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Uncertainty and International Negotiations on Tradable Quota Treaties

Abstract:

Negotiating an international tradable quota treaty between industrialised and developing countries is complicated by uncertain marginal abatement costs and non-uniform quota prices. An initial quota allocation that implies zero expected net cost to developing countries will typically be insufficient to attract their participation in the treaty. Two options to compensate for uncertainty are discussed here, extra emissions quotas and financial transfers. The latter is found to be more effective in facilitating treaty-making, but the scope of co-operation is restricted by the developing countries' risk-aversion.

Keywords: Tradable quotas, uncertainty.

JEL classification: D23, Q25

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1. Introduction

In the literature it is often assumed that industrialised countries may be committed, for political or moral reasons, to signing an international environmental treaty and jointly implement emissions reductions of greenhouse gases in a cost-effective manner (see, *e.g.*, Hoel (1994) and Underdal (1992)). The Kyoto Protocol aims at a market-based reduction of emissions of greenhouse gases in the industrialised (Annex B) countries by 5.2 per cent below 1990 levels in the commitment period 2008 to 2012, and serves as a practical illustration of this tenet[1]. An important issue is how policy can be designed to increase the chances that a treaty amongst industrialised countries will attract additional signatories, particularly developing countries with low abatement cost options. Although these countries may not assist in covering the net costs of reducing emissions, their involvement can significantly increase the cost-effectiveness of a given international sacrifice. Moreover, if the risk of global climate change is to be reduced, it is vital that developing countries - the predicted main future emitter of greenhouse gases - agree to emissions limitations[2].

In general, side payments can be used to transfer resources to the developing countries and thereby provide incentives for them to participate in an international environmental agreement (Barrett (1992a) and Carraro *et al*. (1992, 1993))[3]. Under a tradable quota scheme, transfers are indirectly determined by the initial distribution of emissions quotas: If the initial quota of a country exceeds the country's actual quota demand measured at the equilibrium quota price, revenue from sales of the resulting surplus minus incurred abatement costs determine the implicit net transfers received, and *vice versa*. Hence, an "appropriate" initial quota allocation can serve as an effective device to attract developing countries' to participate in an international tradable quota treaty (Barrett (1992b)). Also, regardless of the initial allocation, subsequent trading can lead to a cost-effective outcome (Montgomery (1972)). This potential for pursuing distributional objectives whilst assuring cost-effectiveness is an important attribute of the tradable quota approach.

Negotiations on a tradable quota treaty between industrialised and developing countries most likely are two-dimensional in the following sense. First, the bargaining parties need to agree upon an aggregate

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[1] See http://www.unfccc.de/index.html

[2] By 2010, global carbon emissions could be 32% higher than in 1990, even if all industrial nations meet their Kyoto commitments, according to US Department of Energy (Global Environmental Change Report, Vol. X, No. 9, May 1998).

[3] Gilles *et al*. (1996) argue that developing countries are unlikely to consider themselves responsible for atmospheric degradation, and may be reluctant to reduce emissions of their own volition.

emissions target. Second, the negotiations will focus upon an acceptable initial quota allocation between industrialised and developing countries[4]. The latter process may be facilitated by reference to some criteria such as “fairness”, GNP, and others (for an overview, see Rose and Tietenberg (1994)). Nevertheless, a focal point in a group of papers has been the allocation that would keep developing countries exactly financially compensated, *i.e.*, implies zero net cost, were they to join (confer, for instance, Bohm and Larsen (1994) and Bohm (1995)). This allocation yields the least cost to the industrialised countries at which developing countries could be drawn into an international agreement.

In this paper we consider negotiations on and the prospect for a tradable quota treaty involving industrialised countries (IC), committed to reducing emissions, and developing countries (DC) which are considered unlikely to reduce emissions of their own volition. The starting point is an emissions target which can be assumed to acceptable in that it reduces the chances of unfavourable global warming with an acceptable probability[5]. Furthermore, we focus on an initial tradable quota allocation which implies zero expected net costs to DC, where net costs equal abatement costs plus quota sales revenues minus quota purchase costs. However, uncertain marginal abatement costs and non-uniform quota prices (henceforth referred to as uncertainty) affect the distributional implications of this quota allocation. In particular, uncertainty may adversely influence the assumed risk-averse DC’s incentives to join the agreement[6].

The IC’s response is to play a leadership role by agreeing to compensate DC in order to make it join the proposed treaty. Consequently, we discuss two compensation options available to IC: (a) extra emissions quotas to DC, and (b) linking the initial quota allocation that implies zero expected cost DC with financial transfers from IC. In total, the main purpose of the paper is to analyse and compare the effectiveness of two compensation options in terms of facilitating a tradable quota treaty.

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[4] We assume that negotiations between developing and industrialised countries on a tradable quota treaty are shaped by earlier and related negotiations. A case in point is the process leading up to the Kyoto Protocol which involved the determination of an aggregate emissions cap and an acceptable initial allocation of tradable emissions quotas (also see Barrett (1998)).

[5] This level of emissions may or may not be Pareto optimal. An emissions level is Pareto optimal when the marginal abatement cost of reducing emissions equal the marginal benefit from reductions. It is difficult to estimate marginal benefits by any reliable approximation. Therefore the treaty’s objective is cast in terms of an exogenous emissions target only. The treaty is cost-effective if it achieves the emissions target at the lowest cost possible. An efficient treaty implies both a Pareto optimal emissions target and cost-effectiveness (Hoel (1993)).

[6] Confer IPCC (1996), chapter 11 for a related discussion.

The paper is organised in five sections. Following the introduction, Section 2 introduces the negotiations framework and specifies the type of uncertainty considered relevant to the negotiations. Section 3 and 4 examines the properties and analyses the effectiveness of the two compensation strategies, respectively. Section 5 concludes the paper.

