The dynamic effect of investment on bargaining positions. Is there a hold-up problem in international agreements on climate change?

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Abstract

This paper presents a theory of international agreements on climate change in which these agreements are viewed as incomplete contracts. It seeks to analyze the dynamic effects of investment by firms on the bargaining power of states in global negotiations on emissions reductions. The existing literature has identified the presence of a hold-up problem in international agreements. In our setting, the public good nature of the problem and the non verifiability of investment levels causes an over-investment by firms compared to the first best investment level under a complete contract. Firms anticipate that their country will agree to a Nash bargaining solution. This paper contributes to the hold up literature. Such a framework has not been used so far to analyze the dynamic properties of investment in the context of climate change agreements.

1 Introduction

This paper presents a theory of international agreements on climate change in which these agreements are viewed as incomplete contracts. It seeks to analyze the dynamic effects of investment on the bargaining power of states in global negotiations on emissions reductions.

The international negotiations on this issue within the framework of the UNFCCC have agreed that targets of greenhouse gases abatements are to be renegotiated. The first negotiation yielded the Kyoto Protocol and targets for its signatories to be reached by 2008-2012; negotiations will soon start on the targets to be reached for the second "commitment period". The result of these renegotiations is clearly uncertain.

However, when investments are made by firms to reduce the cost of abating emissions, they have a long term effect, well beyond the first commitment period.

We aim in this paper to understand the effect of these investments on future negotiations, and more specifically on the bargaining position of countries. The existing literature has identified the presence of a hold-up problem in international agreements. The hold-up problem has been described at length in the literature (Williamson 1985, Grossman and Hart 1986, Hart and Moore, 1988). McLaren (1997) analyses the context of trade policies: firms in a country might anticipate future negotiations in favor of free trade and invest accordingly e.g. by making irreversible investments in the export industry. Firms in this context act as decentralized agents and will reduce the flexibility of the country when it later needs to negotiate. By having a modified outside option, the country is shown to be strategically disadvantaged by its firms previous investments. A country's government would hence benefit from committing never to negotiate on free trade in order to solve the hold-up problem. A similar type of argument is derived by Wallner (2003) for EU enlargement and allows to revalue the welfare effects of EU membership. Because of the incompleteness of contracts,the surplus enhancement made by a country's firms investments will be shared through a transfer, reducing the benefit to the investing country. We differ however from this literature in that we analyze a public good where both parties make an specific investment.

This particularity has a important effect on the results and rather than identifying a hold-up problem, we show there will be overinvestment compared to the first best investment level when firms anticipate a Nash bargained agreement. In this sense this paper contributes to the hold up literature. Such a framework has to our knowledge not been used to analyze the dynamic properties of investment in the context of climate change agreements.

A hold-up problem was identified by Gersbach and Glazer (1999) for a government seeking to reduce emissions within the boundaries of its country. These authors show that marketable emission permits solve the hold-up problem and induce firms to invest in a Pareto efficient manner. Although we replicate this result in the present paper, the hold-up problem we seek to investigate is of a different nature as it involves more than one country and international negotiations.

In the next section, we present our two countries-two period model. We solve by backward induction under different assumptions. We contrast the choice of regulation versus marketable emission permits, both within countries and across borders. This allows us to replicate the result of Gersbach and Glazer (1999) and to therefore rule out the choice by governments of regulation. We also compare the non cooperative and fully cooperative outcomes. This then allows us to derive the resulting incomplete contract that will arise if investment is assumed to be non verifiable and that a contract can not be made contingent on it. Our main result is derived and we show that there will be overinvestment by firms who assume a Nash bargained outcome.

In section 3, we briefly point out to the explanations for our result and identify future extensions and checks to be done. Section 4 concludes.

2 The Model

2.1 Setting

The setting is that of two countries, Home and Foreign which share a public good: greenhouse gases abatement, $M^W = M + M^*.(M \geq 0, M^* \geq 0)$.

Reducing GHG's emissions, reduces climate change and increases social welfare by $a(M + M^*)$ at Home and $a^*(M + M^*)$ in Foreign.. Apart for their different preferences for the public good when $a \neq a^*$, the two countries are symmetric. Firms in each country bear the cost of reducing emissions.

The timeline is represented in Figure (1).

There are n firms in each country. At time 0, each firm can choose to invest in long term reductions of marginal cost of abatement. This investment is denoted by k_i and costs $m(k_i)$ for each firm i. For example, they build wind power capacity, build a cleaner energy generation plant, invest in R&D for hydrogen cars. It is assumed that this investment is irreversible, and therefore sunk. At

