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Flexible emission ceilings and emission off-setting: Principles, results and challenges

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Outline

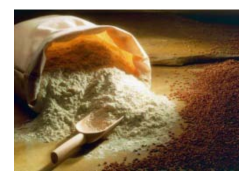
- Motivation and terminology
- Off-setting 1 ceiling exceedance with 1 other pollutant
- Exchange rates and the challenge to define them ex-ante
- Conclusions

Motivation

- Future is unknown
  - *but policy makers decide now on emission ceilings*
- After a set of emission ceilings have been agreed upon
  - we may gain new knowledge; role of national modelers
  - reality may/will deviate from the scenario;
  - > the emissions ceilings may no longer be cost-effective
  - > need for **flexibility** in achieving the ceilings while ensuring **environmental integrity**.

- Could a **limited offsetting** of pollutants **within a country** improve cost-effectiveness and avoid **regret investments**?
- Under what conditions can **environmental integrity** be ensured?

Culinary analogy: menus, dishes, ingredients



A role for off-setting?

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Ambition

Equity

Budget

Negotiation

Targets

- *Health (particles)*
- *Acidification*
- *Eutrophication*
- *Ozone*

Cost-effectiveness (GAINS)

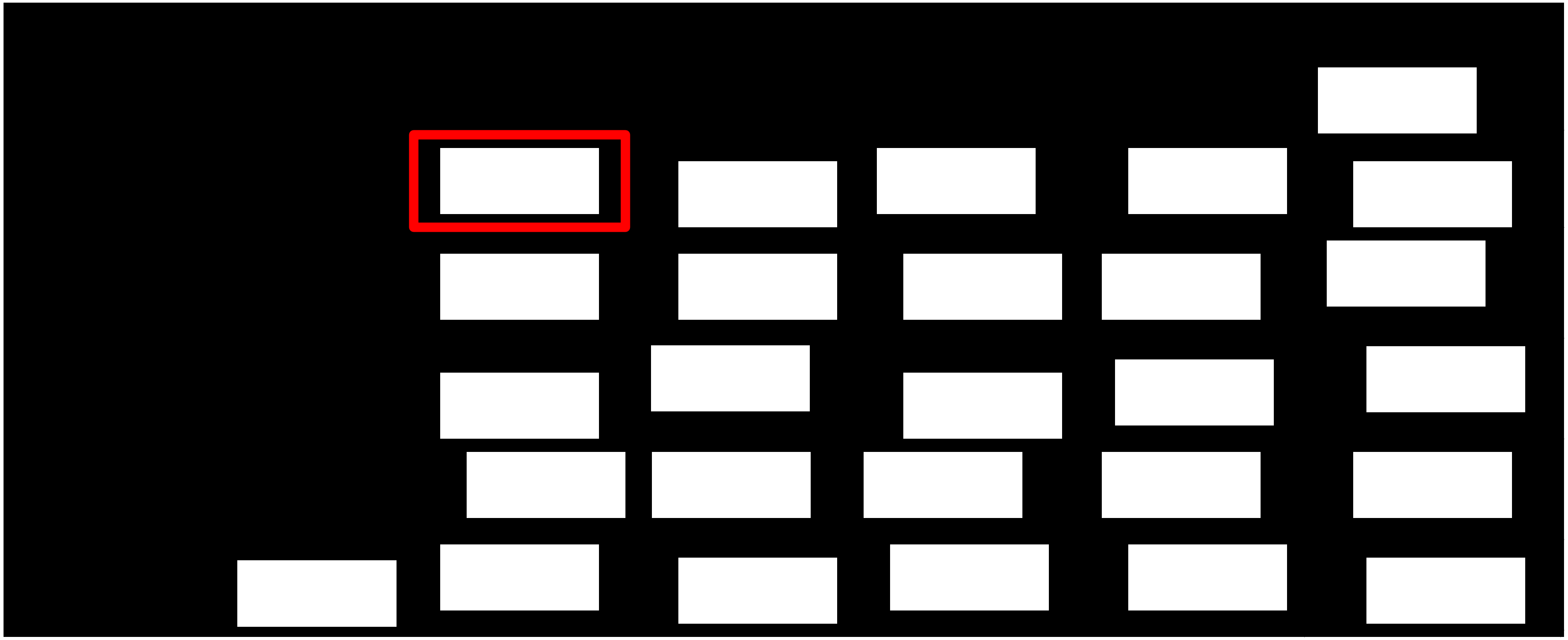
Negotiation

Ceilings

- *SO2*
- *NOx*
- *PM2.5*
- *NH_3*
- *VOC*

‘off-setting’