2. The negotiations framework

For simplicity, we discuss the negotiations in terms of two representative countries DC and IC that would trade on a perfectly competitive quota market. Also, we assume that IC is committed to, first, reducing aggregate emissions and, second, inducing DC to join a tradable quota treaty with a total cap on emissions corresponding to the aggregate emissions target. Third, IC wants DC to commit itself to non-negative emissions limitations *ex-ante* quota trade. Subject to these constraints, IC seeks to minimise the associated costs and is approximately risk-neutral with regard to the incurred costs. Alternately, DC is risk-averse with regard to the costs implied by participating in the treaty. In addition, it is reluctant to join unless it is - as a minimum prerequisite - financially compensated.

Let e_{DC}^{BAU} and e_{IC}^{BAU} denote DC's and IC's emissions business-as-usual levels, *i.e.*, when no abatement of emissions is undertaken. The given emissions target is the sum of the initial quota allocation allocations $\hat{e}_{DC}$ and $\hat{e}_{IC}$, and is henceforth treated as given. These quotas are taken to be time-limited and tradable, and may refer to maximum allowable emissions during a five-year period. Thus, the negotiations concern a treaty that cuts aggregate emissions by at least $\left\{\left(e_{DC}^{BAU} + e_{IC}^{BAU}\right) - \left(\hat{e}_{DC} + \hat{e}_{IC}\right)\right\}$.

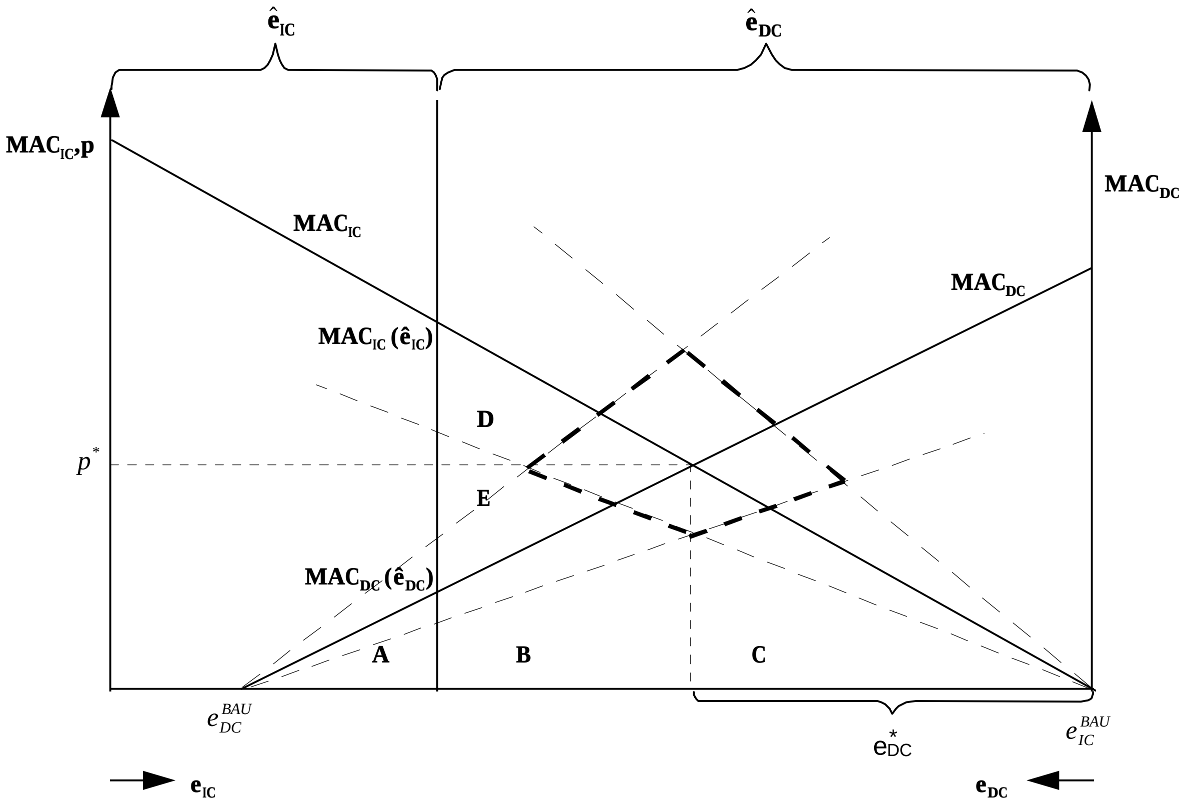
As can be seen in Figure 1, the marginal cost of reducing emissions in country i - MAC_i - is assumed to be linear and increasing in abatement of emissions[7]. Moreover, valued at the initial quota allocation, the countries' marginal abatement costs are asymmetric in that DC offers cheaper abatement options than does IC. Formally, $MAC_{IC}\left(\hat{e}_{IC}\right) > MAC_{DC}\left(\hat{e}_{DC}\right)$.

A cost-effective allocation of emissions (at the end of the considered period) obtains when the countries reduce their emissions e_{DC} and e_{IC} up to the point where the marginal abatement cost equals the

[7] Abatement options with non-positive costs, so-called 'no-regrets' options, are disregarded here. Also, the relative flatness of MAC_{DC} illustrates the assumed low abatement cost options available in DC.

equilibrium price of an emissions quota - p^*. Hence, in equilibrium, DC would export emissions reductions equal to $(\hat{e}_{DC} - e^*_{DC})$ to IC, where e^*_{DC} denotes the market-clearing volume of DC's emissions *ex-post* quota trade.

