Carbon Taxes vs. Carbon Trading

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The Climate Change Problem

Market externality on the largest scale seen by humankind

• Long persistence (>1000 years) of warming & ocean acidification from anthropogenic CO$_2$ emissions

• Large-scale global impacts with possibility of abrupt climate change

• Mitigating CO$_2$ emissions requires innovation and restructuring of long-lived capital stocks  ➔ long lead time for mitigation

Economic instruments to internalize „social costs of carbon“

Carbon tax vs. cap-and-trade of carbon emissions
Outline

1. Putting a Price on Carbon: Carbon Tax vs. Cap & Trade
   - Price instruments and the Green Paradox
   - Quantity instruments and the Carbon Budget Approach

2. International Carbon Markets and Lessons from EU ETS

3. Technology Policy

4. Options and Opportunities for China
Why Weitzman is the Wrong Framework

- Weitzman criteria for static pollution problem
  - **Dynamic stock-pollutant** problem: Quantity instrument performs better in the long run (Newell and Pizer 2003)

  ![Graph a) Tax instrument are preferred in early periods](image1)

  ![Graph b) Quantity instrument are preferred in later periods](image2)

- Weitzman does not consider **supply-side dynamics** and strategic behavior: Green paradox (Sinn 2008)
The Supply-Side of Global Warming

Cumulative historic carbon consumption (1750-2004), estimated carbon stocks in the ground, and estimated future consumption (2005-2100) for business-as-usual (BAU) and ambitious 400-ppm-CO2-eq. scenario.

Source: Kalkuhl, Edenhofer and Lessmann 2009
Lessons from the “Green Paradox”

- Increasing resource taxes change time path of net resource price
  - time-path of extraction is changed
  - Pigouvian taxes on emissions work similar to resource taxes
**Lessons from the “Green Paradox“**

Conventional Pigouvian tax cannot solve the incentive problem for stock-pollutant \( \Rightarrow \) inefficient

\[\max_{R_t} \int_0^\infty (p_t - g^i(S^i_t) - \tau_t)R_t^i e^{-rt} dt\]

\textbf{i-th resource owner’s problem:}

\textbf{Pigouvian tax:}

\[\tau_t = \tau(S_t) = \frac{f_{\$}}{r}\]

How do resource owners anticipate the change of \( r \)?

Pigouvian tax changes with aggregated, cumulative extraction!

But resource owners do only see a weak (or even no) relation between individual extraction and aggregated extraction.

**Conventional Pigouvian tax**

Dynamic (non-linear)

Pigouvian tax

Decreasing cash flow tax or subsidies on non-extraction

Capital source tax

Emissions trading scheme
Lessons from the “Green Paradox“

Hotelling rule for the $i$-th resource owner with $n$ identical resource owners and conventional Pigouvian tax:

$$
\dot{p} + f_S + \frac{f_{SS} \cdot n - 1}{r} R
\quad r = \frac{R}{p - g(S)}
$$

Suboptimal extraction path (“Green Paradox”)

- Acceleration of extraction due to $f_{SS} < 0$
- Tax is inefficient and ineffective
- Resource sector suffers from internal public good problem with respect to $\tau(S_i)$

$$
\tau(S_i) = \tau(\sum_{i=1}^n S^i) = \frac{f_S \left(\sum_{i=1}^n S^i\right)}{r}, \quad \dot{S}^i = R^i
$$

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<tr>
<th>$n=1$</th>
<th>Correct anticipation of damages</th>
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<td>Tax as feedback instrument</td>
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<td>$r = \frac{\dot{p} + f'_{S}}{p - g}$</td>
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<th>$n=\infty$</th>
<th>Only time-path is anticipated</th>
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<td>Tax as open-loop instrument</td>
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<td>$r = \frac{\dot{p} + f_{S} + \frac{f_{SS}}{r}}{p - g(S)}$</td>
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Conventional Pigouvian tax

Dynamic (non-linear) Pigouvian tax

Decreasing cash flow tax or subsidies on non-extraction

Capital source tax

Emissions trading scheme
Lessons from the “Green Paradox“

Dynamic (non-linear) Pigouvian tax is optimal, but difficult to implement

\[ \tau(S^i_t) = \frac{f_s(nS^i_t)}{r} \]