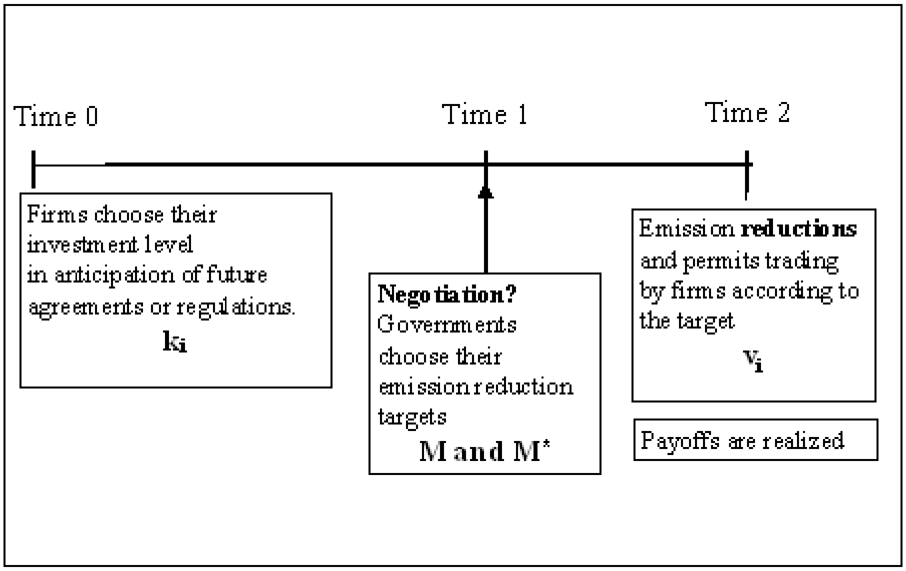

Figure 1:

time 1, each country decides on the level of emission reduction M or M^* it wants to achieve. It divides the burden among all firms. At that point, the country can either enter an international agreement, or act selfishly. It may also decide to implement an emission permits trading system within its borders, or even internationally. Alternatively a country may simply choose to impose a regulation or a tax.

At time 2, the firms need to meet the regulation or fill the emission permits quota they were allocated. The cost of emission reductions for firm i is a function $C(v_i, k_i)$ of v_i, the reductions achieved by this firm, and k_i, the investment it made at time 0 to reduce the cost of abatement. Payoffs are then realized. There is no discounting.

If investments were verifiable and contractible, there could be a complete contract between countries specifying the optimal level of investment to be made in each country. However, in an international context this is hard to imagine. On top of the issue of verifiability, there is also a question of enforcement. We are hence in the context of an incomplete contract. Once investments have been made and given that they are irreversible, the countries can renegotiate the division of surplus created by choosing to cooperate over the level of abatement by each country. Transfers can be made between countries to encourage them to cooperate. These transfers can be induced by the choice of international permits quotas.. Ex ante, each firm will choose investment to maximize its profit by anticipating which scenario will occur: non cooperation, total cooperation or Nash bargaining. The equilibrium level of abatement and of investment is then inefficiently chosen.

Social welfare at Home is denoted the following way:

$$W = a(M + M^*) - \sum_{i=1}^{n} C(v_i, k_i) - \sum_{i=1}^{n} m(k_i) \tag{1}$$

In Foreign:

$$W^* = a^*(M + M^*) - \sum_{i=1}^{n} C(v_i^*, k_i^*) - \sum_{i=1}^{n} m(k_i^*) \tag{2}$$

We choose the following functional forms.

- $C(v_i, k_i) = \dfrac{v_i^2}{2k_i}$

The cost of reducing emissions is symmetric across all firms in both countries. It is increasing in the level of reductions and we make the hypothesis of an increasing marginal cost of reduction ($\frac{\partial C(v_i,k_i)}{\partial v_i} > 0, \frac{\partial^2 C(v_i,k_i)}{\partial v_i^2} > 0$). The cost of reducing emissions is decreasing in the level of prior investment, but at a decreasing rate ($\frac{\partial C(v_i,k_i)}{\partial k_i} < 0, \frac{\partial^2 C(v_i,k_i)}{\partial k_i^2} > 0$).

- $m(k_i) = k_i^2$

Finally, the cost of the investment is assumed to be quadratic.

We solve the model by backward induction.

2.2 At time 2

2.2.1 With no permits trading

Assume at first that governments do not allow for trading. Each firm must abate by the amount it is assigned to by regulation. In this case, the behavior of firms at time 2 is determined by the governments target. We assume that as firms are symmetric, the government will assign equal amounts to each firm. The cost for firm i to meet the target will be:

$$C(v_i, k_i) = \frac{M^2}{2n^2 k_i} \tag{3}$$

The aggregate cost for each country to meet the target it has chosen will thus be:

$$\sum_{i=1}^{n} C(v_i, k_i) = \frac{M^2}{2n^2} \sum_{i=1}^{n} \frac{1}{k_i} \tag{4}$$

$$\sum_{i=1}^{n} C(v_i^*, k_i^*) = \frac{{M^*}^2}{2n^2} \sum_{i=1}^{n} \frac{1}{k_i^*} \tag{5}$$

We will later consider the implications of this result on the choices of targets by the government and hence on firms' incentives to invest.

2.2.2 With permits trading within each country, but no cross country trading

We here consider the case where both countries allow for firms to trade permits within their boundaries. This will occur at price p. Also, quotas have been divided equally across firms, such that each one received a fraction n of the total abatement target M fixed by the government in time 1.

Hence, the maximization problem for firm i at Home is:

$$Max_{v_i} \pi_i = p[v_i - \frac{M}{n}] - \frac{v_i^2}{2k_i} \tag{6}$$

The firm maximizes its profit which is composed of the revenue of sales of permits minus the cost of reducing emissions, $C(v_i, k_i)$. A firm may sell at price p any abatement it has made in excess of its quota $\frac{M}{n}$, which is $[v_i - \frac{M}{n}]$. If it reduces less than its quota ($v_i < \frac{M}{n}$), it will have to buy permits at price p and this will affect negatively its profits.

