Emission Permit Trading with Global Externality Problems

Tapio Palokangas

HECER, P.O. Box 17 (Arkadiankatu 7), FIN-00014 University of Helsinki, Finland.

Tel: +358 50 3182263 Fax: +358 9 191 28736

Abstract

I examine a set of heterogeneous countries where firms produce goods from emitting inputs and fixed resources. Emissions cause global pollution that harms everyone's welfare. There is a benevolent international regulator that grants country-specific emission permits. It is shown that welfare decreases, if the countries 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.

Journal of Economic Literature: H23, F15, Q53

Keywords: GHG emissions; emission caps; emission permit trading

Acknowledgements: The author thanks IIASA (Laxenburg, Austria) for hospitality in July 2017 when this paper was revised and presented in the "IIASA 2017 Workshow on Green Growth Modeling".

Email address: tapio.palokangas@helsinki.fi (Tapio Palokangas)
URL: http://blogs.helsinki.fi/palokang/ (Tapio Palokangas)

1. Introduction

Can emission permit trading cause inefficiency? I examine this problem by a simple model with a set of countries and an international regulator.

Environmental policy in the EU has been dominated by command-and-control rather than incentive-based instruments for the following reasons (Wråke et al. 2012). Because the cap-and-trade system involved no fiscal policy, it was was accepted as a basis for environmental policy. Its essential elements are the following (Goulder 2013). First, the regulator specifies the cap, i.e. the total pollution allowed by all of the facilities covered by the regulatory program. Second, the regulator distributes the allowances, either by auction or through free provision. Third, the system provides for trading of allowances. The problem is then whether the third element is useful at all.

Caplan and Silva (2005) examine emission permit trading in a federation of regions, showing that Pareto efficiency can be established with the help of internationally redistributive transfers. Holtsmark and Sommervoll (2012) consider emission trading when the governments grant emission permits for the domestic firms. They show that the anticipation of emission permit trading changes the governments' behavior so that emissions actually increase, decreasing efficiency. I assume, on the contrary, that there are no redistributive transfers and that emission permits are granted by an international regulator. Furthermore, I ignore market imperfections (cf. Hintermann 2011 and Meunier 2011) and assume competitive emission permit markets.

I examine emission policy on the assumption that the international regulator is benevolent, having the Paretian social welfare function. This mimics well relevant choices of environmental policy. The remainder of this paper is organized as follows. Section 2 presents the structure of the economy. Sections 3 and 4 examine the cases of nontraded and traded emission permits, respectively. Section 5 considers the role of the asymmetry of the countries and section 6 summarizes the results.

2. The economy

I assume that there is 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) as follows:

$$f_i(m_i), \quad f_i' > 0, \quad f_i'' < 0. \tag{1}$$

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

$$u^i(c_i, M), \quad u^i_c \doteq \frac{\partial u^i}{\partial c_i} > 0, \quad u^i_M \doteq \frac{\partial u^i}{\partial M} < 0. \tag{2}$$

A benevolent international *regulator* grants emission permits M_i for the firms $i \in [0,1]$, so that total emissions $\int_0^1 m_k dk$ equal total permits $\int_0^1 M_i di$:

$$\int_0^1 m_k dk = \int_0^1 M_i di \doteq M. \tag{3}$$

It maximizes a function of the utilities (2) of the countries $i \in [0,1]$,

$$U \doteq \int_0^1 w_i u^i(c_i, M) di, \tag{4}$$

where w_i is a positive constant that characterizes the relative size or influence of country $i \in [0,1]$. The Paretian social welfare function (4) is general enough for the comparison of different policies among the countries.

3. Nontraded permits

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,

$c_i = f_i(m_i)$ for $i \in [0,1]$. Plugging this into (4) yields

$$U^N \doteq \int_0^1 w_i u^i(f_i(m_i), M)di. \tag{5}$$

The regulator maximizes utilitarian social welfare (5) by the emission permits $\{m_i\} \doteq \{m_i | \, i \in [0,1]\} = \{M_i\} \doteq \{M_i | \, i \in [0,1]\}$ subject to global pollution (3), having the full control of the allocation of resources, its optimal behavior leads to the *Pareto optimum*. This maximization yields

$$\frac{\partial U^N}{\partial M_i} = \frac{\partial U^N}{\partial m_i} = w_i u_c^i f_i' + \int_0^1 w_k u_n^k dk = 0, \quad i \in [0,1]. \tag{6}$$

4. 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 market for traded emission permits clears.
(iii) The local firms produce from emissions and fixed local resources.

