Working Paper 7/2013

Incentives for Strategic Behavior in the Permit Market

Cathrine Hagem

The CREE Centre acknowledges financial support from The Research Council of Norway, University of Oslo and user partners.
ISBN: 978-82-7988-142-1
ISSN: 1892-9680
http://cree.uio.no

Strategic Behavior and the Environment, 2013, 3: 149–167

Incentives for Strategic Behavior in the Permit Market*

Cathrine Hagem

Research Department, Statistics Norway, P.O. Box 8131, Dep, N-0033 Oslo, Norway; cah@ssb.no

ABSTRACT

In an international permit trading regime, the initial allocation of permits across countries determines the participating countries' trading position. Large permit trading countries on both sides of the market can exploit their market power in the permit market. We analyze how the competitive environment on the permit market affects countries' gain from strategic manipulation of the permit price. We conclude that gains from strategic behavior depend on whether there are other strategic players on the same or opposite side of the market.

Keywords: Emissions permits; strategic permit trading; climate agreements; market power.
JEL Codes: D43; L13; Q54

* The author would like to thank Mads Greaker, Matti Liski, Knut Einar Rosendahl and two anonymous referees for their helpful comments and valuable suggestions. While carrying out this research, the authors have been associated with the Oslo Centre for Research on Environmentally friendly Energy (CREE). CREE is supported by the Research Council of Norway

.ISSN 1944-012X; DOI 10.1561/102.00000027

Introduction

Trade in emissions permits is an important feature of the current international agreement to limit emissions of greenhouse gases (the Kyoto Protocol), and is likely to be an important element also of future environmental agreements. Permit trading is also a central pillar of the EU's policy to meet its emissions reduction target and of the US sulfur program. The starting point of our analysis is an international climate agreement à la the Kyoto Protocol where the participating countries have binding emissions commitment and are allowed to trade permits.

The international permit market has some special features compared to other commodity markets. First, total supply of permits is fixed, corresponding to the total target for emissions. Second, there is no third-party demand. Trading is only among the participants of the agreement. Whether a country becomes a net buyer or seller of permits, and whether its net trade is small or large, is *inter alia* dependent on its initial allocation of permits. Third, strategic manipulation of the permit market can occur even if all of the actual traders on the permit market are relatively small firms with a competitive market behavior.

The purpose of this paper is to analyze how the competitive environment of the international permit market affects countries' incentives for strategic manipulation of the permit price. If a government takes into account the impact on the international permit price when designing its climate policy, we coin the country a strategic agent (or country/trader) in the permit market.

In an international climate agreement, the governments are typically the recipients of the initial endowment of permits. If the government is the sole trader of permits, strategic manipulation of the permit market can occur directly through the government's international permit trade. However, the government may have chosen to allocate the permits to domestic firms and let them trade on the international market. In that case, if the government seeks to manipulate the international permit price, it can introduce a domestic tax/subsidy on emissions (in addition to the permit obligations) in order to manipulate the domestic firms' permit demand, and thereby the permit price (see, e.g., Montero, 2009). Other options that influence the firms' demand for permits are domestic subsidies on renewable energy, which are close substitutes to fossil fuels, and tariffs on permit import or export.

In this paper, we do not evaluate different domestic policy options for strategic manipulation of the permit market, but take as our starting point that strategic behavior is a decision made by the governments. To evaluate a country's incentives for strategic behavior, we analyze its improvement in own welfare by shifting from competitive market behavior to strategic market behavior.

It is a well-known result that given fully competitive markets, trade in emissions permits ensures a cost effective distribution of emissions reductions. However, if a large permit trader exploits its market power in the permit market, cost effectiveness is no longer achieved; see Hahn (1984). Following Hahn (1984), there is a large literature discussing the implications of market power in the permit market. The literature covers analyses of strategic behavior on one side of the market (Ellerman and Wing, 2000; Böhringer, 2002; Böhringer and Löschel, 2003; Hagem *et al.*, 2005; Liski and Montero, 2006; Hagem and Westskog, 2008; Hagem and Westskog, 2009), and strategic manipulation of the permit price on both sides of the market (Westskog, 1996; Liski and Montero, 2011; Malueg and Yates, 2009; Wirl, 2009). Furthermore, a branch of the literature considers incentives for coordination (merger) among large traders, see, e.g., Godal and Meland (2010) and Eyckmans and Hagem (2011).

In all of the above, the strategic players are exogenous. In contrast, we explore a situation where countries, through their domestic climate policies, choose between competitive and non-competitive behavior on the permit market.

Strategic behavior is not restricted to large permit trading countries as several small countries may cooperate in order to manipulate the permit price in their joint favor. Obvious partner candidates in the permit market are the European Union (EU) countries. These countries presently cooperate on a common climate policy, in addition to their commitments under the Kyoto Protocol, and have an internal emissions trading scheme (the EU ETS). For instance, by determining the degree the emissions target will be met by domestic measures relative to permit purchases (the supplementary principle), the EU acts as a strategic buyer in the international permit market even though each individual country behaves as a price taker in the permit market (see Ellerman and Wing, 2000).[1]

[1] According to the Kyoto Protocol, industrialized countries with quantified emissions targets are allowed to meet part of their reduction commitment through investment in emissions-reducing

A country's strategic permit market behavior can be seen as a coordination of all of its domestic firms' permit trade in order to manipulate the permit price in their joint favor. Hence, strategic permit market behavior can be interpreted as a merger among competitive emitters that maximizes their joint welfare.

