Implicit cost of carbon emissions: Design the internal carbon price in the decision-making process

Sustainable Development Laboratory Department of Bioenvironmental Systems Engineering N.T.U.

EGU23-2779

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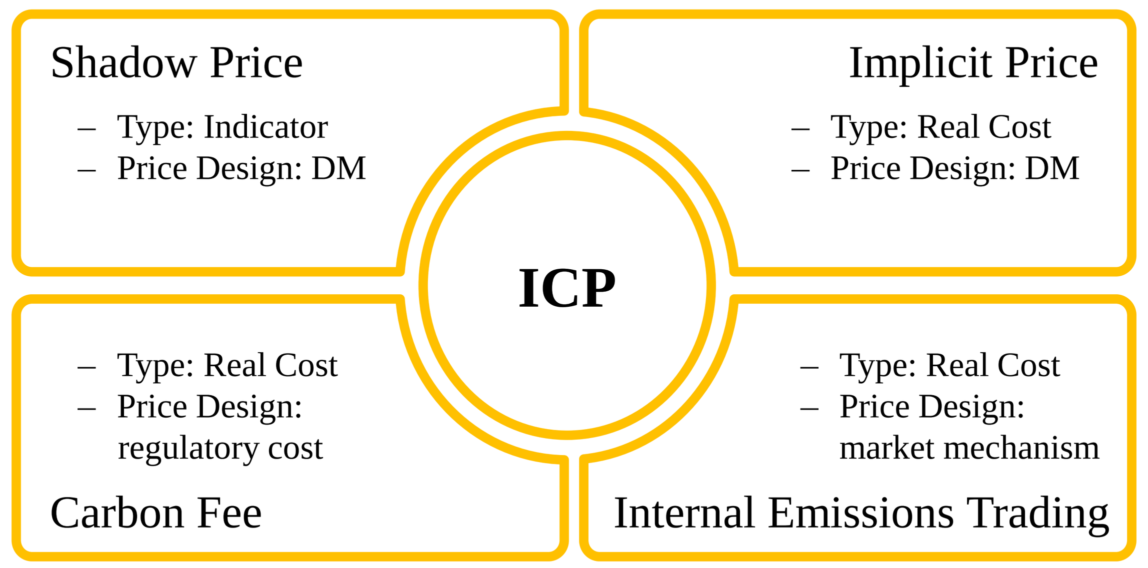
Introduction

Carbon pricing is a cost-benefit policy instrument, which has become the norm in motivating carbon mitigation actions through economic incentives. By putting a price on emissions directly, emitters are responsible for paying for their pollution, namely to internalize the external social cost by increasing their operating costs. With more and more relevant policies published, the cost of emissions is predicted to sustain growth. If emitters cannot effectively reduce their emissions, the added cost of emissions could have a significant impact on the company and thus threaten the competitiveness of the organization. To prevent such a situation, emitters must develop low-carbon transition strategies to adapt their business models as soon as possible.

Internal carbon pricing (ICP) is one of the mitigation strategies increasingly used by companies in response to the regulatory transition. By imposing an "internal" price on emissions, the departments have to bear the mitigation duties within the organization.



▲ The four frequently used types of ICP

The ICP is expected to help improve environmental efficiency, change internal behavior, and navigate greenhouse gas regulations across all departments. The benefits that ICP can provide in explaining why it has recently attracted much more attention. However, **there is still no suitable approach for accurately expressing the implied cost of emissions**. Due to the lack of pricing methodology, it is difficult for enterprises to design the ICP, especially for the type of implicit price.

Aim

To develop a decision-making tool for companies to determine their ICP, which includes two parts:

– **Design the pricing level of ICP;**
– **Design long-term low-carbon transition strategies.**

Method

Our work consists of three sections: **divided-and-conquer, linear programming, and multi-period transition strategy optimization**, as displayed below. Note there are a few assumptions behind our model:

- **01** Considering the group company, which includes the parent company and several subsidiary companies;
- **02** Each subsidiary company is independent;
- **03** The objective of each company is to maximize financial performance;
- **04** The trade-off relationship exists between the financial performance and the corporate mitigation target;
- **05** The marginal value of emissions represents the opportunity cost, which implies the sacrificed financial performance per unit emission and indicates the ICP level.