Overview of off-setting regimes
Number of possible combinations



1 exceedance offset by further reduction of 1 pollutant

		Pollutant to be reduced				
		$PM_{2.5}$	SO_2	NO_x	NH_3	VOC
	$PM_{2.5}$					
Pollutant	SO_2					
that is	NO_x					
increased	NH_3					
	VOC					

Rules for offsetting exceedance in VOC by NOx

	SO2	NOX	PM2.5	NH3	VOC
Health (Particles)	X	X	X	X	
Acidification	X	X		X	
Eutrophication		X		X	
Ozone		X			X

$$T^{n,o} \cdot \Delta NOX + T^{v,o} \cdot \Delta VOC = 0$$

$$\Delta NOX = -(T^{v,o} / T^{n,o}) \cdot \Delta VOC$$

1 exceedance offset by further reduction of 1 pollutant

Exchange rates depend only on source-receptor matrices

		Pollutant to be reduced				
		$PM_{2.5}$	SO_2	NO_x	NH_3	VOC
	$PM_{2.5}$					
Pollutant	SO_2					
that is	NO_x					
increased	NH_3					
	VOC					

1 exceedance offset by further reduction of 1 pollutant

Exchange rates depend only on source-receptor matrices

		Pollutant to be reduced				
		$PM_{2.5}$	SO_2	NO_x	NH_3	VOC
Pollutant that is increased	$PM_{2.5}$	$\emptyset$	$\geq \frac{T^{p,y}}{T^{s,y}}$	$\geq \frac{T^{p,y}}{T^{n,y}}$	$\geq \frac{T^{p,y}}{T^{a,y}}$	$\emptyset$
	SO_2	$\emptyset$	$\emptyset$	$\geq \max\left(\frac{T^{s,ac}}{T^{n,ac}}, \frac{T^{s,y}}{T^{n,y}}\right)$	$\geq \max\left(\frac{T^{s,ac}}{T^{a,ac}}, \frac{T^{s,y}}{T^{a,y}}\right)$	$\emptyset$
	NO_x	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$
	NH_3	$\emptyset$	$\emptyset$	$\geq \max\left(\frac{T^{a,ac}}{T^{n,ac}}, \frac{T^{a,eu}}{T^{n,eu}}, \frac{T^{a,y}}{T^{n,y}}\right)$	$\emptyset$	$\emptyset$
	VOC	$\emptyset$	$\emptyset$	$\geq \frac{T^{v,o}}{T^{n,o}}$	$\emptyset$	$\emptyset$