Pigouvian tax for i-th resource owners
(n identical resource owners)

- Tax changes with individual cumulative extraction
- Resource owners have to anticipate dynamic tax rule

Conventional Pigouvian tax

Dynamic (non-linear) Pigouvian tax

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Capital source tax

Emissions trading scheme

Resource Extraction

Emissions Deposition

Resource owner #1: Big resource stock

Resource owner #2: Small resource stock
Lessons from the “Green Paradox“

Decreasing cash flow tax or subsidies on non-extraction: Commitment and calculation problems

\[
\dot{\theta}_t = -\frac{\phi^*_S}{p^* - g(S^*)} (1 - \theta_t) < 0
\]

Capital source tax: Limited effectiveness and distortions on capital markets.

\[
\nu_t = \frac{f_S}{r(p - g(S))}
\]

Conventional Pigouvian tax
Dynamic (non-linear) Pigouvian tax
Decreasing cash flow tax or subsidies on non-extraction
Capital source tax
Emissions trading scheme
Lessons from the “Green Paradox“

- Carbon price depends on strategic behavior of the fossil resource sector („Green Paradox“)
  - Resource owners anticipate tax path and change their extraction
  - Internalizing of damages is not feasible
  - Increasing taxes could lead to accelerated depletion (as future revenues are cut)

- Government would permanently have to modify the tax to account for economic and strategic uncertainties
  - Daunting informational requirements and reduced planning security for private sector

⇒ Emissions trading scheme – an alternative?
Lessons from the “Green Paradox“

Emissions trading scheme (ETS):

- Determines aggregated extraction path
- But leaves freedom for resource owners:
  - Which resources to extract (coal, oil, gas, conventional/unconventional)?
  - When to extract (if intertemporal flexibility is implemented)?

- How to determine caps?
- How to organize intertemporal permit trade?
- What happens to the resource rents?

... to be explored in the following
Can We Assess the Social Cost of Carbon?

- Monetary valuation of benefits often unfeasible
- High uncertainties which are very difficult to quantify
- Possibility of tipping elements

Cost-benefit-analysis (or „social cost of carbon“) is not well-suited for climate change problem.

Source: Lenton et al., 2008, PNAS 105(6)
Emissions Trading for Optimal Depletion of Carbon Budgets

• National „Carbon bank“:
  – guarantees long-term credibility of the budget
  – provides public information
  – regulates timing of permit use
  – manages climate rent

• Banking and borrowing allows for time-flexibility
  – hedge against uncertainties by establishing futures markets
  – reduce volatility in permit markets
  – capital source taxes flatten the permit price path (Hotelling)
The Carbon Budget Approach

**Global budget:** 850 GtCO$_2$ for the rest of the 21$^{st}$ century (*in order to achieve the 2 °C target*)

- ETS with full coverage guarantees environmental target and cost-efficiency
- Permit prices reflect “depletion” of the budget (Hotelling price)
- Resource rent is transformed into a climate rent
- There is no room left for strategic resource extraction (no „Green Paradox“)

**Global budget** can be divided into **national budgets**
The Carbon Budget Approach

- National budgets: distribute mitigation costs

Source: Flachsland et al. 2009
Allocation rules and regional distribution of mitigation costs

Decomposition of regional mitigation costs:

\[
\Delta C = D + T + \int_{t_0}^{T} \exp(-\rho t)(A(t) - E(t)) p(t) dt
\]

Consumption Losses, 2005-2100

Decomposition effects:
- Domestic Effect
- Energy Trade Effect
- Carbon trade balance

Consumption Losses [%]

Time

2005 2020 2040 2060 2080 2100
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Top-down Emissions Trading: Kyoto Today

Annex-I: economy-wide cap and trade
Non Annex-I: no caps, CDM

Source: Flachsland 2009
Bottom-up: Regional Cap & Trade Systems

Canada ETS
Max 740 Mt CO₂eq
Start: 2010?

US ETS
Max 7.000 Mt CO₂eq
Start: ?

RGGI ETS
170 Mt CO₂
Started: 2009

EU ETS
2.000 Mt CO₂
Started: 2005

Swiss ETS
3 Mt CO₂
Started: 2008

South Korea
Max 590 Mt CO₂eq
Start: 2012?

