Performance of the carbon market when accounting for uncertainties in GHG inventories

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Scope

To include **diversified inventory uncertainty** into emission trading framework in two ways:

1. in the Kyoto targets
2. in the 'quality' of permits by means of **effective** permits

Overview

1. Emission permit optimization problem
2. Effective emission permits
3. Undershooting concept: Model and simulation results
4. Adjustment of the Kyoto targets: Model and simulation results
5. Concluding remarks / Futher extentions

Emission permit optimization problem

The task is to meet targets of the Kyoto protocol and not to allow costs to become higher than necessary:

$$\begin{aligned} \min_{x_i} \textstyle\sum_i c_i(x_i) \\ \text{s.t. } \textstyle\sum_i (x_i - (1-\delta_i)x_i^0) = 0 \end{aligned} \tag{1}$$

i – party of the Kyoto Protocol
x_i – emissions level
$c_i(x_i)$ – cost of keeping (reducing) emission at level x_i
δ_i – agreed Kyoto reduction target
x_i^0 – base year emissions

Effective emission permits

Higher the uncertainty less units of effective permits a party is allocated with:

- Effective emission permits l_i vs. reported emissions x_i

$$l_i = [1 - (1 - 2\alpha)R_i]x_i \tag{2}$$

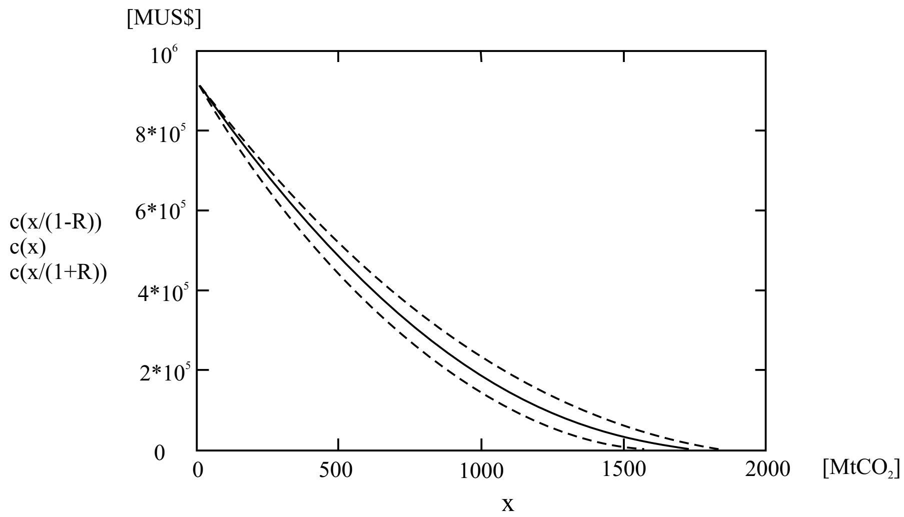
α – assumed risk that the party is non-compliant

R_i – inventory relative uncertainty

Effective *emission permits*

Abatement costs expressed in terms of effective permits

$$c_i(x_i) = c_i\left(\frac{l_i}{1-(1-2\alpha)R_i}\right) \tag{3}$$



Undershooting concept

Δ_i^b, Δ_i^c – uncertainty in base and commitment year (half absolute uncertainty intervals)

- Uncertainty belt:

$$\Delta_i^{bc} = \Delta_i^c + (1 - \delta_i)\Delta_i^b \tag{4}$$

- Verification condition:

$$x_i \leq (1 - \delta_i)x_i^0 - (1 - 2\alpha)\Delta_i^{bc} \tag{5}$$

Undershooting & effective permits

- δ_i^U - reduction factor reflecting undershooting

$$\delta_i^U = \delta_i + 2(1-2\alpha)R_i \tag{6}$$

- Permit market optimization model

$$\begin{aligned} &\min_{l_i} \textstyle\sum_i c_i(\frac{l_i}{1-(1-2\alpha)R_i}) \\ \text{s.t.}\quad &\textstyle\sum_i (l_i - [1-\delta_i^U] x_i^0 [1-(1-2\alpha)R_i]) = 0 \end{aligned} \tag{7}$$

Undershooting & effective permits: Results

- Data

	Kyoto target (%)	Inventory uncertainty (%)
US	7,0	13
OECDE	7,9	10
Japan	6,0	15
CANZ	0,7	20
EEFSU	1,7	30

Undershooting & effective permits: Results

- No uncertainty covered ($\alpha = 0, 5$)