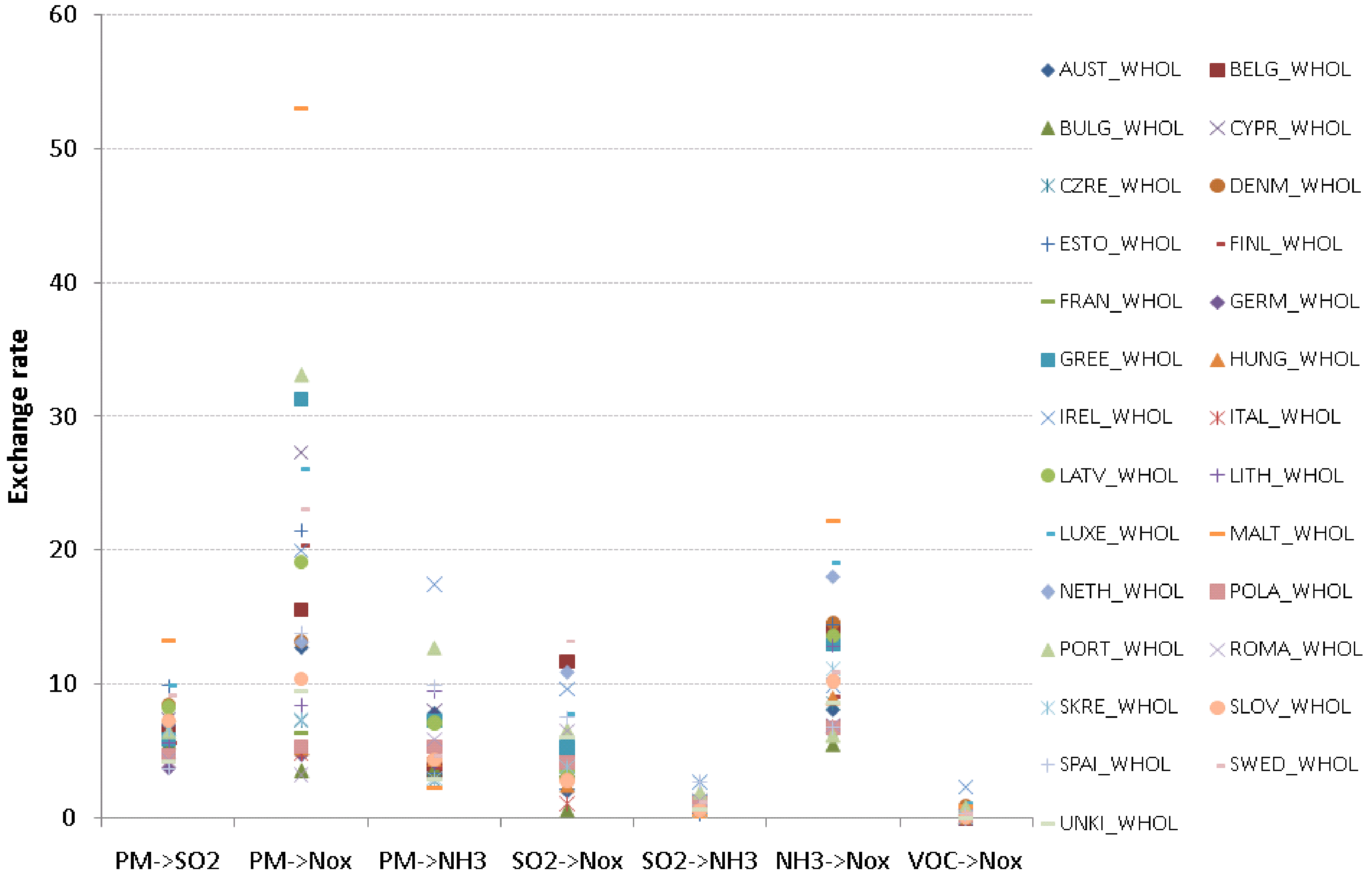
Exchange rates for 2-pollutant trade (7 feasible cases)

Example: UK

	Pollutant to be reduced				
	PM2.5	SO2	NOX	NH3	VOC
Pollutant to increase: PM2.5		4.3	9.5	2.9	
SO2			6.0	0.7	
NOX					
NH3			8.6		
VOC			inf		

Exchange rates are country-specific

Exchange rates for the feasible 2-pollutant cases
Comparison between trading cases and across countries



Overview of off-setting regimes
Number of possible combinations

[redacted]

Challenges for exchange rates for ALL off-setting options

- Exchange rates should be
  - efficient (no unnecessary emission reductions)
  - applicable in all circumstances (‘universal’)

- But such exchange rates do not exist

- Could define rules for off-settings, different for each combination of rules
  - Codification of rules would be intransparent

Exchange rates **cannot** be universal **and** efficient
An Example

	SO2	NOX	PM2.5	NH3	VOC
Health (Particles)	X	X	X	X	
Acidification	X	X		X	
Eutrophication		X		X	
Ozone		X			X