Australia ETS
Max 560 Mt CO₂eq
Start: 2012?

Mexico ETS
Max 640 Mt CO₂eq
Start: 2012?

NZ ETS
98 Mt CO₂eq
Start: ?

Tokyo ETS
Max 55 Mt CO₂
Start: 2010

WCI ETS
800+ Mt CO₂eq
Start: 2012

Midwestern GHG Accord
? Mt CO₂eq
Start: ?

Japan ETS
Max 1.400 Mt CO₂eq
Start: ?

Source: Flachsland 2009
The Value of Early Action

• In a world serious about achieving 2°C, early action is beneficial to China:
EU ETS 2013 - 2020

**EU-wide cap**
- 21% below 2005 levels by 2020
- Linear reduction of 1.74% annually
- Credible long-term trajectory still lacking

**Auctioning principal allocation method**
- 100% for West-European power sector, increasing shares for industry
- Redistribution of auctioning quotas to poorer member states
- Harmonized rules for benchmarking

**Coverage extended to include**
- Aviation, petrochemicals, ammonia, and aluminum
- 2 additional GHGs
- Around 50% of all EU GHG emissions

**Non-trading sectors**
- Road transport, buildings, agriculture, and waste still excluded from ETS
- Sectors required to reduce emissions by 10% by 2020
EU ETS 2013 - 2020

Total EU-27 greenhouse gas emissions by sector, 2006
(Source: European Environment Agency)

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EU ETS covers 2.02 GtCO2
or ~40% of total

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**Goal: Achieve a given abatement level A**

- If coverage is limited to electricity and manufacturing:
  \[ A = A_E + A_M \] at price \( P \)
- If coverage is extended to include buildings:
  \[ A = A_E^* + A_M^* + A_B \] at lower price \( P^* \)
Lessons from EU ETS

Cap
credible long-term trajectory essential for guiding investor expectation

Coverage
‘broad is beautiful’, including additional sectors (e.g. transportation)
enhances cost-effectiveness

Allocation
auctioning superior, avoids distortions related to free allocation,
generates public revenues (‘double dividend’)

Intertemporal flexibility
banking/borrowing likely to smooth price volatility

Price bounds
use of price cap/floor still debated, hybrid model might have
advantage over pure quantity-based ETS design
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The Role of Backstop Technologies

Carbon budget approach: Increasing carbon price (Hotelling) until backstop technologies become competitive

![Graph showing the learning-by-doing effect on backstop technology becoming competitive over time.]
The Need for Technology Policy

**Invention**
Invent new technology

**Innovation**
Make product competitive

**Diffusion**
Adoption by economy

**Public R&D expenditures**
stimulate inventions in new energy technologies

**Production subsidies**
quickly reap learning effects through capacity expansion (e.g. feed-in-tariffs)

**Information programs**
promote information about mitigation technologies for consumers

*Process of technological change by Schumpeter (1942)*
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Emissions Trading: Major Options for China

Move beyond CDM!

(1) Economy-wide cap in global post-2012 regime (Joint Mitigation Plan)
   → Allocation determines distribution
   → Domestic policies required

(2) Domestic cap-and-trade for suited sectors
   → Ensure robust design

(3) Sectoral or economy-wide baseline-and-credit
   → Define reduction targets, profitable international sales of excess reductions
   → First step to cap-and-trade
Summary

• Credibility of commitment is of utmost importance to provoke long-term investments in low carbon technology

• Permit markets need to be regulated in order to establish stable carbon prices and long-term expectations; technology policy should complement permit markets

• Regulation should raise revenues for the state – this is automatically achieved by taxes; permits need to be auctioned

• No tax (or permit) exemptions for whole industries – this strongly reduces efficiency and raises costs

• Optimal tax is extremely difficult to calculate due to uncertainty about economic parameters and strategic behavior in the resource sector

• Emissions trading under a fixed carbon budget guarantees ecological integrity despite uncertainties in economic parameters and strategic behavior of resource owners
Conclusions

• Early action might be beneficial to China in a world which is serious about achieving ambitious emission reductions.

• Initiate model comparison project to systematically explore welfare impacts of economy-wide cap for China under different allowance allocation regimes

• Consider economy-wide, sectoral cap-and-trade and baseline-and-credit: emission targets and institutions