Figure 1. Tradable quota graphics



Compared with the initial quota allocation depicted in the figure, quota trade infers efficiency gains equal to the area (D+E). DC's and IC's optimal domestic abatement costs equals (A+B) and C, respectively. DC's quota sales revenue corresponds to IC's quota purchase costs, and is given by the rectangle (B+E).

Equivalently, and assuming linear MACs, the net costs incurred by DC if choosing to participate in the treaty can generally be expressed as

$$C_{DC} = \overbrace{\tfrac{1}{2}\, p^{*}(e_{DC}^{BAU} - e_{DC}^{*})}^{\text{abatement costs}} - \overbrace{p^{*}(\hat{e}_{DC} - e_{DC}^{*})}^{\text{quota sales reveneue}} \qquad (1)$$

The BAU level e_{DC}^{BAU} in equation (1) can be expected to be reasonably easy to predict, and the initial quota allocation $\hat{e}_{DC}$ is determined through negotiations. Hence, we assume that these parameters are certain. Therefore, uncertain net costs may originate from

1. non-uniform quota prices p, and
2. a stochastic market-clearing emissions level *ex-post* quota trade e_{DC}^{*}.

The rationale for assuming stochastic p and e_{DC}^{*} is that the slopes of the countries' linear MAC curves are deemed uncertain. This supposition is illustrated in Figure 1 by means of the dotted lines surrounding the marginal abatement cost functions, and indicates that the degree of uncertainty increases in emissions abatement[8]. Consequently, the random variables p and e_{DC}^{*} are defined as functions over the sample-space created by the depicted intersections of the dotted lines.

For simplicity, we assume that this sample-space is common knowledge amongst the bargaining parties. A motivation for this approach is that few countries can be expected to accept joining a tradable quota treaty without needing to evaluate the implied net cost of proposed quota allocations between itself and others. Therefore, each negotiating party has an incentive to estimate both its own as well as the other parties' MACs in order to assess net quota demand and implied expected abatement costs and net quota sales revenue. Thus, it can be assumed that, as a result of national efforts as well as those of international organisations, the (confidence intervals of the) MACs of the negotiating parties level will be common knowledge (confer Bohm (1997a, 1997b)).

However, prior to quota trading the bargaining parties cannot ascertain the objective probability distribution of neither the quota prices or the market-clearing volume of emissions. The chosen

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[8] In reality, the traded commodities in focus here, emission reductions, will be "consumed" at discrete points in time, *i.e.*, the dates when each country has to prove that it has an emission quota large enough to cover its emissions during the past 'treaty' period. Thus, holdings of these commodities are useful only at the end of these every five years. Nevertheless, transactions at current prices can take place at any time during each period. Consequently, the prospect for uncertain prices may in practice be the most problematic aspect of uncertainty during real-life negotiations (see Bohm (1998)).

approach is to proceed *as if* the countries adopt a common prior specifying the underlying probability distributions as well as the values of the first two moments of the stochastic variables p and e^*_{DC}.

Specifically, the quota prices are supposed to follow a Gamma distribution. In this manner prices are not restricted apart from being positive:

$$\mathrm{f(p)} = \left[\mathrm{p}^{\mathrm{a\text{-}1}} e^{-bp}\right] / \Gamma(a,b) \text{ for } 0 \le \mathrm{p} \le \infty \qquad (2)$$

where a, b are positive parameters. The mean of the quota price - E(p) - is equal to $\frac{a}{b}$ whereas its variance - Var(p) - is given by $\frac{a}{b^2}$.

The distribution of the market-clearing volume of DC's emissions e^*_{DC} also needs to be non-negative as well as confined by upper and lower bounds. Actual e^*_{DC} will be treated as a random variable within the confines of DC's countries' BAU emissions levels e^{BAU}_{DC} and - for simplicity - 0. Thus, in line with the stated objective of IC, we disregard the possibility of allocating DC a quota beyond its BAU-level. Accordingly, we assume that e^*_{DC} follows a Beta distribution

$$\mathrm{f(e^*_{DC})} = \left[(\mathrm{e^*_{DC}} / \mathrm{m})^{\mathrm{c\text{-}1}}(1 - e^*_{DC} / m)^{d-1}\right] / mB(c,d) \text{ with } 0 \le \mathrm{e^*_{DC}} \le m \qquad (3)$$

where c, d signify positive parameters, and $m \equiv e^{BAU}_{DC}$ is a scaling parameter which represents the maximum attainable value for e^*_{DC}. Let the parameters be scaled such that $\mathrm{d} \equiv \mathrm{a} - \mathrm{c}$ [9]. The associated mean and variance then equals $e^{BAU}_{DC}\left(\frac{c}{a}\right)$ and $(e^{BAU}_{DC})^2\left(\frac{c(a-c)}{a^2(a+1)}\right)$, respectively.

[9] The restriction c+d=a combined with a≥2 will ensure a distribution of DC's market-clearing emissions level e^*_{DC} with a strictly positive mode instead of a uniform distribution shape (see Hughes Hallett (1994a)).

Lastly, the quota prices p and market-clearing emissions level e^*_{DC} are independently distributed. The motivation for this assumption is two-fold. First, market power is supposed to be negligible. The rationale for this is that the countries' right of withdrawal from the agreement provides a significant check on each signatory's incentives to manipulate the quota price. Second, the bargaining countries can be viewed as prospective 'small' price-takers in an international tradable quota market.

The outlined specification of stochastic quota prices and DC's market-clearing emissions volume facilitates an evaluation of initial quota allocations in terms of DC's net cost. In as much as the aggregate emissions target is treated as given, next we consider negotiations on the initial distribution of the aggregate tradable quota.