Linear Programming (Simplex / Dual Simplex Method)

$$Max\ FP_i = \sum_{j=1}^{m}(P_j - \bar{v}\bar{R}_j)Q_j = \bar{C}\cdot\bar{X}$$

s.t. (1) Resource availability: $\forall k \in \mathbf{N}, \sum_{j=1}^{m} R_{kj}Q_j \le R_k^{(t)}$ ······ **Divide**

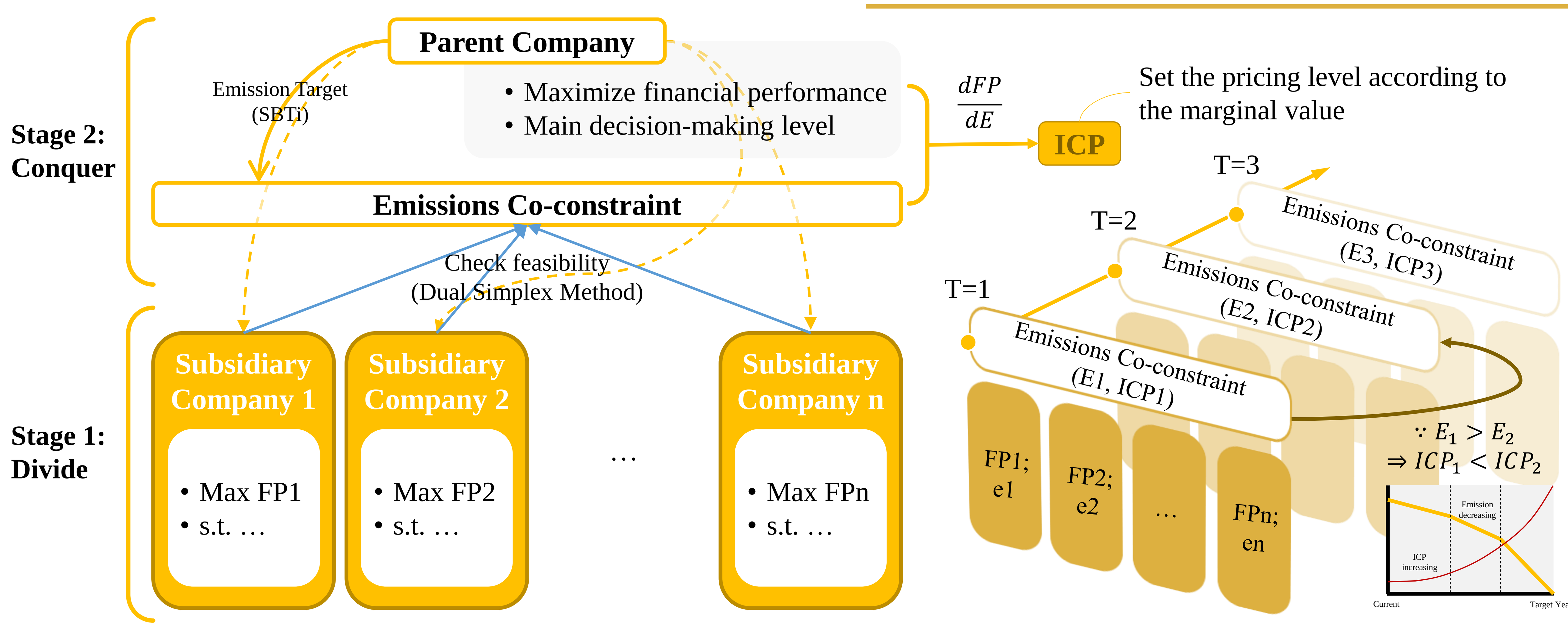
(2) Emission constraint: $\sum_{i=1}^{n}\sum_{j=1}^{m} e_jQ_j \le E^{(t)}$ ······ **Conquer**

(3) Non − negative variable: $\forall Q_j \ge 0$

Multi-period Optimization (Genetic Algorithm)

$$Max\left(\sum_{t=d+1}^{T+1}\frac{ICP_t\cdot\Delta E_t}{1+r_t} + \sum_{t=d+1}^{T}\frac{ICP_t\cdot\Delta E_t}{1+r_t}\right)$$

s.t. (4) $\Delta E_t = \sum_{s=1}^{P}\rho_{(t-\delta)s}\times FP_d\times x_{(t-1)s}$; (5) $\sum_t\sum_s x_{ts} = 1$