The first order condition of this maximization problem is:

$$v_i = pk_i \tag{7}$$

The market clearing condition dictates that total emission reductions within the country must be equal to the total amount of quotas, the target chosen by government at time 1.

$$\sum_{i=1}^{n} v_i = M \tag{8}$$

This allows us to derive the equilibrium price:

$$p = \frac{M}{\sum_{i=1}^{n} k_i}$$

This implies that the total revenue for firm i at time 2 is:

$$\begin{aligned} \pi_i &= \frac{M}{\sum_{i=1}^{n} k_i}\left(\frac{Mk_i}{\sum_{i=1}^{n} k_i} - \frac{M}{n}\right) - \frac{M^2 k_i}{2\left(\sum_{i=1}^{n} k_i\right)^2} \\ &= \frac{M^2 k_i}{2\left(\sum_{i=1}^{n} k_i\right)^2} - \frac{M^2}{n\sum_{i=1}^{n} k_i} \end{aligned} \tag{9}$$

In the aggregate, the revenue of permits sales and costs of permits purchase will cancel out, such that the total cost for all n firms in Home to meet the government's target M when there are intra country permits is:

$$\sum_{i=1}^{n} C(v_i, k_i) = \frac{M^2}{2\left(\sum_{i=1}^{n} k_i\right)} \tag{10}$$

Given the symmetry of both countries, we can derive the same results for foreign, such that the total cost for all n firms in Foreign to meet the government's target M^* is:

$$\sum_{i=1}^{n} C(v_i^*, k_i^*) = \frac{M^{*2}}{2\left(\sum_{i=1}^{n} k_i^*\right)} \tag{11}$$

These both equations will be necessary to derive the behavior of countries at time 1 and of firms at time 0.

2.2.3 With permits inter and intra countries

We here consider the case where countries would have agreed at time 1 to allow for cross border permits trading.

The maximization problem for firm i at Home is the same and leads to the same first order condition as in equations 6 and 7:

$$v_i = pk_i \tag{12}$$

Identically in Foreign:

$$v_i = pk_i^* \tag{13}$$

where p is the international price.

Given that firms can now trade across borders, the market clearing condition equates total world emission reductions and total world targets by governments as denoted in equation 14.

$$\sum_{i=1}^{n} v_i + \sum_{i=1}^{n} v_i^* = M + M^* \tag{14}$$

The international price for permits will thus be:

$$p = \frac{(M + M^*)}{\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)} \tag{15}$$

In parallel with equation 9, we derive the total revenue for firm i at time 2 when there are both inter and intra permits trading.

$$\pi_i = \frac{(M + M^*)^2 k_i}{2\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)^2} - \frac{(M + M^*) M}{n\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)} \tag{16}$$

This implies that the aggregate cost for all n firms in Home to meet the government's target M is:

$$\sum_{i=1}^{n} C(v_i, k_i) = \frac{(M + M^*) M}{\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)} - \frac{(M + M^*)^2 \sum_{i=1}^{n} k_i}{2\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)^2} \tag{17}$$

The same applies to Foreign where the aggregate cost for all n firms in Foreign is:

$$\sum_{i=1}^{n} C(v_i^*, k_i^*) = \frac{(M + M^*) M^*}{\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)} - \frac{(M + M^*)^2 \sum_{i=1}^{n} k_i^*}{2\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)^2} \tag{18}$$

And total cost for Foreign and Home firms is:

$$\sum_{i=1}^{n} C(v_i, k_i) + \sum_{i=1}^{n} C(v_i^*, k_i^*) = \frac{(M + M^*)^2}{2\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)} \tag{19}$$

This will allow us to compare the effect of the decision by governments to allow for cross border trading.

2.3 At time 1

In this section we will compute the different possible scenarios of governmental decision in both countries. We can assume no cooperation at all, or at the other extreme, full cooperation. If however, a complete contract enabling full cooperation to be sustained is not feasible, we assume there will be Nash bargaining.

In each of these three possibilities, we also consider the choice of implementing permits trading schemes.

2.3.1 The non cooperative case

We now describe the decision of each government on M and M^* . We first assume that a government cannot implement a permits scheme, but may credibly impose a regulation forcing firms to reduce their emissions by a given amount.

With no permits trading Given equation 4, the government maximizes social welfare. The cost of investment by firms at time 0 is sunk and is thus not taken into account.

$$Max_M a\left(M+M^*\right)-\frac{M^2}{2n^2}\left(\sum_{i=1}^{n}\frac{1}{k_i}\right) \tag{20}$$

The resulting first order conditions and the choice of target when there is no cooperation, and no permits (NCNP), will be symmetric in each country. At Home:

$$M^{NCNP}=\frac{an^2}{\left(\sum_{i=1}^{n}\frac{1}{k_i}\right)} \tag{21}$$

and in Foreign:

$$M^{NCNP*}=\frac{a^*n^2}{\left(\sum_{i=1}^{n}\frac{1}{k_i^*}\right)} \tag{22}$$

With intra Home and intra Foreign permits: Now consider the case where intra country, but not inter country permits trading is allowed. Indeed if we assume that countries are not cooperating when fixing their target, it would be a strong assumption to have them trading permits. At Home, the government maximizes social welfare. Investments of time 0 are sunk and irreversible such that government maximizes welfare achieved from the target minus the cost of reaching that target when it allows for intra firm permits trading (as derived in section 2.2.2 in equation 10):

$$Max_M a\left(M+M^*\right)-\frac{M^2}{2\left(\sum_{i=1}^n k_i\right)} \tag{23}$$