3. Negotiation strategies

DC is reluctant to join the tradable quota treaty unless it is financially compensated. Consequently, negotiations over allocations that yields positive expected cost to DC are ruled out *ex-ante*. Thus, a natural starting-point is for a cost-minimising IC to propose the initial quota allocation that yields zero expected net cost to DC. If deemed acceptable by DC, IC then effectively minimises the cost associated with facilitating the treaty.

The general expression for DC's expected net cost is given by the expectation of C_{DC}:

$$E(C_{DC}) = E\left[\overbrace{\tfrac{1}{2}\,p(e^{BAU}_{DC} - e^*_{DC})}^{\text{abatement costs}} - \overbrace{p(\hat{e}_{DC} - e^*_{DC})}^{\text{quota sales reveneue}}\right] = e^{BAU}_{DC}\left(\frac{a+c}{2b}\right) - \hat{e}_{DC}\,\frac{a}{b} \tag{4}$$

By implication, the initial quota allocation $\hat{e}^{\circ}_{DC} = e^{BAU}_{DC}\left(\frac{a+c}{2a}\right) < e^{BAU}_{DC}$ implies zero expected net cost to DC. Equivalently, DC's expected abatement costs equal exactly its expected quota sales revenue. Since $a > c$, this allocation specifies an initial quota smaller than DC's business-as-usual level[10].

However, the variance of DC's net costs is relevant to the negotiations in so far as DC exhibits risk-averse preferences. Risk-sensitivity requires DC's evaluation of the proposed initial allocation to be a

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[10] However, if $a \approx c$, then the initial allocation which keeps DC financially compensated is approximately equal to its BAU-level. Equivalently, such a treaty would entail negligible emissions reductions *ex-ante* quota trade.

function of the second (and possibly higher) moment of its net costs. Accordingly, we first assume that for a given certain initial net income denoted by M, DC agrees to join the treaty if and only if

$$E\{u(M - C_{DC})\} \geq u(M) \qquad (5)$$

i.e., conditional upon the expected utility from participating being greater than or equal to the country's initial welfare. Second, we adopt a mean-variance approach, the implication of which is that the participation constraint in equation (5) can be rewritten as[11]

$$-E(C_{DC}) - rVar(C_{DC}) \geq 0, \ \mathrm{r} > 0 \qquad (6)$$

where the coefficient r signifies DC's degree of constant absolute risk-aversion (Varian (1992)). An advantage of the mean-variance approach is that r reflects the DC's preference for avoiding risk; increasing r trades greater security (as indexed by Var(C_{DC})) for less ambition (as indexed by E(C_{DC})). In this case, varying r traces out the trade-off between lower average net costs and greater stability of these costs.

The variance of DC's net costs, evaluated at the considered initial allocation $\hat{e}^{\circ}_{DC} = e^{BAU}_{DC}\left(\frac{a+c}{2a}\right)$, is given by[12]:

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[11] If $m_i = E[w - E(w)]^j$ for j=2,3 ... and w denotes positive income, then $E(w) + \sum_{2}^{k} a_j m_j$ is the expectation of any standard utility function, u(w) say, given suitable values for a_j and $k = \infty$. To introduce E(u) as an objective is to specify that the decisions must follow from a von Neumann-Morgenstern utility function which associated utility values with different (risky) outcomes for w and hence the underlying target variables. Truncating the linear combination at k=2 produces the familiar mean-variance decision model, and a computable second-order approximation to the von Neumann-Morgenstern utility function.

[12] Since p~Γ(a,b) and e^{*}_{DC} ~B(c,d,m), it follows that $(p \cdot e^{*}_{DC})$ will be defined by a Gamma distribution with parameters c and λ=b/m. Hence, $Var(p \cdot e^{*}_{DC}) = m^2\left(\frac{c}{b^2}\right) = (e^{BAU}_{DC})^2\left(\frac{c}{b^2}\right)$ (see Hughes Hallett (1994b) for proof).

$$Var(C_{DC}) = Var\left[\overbrace{\tfrac{1}{2}\,p(e_{DC}^{BAU} - e_{DC}^{*})}^{\text{abatement costs}} - \overbrace{p(\hat{e}_{DC}^{\circ} - e_{DC}^{*})}^{\text{quota sales reveneue}}\right]$$

$$= \frac{1}{4}\left[(e_{DC}^{BAU} - 2\cdot\hat{e}_{DC}^{\circ})^2 Var(p) + Var(pe_{DC}^{*}) + 2Cov((e_{DC}^{BAU} - 2\cdot\hat{e}_{DC}^{\circ}\hat{e}_{DC})p, pe_{DC}^{*})\right] \qquad (7)$$

$$= \frac{(e_{DC}^{BAU})^2}{4ab^2}\left[c(a-c)\right] = Var(p)(e_{DC}^{BAU})^2\,\frac{\left[c(a-c)\right]}{4a^2} > 0$$

which is positive since the quota price p is non-uniform. Inserting the derived expected level and variance of DC's net costs in the participation constraint and rearranging, yields

$$r \le \frac{E(C_{DC})}{Var(C_{DC})} = \frac{0}{\frac{(e_{DC}^{BAU})^2}{4ab^2}\left[c(a-c)\right]} = 0 \qquad (8)$$

Equation (8) shows that the DC's participation constraint holds for $r = 0$ only. Equivalently, the considered initial quota allocation $\hat{e}_{DC}^{\circ}$ attracts DC to join the treaty conditional upon it being risk-neutral. *Thus, when allowing for uncertainty, an initial quota allocation that keeps a risk-averse DC exactly financially compensated is insufficient to attract its participation in a tradable quota treaty.*

Being committed to the specified amount emissions reductions $\left\{\left(e_{DC}^{BAU} + e_{IC}^{BAU}\right) - \left(\hat{e}_{DC} + \hat{e}_{IC}\right)\right\}$ and cost-effectiveness, IC is willing to provide compensation for uncertainty in order to induce DC to become party to the tradable quota treaty. A cost-minimising strategy for IC is therefore to propose compensation just sufficient to make DC join the treaty, given the latter's degree of risk-aversion. Next we consider the general properties of two alternative strategies open to IC for providing compensation: *extra emissions quota* and *financial transfers* to DC. A discussion of the effectiveness of the alternative strategies is deferred to the next section.