The profitability of mergers has been widely analyzed in the literature, both theoretically, see, e.g., Salant *et al.* (1983), Perry and Porter (1985), Fauli-Oller (1997), and Huck and Konrad (2004), and empirically, see, among others, Ravenscraft and Scherer (1989). We know from Salant *et al.* (1983) that cooperation (mergers) among strategic sellers may reduce the joint welfare of the merging agents. The reason is that a merger implies a contraction in output among the merging agents, and this is met by the increased output of the outsiders, which harms the merging agents. Godal and Meland (2010) analyze mergers of Cournot players in a setting where there are strategic players on both side of a permit market. They show that the response from the outsiders makes a cartel of Cournot players less profitable, regardless of which side of the market the outsiders belong.

Both Salant *et al.* (1983) and Godal and Meland (2010) only examine cartels between agents that would be strategic if acting alone. Perry and Porter (1985) consider strategic behavior among previously competitive agents. However, they only consider strategic behavior on one side of the market. Our contribution to the literature is that we show how the gain from strategic behavior depends not only on the number of other strategic agents, but also on which side of the market the other strategic agents belong. Our main finding is that profitable strategic behavior in a setting where the other strategic agents are on the same side of the market *can* become unprofitable in a setting where the other strategic agents are on the opposite side of the market. This is especially relevant for the permit market, where market power typically can occur on both sides of the market.

When it comes to the modeling of strategic behavior on both sides of the permit market, one approach in the literature is to utilize the dominant agents-competitive fringe model: some strategic countries engage in Cournot behavior, whereas other permit trading countries are price-

projects in developing countries (the Clean Development Mechanism, CDM), or in other industrialized countries (Joint Implementation, JI). However, the EU Commission did not accept national allocation plans for the EU ETS for 2008–2012, if there were no restrictions on the amount of emissions credits they could buy from non-EU countries, through either the CDM or the JI. See Neuhoff *et al.* (2006).

takers and clear the market, see Westskog (1996) and Godal and Meland (2010). Another approach is to utilize bilateral oligopoly models with supply-function equilibria, introduced by Klemperer and Meyer (1989) and extended by Hendricks and McAfee (2010), see Malueg and Yates (2009), Wirl (2009), and Godal and Meland (2010). We use the first approach in this paper. Thus, we implicitly assume that the competitive fringe is sufficiently large to clear the market.

In the next section, we present the setup for the climate agreement model. In section ''Results from the Literature,'' we replicate the relevant main results from the literature. Thereafter, in section ''Incentives for Strategic Behavior,'' we derive the incentives for strategic behavior. In section ''Numerical Example,'' we provide a numerical example where we discuss the equilibrium outcomes for strategic behavior. Concluding remarks are given in the last section.

The Model

Let $N = \{1, 2, \ldots, n\}$ denote the number of countries participating in the climate agreement.[2] In the following, we use ''country,'' ''trader,'' and ''agent'' interchangeably. The constraint on total emissions is denoted $\bar{\varepsilon}$. A system of tradable emissions permits is implemented among the participating countries, and permits are grandfathered, i.e., given free to the participants. Let e_i denote emissions from an individual participating country i, and let ε_i denote its initial endowment of permits. The total emissions constraint for the agreement members is then

$$\sum_i e_i \leq \bar{\varepsilon} = \sum_i \varepsilon_i. \tag{1}$$

We assume throughout the analysis that (1) is satisfied with equality.

We assume that all members of the agreement choose their emissions level in order to maximize their welfare (W):

$$W_i = \omega_i(e_i) + p \cdot [\varepsilon_i - e_i], \tag{2}$$

[2] We model the permit market with countries as the trading agents, although all conclusions of the paper are unaffected by whether governments or competitive firms are the actual permit traders as long governments can exploit their potential market power through their domestic climate policy, as discussed in the previous section. Also, "a country" in our model can be interpreted as a coordinated group of countries, with a common climate policy, for instance the EU.

where p is the price of permits and $\omega_i(e_i)$ denotes the benefits (income) of country i being able to emit. We consider distributions of emissions for which incomes are strictly increasing and concave in emissions, such that $\omega_i' > 0$, $\omega_i'' < 0$. This signifies that incomes fall with emissions reductions, and that the larger the reduction in emissions, the higher the loss in income of additional emissions reductions.

We distinguish between small and large traders in the permit market. The large traders are sufficiently large to influence the market price. These agents may or may not act strategically in the permit market. As discussed in the introduction, the government decides whether a country behaves strategically, through its domestic climate policies. All of the small traders are too small to influence the price function to any important degree and thus are assumed to behave competitively. In total, there are six types of traders: small buyers and small sellers, large nonstrategic buyers and large nonstrategic sellers, and large strategic sellers and large strategic buyers.

Let subscript f denote competitive agents and subscript k denote strategic agents, which are assumed to act as Cournot players.