The first order condition thus dictates the optimal choice of target for the non cooperative government to be:

$$M^{NCP}=a\sum_{i=1}^n k_i \tag{24}$$

Similarly, in Foreign, the government will choose its target as a function of the aggregate sunk investment made by firms at time 0.

$$M^{NCP*}=a^*\sum_{i=1}^n k_i^* \tag{25}$$

One may then derive the social welfare levels for each country implied by a non-cooperative outcome at time 1. The cost of investment at time 0 is not accounted for given that it is sunk.

$$V^{NCP}=\frac{a\sum_{i=1}^n k_i}{2}+aa^*\left(\sum_{i=1}^n k_i^*\right) \tag{26}$$

$$V^{NCP*}=\frac{a^*\sum_{i=1}^n k_i^*}{2}+aa^*\left(\sum_{i=1}^n k_i\right) \tag{27}$$

This measure is important as it constitutes the outside option for the government if it implements permits.

2.3.2 Cooperative case

We now consider the case where a complete contract is implementable and investment can be verified. This means that an agreement between countries can be made contingent on the realized investments. Thereafter, the targets M and M^* or an international permits market are assumed to be enforceable by an international body. We consider the three cases of permits implementation.

With no permits We start by assuming that although countries coordinate their choice of targets, they do not implement any permits trading system. Firms will thus face the cost of reducing their emissions by exactly the amount they are obliged to by regulation, as given by equation 4. The maximization problem of governments when choosing their targets is:

$$Max_{M^{FNP},M^{FNP*}}(a+a^*)(M^{FNP}+M^{FNP*}) \\ -\frac{M^{FNP^2}}{2n^2}\left(\sum_{i=1}^{n}\frac{1}{k_i}\right)-\frac{M^{FNP*^2}}{2n^2}\left(\sum_{i=1}^{n}\frac{1}{k_i^*}\right) \quad (28)$$

The resulting targets are:

$$M^{FNP}=\frac{(a+a^*)n^2}{\left(\sum_{i=1}^{n}\frac{1}{k_i}\right)} \quad (29)$$

$$M^{FNP*}=\frac{(a+a^*)n^2}{\left(\sum_{i=1}^{n}\frac{1}{k_i^*}\right)} \quad (30)$$

However, at this point we need to clarify the no permits case. As we can see in equations 21-22 and 29-30, both in the non cooperative and cooperative case, targets will be a function of the aggregate investment by firms. Hence when firms invest at time 0, they will anticipate that to minimize their future costs they should invest nothing. This is the hold-up problem identified by Gersbach and Glazer (1999) in a one country setting. In that case it would be extremely costly for the government to remain committed to its regulation. The only way to induce firms to invest would be to commit to a strong penalty for not meeting the regulation. However, these authors consider that the government is unable to commit to the stringency of the regulation. By making the same assumption, we here replicate their result. By assuming that the government can, on the contrary to regulation, commit to issue marketable permits they show that the hold-up problem they have identified can be solved. We will explain this below.

Note that the hold-up problem we referred to earlier is of a different nature as it occurs through the bargaining position effect of investment. Given that Gersbach and Glazer operate in a one country set-up, they did not consider this type of issue.

With intra country permits: If countries act as one, they choose the first best targets by maximizing joint total social welfare.

$$Max_{M^{FP},M^{FP*}}(a+a^*)(M^{FP}+M^{FP*}) - \frac{(M^{FP})^2}{2\left(\sum_{i=1}^{n} k_i\right)} - \frac{(M^{FP*})^2}{2\left(\sum_{i=1}^{n} k*_i\right)} \quad (31)$$

The first order conditions confirm that each country takes into account the externality of its emissions reductions on the other country's welfare. Each target is thus a function of both preference parameters a and a^* and of the aggregate investment of firms. This result is an application of the Coase theorem, leading to an efficient outcome where the sum of the marginal benefits from reducing emissions in each country is equal to the marginal cost.

With the specified functional forms, the first best with permits (FB) targets will be:

$$M^{FP} = (a+a^*)\left(\sum_{i=1}^{n} k_i\right) \quad (32)$$

$$M^{FP*} = (a+a^*)\left(\sum_{i=1}^{n} k_i^*\right) \quad (33)$$

The targets chosen to maximize joint social welfare are a function of respective investment levels and the preferences of each country. This is an important feature of the complete contract case, and confirms the importance of the investment level being verifiable by a third party. The freeriding problem is overcome here by a contract being verifiable by a third party.

This implies welfare levels, taking the investment as sunk are the following:

$$V^{FP} = a(a+a^*)\sum_{i=1}^{n} k_i^* + \left(\frac{a^2 - {a^*}^2}{2}\right)\sum_{i=1}^{n} k_i \quad (34)$$

$$V^{FP*} = a^*(a+a^*)\sum_{i=1}^{n} k_i + \left(\frac{{a^*}^2 - a^2}{2}\right)\sum_{i=1}^{n} k_i^* \quad (35)$$

We complete here our discussion related to Gersbach and Glazer (1999). We can now see that if the government can commit to issuing permits it will induce firms to invest. Indeed, if firms acted cooperatively, they could collude, invest nothing and make sure that the government issues no permits, as given by equations 24-25 and 32-33. However, we assume that firms do not cooperate. If one firm deviates and decides to invest, it will induce the government at time 1 to issue permits. If the firm is the only one to have invested, it will sell permits at $p = a$ and make a profit. In equilibrium, all firms will hence have an incentive to invest as will shall see in section 2.4.