Extra emissions quota

This strategy amounts to assigning a larger tradable quota to DC than the initial quota allotment which implies zero expected net cost, albeit not in excess of DC's BAU-level. Consequently, the range of negotiable initial quotas to DC is given by the interval $\hat{e}_{DC} \in \left\{e_{DC}^{BAU}\left(\frac{a+c}{2a}\right), e_{DC}^{BAU}\right\}$. Since the aggregate quota allotment, and thereby the total emissions level, remains unchanged, this strategy implies IC obtaining a *ditto* smaller initial quota.

Assuming a competitive quota market, the compensatory quota allotted to DC will be exported and by that transformed into increased expected quota sales revenue, *i.e.*, similar to a lump sum redistribution of income. Conversely, the expected cost to IC from agreeing to the extra emissions quota to DC corresponds to the industrialised country's increase in expected quota purchase costs. The theoretic rationale for this is the result proved by Montgomery (1972), namely that the cost-effective and market-clearing allocation of emissions is independent of the initial quota allocation if the quota price is competitive and no transactions costs obtain. An additional condition is that income effects of (moderate) changes in the initial quota allocation are the same across countries, *e.g.*, all insignificant (Bohm (1992)). Then only the equilibrium volume of quota trade is affected by the change in the initial quota distribution.

Moreover, we assume that the probability distributions of both p and e_{DC}^{*}, as well as the parameters of these distributions, are unaffected by exogenous changes in the initial quota allocation. Then DC's expected net cost implied by extra emissions quota equals

$$\mathrm{E}(C_{DC}^{EQ}) = E\left[\overbrace{\tfrac{1}{2}\, p(e_{DC}^{BAU} - e_{DC}^{*})}^{\text{abatement costs}} - \overbrace{p(d \cdot \hat{e}_{DC}^{\circ} - e_{DC}^{*})}^{\text{quota sales reveneue}}\right] = (1-d)\left(\frac{a+c}{2b}\right)e_{DC}^{BAU}, \; d > 1 \qquad (9)$$

where superscript EQ signifies extra emissions quota.

The parameter δ measures the extent of extra emissions quota added to the allocation that implies zero expected cost to DC - $\hat{e}_{DC}^{\circ}$. From equation (9) it follows that assigning a larger initial quota to DC - setting δ>1 - reduces its expected net cost through higher expected quota sales revenue.

The variance of net costs implied by the compensatory initial quota is equal to

$$Var(C_{DC}^{EQ}) = Var(p)(e_{DC}^{BAU})^2 \frac{\left[\left(d^2 - 2d\right)(a+c)^2 + a(a+3c))\right]}{4a^2} > 0, \; d > 1 \qquad (10)$$

From equation (10) we get that

$$\frac{\partial Var(C_{DC}^{EQ})}{\partial \delta} = (\delta - 1)\frac{Var(p)(e_{DC}^{BAU})^2 (a+c)^2}{2a^2} > 0 \text{ for } \delta > 1 \qquad (11)$$

Thus, facilitating an extra emissions quota to DC generically enlarges the variance of its net costs.

Simultaneously, equation (11) shows that the variance of DC's net costs obtains a minimum value for the allocation that yields zero net cost (*i.e.*, for δ=1), and is strictly increasing in extra emissions quotas from this point on.

<u>*Financial transfers*</u>

The alternative strategy is to retain the allocation that implies zero expected net cost to DC and minimises the variance of these cost, but in addition provide *ex-ante* compensation for uncertainty to DC *via* financial transfers[13]. Since IC is taken to be risk neutral, the certainty equivalent of IC's expected cost of agreeing to allocating a larger emissions quota to DC may be provided as money transfers. This cost is given by $(\delta - 1)\left(\frac{a+c}{2b}\right)e_{DC}^{BAU}$, and corresponds to the increase in IC's expected quota purchase costs[14]. Therefore, DC's expected cost implied by the financial transfers strategy is comprised of the expected net cost of the initial allocation $\hat{e}_{DC}^{\circ}$, minus the financial transfer:

$$\mathrm{E}(C_{DC}^{FT}) = \overbrace{E(C_{DC})\Big|_{e_{DC}^{\circ}=e_{DC}^{BAU}\left(\frac{a+c}{2a}\right)}}^{=0} - \overbrace{(\delta - 1)\left(\frac{a+c}{2b}\right)e_{DC}^{BAU}}^{\text{Financial transfer}} = (1-\delta)\left(\frac{a+c}{2b}\right)e_{DC}^{BAU}, \ \delta > 1 \quad (12)$$

where superscript FT denotes financial transfers.

Trivially, such transfers decrease DC's expected net cost and equals its expected net cost implied by the extra emissions quota strategy. Moreover, a financial transfer to DC is certain and independent of

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[13] In so far as the allocation that implies zero expected net cost to the risk-averse DC also minimises these costs' variance, we do not consider a strategy involving a smaller initial quota than $\hat{e}_{DC}^{\circ}$ balanced by increased financial transfers.

[14]

stochastic quota prices and the market-clearing level of DC's emissions e^{*}_{DC}. Hence, the variance of DC's net costs is unaffected by this particular form of transfers.