Example ***Part 1****(SO2 -> NOx):*

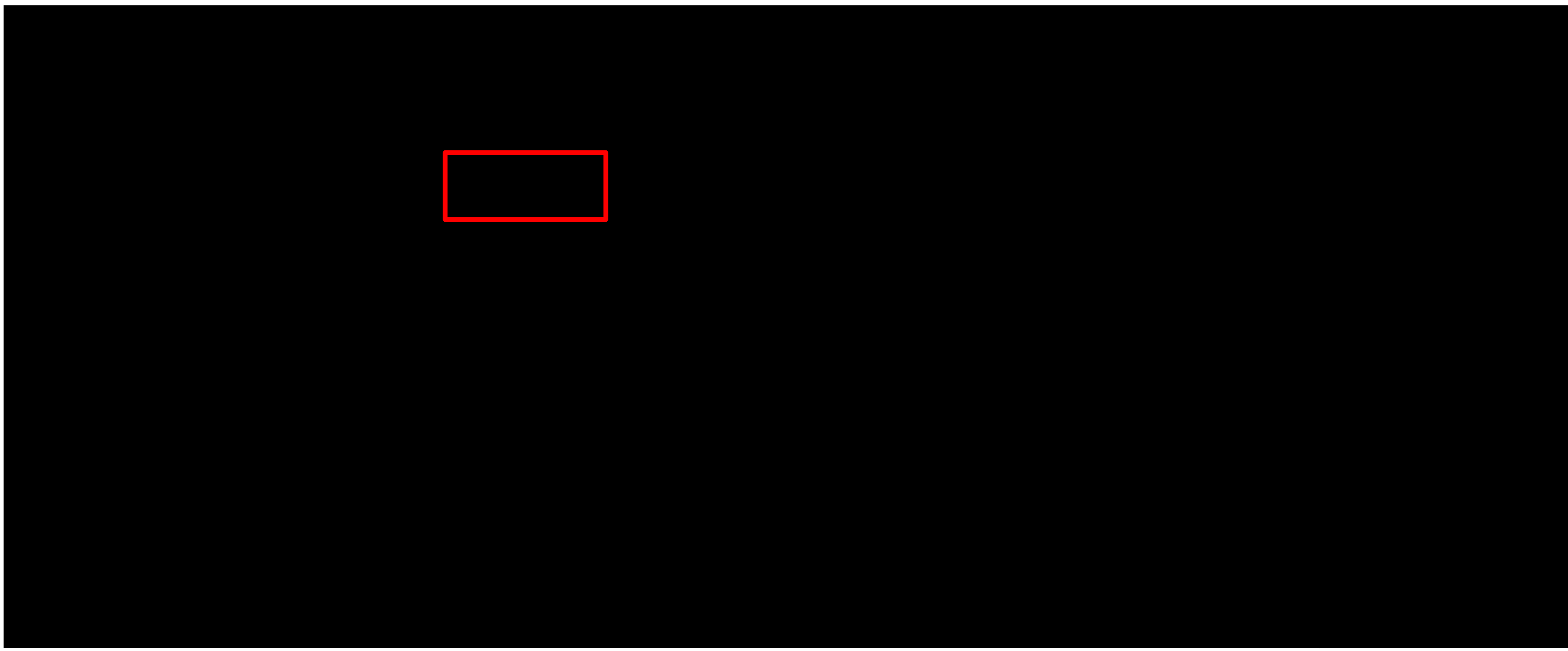
- *Use SO2-NOx exchange rate to calculate NOx reduction*

Example ***Part 2****(SO2 -> (NOx,NH3):*

- *NH3 is compensating parts of SO2*
- *Need to reduce less NOx than without NH3 reduction (Part 1)*
- *The simple SO2-NOx exchange rate overestimates need for NOx reduction*

Restriction to the 1:1 cases?

Limited flexibility, but simple rules



Summary and Conclusions

- Offsetting within a country
  - increases flexibility in meeting national ceilings
  - Allows stakeholders to react on new information (post signature)
  - can avoid regret investments
- Environmental integrity can always be checked
  - Downwind effects can also be considered
  - Offsetting more certain with less certain emissions?
- But there are no exchange rates that are
  efficient AND *universal*
  -> difficult to put rules into a protocol

- Compromise? Restriction to (1:1) offset regime (1 exceedance, 1 offset)
  - Requires 7 values for exchange rates per country
  - Values could be part of a revised protocol?