The subset of countries acting competitively will be called the *fringe* and is denoted by $F \subseteq N$. The subset of countries acting strategically is denoted by $K \subseteq N$. These two subsets form a partition of the set of post–Kyoto climate agreement members: $F \cup K = N$ and $F \cap K = \varnothing$. Hence, the total emission constraint (1), can now be rewritten as:

$$\sum_{f \in F} e_f + \sum_{k \in K} e_k \equiv e_F + e_K = \bar{\varepsilon} \tag{3}$$

Results From the Literature

From the literature (e.g., Hahn, 1984) we know that a cost-effective distribution of emissions across countries is achieved when marginal benefits of emissions (or marginal abatement costs) are equalized across countries. Furthermore, with a competitive permit market, $K = \varnothing$, cost effectiveness will be achieved, regardless of the initial distribution of permits, as every fringe member takes the price of permits as given and chooses its emissions level to maximize individual welfare given by (2). The solution of this maximization exercise gives rise to the standard first-order conditions:

$$\omega_f'(e_f) = p \tag{4}$$

For every member of the fringe, the first-order condition (4) defines each country's optimal emissions as a function of the price of emissions:

$$e_f = \omega_f'^{-1}(p), \quad \frac{de_f}{dp} = \frac{1}{\omega_f''} < 0, \tag{5}$$

where $\frac{de_f}{dp}$ is found from totally differentiating the first-order condition (4). Aggregating these implicit emissions functions over all fringe members and inverting, yields a downward sloping, inverse aggregate emissions permit demand function for the group of fringe countries:

$$p = p(e_F), \quad p' = \frac{1}{\sum_f \frac{1}{\omega_f''}} < 0. \tag{6}$$

If one trader has market power in the permit market, cost effectiveness is no longer achieved (Hahn, 1984). Westskog (1996) extends Hahn's research by considering several countries with market power on both sides of market. Following her setup, the optimizing problem of Cournot player j is to maximize (2) subject to

$$p = p\left(\bar{\varepsilon} - \sum_{k \neq j} e_k - e_j\right), \tag{7}$$

We find that the first-order condition for the each of the strategic agents' optimization problem is:

$$-\frac{\partial p}{\partial e_j}(\varepsilon_j - e_j) + p = \omega_j'(e_j). \tag{8}$$

We assume that the second-order conditions are satisfied $\left(\frac{\partial^2 W_j}{\partial e_j \partial e_j} < 0\right)$. Equation (8) defines agent j's reaction function, $e_j = e_j(\sum_{k \neq j} e_k)$, which expresses the strategic agent j's optimal emissions decision (best response) as a function of the emissions from the other strategic agents. To ensure the existence of a unique stable equilibrium (for a given set of nonstrategic agents), we assume that the aggregate reaction function is downward sloping with an absolute value less than unity.[3]

The first-order condition in (8) shows the standard result whereby strategic sellers ($(\varepsilon_j - e_j) > 0$) supply too few permits (hence emit too much) in

[3] That is, $-1 < \frac{\partial \sum_{k \neq j} e_k}{\partial e_j} < 0 \; \forall j \in K$.

order to drive up the market price compared with the competitive market outcome. The strategic sellers' marginal benefits from emissions are therefore lower than the marginal benefits of emissions for the fringe, and emissions are not cost-effectively distributed across countries. A similar, but reverse argument applies to strategic buyers ($(\varepsilon_j - e_j) < 0$) who have an interest in limiting their demand for permits to drive down the market price.

Incentives for Strategic Behavior

To evaluate a country's incentives for strategic behavior, we analyze its improvement in welfare by shifting from competitive market behavior to strategic market behavior.

If a previously competitive large trader decides to behave strategically in the permit market, the group of strategic agents increases by one, whereas the group of competitive agents decreases by one. Let $F = \bar{F}$ denote the initial subset of fringe countries and let $F = \bar{F} - 1$ denote the subset with one less country in the fringe, as one (more) of the large traders decides to behave strategically in the permit market. Consider a large country, with an initial endowment of permits given by ε^L. Let e_k^* and e_f^* denote the equilibrium outcome of its emissions given strategic (Equation (8)) and nonstrategic (Equation (4)) behavior, respectively.

A shift from nonstrategic to strategic behavior in the permit market is welfare improving for the country i if:

$$\begin{aligned} W_i(\bar{F}-1) &= \omega_i(e_k^*) + p(\bar{F}-1)\cdot(\varepsilon^L - e_k^*) > W_i(\bar{F}) \\ &= \omega_i(e_f^*) + p(\bar{F})\cdot(\varepsilon^L - e_f^*). \end{aligned} \tag{9}$$

A country's decision regarding its competitive behavior in the permit market can be seen as the first stage of a two-stage game, where the country in the first stage can correctly anticipate the equilibrium outcomes of the permit market in the second stage. Hence, a welfare maximizing agent will not behave strategically if (9) is not satisfied.