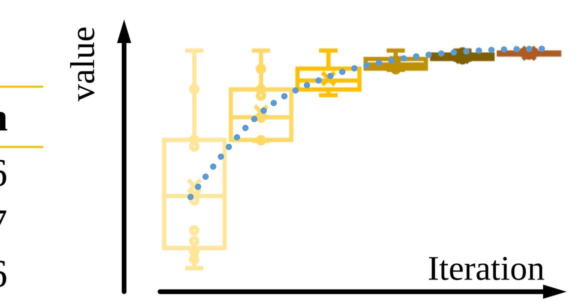


Result

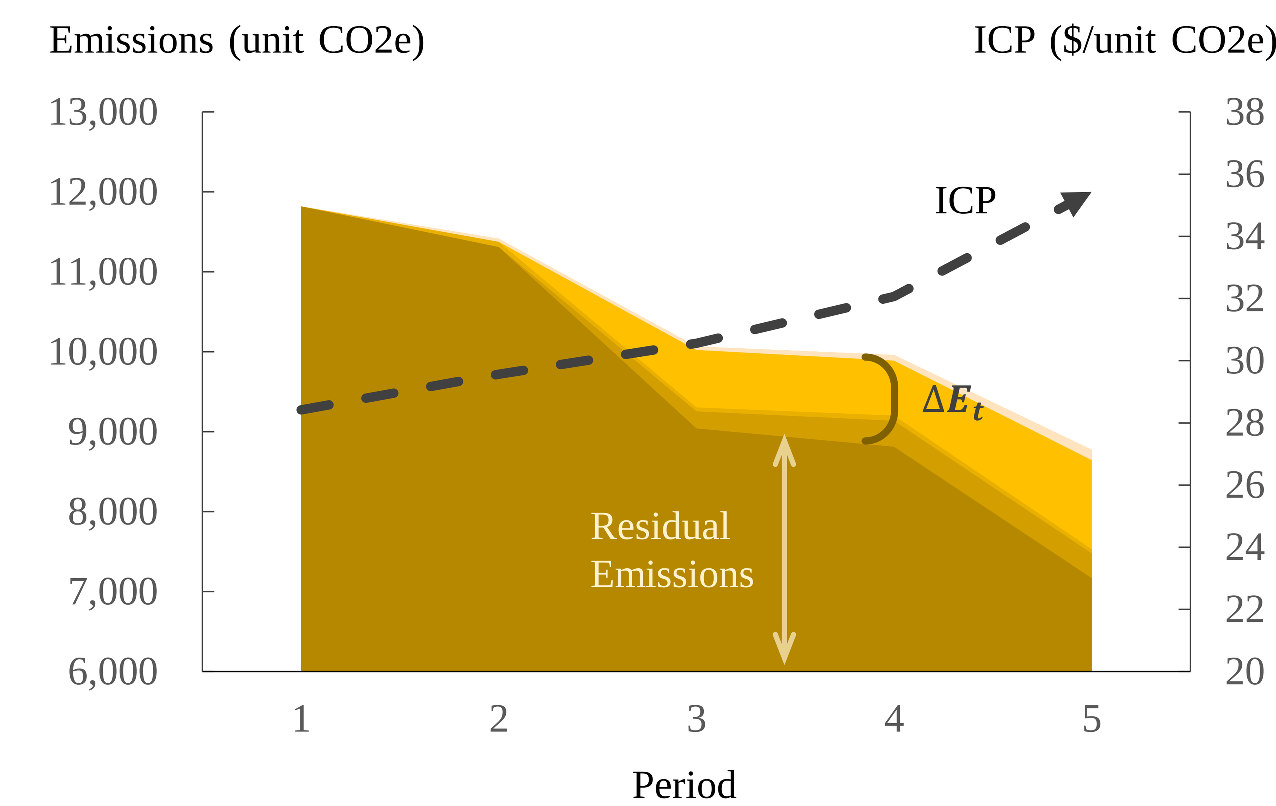
The result is presented with a hypothetical example to demonstrate how our model work. We choose the financial sector as the imagined analysis object, and the parameters used in the model are set up according to the sector's statistical data. For the multi-period transition planning, we consider five mitigation strategies with an investment horizon of 0, 1, 2, 1, and 2 periods, regarding carbon offset acquisition, equipment update, energy transition, operation efficiency improvement, and R&D. The output is as follows.

▼ The optimal percentage of investment

x_{ts}	s=1	s=2	s=3	s=4	s=5	sum
t=1	0.00	0.02	0.13	0.04	0.07	0.26
t=2	0.00	0.02	0.12	0.03	0.10	0.27
t=3	0.00	0.04	0.19	0.04	0.09	0.36
t=4	0.00	0.06	0.00	0.04	0.00	0.10
W*	1,280,678.593					



▲ The value converges with the iteration increase.



Conclusion

This paper proposes an analysis of internal carbon pricing based on marginal value with linear programming. By identifying the optimal pricing level, companies could determine the low-carbon transition roadmap that is consistent with the mitigation target.