4. Effectiveness of negotiation strategies

The industrialised country IC seeks to minimise the costs incurred when compensating DC for uncertainty, subject to the constraint that DC agrees to become a party to the tradable quota treaty. By implication, a negotiation strategy for IC is defined as follows: For a given degree of risk-aversion exhibited by DC, the industrialised country optimally selects a minimum degree of compensation sufficient for DC to join. Thus, the relative effectiveness of the two compensation strategies - extra emissions quota and financial transfers - can be discussed in terms of DC's participation constraint. Consider first the extra emissions quota alternative. Inserting the derived mean and variance of DC's net cost implied by this negotiation strategy into equation (6), we see that DC's participation constraint now is satisfied for the following values of risk-aversion:

$$r \le \frac{-E(C_{DC}^{EQ})}{Var(C_{DC}^{EQ})} = \frac{(d-1)2ab(a+c)}{e_{DC}^{BAU}\left[\left(d^2-2d\right)(a+c)^2+a(a+3c)\right]} \equiv r^{EQ} \qquad (13)$$

Equation (13) shows that, for each degree of risk-aversion such that $r \le r^{EQ}$, there exists an initial quota, indexed by δ, that provides DC with sufficient incentive to join the treaty.

Ceteris paribus, agreeing to allocate an extra emissions quota to DC reduces its expected net cost. By implication, r^{EQ} - the maximum value of r consistent with the participation constraint - increases. However, an obverse effect is caused by an amplified variance of net costs, and diminishes the level of r consistent with DC's participation. The latter effect dominates for a sufficiently large extra emissions quota. *Thus, extra emission quotas cannot be used to attract a DC with risk-aversion greater than*

$$r^{EQ}(d^{*}) = \frac{ab}{e_{DC}^{BAU}\sqrt{c(a-c)}} = \frac{E(p)}{e_{DC}^{BAU}}\frac{b^2}{\sqrt{c(a-c)}} \qquad (14)$$

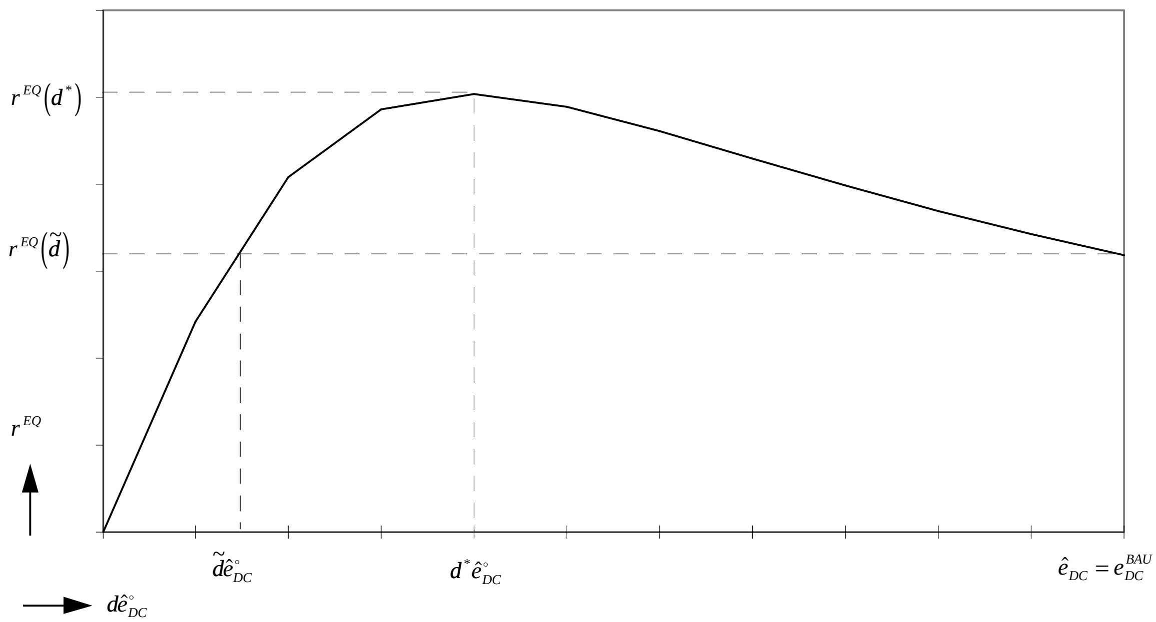
where $d^* = 1 + \frac{\sqrt{c(a-c)}}{a+c} \Leftrightarrow \frac{¶\,\mathrm{r}^{\mathrm{EQ}}}{¶ d} = 0.$ Consequently, DC’s degree of risk-aversion acts as an effective constraint on its incentives to join the tradable quota agreement.

In the special case where $r^{EQ} = r^{EQ}\left(d^*\right)$ obtains, the maximum initial quota to DC that IC will be willing to concede to make a risk-averse DC join the agreement, equals

$$d^* = \frac{\sqrt{\quad}}{\quad}$$

In total, uncertainty and risk-sensitivity on behalf of DC generally restricts the efficiency of using "appropriate" initial quota allocation to make developing countries join an international tradable quota treaty: Even in the case when $c = d$ and the maximum initial quota entails no emissions reductions *ex-ante* quota trade, DC will join conditional upon its degree of risk-aversion not exceeding $r^{EQ}\left(d^{*}\right)$.

Figure 2. DC's participation constraint and extra emissions quotas $(c < d)$



Next consider linking financial transfers with the initial allocation that implies zero net cost to DC. Inserting the relevant expressions for mean and variance in equation (6), the DC's participation constraint implied by this strategy becomes

$$r \leq \frac{-E(C^{FT}_{DC})}{Var(C^{FT}_{DC})} = (d-1)\frac{E(p)}{e^{BAU}_{DC}}\frac{2b^2(a+c)}{(c(a-c))} \equiv r^{FT} \qquad (15)$$

where r^{FT} denotes the highest value of DC's risk-aversion, for each degree of compensation provided by IC as indexed by δ, consistent with it choosing to join the treaty.