To manipulate the permit price, the strategic agent chooses an emission level which deviates from the competitive level. Whether a decision to become a strategic agent is profitable, depends on whether the subsequent impact on the equilibrium price in stage two is sufficient to offset the net loss of the lower sales (purchase) of permits. The impact on the equilibrium price is not only dependent on the agents' own trade in permits, but also on the magnitude of other strategic agents and their responses to the entrance of a new strategic agents. We assume that each large country considers the competitive environment (the other strategic agent) as given. Thus, we do not consider any coordination of strategic behavior among the large countries.

Responses from Other Strategic Agents

The shift from being a competitive agent to becoming a strategic agent has two effects on the other strategic agents' emissions decisions. One effect occurs because the new strategic agent chooses another emissions level than it would as a price-taker. A new strategic seller increases emissions (reduces permit sale) relative to its competitive emissions level. The benefit of this action in terms of higher permit price is partly offset by the decrease in the emissions from all of the other strategic agents, as their reaction functions are downward sloping in emissions from other strategic agents. Correspondingly, a new strategic buyer is harmed by the other strategic agents' increased emissions as a response to its reduction in emissions, relative to its competitive outcome. These mechanisms are the same as occur when incumbent strategic agents alter their trading position, *inter alia* due to a merger, and are described in Salant *et al.* (1983) for strategic sellers only, and in Godal and Meland (2010) for strategic agents on both sides of the market.

The other effect occurs because an increase in the number of strategic agents makes the price more responsive to changes in the emissions from the strategic agents.

From (8), we see that the strategic agents' optimal emissions depend on the price response to increased emissions ($\frac{\partial p}{\partial e_F}$). Furthermore, from (6), we see that the impact on the price derivative is given by

$$\frac{\partial p(\overline{F}-1)}{\partial e_F} - \frac{\partial p(\overline{F})}{\partial e_F} = \frac{1}{\sum_{f \in \overline{F}-1} \frac{1}{\omega_f''}} - \frac{1}{\sum_{f \in \overline{F}} \frac{1}{\omega_f''}}. \tag{10}$$

Consider now a situation where one agent shifts from being a competitive agent to becoming a Cournot player. For illustrative purposes, assume that the new strategic agent keeps the competitive emissions level, which implies that emissions from each of the remaining fringe countries are kept at the same level. Hence, as we see from (10), the isolated effect of an increase in the number of strategic agents (decrease in fringe countries) makes the price function more responsive to changes in emissions from the strategic agents.

We see from the first-order conditions, (8), that a more responsive price function (for a given p) leads to lower emissions from the strategic buyers and higher emissions from the strategic sellers.

Increased emissions from the other strategic agents will imply a reduction in their net sales and thus a higher permit price. Correspondingly, lower emissions from the other strategic agents lead to a lower permit price. A strategic seller benefits from a higher permit price, whereas a strategic buyer benefits from a lower permit price. Hence, we can derive the following proposition:

Proposition 1 *A country's decision to become a strategic player makes cet. par. the price more responsive to increases in the other strategic agents' emissions. A more responsive price function leads to a shift in each of the other strategic players' optimal emissions. The new strategic player benefits from the direction of the shift by the strategic players on the same side of the market, but is harmed by the direction of the shift by the strategic players on the other side of the market.*

To sum up, the shift from competitive to strategic agent has two effects on the other strategic agents' emissions decisions. One is due to a more responsive price function, the other to the change in the emissions from the new strategic agent. The first effect has an ambiguous impact on the benefit from strategic behavior, depending on the trading position of the other strategic agents. The second effect reduces the benefit from strategic behavior independently of the trading position of the other strategic agents. To explore the final impact on the incentives for strategic behavior, we must consider the impact on the equilibrium outcomes.

Equilibrium Outcome

To enable us to draw some tractable analytical results, we need to make some simplifications. We aim to make the model as simple as possible, while at the same time being able to focus on the impact on strategic market power on both sides of the market. Trade in permits and hence potential market power depends on the country's abatement cost function and the initial endowment of permits. We confine the analysis to linear marginal abatement cost, where the marginal abatement costs for any given *percentage* emission reduction are equal across all agents. Hence[4]

$$\omega_i'(e_i) = \gamma - \frac{\gamma}{e_i^0} e_i, \tag{11}$$

where e_i^0 is business-as-usual emissions from country i.

Let μ denote the total share of permits relative to total business-as-usual emissions. Thus, $\mu = \frac{\bar{\varepsilon}}{\bar{e}^0}$, where $\bar{e}^0$ is total business-as-usual (BaU) emissions. Given (11), an initial distribution of permits where all countries receive the same share of permits relative to their BaU emissions would induce no trade. Hence, to insure trade in permits we assume the permits are unevenly distributed. Countries constituting half of the BaU emissions receive fewer permits than average, while the other half more than average. It is thus the differences in the initial endowment of permits that determine whether the agents become buyers or sellers of permits.

We also assume that the potential strategic agents (the large traders) are equal in size, measured in business-as-usual emissions. This symmetry of the model not only allows us to derive some interpretable analytical results, it also enables us to consider the impact of market power on both sides of the market without having the results affected by the various *sizes* of the strategic agents.