With inter and intra country permits: We proceed to the same analysis but now assume that countries agree to make their emission permits transferable across borders. The total expected cost for firms is then characterized at Home by equation 17. The maximization of joint social welfare then takes the following form:

$$Max_{M^{FTP},M^{FTP*}}(a+a^*)(M^{FTP}+M^{FTP*})-\frac{\left(M^{FTP}+M^{FTP*}\right)^2}{2\left(\sum_{i=1}^n k_i+\sum_{i=1}^n k_i^*\right)} \quad (36)$$

The first order condition expressed in equation 37 does not pin down a particular value for each target, but rather an optimal total value of targets. This occurs because the presence of international permits implies that the first best allocation of costs will occur naturally through the market and that only the aggregate level of reductions affects welfare. The total emission reductions target needed to reach first best can be allocated to each country indifferently, given that permits will ensure that this target is achieved at least cost by equating marginal costs across countries. The first best targets with "total permits" (FTP) are given in equation 37.

$$(M^{FTP}+M^{FTP*})=(a+a^*)\left(\sum_{i=1}^n k_i+\sum_{i=1}^n k_i^*\right) \quad (37)$$

We assume that the allocation of particular targets will be the result of a bargaining process between the two governments: although the total reductions are chosen optimally, the burden of the cost does vary with this allocation. The solution is thus indetermined. One possible that social welfare levels are identical to the case where permits cannot be traded across borders, as given in equations 34 and 35:

$$V^{FTP}=V^{FP} \quad (38)$$

$$V^{FTP*}=V^{FP*} \quad (39)$$

We have thus shown in this section that inter country permits, when governments have equal bargaining power, do not affect social welfare as compared to the case with "intra country" permits.

2.3.3 The Bargaining case

We have assumed that investments are non-verifiable. If they were, an agreement could be made before time 0, which would lead to the total cooperation first best case. Targets would be set in advance through a complete contract and would be made contingent on investment levels.

Given that investments are non-verifiable, countries are bound to "renegotiate" or rather in this case negotiate at time 1. We assume that social welfare is transferable such that the negotiation, based on the bargaining power of each country, will devise a transfer that ensure participation of both countries in the agreement. The surplus of cooperation versus non cooperation will be shared according to a Nash bargaining process.

The transfer must be agreed upon in order to make each country at least as well off in the agreement as in its outside option where it would act non-cooperatively and free-ride. At time 1, when the countries negotiate, they take as given the investment levels of their firms. The investments are assumed to be irreversible, otherwise there would be no benefit of negotiation.

We consider the different permit markets that might be implemented. As stated earlier, we now rule out the possibility of simple regulation without permits.

With inter country permits in non cooperation and (inter and) intra country permits in cooperation Given the public nature of the good, cooperation is Pareto superior to non cooperation. We can show this by calculating the surplus of cooperation over non cooperation for each country.

For Home, we substract social welfare under no cooperation (as given by equation 26) from social welfare under full cooperation with permits (inter and intra or intra only) (equation 34) and obtain the surplus:

$$S = a^2 \sum_{i=1}^{n} k_i^* - \frac{{a^*}^2}{2} \sum_{i=1}^{n} k_i \tag{40}$$

Symmetrically, the surplus for Foreign:

$$S^* = {a^*}^2 \sum_{i=1}^{n} k_i - \frac{a^2}{2} \sum_{i=1}^{n} k_i^* \tag{41}$$

These results confirm that total surplus is always positive. Note also that each country's surplus is increasing in the other country's aggregate investment and decreasing in its own. This is due to the public good nature of the problem.

$$S^T = \frac{{a^*}^2}{2}\sum_{i=1}^{n} k_i + \frac{a^2}{2}\sum_{i=1}^{n} k_i^* > 0 \tag{42}$$

Assuming equal bargaining power, the Nash maximand will be maximized in order to derive the transfer needed from Home to Foreign to ensure participation in the agreement.

$$Max_t (V^{FP} - t - V^{NCP})^{\frac{1}{2}} (V^{FP*} + t - V^{NCP*})^{\frac{1}{2}} \tag{43}$$

The first order condition of this maximization problem yields the equilibrium transfer under this incomplete contract.

$$t^{TP} = \frac{3}{4}a^2 \sum_{i=1}^{n} k_i^* - \frac{3}{4}{a^*}^2 \sum_{i=1}^{n} k_i \tag{44}$$

Notice that if countries had the same preferences and the same amount of aggregate investment, the transfer would be zero.