This game is solved in reverse order.

4.1. 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

$$\Pi_i \doteq f_i(m_i) - pm_i. \tag{7}$$

The firm maximizes its profit (7) 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 as follows:

$$\Pi_i = \max_{m_i}[f_i(m_i) - pm_i] \text{ and } p = f_i'(m_i) \text{ with } \frac{dp}{dm_i} \doteq f_i'' < 0. \tag{8}$$

4.2. The market for emission permits

Inverting the profit-maximization condition in (8), one obtains emissions in country i as a function of the price p for emission permits:

$$m_i = N_i(p) \quad \text{with} \quad N_i' \doteq 1/f_i'' < 0. \tag{9}$$

Inserting the demand functions (9) into the equilibrium condition (3) 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:

$$p(M) \quad \text{with } M \doteq \int_0^1 M_i di \text{ and } p' = \left(\int_0^1 N_k' dk \right)^{-1} < 0. \tag{10}$$

Plugging (10) into (9) yields emissions m_i of country $i \in [0,1]$ as a function of total emission permits M:

$$m_i(M) \doteq N_i(p(M)) \text{ with } m_i' \doteq N_i' p' = \frac{N_i'}{\int_0^1 N_k' dk} \in [0,1]. \tag{11}$$

Household $i \in [0,1]$ consumes the income of country i that contains profits Π_i and the revenue for emission permits, pM_i. Given this, (8), (10) and (11), consumption in that country becomes a function of M and M_i:

$$\begin{aligned} c_i &= \Pi_i + pM_i = \max_{m_i} [f_i(m_i) - pm_i] + pM_i \\ &= \max_{m_i} \big[f_i(m_i) - p(M) m_i \big] + p(M) M_i \doteq C_i(M_i, M) \\ &\text{with } \frac{\partial C_i}{\partial M_i} = p = f_i' \text{ and } \frac{\partial C_i}{\partial M} = (M_i - m_i) p'. \end{aligned} \tag{12}$$

4.3. The regulator

The regulator maximizes social welfare (4) by the emission permits $\{M_i\}$ subject to consumption (12) and global pollution (3). It is equivalent to

maximize

$$U^T = \int_0^1 w_i u^i\big(C_i(M_i, M), M\big)di. \tag{13}$$

This yields the first-order conditions [cf. (3), (10) and (12)]

$$\begin{aligned}\frac{\partial U^T}{\partial M_i} &= w_i u_c^i \underbrace{\frac{\partial C_i}{\partial M_i}}_{=f_i'} + \Bigg(\int_0^1 w_k u_c^k \underbrace{\frac{\partial C_k}{\partial M}}_{=(M_k - m_k)p'} dk + \int_0^1 w_k u_M^k dk\Bigg) \underbrace{\frac{\partial M}{\partial M_i}}_{=1} \\ &= w_i u_c^i f_i' + \int_0^1 w_k u_M^k dk + p' \int_0^1 (M_k - m_k) w_k u_c^k dk = 0, \quad i \in [0,1]. \end{aligned} \tag{14}$$

If the countries $i \in [0,1]$ are heterogeneous, then (14) violates the Pareto optimality conditions (6) by the term $p' \int_0^1 (M_k - m_k) w_k u_c^k dk$. Only if the countries $i \in [0,1]$ are identical, i.e. $m_k = M_k = M$ for $k \in [0,1]$, the conditions (14) changes into (6). This result can be summarized as follows:

Proposition 1. *If the countries are heterogeneous, then emission permit trading decreases welfare.*