Hence, a country becomes a buyer of permits if its initial endowment of permits is given by

$$\varepsilon_i = (\mu - \theta) e_i^0, \tag{12}$$

whereas it becomes a seller of permits if

$$\varepsilon_j = (\mu + \theta) e_j^0. \tag{13}$$

Let subscript s denote a strategic seller of permits, and let subscript b denote a strategic buyer of permits. Furthermore, let S denote the number of strategic sellers, and B denote the number of strategic buyers.

Solving the model, we find the equilibrium outcome for emissions from all types of agent and the equilibrium permit price, as functions of S and B (see Appendix A). To simplify the presentation, we focus on the behavior

[4] Note that (11) is a mirror image of a marginal abatement cost, given by $c'(a_i) = \frac{\gamma}{e_i^0} a_i$, where abatement, a_i, is the difference between business as usual emissions, e_i^0, and actual emissions, e_i.

of a potential strategic seller of permits. However, due to the symmetry of the model, all the general results also hold for a potential strategic buyer of permits, and these results will therefore be phrased in a general manner.

We find:

$$e_s^*(S+1) - e_s^*(S) = \frac{2 \cdot B \cdot (e_k^0)^4 \cdot \theta}{(\bar{e}^0 + e_k^0) \cdot (\bar{e}^0 - e_k^0(B+S)) \cdot (\bar{e}^0 - e_k^0(B+S-1))} \geq 0 \quad (= 0 \text{ for } B = 0).$$

$$e_b^*(S+1) - e_b^*(S) = -\frac{2 \cdot (e_k^0)^3 \cdot \theta \cdot (\bar{e}^0 - e_k^0(B-1))}{(\bar{e}^0 + e_k^0) \cdot (\bar{e}^0 - e_k^0(B+S)) \cdot (\bar{e}^0 - e_k^0(B+S-1))} < 0. \tag{14}$$

From (14), we see that the agent's shift from competitive to strategic behavior leads to higher (or equal) emissions from the other strategic sellers and lower emissions from the strategic buyers.[5] As lower emissions cet. par. lower the equilibrium permit price, the responses from the other strategic sellers benefit the new strategic seller, whereas the responses from the strategic buyers are harmful.

Furthermore, we find:

$$(e_s^*(S+1) - e_s^*(S)) \cdot S + (e_b^*(S+1) - e_b^*(S)) \cdot B = -\frac{2 \cdot B \cdot (e_k^0)^3 \cdot \theta}{(\bar{e}^0 + e_k^0) \cdot (\bar{e}^0 - e_k^0(B+S))} \leq 0 \quad (= 0 \text{ for } B = 0). \tag{15}$$

From (15), we see that an agent's shift from competitive to strategic behavior leads to, in total, lower emissions from all the other strategic agents (for $B > 0$). Lower emissions from the strategic agents imply higher emissions from the fringe countries, and this lowers the equilibrium permit price. Hence, the total response from the incumbent strategic agents hurts the new strategic seller.

[5] Perry and Porter (1985) consider a situation where only sellers can change their position from competitive to strategic agents, which in our setting corresponds to $B = 0$. Hence, also in their model, because of linearity, the output of each strategic seller is independent of the number of strategic sellers.

The new strategic seller sells fewer permits as a strategic seller than it would as a price-taker. In total, we find that emissions from each of the remaining price-taking countries have decreased (or remain constant), as

$$p^*(S+1) - p^*(S) \\ = \frac{(\bar{e}^0 - 2 \cdot e_k^0 \cdot B) \cdot \gamma \cdot \theta \cdot (e_k^0)^2}{(\bar{e}^0 - e_k^0 \cdot (B+S)) \cdot (\bar{e}^0 + e_k^0) \cdot (\bar{e}^0 - e_k^0 \cdot (B+S+1))} \geq 0. \quad (16)$$

We see that the price increase is lower the higher share of the strategic agent being on the buyer's side of the market. Furthermore, we see that (16) equals zero for $e_g^0 \cdot B = \frac{1}{2}\bar{e}^0$, which is only satisfied if all of the buyers are strategic players. In that case, there is no impact on the equilibrium price of becoming a strategic seller. Hence, there is nothing to gain from strategic behavior.

We derive the following proposition:

Proposition 2 *Profitable strategic behavior in a setting where the other strategic agents are on the same side of the market can be unprofitable in a setting where the other strategic agents are on the opposite side of the market.*

Proof of Proposition 2: See appendix B ■

Hence, the benefit of acting strategically in the market is not only dependent on the total magnitude of the market power of the other strategic agents, but also on whether the other strategic agents are on the same or opposite side of the market. This conclusion is opposed to Perry and Porter (1985) who considered strategic behavior on only one side of the market. They found that there is always an incentive to behave strategically.

Note that as Proposition 2 holds for our specification of the permit market, it must also hold for a more general specification of the permit market (as our model is one specification of a more general model of the permit market).

As the benefit of acting strategically is dependent on other strategic agent on both sides of the market, we may face several Nash equilibria. This is illustrated by the numerical example provided in section ''Numerical Example.''

Numerical Example

We have conducted a numerical example where we consider a case in which there are six countries with potential market power, three on the sellers'

Table 1. Welfare for a large seller and a large buyer, depending on their own and other large traders' strategic behavior.