As a result of this transfer, social welfare levels under a Nash bargaining agreement (A) will be:

$$V^A = V^{FP} - t = \frac{a^2 + 4aa^*}{4}\sum_{i=1}^{n} k_i^* + \frac{2a^2 + {a^*}^2}{4}\sum_{i=1}^{n} k_i \tag{45}$$

$$V^{A*} = V^{FP*} + t = \frac{{a^*}^2 + 4aa^*}{4}\sum_{i=1}^{n} k_i + \left[\frac{2{a^*}^2 + a^2}{4}\right]\sum_{i=1}^{n} k_i^* \tag{46}$$

Rather than assuming a pure monetary transfer between countries, one might more plausibly consider it as a different allocation of targets $\bar{M}$ and $\bar{M}^*$, where the total reduction of emissions remains first best and where permits are traded across borders.

$$\bar{M} + \bar{M}^* = M^{FP} + M^{FP*} = (a + a^*)\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right) \tag{47}$$

If the transfer was positive, it corresponds to Home having a higher allocated target $\bar{M}$ and Foreign a lower target $\bar{M}^*$ and Home firms having to buy permits from Foreign firms. The social welfare levels must correspond to equations 45 and 46.

$$a(\bar{M} + \bar{M}^*) - \frac{\left(\bar{M} + \bar{M}^*\right)\bar{M}}{\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)} + \frac{\left(\bar{M} + \bar{M}^*\right)^2 \sum_{i=1}^{n} k_i}{2\left(\sum_{i=1}^{n} k_i + \sum_{i=1}^{n} k_i^*\right)^2} = V^A \tag{48}$$

$$a^*(\bar{M}+\bar{M}^*) - \frac{\left(\bar{M}+\bar{M}^*\right)\bar{M}^*}{\left(\sum_{i=1}^n k_i + \sum_{i=1}^n k_i^*\right)} + \frac{\left(\bar{M}+\bar{M}^*\right)^2 \sum_{i=1}^n k_i^*}{2\left(\sum_{i=1}^n k_i + \sum_{i=1}^n k_i^*\right)^2} = V^{A*} \quad (49)$$

This yields as a result:

$$\begin{aligned} \bar{M} &= M^{FP} + \frac{t}{(a+a^*)} \qquad (50) \\ &= \left[(a+a^*) - \frac{3a^{*^2}}{4(a+a^*)}\right]\sum_{i=1}^n k_i + \frac{3a^2}{4(a+a^*)}\sum_{i=1}^n k_i^* \end{aligned}$$

$$\begin{aligned} \bar{M}^* &= M^{FP*} - \frac{t}{(a+a^*)} \qquad (51) \\ &= \left[(a+a^*) - \frac{3a^2}{4(a+a^*)}\right]\sum_{i=1}^n k_i^* + \frac{3a^{*^2}}{4(a+a^*)}\sum_{i=1}^n k_i \end{aligned}$$

Which confirms that if transfers are zero, there is no difference between the first best with permits and the Nash bargained agreement.

Having computed these different cases, we can now briefly make a summary of how each case will involve a different social welfare and cost for firms at Home (Foreign obtains symmetric results).

No cooperation with intra permits: $V^{NCP} = \frac{a\sum_{i=1}^n k_i}{2} + aa^*\left(\sum_{i=1}^n k_i^*\right)$

$M^{NCP} = a\sum_{i=1}^n k_i$

$\pi_i^{NCP} = \frac{M^{NCP^2} k_i}{2\left(\sum_{i=1}^n k_i\right)^2} - \frac{M^{NCP^2}}{n\sum_{i=1}^n k_i}$

$= \frac{a^2 k_i}{2} - \frac{a^2\sum_{i=1}^n k_i}{n}$

First best (Full cooperation) with intra and inter permits: $V^{FP} = a(a+a^*)\sum_{i=1}^n k_i^* + \left(\frac{a^2 - a^{*^2}}{2}\right)\sum_{i=1}^n k_i$

$M^{FP} = (a+a^*)\left(\sum_{i=1}^n k_i\right)$

$\pi_i^{FP} = \frac{(a+a^*)^2 k_i}{2} - \frac{(a+a^*)^2\left(\sum_{i=1}^n k_i\right)}{n}$

Nash Bargaining Agreement with intra and inter permits: $V^A = V^{FP} - t = \frac{a^2+4aa^*}{4}\sum_{i=1}^n k_i^* + \frac{2a^2+{a^*}^2}{4}\sum_{i=1}^n k_i$

$\bar{M} = \left[(a+a^*) - \frac{3{a^*}^2}{4(a+a^*)}\right]\sum_{i=1}^n k_i + \frac{3a^2}{4(a+a^*)}\sum_{i=1}^n k_i^*$

$\pi_i^A = \dfrac{(a+a^*)^2 k_i}{2} - \dfrac{(a+a^*)}{n}\left\{\left[(a+a^*) - \frac{3{a^*}^2}{4(a+a^*)}\right]\sum_{i=1}^n k_i + \frac{3a^2}{4(a+a^*)}\sum_{i=1}^n k_i^*\right\}$

$\pi_i^{A*} = \dfrac{(a+a^*)^2 k_i^*}{2} - \dfrac{(a+a^*)}{n}\left\{\left[(a+a^*) - \frac{3{a^*}^2}{4(a+a^*)}\right]\sum_{i=1}^n k_i^* + \frac{3a^2}{4(a+a^*)}\sum_{i=1}^n k_i\right\}$

We have shown that symmetric results are obtained for Foreign.

We can now go one step further and analyze the investment decisions of firms at time 0.

2.4 At time 0

At time 0, firms decide on their investment. We saw above that if they anticipate a regulation and that the government is not credible in the imposition of a penalty in case of non respect, they will not invest. Besides, this hold-up problem identified Gersbach and Glazer has been showed to be solved by the threat of emission permits to be issued. Such a policy instrument is assumed to be more credible than a regulation. We therefore have assumed the presence of permits, but now extend Gersbach and Glazer's framework by analyzing the investment decisions of firms when they anticipate international agreements.

