# Emission Permit Trading with Global Externality Problems

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# Abstract

- A set of heterogeneous countries where firms produce goods from fixed resources and emitting inputs.
- Emissions cause global pollution (e.g. GHGs).
- An international benevolent regulator that determines firm-specific emission permits.
- Welfare decreases, if the firms are allowed to trade in emission permits.
- If the sellers of permits are on the average richer than the buyers, then the regulator grants too much, and if poorer, too little permits from the welfare point of view.

# Motivation

- ***The research question***:

  *Does emission permit trading cause inefficiency, when production causes simultaneous localized and global externality problems (e.g. smog and global warming)?*

- I examine this in a simple framework where a benevolent international regulator determines emission permits.
- In Palokangas (2015), I derive the same results in an extended case where the regulator is self-interested, elected by the countries, and subject to lobbying by the countries (cf. Dixit et al. 1997).

# Literature 1

- Caplan and Silva (2005) examine joint tradable permits when pollutants cause regional and global externalities. They find that joint domestic and commonly international permit markets are Pareto efficient.
- Holtsmark and Sommervoll (2012) consider emission trading when the governments set their national emission targets individually and grant emission permits for the domestic firms. They find that emission permit trading increases emissions and decreases efficiency.
- In contrast to these articles, I assume a benevolent international regulator that issues emission permits.

# Literature 2

- Montgomery (1972), Shiell (2003) and MacKenzie et al. (2008) consider the redistributive effects of the initial allocation of emission permits. I use the representative household framework to ignore all such redistributive effects.
- I ignore the effects of market imperfections (cf. Hintermann 2011 and Meunier 2011), and assume that there is a competitive market for emission permits.

# Production

- A "continuum" of heterogeneous ***countries*** $i \in [0,1]$ that produce the same ***numeraire*** good.
- Because all markets are competitive, it can be assumed that the representative firm in country $i$ (hereafter called ***firm*** $i$) produces the quantity $f_i$ of the good from emissions $m_i$ and fixed local resources (e.g. land and labor):

$$f_i(m_i), \quad f_i' > 0, \quad f_i'' < 0, \quad f_i(0) = 0.$$

- A ***regulator*** grants emission permits $M_i$ for firms $i \in [0,1]$.
- Total emissions $M \doteq \int_0^1 m_k dk$ equal total permits $\int_0^1 M_i di$:

$$\int_0^1 m_k dk = \int_0^1 M_i di \doteq M.$$

# Households

- The representative household (hereafter ***household*** $i$) earns and consumes all income in country $i \in [0, 1]$.
- At each time $t$, it derives utility $u^i$ from consumption $c_i$ and global pollution $n$ according to the strictly concave function

$$u^i(c_i, M), \quad u^i_c \doteq \frac{\partial u^i}{\partial c_i} > 0, \quad u^i_M \doteq \frac{\partial u^i}{\partial M} < 0.$$

# The regulator

- I assume that the regulator is benevolent.
- It maximizes a function of the utilities of countries $i \in [0, 1]$,

$$U \doteq \int_0^1 w_i u^i(c_i, M) di,$$

where $w_i$ is a positive constant that characterizes the size or influence of country $i \in [0, 1]$.

- This ***Paretian social welfare function*** is general enough for the comparison of different policies in the case of heterogeneous countries.

# Setup

- Nontraded emission permits $M_i$ determine emissions $m_i = M_i$ in all countries $i \in [0, 1]$.
- In that case, each country consumes what it produces,

$$c_i = f_i(m_i) \text{ for } i \in [0, 1].$$

- Plugging this into the social welfare function yields

$$U^N \doteq \int_0^1 w_i u^i(f_i(m_i), M) di.$$

- The regulator maximizes this by the emission permits $m_i = M_i, \in [0, 1]\}$, subject to the accumulation of GHGs.
- The maximization yields the ***Pareto optimum conditions***

$$\frac{\partial U^N}{\partial M_i} = \frac{\partial U^N}{\partial m_i} = w_i u_c^i f_i' + \int_0^1 w_k u_M^k dk = 0. \quad i \in [0, 1].$$

# Extensive game

With traded permits, there is an extensive form game with the following stages:

(i) The regulator sets the emission permits $\{M_i\} \doteq \{M_i | \, i \in [0,1]\}$.