IC is taken to be indifferent with regard to the two alternative strategies[15]. Similarly, we may assume that the maximum amount of financial transfers available from IC corresponds to the expected cost of

[15] Implicitly we suppose that IC's total cost of public funds incurred when facilitating compensation are equal across the two alternative strategies. In reality, financial transfers may have a significant drawback in that they imply a transparent, out-of-pocket cost which may seem politically unattractive as compared to the small direct or up-front costs of the 'in-kind transfers' in the form of an extra emissions quota.

the maximum quota in equation (14). Thus, financial transfers can be used to induce DC to join the treaty conditional on its risk-aversion r being smaller than or equal to

$$r^{FT}(d^*) = \frac{2ab}{e_{DC}^{BAU}\sqrt{c(a-c)}} = \frac{E(p)}{e_{DC}^{BAU}}\frac{2b^2}{\sqrt{c(a-c)}} \tag{16}$$

where $d^* = 1 + \frac{\sqrt{c(a-c)}}{a+c}$, and signifies the largest extra initial quota that a cost-minimising IC may be willing to concede to DC.

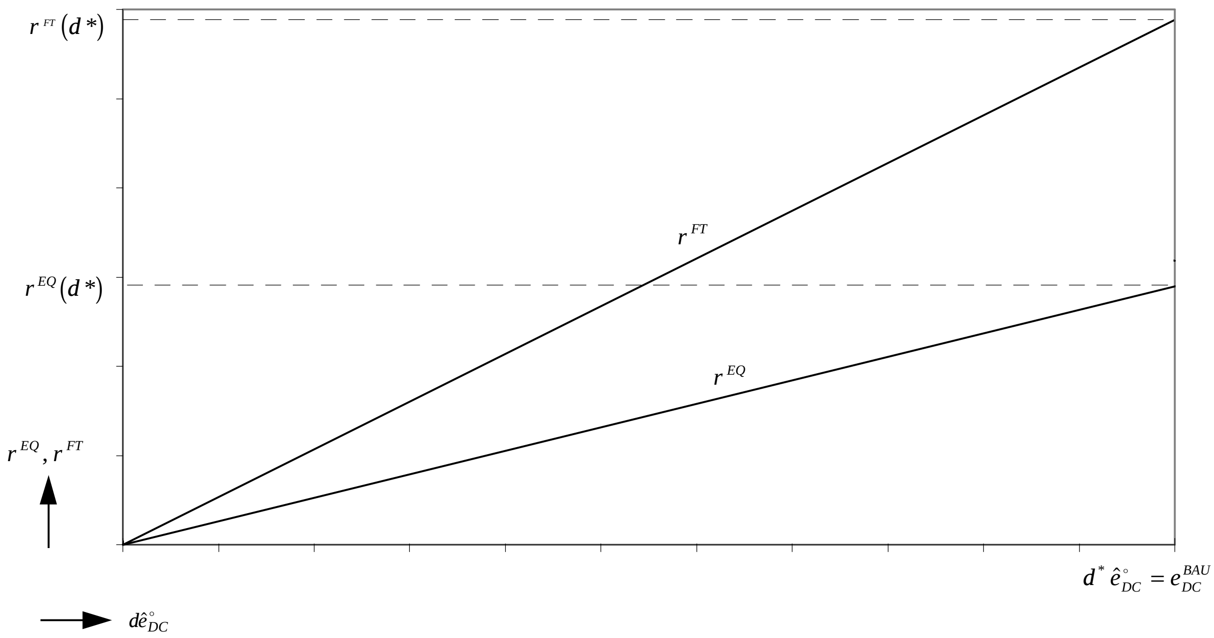
A comparison with the maximum value of r^{EQ} implied by the extra emissions quota strategy in equation (14), shows that $r^{FT}(d^*) = 2r^{EQ}(d^*)$. This result holds regardless of the relative values of parameters c, d. *Therefore, evaluated at equal cost to IC, financial transfers can be used to attract a DC exhibiting a higher degree of risk-aversion as compared to the extra emissions quota strategy. Nevertheless, a tradable quota treaty is only feasible if DC's degree of risk-aversion does not exceed* $r^{FT}(d^*)$.

Moreover, a DC exhibiting a degree of risk-aversion equal to or smaller than $r^{EQ}(d^*)$ - the maximum level implied by the extra emissions quota strategy - can generally be attracted to join the treaty at lower cost to IC by means of the financial transfer strategy in so far as

Both of these points are illustrated in Figure 3[16]. Evaluated at the maximum quota IC would concede to DC in order to attract its participation (as measured by $d^{*}\hat{e}^{\circ}_{DC}$), the financial transfer strategy can induce a DC with risk-aversion given by $r^{FT}\left(d^{*}\right)$ as opposed to the maximum level implied by the extra emissions quota strategy, namely $r^{EQ}\left(d^{*}\right)$.

Also, due to the differences in the steepness of the participation constraints implies by each strategy, the financial strategy can induce a DC at lower cost to IC for each degree of risk-aversion below $r^{EQ}\left(d^{*}\right)$.

Figure 3. Relative effectiveness of negotiation strategies



Taken together, this implies that linking financial transfers with an initial quota allocation which implies zero expected net cost to DC, is likely to prove more powerful in inducing DC's participation. It thereby dominates extra emissions quotas as the cost-minimising IC's negotiation strategy.