Strategic key (S, B)	Profit for large strategic seller (W_σ^s).	Profit for large competitive seller (W_σ^{fs}).	Profit for large strategic buyer (W_β^b).	Profit for large competitive buyer (W_β^{fb}).
(0,0)		60.63		33.13
(0,1)		60.32	33,28	33.43
(0,2)		59.95	33.63	33.82
(0,3)		59.47	34.07	34.33
(1,0)	60.78	60.93		32.82
(1,1)	60.44	60.63	32.94	33.13
(1,2)	60.00	60.23	33.28	33.52
(1,3)	59.43	59.72	33.73	34.06
(2,0)	61.13	61.32		32.45
(2,1)	60.78	61.02	32.50	32.73
(2,2)	60.32	60.63	32.82	33.13
(2,3)	59.68	60.08	33.24	33.68
(3,0)	61.57	61.83		31.97
(3,1)	61.23	61.56	31.93	32.22
(3,2)	60.74	61.18	32.18	32.58
(3,3)	60.02	60.63	32.52	33.13

Strategic key denotes number of strategic sellers (S) and buyers (B).

side, and three on the buyers' side. The values of the parameters of the simulations are given in Appendix C.

Table 1 presents the outcome for the profit of a large permit buyer and a large permit seller depending on their own behavior on the permit market (strategic or competitive behavior) and of the combination of strategic agents on the market (S, B).

Our numerical example illustrates Proposition 2. Given that three strategic agents are on the opposite side of the market, strategic behavior is unprofitable. However, if a majority of the three strategic agents is on the same side of the market, strategic behavior is profitable.[6]

Given three large traders on both sides of the market, both (3,0) and (0,3) are Nash equilibria. Hence, given that all the other large sellers behave strategically, but none of the large buyers behaves strategically, it also profitable for the last large sellers to behave strategically in the market, whereas a large buyer is better off behaving competitively, given three strategic sellers and no other strategic buyers, and vice versa.[7] There are no other Nash equilibrium combinations of strategic agents.

For the large sellers, the outcome of (3,0) exceeds (0,3), and for the large buyers the outcome of (0,3) exceeds (3,0).[8] There is thus a "first mover advantage" in our example. Large permit traders are better off if they and the other large traders on the same side of the market act strategically first, such that the large traders on the other side of the market do not gain from strategic behavior. In our model, we have assumed that the agent takes the other agents' strategic behavior as given. We have hence ignored any coordination between the large traders, and cannot determine which of the Nash equilibria prevails.

So far, we considered the case in which the potential strategic agents are evenly distributed across both sides of the permit market. However, we find situations with a unique Nash equilibrium outcome of strategic agents if there is an uneven distribution of potential strategic players. For instance, we see from Table 1 that if there are three large sellers and two large buyers the only Nash equilibrium combination of strategic agents is (3,0)).[9]

---

[6] For the large seller, we have that $W_\sigma^s(1,3) = 59.43 < W_\sigma^{fs}(0,3) = 59.47$, and $W_\sigma^s(3,1) = 61.23 > W_\sigma^{fs}(2,1) = 61.02$, see Table 1. From Table 1 we see that a similar argument holds for the large buyer.

[7] From Table 1, we see that $W_\sigma^s(3,0) = 61.57 > W_\sigma^{fs}(2,0) = 61.32$, $W_\beta^b(3,1) = 31.93 < W_\beta^{fb}(3,0) = 31.97$, $W_\beta^b(0,3) = 34.07 > W_\beta^{fb}(0,2) = 33.63$, and $W_\sigma^s(1,3) = 59.43 < W_\sigma^{fs}(0,3) = 59.47$.

[8] $W_\sigma^s(3,0) = 61.57 > W_\sigma^{fs}(0,3) = 59.47$, see Table 1.

[9] (3,0) is a Nash equilibrium combination of strategic agents as $W_\sigma^s(3,0) = 61.57 > W_\sigma^{fs}(2,0) = 61.32$, and $W_\beta^b(3,1) = 31.93 < W_\beta^{fb}(3,0) = 31.97$. By checking the other outcomes, given by Table 1, we see that (3,0) is the only equilibrium. Note that due to the choice of abatement-cost function, a large nonstrategic country has exactly the same behavior on the permit market as a group of small traders (on the same side of the market) with the same (total) business-as-usual emissions. Hence, one less large nonstrategic trader does not change the outcome of strategic

Concluding Remarks

The purpose of this paper was to explore how a country's profitability of strategic behavior in the permit market depends on other strategic countries' trading positions. In order to derive some tractable results we have used a very simplified model. Obviously, our model is an unrealistic description of the real world, as we know countries differ in size and benefit of emissions. However, although simple, we argue that our model is able to capture essential features about strategic behavior in the permit market, not discussed in previous literature. We have shown that the benefit of acting strategically in the market not only depends on the total magnitude of the market power of the other strategic agents, but also on whether the other strategic agents are on the same or opposite side of the market. Our main finding is that profitable strategic behavior in a setting where the other strategic agents are on the same side of the market *can* be unprofitable in a setting where the other strategic agents are on the opposite side of the market (see Proposition 2).