DENOTATION | FP is denoted as *financial performance*. Q_j is *the amount of product j* produced by the subsidiary company *i*. P_j is *the selling price of product j*, and $\bar{v}, \bar{R}_j$ represent *the price and the demand of resources* for unit Q_j produced. $R_k^{(t)}$ is denoted as *the upper limit of the resource*. $E^{(t)}$ is *the emission limitation*, which consists of the mitigation target. e_j represents *the physical emission intensity of the product j*. r_t is *the interest rate in period t*. x_{ts} is *the investment percentage* of each mitigation strategy *s* in each period *t*. ρ means *the investment return*, and δ is set to be *the investment horizon*. d is denoted as *the decision period*.

FOR FURTHER INFORMATION
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01 Internal Carbon Pricing (ICP)

- **What** /
  A mitigation strategy voluntarily used by companies within their organization.
- **Why** /
  For the reason to adjust to the regulatory transition, reduce carbon emission, promote employees' behavior change, etc.
- **How** /
  Shadow price, implicit price, carbon fee, internal emissions trading (See Table 1).

Problem?
Lack of pricing methodology!

which may result in…

1. Inefficient & invalid ICP
2. Unwilling to use ICP
3. Price varies among companies

Table 1: The four frequently used types of ICPs

ICP	Description	Type	Price Design	Pros	Cons
Shadow Price	An investment indicator that considers the climate-related risk in the portfolio selection process.	Indicator	Depend on the decision-maker	Easy, convenient	Hard to create motivation to reduce carbon in practical
Implicit Price	A fund-collected mechanism that considers the emissions of each department. The more the emissions, the more the burden to pay.	Real Cost	Depend on the decision-maker	Motivate the practical reduction action	Hard to design the pricing level
Carbon Fee	A fund-collected mechanism that considers the emissions of each department. The more the emissions, the more the burden to pay.	Real Cost	Depend on the climate-related regulatory cost	Motivate the practical reduction action	Regulatory cost might not reflect the mitigation target and ambition of the company
Internal Emissions Trading	A trading scheme that allocates the emission allowance to each department in advance. The departments are asked to limit their emissions below the allowance.	Real Cost	Depend on the market mechanism	Allocate the emission efficiently; Motivate the practical reduction action	Costly; Hard to management

02 Research Structure

Aim

develop a decision-making tool for companies to determine their ICP

Objective 1

Design the pricing level of ICP

Method

- Linear Programming (Simplex & Dual Simplex)
- Divide-and-conquer (for reducing problem scale)

Objective 2

Design long-term low-carbon transition strategies

Method

- Multi-period Optimization (by genetic algorithm)

Objective I

Design the pricing level of ICP

Method

- Linear Programming (Simplex & Dual Simplex)
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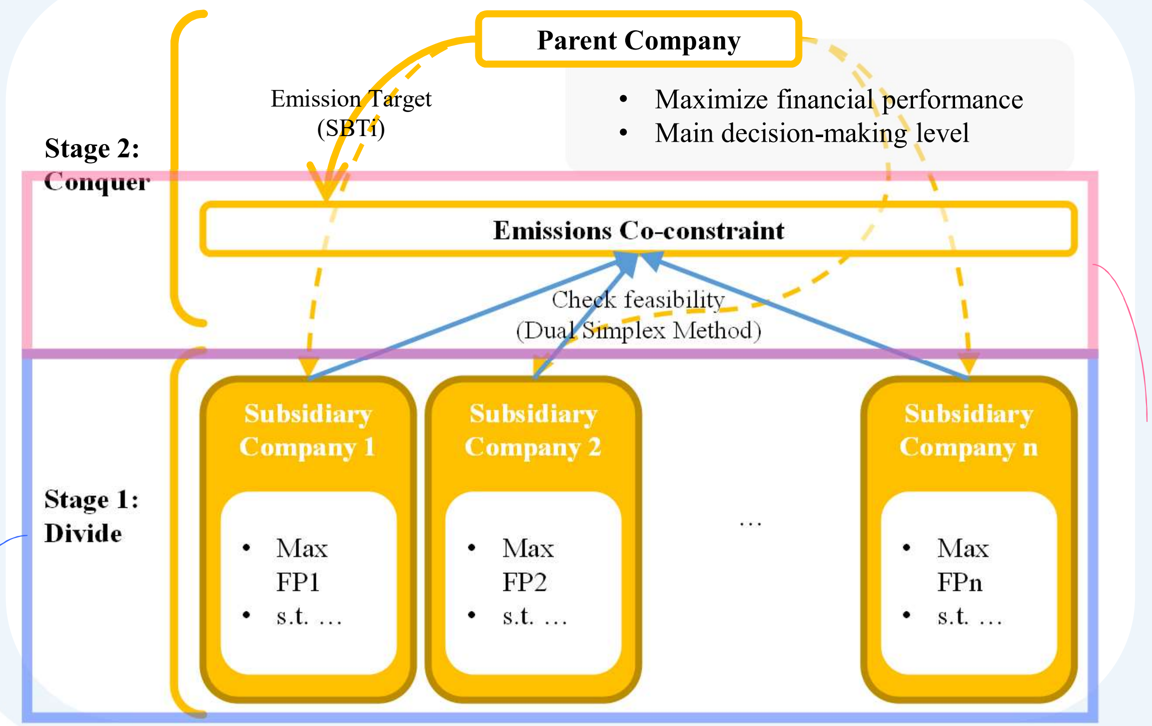