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[16] Without loss of generality, the figure illustrates the participation constraints that obtain when c=d. Thus, the initial quota to DC which equals its BAU-level yields the maximum level of r consistent with DC agreeing to join the treaty.

5. Concluding remarks

The objective of the paper has been to investigate the prospect for a tradable quota treaty between industrialised countries, committed to aggregate emissions reductions, and individually rational and risk-averse developing countries. This discussion commands policy relevance in as much as the reduction of global emissions of greenhouse gases necessitates limits on emissions in developing countries. A concerted real-life effort to reduce the risk for climate change may therefore take the form of an international tradable quota treaty involving both industrialised and developing countries.

However, negotiations concerning such an agreement probably will be affected by uncertainty concerning the parties marginal abatement costs.

Summing up, in this paper

1. The underlying marginal abatement cost uncertainty has been modelled as stochastic quota prices and a random market-clearing emissions level. The moments of the probability distributions of these variables are considered common knowledge by the negotiating parties. Together with assumed linear marginal abatement costs, these assumptions facilitate an evaluation of the range of negotiable initial quota allocations in terms of the implied stochastic net cost.

2. An analytical focal point is the initial quota allocation that implies zero net cost and thereby exact financial compensation to the developing country DC. First, this particular allocation represents the least cost to the industrialised country IC at which DC might be attracted to join the treaty. Second, it is shown to minimise the variance of the implied net costs to the risk-averse DC. Nonetheless, it is precisely DC's risk-aversion that renders this quota insufficient to attract its participation in a treaty.

3. Being committed to establishing a treaty, IC considers compensating for uncertainty by means of either extra emissions quotas, or linking financial transfers with an initial quota allocation that implies zero expected cost to DC. The analysis has shown the latter alternative to be more effective in terms of inducing DC participate in the treaty. First, at equal cost to industrialised countries, financial transfers can be implemented to attract a more risk-averse DC than may be achieved with extra emissions quotas. Second, a DC with a specific degree of risk-aversion can be induced to join

the treaty at comparatively lower cost to the industrialised countries *via* the financial transfer strategy.

4. However, both the financial transfer and the extra emissions quota strategy implies a maximum degree of risk-aversion consistent with developing countries agreeing to join the treaty. In this sense the existence of risk-aversion restricts the scope for an international tradable quota treaty.

References

Barrett, S. (1992a): Convention on Climate Change. Economic Aspects of Negotiations, OECD, Paris.

Barrett, S. (1992b): Acceptable' Allocations of Tradeable Carbon Emission Entitlements in a Global Warming Treaty, in Combating Global Warming, UNCTAD, New York.

Barrett, S. (1998): On the Theory and Diplomacy of Environmental Treaty-Making, *Environmental and Resource Economics* **11,** 3-4, 317-333.

Bohm, P. (1992). Distributional Implications of Allowing International Trade in CO_2 Emission Quotas, *The World Economy* **15**, 1, 107-114.

Bohm, P. and B. Larsen (1994): Fairness in a Tradeable-Permit Treaty for Carbon Emissions Reductions in Europe and the former Soviet Union, *Environmental and Resource Economics* **4**, 219-239.

Bohm, P., 1995, An Analytical Approach to Evaluating the National Net Costs of a Global System of Tradeable Carbon Emission Entitlements, UNCTAD, Geneva.

Bohm, P. (1997a): Joint Implementation as Emission Quota Trade: An Experiment Among Four Nordic Countries, Nord 1997:4, Nordic Council of Ministers, Copenhagen.

Bohm, P. (1997b): Are Tradable Carbon Emission Quotas Internationally Acceptable? An Inquiry with Diplomats as Country Representatives, Nord 1997:8, Nordic Council of Ministers, Copenhagen.

Bohm, P. (1998): Compensation for uncertainty - efficient approaches to making international emissions trading attractive to non-rich countries, Working Paper, Department of Economics, Stockholm University.

Carraro, C. and D. Siniscalco (1992): The international dimension of environmental policy, *European Economic Review* **36**, 379-387.

Carraro, C. and D. Siniscalco (1993): Strategies for the International Protection of the Environment, *Journal of Public Economics* **52**, 309-28.

Gilles, R. and T. Tazdaid (1996): International Bargaining in the Presence of Global Environmental Change, *Environmental and Resource Economics* **40**, 271-286.

Hoel, M. (1993): Cost-effective and Efficient International Environmental Agreements, *International Challenges* **13**, no. 2.

Hoel, M. (1994): Efficient Climate Policy in the Presence of Free Riders, *Journal of Environmental Economics and Management* **27**, 259-274.

Hughes Hallett, A.J. (1994a): Policy Options for Stabilizing Earnings in a Speculative Market: A Structural Analysis, *World Development* **22**, 11, 1717-1728.

Hughes Hallett, A.J. (1994b): "Stabilizing Earnings in a Speculative Market: Production Controls Versus Price Stabilization", in eds.: D. Sapsford and W. Morgan, *The Economics of Primary Commodities*, Edward Elgar.

Intergovernmental Panel on Climate Change (IPCC) (1996): *Climate Change 1995. Economic and Social Dimensions of Climate Change*, Cambridge University Press.

Montgomery, D. (1972): Markets in Licenses and Efficient Pollution Control Programs, *Journal of Economic Theory* **5**, 395-418.

Rose, A. and T. Tietenberg (1993): An International System of Tradeable CO_2 Entitlements: Implications for Economic Development, *Journal of Environment and Development* **2**, 1-36.

Underdal, A. (1992): Leadership in International Environmental Negotiations: Designing Feasible Solutions, Working Paper 1992:8, Center for International Climate and Energy Research, University of Oslo.

Varian, H. (1992): *Microeconomic Analysis*, W.W. Norton & Co., New York and London.