(ii) The international market for emission permits clears.

(iii) The local firms produce from emissions and fixed local resources.

This game is solved in reverse order.

# Firms

- With emission permit trading, the representative firm in country $i \in [0,1]$ purchases emission permits $m_i$ at the price $p$ in the competitive market to produce $f_i(m_i)$.
- The profit of that firm is

$$\Pi_i \doteq f_i(m_i) - pm_i.$$

- The firm maximizes this profit by emissions $m_i$, given the price $p$ for emissions permits. This leads to the equilibrium profit and the profit-maximization condition for the firm:

$$\Pi_i = \max_{m_i}[f_i(m_i) - pm_i] \text{ and } p = f_i'(m_i) \text{ with } \frac{dp}{dm_i} \doteq f_i'' < 0.$$

# The market for emission permits 1

- Inverting the profit-maximization condition, I obtain country $i$'s emissions as a function of the emission permit price $p$:

$$m_i = N_i(p) \quad \text{with} \quad N_i' \doteq 1/f_i'' < 0.$$

- Inserting the demand functions into the equilibrium condition yields $\int_0^1 M_i di = \int_0^1 m_k dk = \int_0^1 N_k(p) dk$.
- Differentiating this equation totally, one obtains the price for emission permits as a function of total emissions $M$:

$$p(M) \quad \text{with} \;\; M \doteq \int_0^1 M_i di \;\; \text{and} \;\; p' = \left( \int_0^1 N_k' dk \right)^{-1} < 0.$$

# The market for emission permits 2

- Plugging this into the first equation yields emissions $m_i$ of country $i \in [0, 1]$ as a function of total emission permits $M$:

$$m_i(M) \doteq N_i(p(M)) \text{ with } m_i' \doteq N_i' p' = \frac{N_i'}{\int_0^1 N_k' dk} \in [0, 1].$$

- Household $i \in [0, 1]$ consumes the income of country $i$: profits $\Pi_i$ and the revenue for emission permits, $pM_i$.
- Consumption in country $i$ becomes a function of $M$ and $M_i$:

$$c_i = \Pi_i + pM_i = \max_{m_i}[f_i(m_i) - pm_i] + pM_i$$
$$= \max_{m_i}\big[f_i(m_i) - p(M)m_i\big] + p(M)M_i \doteq C_i(M_i, M)$$
$$\text{with } \frac{\partial C_i}{\partial M_i} = p = f_i' \text{ and } \frac{\partial C_i}{\partial M} = (M_i - m_i)p'.$$

# The regulator 1

- The regulator maximizes social welfare

$$U^T = \int_0^1 w_i u^i \big( C_i(M_i, M), M \big) di.$$

- This yields the first-order conditions

$$\frac{\partial U^T}{\partial M_i} = w_i u_c^i \underbrace{\frac{\partial C_i}{\partial M_i}}_{=f_i'} + \left( \int_0^1 w_k u_c^k \underbrace{\frac{\partial C_k}{\partial M}}_{=(M_k - m_k)p'} dk + \int_0^1 w_k u_M^k dk \right) \underbrace{\frac{\partial M}{\partial M_i}}_{=1}$$

$$= w_i u_c^i f_i' + \int_0^1 w_k u_M^k dk + p' \int_0^1 (M_k - m_k) w_k u_c^k dk = 0, \quad i \in [0, 1]$$

# The regulator 2

- If the countries $i \in [0, 1]$ are heterogeneous, then this violates the Pareto optimality conditions by the last term.