Firms may anticipate either a no cooperation or a fully cooperative outcome if investment is verifiable and a complete contract can be made between countries. However, we have shown in the previous sections that if investment is non verifiable, a contract cannot be made contingent on its level, and will hence be incomplete. If firms anticipate this, they will invest accordingly.

We now consider the different possible anticipations and their resulting investment decisions.

Non cooperation with permits: If firm i at Home anticipates that its government will not cooperate with Foreign at time 1, but that it will introduce permits within its borders, it will solve the following maximization problem.

$$Max_{k_i} \pi_i^{NCP} - k_i^2 \tag{52}$$

The solution to this problem yields the following investment level by firm i at Home and in Foreign respectively:

$$k_i^{NCP} = \frac{(n-2)a^2}{4n} \quad (53)$$

$$k_i^{NCP*} = \frac{(n-2)a^2}{4n} \quad (54)$$

Cooperation with permits: Optimally, if there were a complete contract, firm i would maximize profits by anticipating that their profit at time 2 will be π_i^{FP}:

$$Max_{k_i}\pi_i^{FP} - k_i^2 \quad (55)$$

The first order conditions yield the efficient levels of investment, where the marginal cost of investment is equal to its marginal benefit. Given the first order conditions of time 1's target choice, this marginal benefit is the decrease in C_i, the cost of reducing emissions, given the expectation of the target :Firms at Home would therefore invest at time 0 an amount k_i^{FP} while those in Foreign will invest k_i^{FP*}.

$$k_i^{FP} = \frac{(n-2)(a+a^*)^2}{4n} \quad (56)$$

$$k_i^{FP*} = \frac{(n-2)(a+a^*)^2}{4n} \quad (57)$$

We see here that firms anticipate that when there is a complete contract, there will be no free riding. Countries will choose their targets by taking into account the effect of their emissions on the other country's welfare (which explains why both a and a^* are in equation 56. They will thus choose higher targets, which imposes a higher responsibility to firms. This gives them an incentive to invest more than when countries do not cooperate.

Given the symmetry of both countries and given they act jointly, they will each invest the same amount. With verifiable investment, and therefore the possibility of writing a complete contract, the investment levels will be Pareto efficient. The presence of a third party able to enforce the agreement allows the optimal provision of the public good to be reached.

Nash bargaining agreement with permits: Finally, we assume that firms anticipate that there will be a Nash bargaining process at time 1. They anticipate that they will receive emission quotas of $\frac{\bar{M}}{n}$ (or equivalently $\frac{M^{FP}}{n}$ and pay a share n of the transfer which is needed to ensure participation in the agreement). This corresponds to a profit at time 2 of π_i^A. The profit maximization problem at time 0 will hence be :

$$Max_{k_i} \pi_i^A - k_i^2 \tag{58}$$

Firm i will choose an investment level of k_i^A (Home) or k_i^{A*} (Foreign)

$$k_i^A = \frac{(n-2)(a+a^*)^2}{4n} + \frac{3a^{*2}}{8n} \tag{59}$$

$$k_i^{A*} = \frac{(n-2)(a+a^*)^2}{4n} + \frac{3a^2}{8n} \tag{60}$$

Comparing all three possible anticipations, we have the following proposition.

Proposition 1 *In the case of a global public good, investment by firms that anticipate no cooperation and freeriding by their country's government will be lower than investment under the first-best (complete contracting) case. In the presence of an incomplete contract, investment will be highest. There is overinvestment.*

$$\begin{aligned} k_i^{AP} &> k_i^{FP} > k_i^{NCP} \\ k_i^{AP*} &> k_i^{FP*} > k_i^{NCP*} \end{aligned} \tag{61}$$

In the next section we attempt to give the intuition of this result and contrast it with the existing literature.

3 Why overinvestment?

The result in proposition 1 contradicts the previous results by McLaren (1997) and Wallner (2003) who demonstrated a hold-up problem whereas we here show there is overinvestment by firms who anticipate a negotiation.

This result is due to the global public good nature of the problem. The benefits from emission reductions in one country also affect the welfare of the other country. On the other hand, the countries are also linked on the costs side by the permits: any investment by a firm in one country affects the permits market in the future and hence the incentives to invest at time 0. As a result, at the point of negotiation, the first best welfare, and the outside option non cooperative welfare are both a function of the investment of both countries. So is the surplus of the agreement where k_i and k_i^* are both in equations 40 and 41. This means that for example, home's investment has a effect on the relative bargaining position of both countries. This is the particularity of a public good setting.

An important mechanism behind our result, is that firms do not anticipate the fact that other firms in the other country are investing. If they would take the other country's investment into account (or if both countries were integrated), they would invest at a first best level. Firms in the first-best limit their investment because it would increase their target more than in the bargained case, in which part of the increase is absorbed by the other country: $\frac{\partial \bar{M}}{\partial k_i} < \frac{\partial M^{FB}}{\partial k_i}$.

Another possible mechanism is that firms overinvest due to the effect their investment has on the targets. They anticipate they will be able to sell permits to firms who have not invested to a larger extent given that the effect of investment on the target is different under the bargained solution.