As discussed in the introduction, countries may behave strategically in the permit markets although the actual trade in permits is between competitive behaving firms. International negotiations on climate policy for the post–Kyoto period after 2012 have proven to be difficult. But when (or if) there will be a new agreement involving permit trade, our results offer an insight into how potentially large traders, and groups of small, competitive traders, like the EU countries, could organize their domestic climate policy. Expectations or observations of other large traders' domestic policy design may prevent large traders on the other side of the market from behaving strategically. However, we have only focused on the pecuniary impacts of strategic behavior. Obviously, there may be political concerns that affect governments' willingness to impose domestic policy measures which enable them to exploit their potential market power.

To prevent the exploitation of market power, regulations on domestic policy instruments could be included in the international climate agreement. For instance, a clause that forbids domestic taxes/subsidies on emissions and tariffs on permit trade, and demands that all countries let their domestic firms trade directly on the permit market, would make manipulation of the permit price more difficult. The literature also shows that market

behavior among the remaining large traders. Thus, we can use the output from Table 1 to find the equilibrium outcomes also for the case where there are only two large buyers.

power can be mitigated by countries' opportunity to store unused permits for later use, see Liski and Montero (2011), and by auctioning the permits, see Montero (2009). However, strategic manipulation of the permit market is probably impossible to abolish completely by this approach, as countries may still influence their domestic emitters' permit demand by changes in other existing taxes or subsidies on fossil fuels and close substitutes.

Appendix A

Solving the model yields the following Nash–Cournot equilibrium outcome[10]:

$$e_s^* = \frac{\begin{array}{l}(e_k^0)^3(-\bar{\varepsilon} - \theta\bar{e}^0 + S\bar{\varepsilon} + S\theta\bar{e}^0 + B\bar{\varepsilon} - B\theta\bar{e}^0)\\ \quad + (e_k^0)^2(-2\bar{e}^0\bar{\varepsilon} + \bar{e}^0 S\bar{\varepsilon} - (\bar{e}^0)^2\theta + \bar{e}^0 B\bar{\varepsilon}) - e_k^0(\bar{e}^0)^2\bar{\varepsilon}\end{array}}{\bar{e}^0(\bar{e}^0 + e_k^0)(e_k^0 S - \bar{e}^0 + e_k^0 B - e_k^0)},$$

$$e_b^* = \frac{\begin{array}{l}(e_k^0)^3(-\bar{\varepsilon} + \theta\bar{e}^0 + S\bar{\varepsilon} + S\theta\bar{e}^0 + B\bar{\varepsilon} - B\theta\bar{e}^0)\\ \quad + (e_k^0)^2(-2\bar{e}^0\bar{\varepsilon} + \bar{e}^0 S\bar{\varepsilon} + (\bar{e}^0)^2\theta + \bar{e}^0 B\bar{\varepsilon}) - (e_k^0)(\bar{e}^0)^2\bar{\varepsilon}\end{array}}{\bar{e}^0(\bar{e}^0 + e_k^0)(e_k^0 S - \bar{e}^0 + e_k^0 B - e_k^0)}, \qquad \text{(A1)}$$

$$p^* = \frac{\begin{array}{l}\gamma((e_k^0)^2((S+B)(\bar{e}^0 - \bar{\varepsilon}) - (S-B)\theta\bar{e}^0)\\ \quad + (\bar{e}^0)^2(e_k^0(S+B) - e_k^0 + \bar{\varepsilon}) - \bar{e}^0 e_k^0\bar{\varepsilon}(S+B-1) - (\bar{e}^0)^3)\end{array}}{(-\bar{e}^0 + e_k^0(B+S))(\bar{e}^0 + e_k^0)\bar{e}^0}.$$

Appendix B

We prove Proposition 2 by considering two extreme outcomes of the distribution of the share of strategic agents across sellers and buyers. The strategic buyers (sellers) cannot exceed the total number of buyers (sellers). Hence, $e_k^0 \cdot B \leq \frac{1}{2}\bar{e}^0$ and $e_k^0 \cdot S \leq \frac{1}{2}\bar{e}^0$. Consider a permit seller that shifts from competitive to strategic behavior, such that the number of strategic sellers increases by one. For $B = 0$, we know that an increase in the number of strategic sellers does not affect the other strategic sellers' equilibrium outcomes of emissions (see (14)). The only impact on the new equilibrium permit price is caused by the change in emissions from the new strategic

---

[10] We used the software program *Maple* to solve the model.

agent. Moreover, as that change follows from the first-order condition of the optimizing problem, given by (8), the welfare following from strategic behavior must outweigh the welfare following from competitive behavior. Hence, in the setting described above, strategic behavior is beneficial for large sellers for all outcomes of S ($\leq \frac{1}{2}\frac{\bar{e}^0}{e_k^0}$) and (9) is satisfied.[11]

For $B = \frac{1}{2}\frac{\bar{e}^0}{e_k^0}$, we see from (16) that the equilibrium price does not increase when a large seller decides to behave strategically. Hence, $p(\bar{F}-1) = p(\bar{F})$ for $B = \frac{1}{2}\frac{\bar{e}^0}{e_k^0}$ in (9). The emissions increase due to strategic behavior by agent i does not lead to any gain in terms of increased permit price, but only induces a loss, as $\omega_i(e_s^*) - \omega_i(e_f^*) + p \cdot (e_f^* - e_s^*) < 0$, since $e_s^* > e_f^*$, $\omega_i'' < 0$, and $\omega_i'(e_f^*) = p$. Hence, in this setting, $B = \frac{1}{2}\frac{\bar{e}^0}{e_k^0}$, strategic behavior is not beneficial for the large seller and (9) is not satisfied for any number of S. This proves Proposition 2.