**Proposition**

*If the countries are heterogeneous, then emission permit trading decreases welfare.*

# The role of asymmetry 1

- In order to consider the effect of emission permit trading on total emissions, I introduce a parameter $\beta$ so that
  - $\beta = 0$ holds true without trading (i.e. with $m_i = M_i$)
  - $\beta = 1$ with trading $m_i \neq M_i$.
- This combines the FOCs without and with trading as

$$\frac{\partial H}{\partial M_i} = (1-\beta)\frac{\partial U^N}{\partial M_i}\bigg|_{m_i = M_i} + \beta\frac{\partial U^T}{\partial M_i}\bigg|_{m_i \neq M_i} = 0 \text{ for } i \in [0,1].$$

- The effect of $\beta$ on emission permits $M_i$ is first derived for continuous $\beta \in [0,1]$, and the result is then extended for the discrete choice $\beta \in \{0,1\}$ by the mean value theorem.

# The role of asymmetry 2

With continuous $\beta \in [0, 1]$, I obtain

$$\frac{dM_i}{d\beta} = -\frac{\partial^2 H}{\partial M_i \partial \beta} \Big/ \frac{\partial^2 H}{\partial M_i^2} > 0 \quad \Leftrightarrow$$

$$\int_{M_k > m_k} (M_k - m_k) w_k u_c^k dk < \int_{m_k > M_k} (m_k - M_k) w_k u_c^k dk$$

for $i \in [0, 1]$, where $w_k u_c^k$ is the marginal utility of income $u_c^k$ in country $k$, weighed by the size $w_k$ of that country,

$\int_{M_k > m_k} (M_k - m_k) w_k u_c^k dk$ the value of the net supplies $M_k - m_k$ of emission permits throughout the countries $k$ with $M_k > m_k$, and

$\int_{m_k > M_k} (m_k - M_k) w_k u_c^k dk$ the value of the net demands $m_k - M_k$ for permits throughout $k$ with $m_k > M_k$.

# The role of asymmetry 3

- Then, by the mean value theorem, there is $\xi \in (0,1)$ s.t.

$$M_i\Big|_{\beta=1} - M_i\Big|_{\beta=0} = \frac{dM_i}{d\beta}\Bigg|_{\beta=\xi}\beta > 0 \quad \Leftrightarrow$$

$$\int_{M_k > m_k} (M_k - m_k) w_k u_c^k dk$$

$$< \int_{m_k > M_k} (m_k - M_k) w_k u_c^k dk \;\text{ for } i \in [0,1].$$

- This result can be rephrased as follows:

# The role of asymmetry 3

## Proposition

(a) *If the suppliers of emission permits (i.e. countries $k$ with $M_k > m_k$) are on the average "richer" (i.e. with a lower marginal utility of income $w_k u_c^k$) than the demanders of emission permits (i.e. countries $k$ with $m_k > M_k$), then the regulator provides more emission permits $M_i$ to all countries $i \in [0,1]$, $M_i\big|_{\beta=1} > M_i\big|_{\beta=0}$, aggravating global pollution $n$.*

(b) *If the suppliers of emission permits are on the average "poorer" than the demanders of those , then the regulator provides less emission permits $M_i$ to all countries $i \in [0,1]$, $M_i\big|_{\beta=1} < M_i\big|_{\beta=0}$, alleviating global pollution $n$.*

# Conclusions 1

- Environmental policy is at the international level (e.g. in the EU) commonly restricted to command-and-control rather than incentive-based instruments.
- Therefore, I consider the design of international emission policy without fiscal instruments when the use of an emitting input causes global externality problems.
- The use of non-traded emission permits leads to Pareto optimum: the marginal product of emissions is equal to the disutility of global warming in terms of consumption.

# Conclusions 2

- Emission permit trading restricts the regulator's policy set by equalizing the marginal product of emissions for all countries. Then,
  - too much emission permits are granted to all countries, aggravating global pollution, if the suppliers of emission permits are on the average richer, having a lower marginal utility of income, than the demanders of those, and
  - too little emission permits are granted, alleviating global pollution, if the demanders of emission permits are on the average richer than the suppliers of those.
- If it is impossible to use incentive-based instruments, then attempts to improve the working of emission caps by emission permit trade may be counterproductive.