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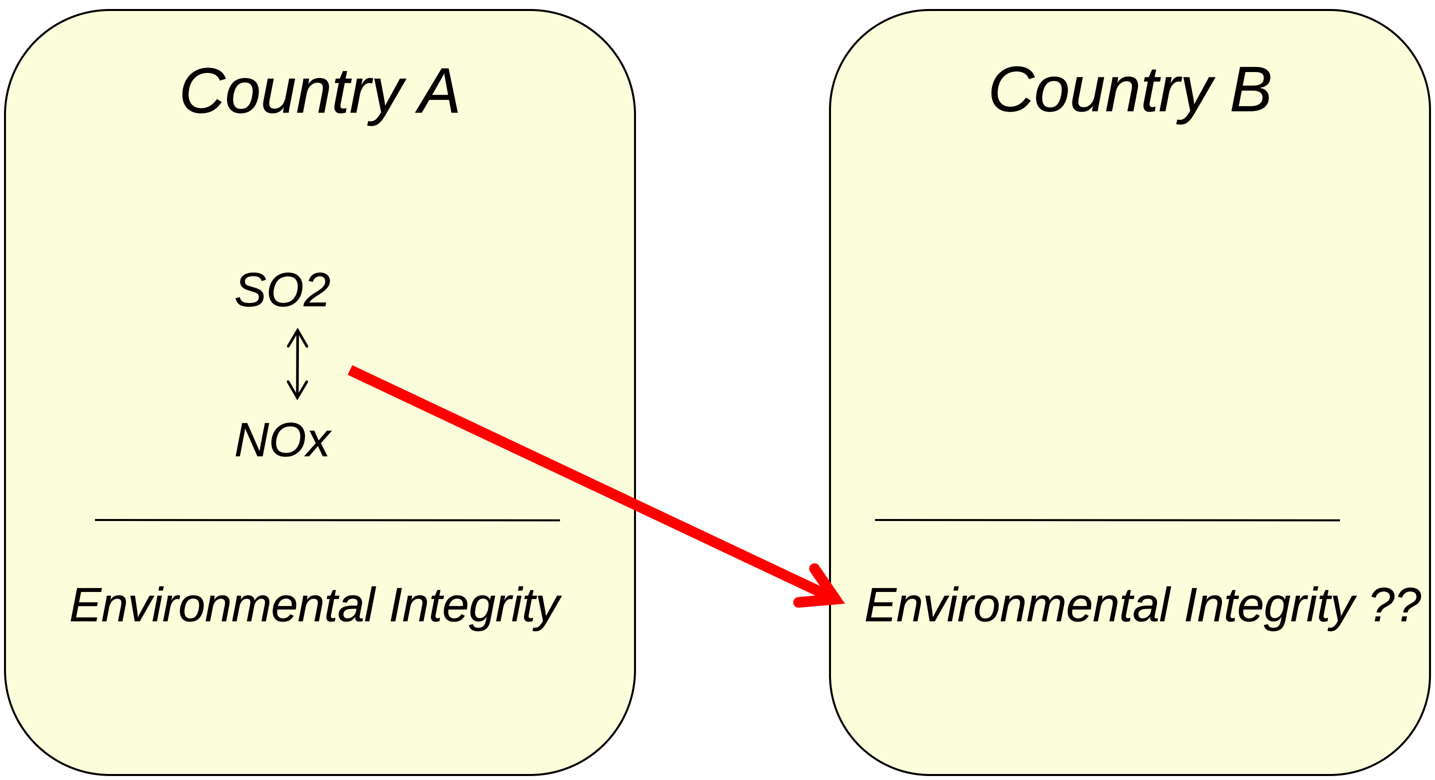
The efficient set of exchange rates for Part 2

$$R_{\mathrm{NO}_x,\mathrm{SO}_2} = \frac{\left(\frac{T^{s,ac}}{T^{a,ac}} - \frac{T^{s,y}}{T^{a,y}}\right)}{\left(\frac{T^{n,ac}}{T^{a,ac}} - \frac{T^{n,y}}{T^{a,y}}\right)}$$

$$R_{\mathrm{NH}_3,\mathrm{SO}_2} = \frac{\left(\frac{T^{s,ac}}{T^{n,ac}} - \frac{T^{s,y}}{T^{n,y}}\right)}{\left(\frac{T^{a,ac}}{T^{n,ac}} - \frac{T^{a,y}}{T^{n,y}}\right)}$$

Downwind effects

- Potential Problem:



Downwind effects

Conditions for avoiding adverse effects

		Pollutant to be reduced				
		$PM_{2.5}$	SO_2	NO_x	NH_3	VOC
Pollutant that is increased	$PM_{2.5}$	$\emptyset$	$\geq \max_B \frac{T^{p,y}}{T^{s,y}}$	$\geq \max_B \frac{T^{p,y}}{T^{n,y}}$	$\geq \max_B \frac{T^{p,y}}{T^{a,y}}$	$\emptyset$
	SO_2	$\emptyset$	$\emptyset$	$\geq \max_B \max\left(\frac{T^{s,ac}}{T^{n,ac}}, \frac{T^{s,y}}{T^{n,y}}\right)$	$\geq \max_B \max\left(\frac{T^{s,ac}}{T^{a,ac}}, \frac{T^{s,y}}{T^{a,y}}\right)$	$\emptyset$
	NO_x	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$
	NH_3	$\emptyset$	$\emptyset$	$\geq \max_B \max\left(\frac{T^{a,ac}}{T^{n,ac}}, \frac{T^{a,eu}}{T^{n,eu}}, \frac{T^{a,y}}{T^{n,y}}\right)$	$\emptyset$	$\emptyset$
	VOC	$\emptyset$	$\emptyset$	$\geq \max_B \frac{T^{v,o}}{T^{n,o}}$	$\emptyset$	$\emptyset$

Choosing exchange rates sufficiently high will ensure environmental integrity also in down-wind countries