5. The role of asymmetry

In order to consider the effect of emission permit trading on total emissions, I introduce a parameter β so that $\beta = 0$ holds true without trading (i.e. with $m_i = M_i$), and $\beta = 1$ with trading $m_i \neq M_i$. This combines the equilibrium conditions without and with trading, (6) and (14), as follows:

$$\begin{aligned}\frac{\partial U}{\partial M_i} &= (1-\beta)\frac{\partial U^N}{\partial M_i}\bigg|_{m_i = M_i} + \beta \frac{\partial U^T}{\partial M_i}\bigg|_{m_i \neq M_i} \\ &= (1-\beta)[w_i u_c^i f_i' + \int_0^1 w_k u_M^k dk] \\ &\quad + \beta\Bigg[w_i u_c^i f_i' + p' \int_0^1 (M_k - m_k) w_k u_c^k dk + \int_0^1 w_k u_M^k dk\Bigg]\end{aligned}$$

$$= w_i u_c^i f_i'(m_i) + \int_0^1 w_k u_M^k dk + \beta p' \int_0^1 (M_k - m_k) w_k u_c^k dk = 0$$

$$\text{for } i \in [0,1]. \tag{15}$$

The effect of β on emission permits M_i is first derived on the assumption that β is continuous in the limit $[0,1]$, and the result is then extended for the discrete choice $\beta \in \{0,1\}$ by the mean value theorem. Given (11) and (15), I obtain

$$\frac{\partial^2 H}{\partial M_i \partial \beta} = \underbrace{p'}_{-} \int_0^1 (M_k - m_k) w_k u_c^k dk > 0 \;\Leftrightarrow\; \int_0^1 (M_k - m_k) w_k u_c^k dk < 0$$

$$\Leftrightarrow \int_{M_k > m_k} (M_k - m_k) w_k u_c^k dk < \int_{m_k > M_k} (m_k - M_k) w_k u_c^k dk \;\text{ for } i \in [0,1], \tag{16}$$

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 emission permits throughout the countries k with $m_k > M_k$.

Differentiating (15) totally, and noting (16) and the second-order condition $\frac{\partial^2 H}{\partial M_i^2} < 0$, one obtains

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

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

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

$$M_i\big|_{\beta=1} - M_i\big|_{\beta=0} = \left.\frac{dM_i}{d\beta}\right|_{\beta=\xi} \beta > 0 \;\Leftrightarrow$$
$$\int_{M_k > m_k} (M_k - m_k) w_k u_c^k dk < \int_{m_k > M_k} (m_k - M_k) w_k u_c^k dk \text{ for } i \in [0,1].$$

This result can be rephrased as follows:

Proposition 2. *With the introduction of emission permit trading (i.e. an increase of β from 0 to 1), the following happens:*

(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 (i.e. countries k with $M_k > m_k$) are on the average "poorer" (i.e. with a higher 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 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.*

6. Conclusions

Environmental policy is at the international level (e.g. in the European Union) commonly restricted to command-and-control rather than incentive-based instruments. Therefore, it is instructive to consider the design of international emission policy without fiscal instruments when local emissions cause global externality problems. Assuming that the international regulator with the Paretian welfare function grants emission permits, I ask whether emission permit trade is welfare enhancing. The results are the following.

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. Emission permit trading restricts the regulator's feasibility set by equalizing the marginal product of emissions for all countries.

With the introduction of emission permit trading, the regulator provides totally too much emission permits from the welfare point of view, 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, if the demanders of emission permits are on the average richer.

While a great deal of caution should be exercised when a highly stylized game-theoretic model is used to explain international environmental policy, the following judgement nevertheless seems to be justified. 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.

References

Atkinson, A.B., and Stiglitz, J.E. (1980) *Lectures on Public Economics.* MacGraw-Hill: London.

Caplan, A.J., and Silva, E.C.D. (2005) "An efficient mechanism to control correlated externalities: redistributive transfers and the coexistence of regional and global pollution permit markets." *Journal of Environmental Economics and Management*, 49: 68–82.

Goulder, L.H. (2013) "Markets for pollution allowances: what are the lessons?" *Journal of Economic Perspectives*, 27: 87–102.

Hintermann, B. (2011) "Market power, permit allocation and efficiency in emission permit markets." *Environmental and Resource Economics*, 49: 327–349.

Holtsmark, B., and Sommervoll, D.E. (2012) "International emissions trading: good or bad?" *Economics Letters*, 117: 362–364.

Meunier, G. (2011) "Emission permit trading between imperfectly competitive product markets." *Environmental and Resource Economics*, 50: 347–364.

Wråke, M., Burtraw, D., Löfgren, Å., and and Zetterberg, L. (2012) "What have we learnt from the European Union's emissions trading system?" *Ambio*, 41: 12–22.