ a **fixed FIP** shifts risks from the regulator to the power plant operator

⇒ a **sliding FIP** acts like a more market-based FIT

- How a sliding FIP changes the operator's behavior when compared to an FIT?

Promotion of RES

- **contracts for differences CFDs**

  the subsidized power plant operator receives/pays the difference between the market price and a predefined strike price

→ operator receives money for market prices below the strike price

→ operator has to pay if market prices are above the strike price

- What are advantages/disadvantages from the perspective of the regulator and the power plant operator?

Marginal abatement cost of RES – exercise

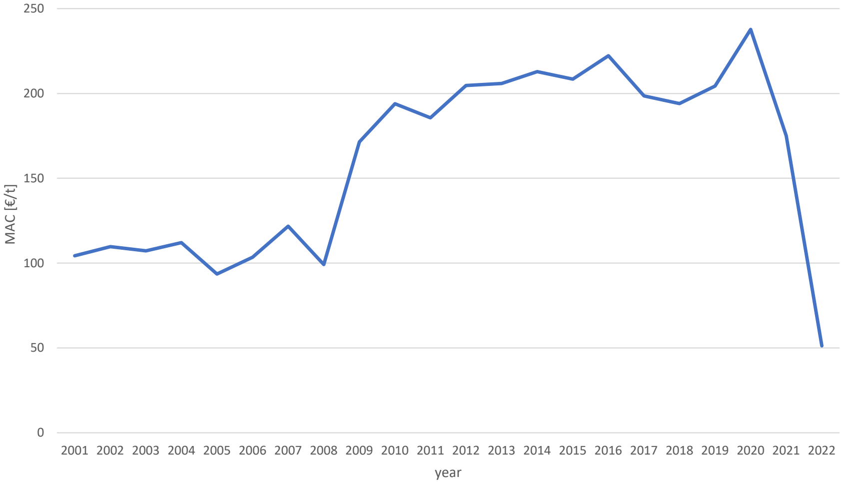

Figure: Development of abatement cost of RES-based electricity generation in Germany. Own illustration based on data provided by Information Platform of the German Transmission System Operators (2018,b).

EUA price development

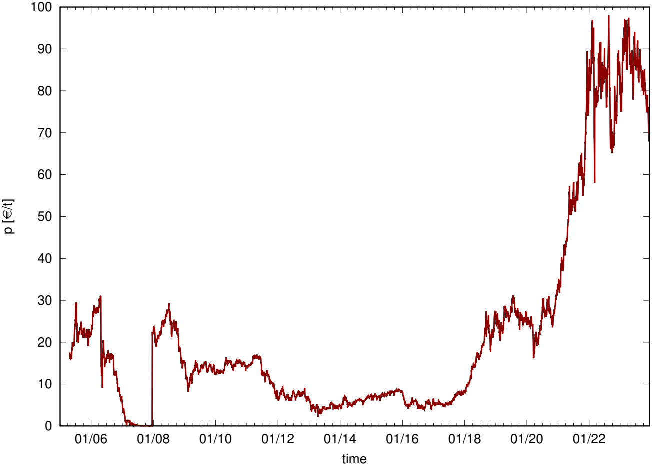

Figure: Development of the allowance price of the EU ETS between April 25, 2005 and December 6, 2023. Own illustration based on investing.com (2023).

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Promotion of RES

regulator's assumption

- subsidies for RES are "too high"

⇒ high additional profits of RES-based operators

⇒ undesired redistribution electricity consumers to electricity producers

idea

→ redution of additional profits

→ increase **efficiency** without deteriorating **effectiveness**

- reverse auctions for RES

⇒ shift from price-based promotion scheme to a quantity-based promotion scheme

Auctions

usual auction

→ the auctioneer wants to sell a good for the highest price possible

→ the bidder wants to buy the good as cheap as possible

→ efficiency is achieved if the bidder with the highest willingness to pay acquires the good

reverse auction

→ the auctioneer wants to buy a good for the lowest price possible

→ the bidder wants to sell the good as expensive as possible

→ efficiency is achieved if the bidder with lowest cost sells the good

- In a reverse auction the roles of bidder and auctioneer are reversed

Multi unit reverse auctions

uniform pricing

→ all successful bidders receive the highest successful bid

pay-as-bid (discriminatory) pricing

→ all successful bidders receive their bid as payment

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Excursus – LCOE

Levelized **C**ost **o**f **E**lectricity (LCOE)

$$LCOE = \frac{\sum_{t=0}^{n} \frac{C_{I,t}+C_{O\&M,t}+C_{F,t}+C_{CO2,t}+C_{D,t}}{(1+i)^t}}{\sum_{t=0}^{n} \frac{E_t}{(1+i)^t}} \tag{15}$$