The overinvestment is caused by the contract incompleteness and is different from a classic freerider problem. If the contract were complete, the presence of a third party capable of enforcing the agreement solves both the overinvestment and the freeriding. In the incomplete contract, the outcome is better than the second best pure freeriding and non cooperative solution, however the unverifiability creates the overinvestment.

4 Conclusion

This paper has developed a model where international agreements are viewed as incomplete contracts. It seeks to understand the dynamic effect of a country's firms investments on the bargaining position of that country at the international level. It hence extends the incomplete contract literature to a new area and innovates by allowing both parties to make a relationship specific investment and by considering the case of a public good. It shows that the results of hold-up in the case of international negotiation depends on the nature of the problem being negotiated and thus differs from McLaren (1997) and Wallner (2003). The result of Gersbach and Glazer (1999) is replicated. Finally, it differs from the public good literature by demonstrating that a strong third party is not sufficient to enforce a first-best provision when verifiability is an issue.

Having introduced the setting, we develop in the first section the model that allows us to contrast the complete agreement first-best equilibrium with the incomplete contract solution. Overinvestment occurs because countries are linked both on the benefit and the cost side. Firms do not take into account when investing that there investment will affect also the other country. Also, they do not anticipate that firms in the other country are also investing.

When linked to the real environmental negotiations within the UNFCCC where targets are meant to be renegotiated periodically, firms are uncertain about their future abatement responsibilities and do not possess the property rights to given levels of control. If they were certain about the future M_k, thy could act optimally and make the appropriate long term investments whose returns are then certain. Hence by prolonging the period between two renegotiations, one reduces the overinvestment and would give an incentive to invest more optimally in the long term.

Extensions to this model should be investigated. We need to understand more profoundly the underlying mechanics that affect the overinvestment results and disentangle the effect of permits versus the global publicness of the good. Also, the model needs to be rewritten in a more general setting in order to verify the general character of our result.

5 Bibliography

References

[1] AGHION, P., DEWATRIPONT, M. and REY, P., "Renegotiation Design with Unverifiable Information", Econometrica, 62(2):257-282, 1994

[2] BARRETT, S., "Self-enforcing International Environmental Agreements", Oxford Economic Papers 46: 878-894, 1994

[3] BATTIGALLI, P. and MAGGI, G., "International Agreements on Product Standars: an incomplete-contracting theory", mimeo, February 2003

[4] BAUMOL, W.J. and OATES, W.E., "The Use of Standards and Prices for Protection of the Environment", Swedish Journal of Economics, 73: 42-54, 1971

[5] BAUMOL, W.J. and OATES, W.E., The Theory of Environmental Policy, Cambridge, England, Cambridge University Press, 1988

[6] BOOM, J.T., "The Effect of Emissions Trade on International Environmental Agreements", Working Paper 00-1, Department of Economics, The Aarhus School of Business, 2000

[7] EUROPEAN COMMISSION, "Proposal for a directive establishing a framework for greehouse gas emissions trading within the European Community", 23 October 2001

[8] GERSBACH, H. and GLAZER, A., "Markets and Regulatory Hold-up Problems", Journal of Environmental Economics and Management, 37:151-164, 1999

[9] GRAFTON, R.Q. and DEVLIN, R.A., "Paying for Pollution - Permits and Charges", Scandinavian Journal of Economics, 98(2): 275-288, 1999

[10] HAHN, R.W., "Market Power and Transferable Property Rights", Quarterly Journal of Economics, 99(4): 753-765, 1996

[11] HARSTAD, B., "Majority Rules and Incentives", Stockholm University, mimeo, 2004

[12] HART, O. and MOORE, J., "Incomplete Contracts and Renegotiation", Econometrica, 56(4):755-785, 1988

[13] HART, O. and MOORE, J., "Foundations of Incomplete Contracts", Review of Economic Studies, 66:115-138, 1999

[14] KERR, S., Global Emissions Trading, Cheltenham, UK, Edward Elgar, 2000

[15] MASKIN, E. and TIROLE, J, "Unforeseen Contingencies and Incomplete Contracts", Review of Economic Studies, 66:83-114, 1999

[16] MCLAREN, J., "Size, Sunk Costs, and Judge Bowker's Objection to Free Trade", American Economic Review, 87(3):400-420, 1997

[17] MONTGOMERY, D.W., "Markets in Licenses and Efficient Pollution Control Programs", Journal of Economic Theory, 5, 395-418, 1972

[18] NASH, J.F., "The Bargaining Problem", Econometrica,18(2):155-162, 1950

[19] PEARCE, D., "Save the Planet: Sell Carbon", World Economics, 1(3): 61-79, 2000

[20] RASUL, I., "Household Bargaining over Fertility: Theory and Evidence from Malaysia", mimeo,University of Chicago, March 2003

[21] TIETENBERG, T., "The tradable permits approach to protecting the commons: what have we learned?", Fondazione Eni Enrico Mattei, Nota di Lavoro 36.2002, June 2002

[22] UNCTAD (T. TIETENBERG ET AL.), "Greehnhouse Gas Emissions Trading: Defining the Principles, Modalities, Rules and Guidelines for Verification, Reporting and Accountability", mimeo available at www.colby.edu/personal/thtieten, August 1998

[23] WALLNER, K., "Specific investments and the EU enlargement", Journal of Public Economics, 87:867-882, 2003