$$Max\ FP_i = \sum_{j=1}^{m}(P_j - \bar{v}\bar{R}_j)Q_j = \bar{C}\cdot\bar{X}$$

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(2) $Emission\ constraint$: $\sum_{i=1}^{n}\sum_{j=1}^{m} e_j Q_j \le E^{(t)}$

(3) $Non-negative\ variable$: $\forall Q_j \ge 0$

Step 2. Check feasibility

If current solution is feasible

→ set $\frac{dFP}{dE}$ as ICP (marginal value of emission);

else, back to step 1.

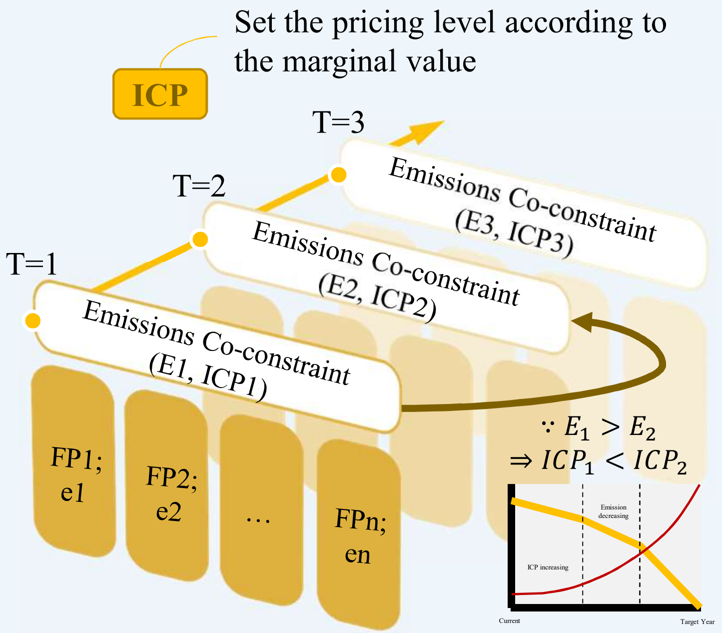
Step 1. Solving LP by part

Objective 2

Design long-term low-carbon transition strategies

Method

- Multi-period Optimization (by genetic algorithm)



To maximize the financial performance within following few years, the DM has to decide the optimal allocation of investment in emission-reducing projects (in %)

1st type benefit: reducing emission can help reducing the payment which come from ICP

$$Max\left(\sum_{t=d+1}^{T+1}\frac{ICP_t \cdot \Delta E_t}{1+r_t}+\sum_{t=d+1}^{T}\frac{ICP_t \cdot \Delta E_t}{1+r_t}\right)$$

2nd type benefit: reducing emission can help reducing the payment which come from ICP

Net Present Value

$$s.t. \quad (4)\ \Delta E_t = \sum_{s=1}^{P}\rho_{(t-\delta)s} \times FP_d \times x_{(t-1)s}\,; \qquad (5)\ \sum_t\sum_s x_{ts} = 1$$

Denotation

- $\boldsymbol{FP}$ denotes *financial performance.*
- $\boldsymbol{Q_J}$ is *the amount of product j* produced by the subsidiary company *i*.
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- $\boldsymbol{R_k^{(t)}}$ denotes *the upper limit of the resource*.
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- $\boldsymbol{e_j}$ represents *the physical emission intensity of the product j.*
- $\boldsymbol{r_t}$ is *the interest rate in period t.*
- $\boldsymbol{x_{ts}}$ is *the investment percentage* of each mitigation strategy *s* in each period *t*.
- $\boldsymbol{\rho}$ means *the investment return*.
- $\boldsymbol{\delta}$ is set to be *the investment horizon*.
- $\boldsymbol{d}$ denotes *the decision period*.

Thank You For Reading!

Photography not allowed

This presentation participates in OSPP

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Outstanding Student & PhD candidate Presentation contest

Abstract

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