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## On the relativity of environmental bounds

Nothing gets eaten as hot as it gets cooked

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## Elastic demand in optimisation models

- » **Where bottom-up and top down methodologies meet**
  - » Interpretation – what does it represent
  - » How to quantify
  - » **How elastic demand reacts on (environmental) limitations**

## Quantifying energy service elasticities

$$EDE = -\sigma(1-\delta) + \delta ESE \quad 5 \text{ (Vanregemorter)}$$

$\delta$  : budget share of energy in ES

$\sigma$  : elasticity of substitution  $> 0$

Conclusions :

$EDE < ESE < 0$  if  $\sigma$  big

$ESE < EDE < 0$  if  $\sigma$  small

$ESE \nearrow$  then  $EDE \nearrow$

## Guidelines for ESE quantification

- » Assume  $EDE$  is known
- » Determine  $\delta$  and  $\sigma$  (3 model runs)
  - » Price increase and  $ESE = 0 \rightarrow EDE1$
  - » Arbitrary  $ESE2 \rightarrow ED2$
  - »  $\delta = (ED1-ED2)/ES2$  ,  $\sigma = ED1/(\delta - 1)$
- »  $ESE = (EDE + \sigma(1-\delta))/\delta$

## Simple model

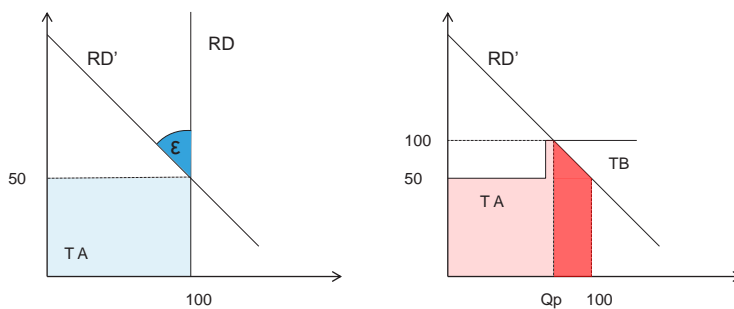
- » Reference scenario : Demand 100 – No carbon constraint - inelastic demand
- » Carbon intensive technology A : Cost € 5/GJ CO<sub>2</sub>: 100 kg / GJ
- » Carbon free technology B : Cost € 10 /GJ
- » Solution : Activity A : 100 - B: 0, Cost 500, Shadow price 5 € /GJ, CO<sub>2,ref</sub> 10000 kg
- »
- » Policy scenario : Demand elasticity  $\epsilon$  , CO<sub>2,pol</sub> < CO<sub>2,ref</sub>
- » Solution : see next picture
- »



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## Graphical representation



### Conclusions:

- Shift in shadow price causes considerable demand loss, even for a very small policy objective.
- Technology A makes a profit.



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## Realistic ?

- » Yes for markets with real marginal pricing - all customers pay the same price
- » Other markets for energy services - housing, transport ?
  - »
- »



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## Relative bounds

- » Per unit of activity limitation : kg CO<sub>2</sub>/ GJ delivered
- » Reference scenario CO<sub>2</sub>R<sub>ref</sub> : 100 kg /GJ
  - Policy scenario CO<sub>2</sub>R<sub>pol</sub> < CO<sub>2</sub>R<sub>ref</sub>
  - Policy scenario CO<sub>2</sub>R<sub>pol</sub> < CO<sub>2</sub>R<sub>ref</sub>

Solution: **always requires mix of technology A and technology B**

Shares of A and B determined by relative constraint

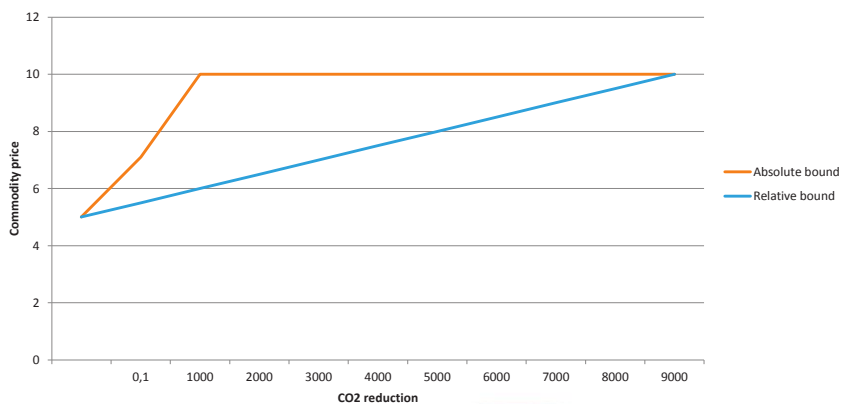
Dual value of commodity determined by shares of A & B



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## Effect on commodity prices of absolute and relative bounds



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