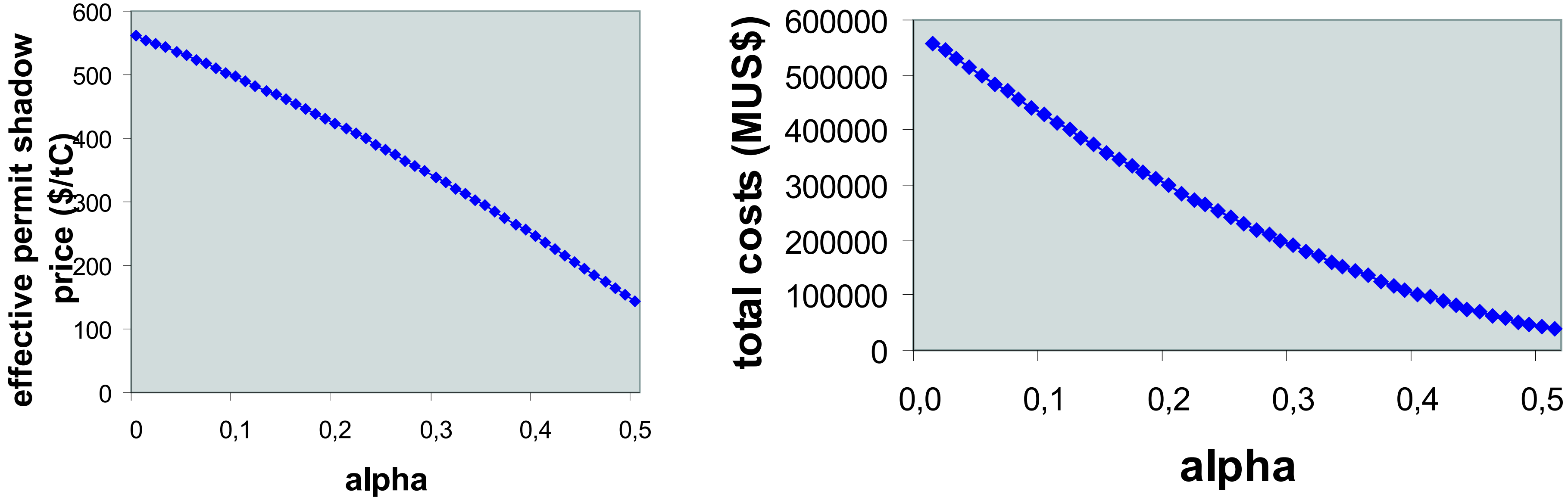
	Effective emission permits (MtC/year)	Reported emissions (MtC/year)	Effective permits traded (MtC/year)	Marginal cost ($/tC)	Market shadow price ($/tC)
US	1561,6	1561,6	310,8	-142,5	-142,5
OECDE	959,4	959,4	99,1	-142,5	-142,5
Japan	321,1	321,1	63,5	-142,5	-142,5
CANZ	248,4	248,4	32,9	-142,5	-142,5
EEFSU	807,8	807,8	-506,3	-142,5	-142,5

Undershooting & effective permits: Results

- Accepted risk of 30% ($\alpha = 0,3$)

	Effective emission permits (MtC/year)	Reported emissions (MtC/year)	Effective permits traded (MtC/year)	Marginal cost ($/tC)	Market shadow price ($/tC)
US	1178,8	1243,6	125,7	-317,8	-335,2
OECDE	826,1	860,5	72,0	-321,8	-335,2
Japan	268,9	286,1	57,7	-315,1	-335,2
CANZ	159,7	173,5	-6,6	-308,4	-335,2
EEFSU	625,4	710,6	-248,8	-295,0	-335,2

Shadow prices and total costs on effective permit market for different levels of uncertainty covered

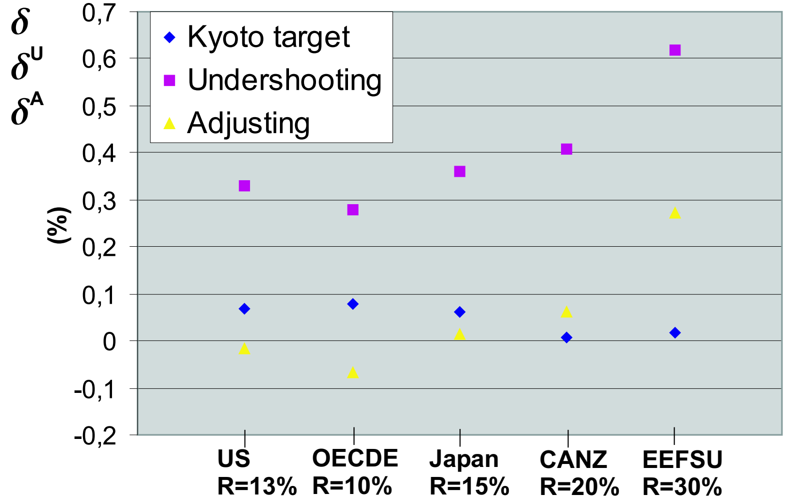


Adjustment of the Kyoto targets

- R^M - reference uncertainty level

$$\delta_i^A = \delta_i + (1 - 2\alpha)(2R_i - R^M) \tag{8}$$

- Reduction factors - standard Kyoto target (δ), undershooting (δ^U), adjustment (δ^A)