- $C_{I,t}$ investment cost in year t
- $C_{O\&M,t}$ operation and maintenance cost in year t
- $C_{F,t}$ fuel cost in year t
- $C_{CO2,t}$ CO_2 emission cost in year t
- $C_{I,t}$ decommissioning cost in year t
- E_t electricity generation in year t
- i interest rate (discount factor)

Reverse auctions for RES in Germany

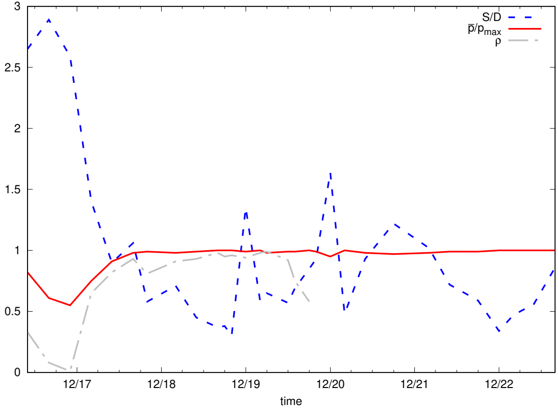

Figure: S/D depicts the ratio of supply and demand with $S/D > 1$ indicating excessive supply and $S/D < 1$ excessive demand. $\bar{p}/p_{max}$ depicts the ratio of the weighted average and the admitted maximum price p_{max} with values close to 1 indicating that almost all bidders bid the maximum price. ρ corresponds to the share of successful bids which were realized before expiration (data is restricted to those auction rounds with expired realization periods); taken from Schäfer (2023)

Bidding strategies

excessive demand

- it is rational to place a maximum bid under uniform and pay-as-bid pricing (analogous to bid shading in classical auctions)

excessive supply

- bidding for real options (like buying a put option)
- switch to long-run profit maximization

→ crowding out of competitors

→ increase market share

Reverse auction with endogenous quantity

general idea

- the regulator announces a procedure which allows to choose the best quantity

the regulator's two objectives

- RES-based electricity generation shall be expanded (**effectiveness**)
- redistribution (additional profits) shall be limited (**efficiency**)

→ applies to the **high price period** only!

→ approach follows Schäfer (2023)

Quantification of the regulator's objective

For the following analysis we assume a reverse auction with **single unit bidders** under **uniform pricing** and (at first) **truthful bidding** of l successful bidders out of n total bidders.

- an increase of installed wind turbines is proportional to the number of l awarded bidders

$$\chi(l) := \min\left\{\frac{\sum_{i=1}^{l} q_i}{Q_{max}}, 1\right\}$$

$\Rightarrow$ the higher the value of $\chi(l)$, the better for the regulator (except for values above Q_{max})

$\Rightarrow$ increasing $\chi(l)$ corresponds to higher **effectiveness**

Quantification of the regulator's objective

- the share of uncovered cost $C(I)$ on subsidies $S(I)$ is an indicator for redistribution

$$\varphi(I) := \frac{C(I)}{S(I)}.$$

- with uncovered cost

$$C = K - R$$

$\Rightarrow$ the higher the value of $\varphi(I)$, the better for the regulator

$\Rightarrow$ increasing $\varphi(I)$ corresponds to higher **efficiency**

Quantification of the regulator's objective

- the regulator can easily calculate the individual subsidy rate

$$s_i = p_i - \overline{p}_{spot}$$

  which corresponds to uncovered LCOE under truthful bidding
- allowing to calculate uncovered cost under the assumption of truthful bidding

$$C(I) = \sum_{i=1}^{I} s_i q_i$$

- and eventually

$$S(I) = s_I \sum_{i=1}^{I} q_i$$

The regulator's objective function

- determination of the optimal quantity turns into utility maximization for the regulator

$$u = \left[\alpha\varphi(I)^{\theta} + \beta\chi(I)^{\theta}\right]^{1/\theta},$$

- with $\alpha + \beta = 1$ and $\alpha \geq 0 \leq \beta$ ensuring constant returns to scale
- the chosen CES utility function includes the whole range of substitution elasticities from perfect complements ($\sigma = 0$, $\theta = -\infty$) to perfect substitutes ($\sigma = \infty$, $\theta = 1$)
- for $\sigma = 1$ the function corresponds to a Cobb-Douglas utility function $\varphi(I)^{\alpha} \cdot \chi(I)^{\beta}$

$\Rightarrow$ very flexible

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