Appendix C

In the numerical model, we have used the following values for the parameters:

$$\bar{e}^0 = 100, \quad \bar{\varepsilon} = 75, \quad e_k^0 = 10, \quad \gamma = 10, \quad \theta = 5.5.$$

(Note that e_k^0 is the business-as-usual emissions for all large traders).

References

Böhringer, C. 2002. "Climate Politics from Kyoto to Bonn: From Little to Nothing?" *The Energy Journal* 23: 51–73.

Böhringer, C. and A. Löschel. 2003. "Market Power and Hot Air in International Emissions Trading: The Impacts of US Withdrawal From the Kyoto Protocol." *Applied Economics* 35(6): 651–664.

Ellerman, A. D. and I. S. Wing. 2000. "Supplementarity: An Invitation to Monopsony." *The Energy Journal* 21(4): 29–59.

Eyckmans, J. and C. Hagem. 2011. "The European Union's Potential for Strategic Emissions Trading Through Permit Sales Contracts." *Resource and Energy Economics* 33(1): 247–267.

Fauli-Oller, R. 1997. "On Merger Profitability in a Cournot Setting." *Economics Letters* 54(1): 75–79.

Godal, O. and F. Meland. 2010. "Permit Markets, Seller Cartels and the Impact of Strategic Buyers." *The B.E. Journal of Economic Analysis and Policy* 10(1 (Advances)): Article 29.

[11] Perry and Porter (1985) confirm this result.

Hagem, C., S. Kallbekken, O. Mæstad and H. Westskog. 2005. "Enforcing the Kyoto Protocol: Sanctions and Strategic Behavior." *Energy Policy* 33(16): 2112–2122.

Hagem, C. and H. Westskog. 2008. "Intertemporal Emission Trading with a Dominant Agent: How Does a Restriction on Borrowing Affect Efficiency?" *Environmental and Resource Economics* 40(2): 217–232.

Hagem, C. and H. Westskog. 2009. "Allocating Tradable Permits on the Basis of Market Price to Achieve Cost Effectiveness." *Environmental and Resource Economics* 42(2): 139–149.

Hahn, R. W. 1984. "Market Power and Transferable Property Rights." *The Quarterly Journal of Economics* 99(4): 753–765.

Hendricks, K. and R. P. McAfee. 2010. "A Theory of Bilateral Oligopoly." *Economic Inquiry* 48(2): 391–414.

Huck, S. and K. A. Konrad. 2004. "Merger Profitability and Trade Policy." *Scandinavian Journal of Economics* 106(1): 107–122.

Klemperer, P. D. and M. A. Meyer. 1989. "Supply Function Equilibria in Oligopoly under Uncertainty." *Econometrica* 57(6): 1243–1277.

Liski, M. and J.-P. Montero. 2006. "On Pollution Permit Banking and Market Power." *Journal of Regulatory Economics* 29(3): 283–302.

Liski, M. and J. P. Montero. 2011. "Market Power in an Exhaustible Resource Market: The Case of Storable Pollution Permits." *The Economic Journal* 121(551): 116–144.

Malueg, D. A. and A. J. Yates. 2009. "Bilateral Oligopoly, Private Information, and Pollution Permit Markets." *Environmental and Resource Economics* 43(4): 553–572.

Montero, J.-P. 2009. "Market Power in Pollution Permit Markets." *The Energy Journal* 30: 115–142.

Neuhoff, K., M. Åhman, R. Betz, J. Cludius, F. Ferrario, K. Holmgren, G. Pal, M. Grubb, F. Matthes, K. Rogge, M. Sato, J. Schleich, J. Sijm, A. Tuerk, C. Kettner and N. Walker. 2006. "Implications of Announced Phase II National Allocation Plans for the EU ETS." *Climate Policy* 6(4): 411–422.

Perry, M. K. and R. H. Porter. 1985. "Oligopoly and the Incentive for Horizontal Merger." *The American Economic Review* 75(1): 219–227.

Ravenscraft, D. J. and F. M. Scherer. 1989. "The Profitability of Mergers." *International Journal of Industrial Organization* 7(1): 101–116.

Salant, S. W., S. Switzer and R. J. Reynolds. 1983. "Losses from Horizontal Merger: The Effects of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium." *The Quarterly Journal of Economics* 98(2): 185–199.

Westskog, H. 1996. "Market Power in a System of Tradeable CO_2 Quotas." *The Energy Journal* 17(3): 85–103.

Wirl, F. 2009. "Oligopoly Meets Oligopsony: The Case of Permits." *Journal of Environmental Economics and Management* 58(3): 329–337.