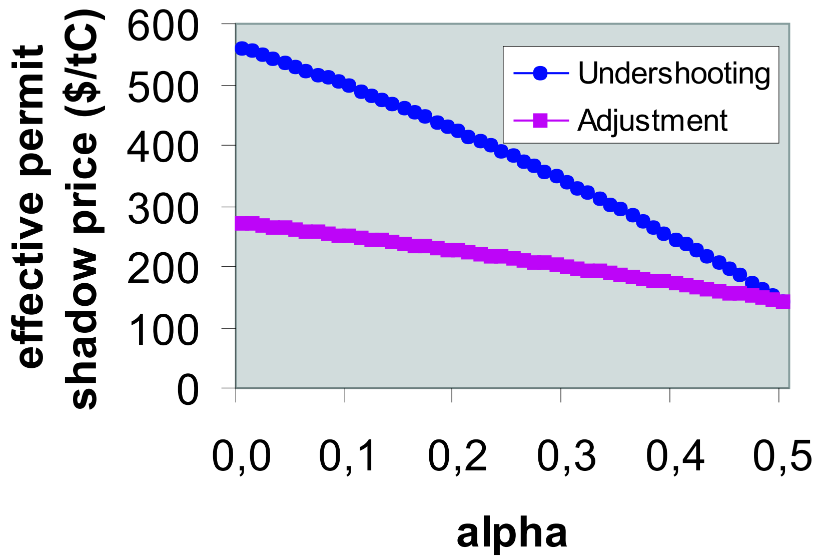


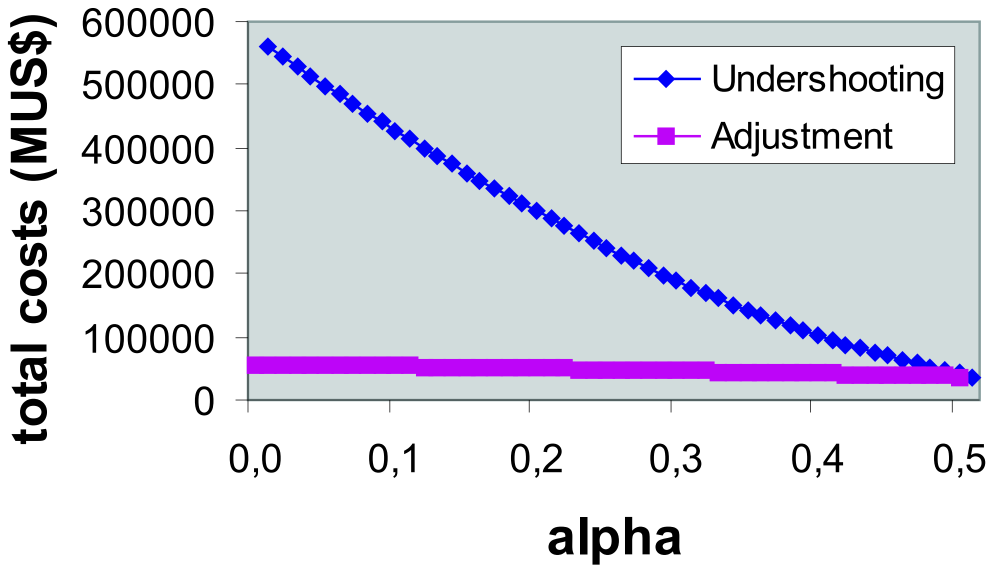
Adjustment & effective permits

- Permit market optimization task:

$$\min_{l_i} \sum_i c_i\left(\frac{l_i}{1-(1-2\alpha)R_i}\right) \tag{9}$$
$$\text{s.t.} \quad \sum_i (l_i - [1-\delta_i^A] x_i^0 [1-(1-2\alpha)R_i]) = 0$$

Shadow prices and total costs on effective permit market: undershooting vs. adjustment





Concluding remarks

- We have examined feasibility of incorportating uncertainty into the Kyoto framework in the context of permit trading.
- The system of **effective** permits allowed us to reflect inventory quality, which is diversified among market participants.
- **Undershooting** Kyoto targets with uncertainty belt resulted in extremely high costs.
- Reasonable results were obtained when penalizing parties just for differing from reference uncertainty (**adjustment procedure**).

Further works

- Limitations of the analysis - interval distribution of uncertainty
- Stochastic setting
  1. Undershooting and adjustment conditions already developed
  2. Problems with definition of effective permits (nonlinearities...)
  3. Expectations: abatement costs for the same risk α will be lower in the stochastic approach (normal probability distributions) than in the interval case.