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How does the design of international environmental agreements affect investment in environmentally-friendly technology?

Basak BAYRAMOGLU^{*}

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Abstract

In this paper, we investigate how the design of international environmental agreements (IEAs) affects the incentives for the private sector to invest in environmentally-friendly technology. The givens are a transboundary pollution problem involving two asymmetric countries in terms of benefits arising from global abatement. There is a single polluting firm in each country. We account for two types of IEAs: an agreement based on a uniform standard with transfers

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and an agreement based on differentiated standards without transfers. To carry out this study, we use a two-stage game where the private sector anticipates its irreversible investment given the expected level of abatement standards resulting from future negotiations. Our findings indicate that the implementation of the agreement based on a uniform standard with transfers may be preferable for the two countries, as it creates greater incentives for firms to invest in costly abatement technology. This result arises when this technology's level of the sunk cost of investment is low. If this level is sufficiently high, the implementation of the same agreement is not beneficial to countries, because it takes away the incentive of each firm to invest in new abatement technology. Moreover, this agreement is not able to generate any positive gains for either country through cooperation, thus no country is motivated to cooperate.

Keywords: agreements, standards, transfers, technology adoption, irreversible investment, bargaining, transboundary pollution.

JEL: Q50, C71.

1 Introduction

A study by the Organization for Economic Cooperation and Development (OECD, 2005) points out that “clear and concrete objectives and targets under multilateral environmental agreements (MEAs) create a framework within which the business sector can both align its practices with MEA goals and seize new business opportunities. Some MEAs include clear objectives, e.g., those established under the Montreal and the Kyoto Protocols. Most MEAs, however, have general objectives, which cannot always be easily translated into concrete action by the private sector...” (6). There is a need to design IEAs that incites the business sector to undertake environmentally-friendly action. In this paper, in the context of a transboundary pollution problem

involving two countries, we investigate how the design of IEAs affects investment in environmentally-friendly technology. From this perspective, we account for two types of IEAs: an agreement based on a uniform standard with transfers and an agreement based on differentiated standards without transfers, two types of agreements that have in fact been signed by countries in the past. In an extension, we also account for an agreement based on differentiated standards with transfers (agreement DT).

Firstly, we consider an agreement based on a uniform standard with transfers (UT). A uniform standard is a uniform percentage reduction rate of the emissions in a base year for all countries affected by the environmental problem. Indeed, the majority of IEAs involving transboundary pollution problems are characterized by uniform standards (Hoel (1991), Finus, (2001)). The transfer payments are used to ensure the participation of some countries in the IEA. The Montreal Protocol on Substances that Deplete the Ozone Layer (1987) is an example of a UT. It specifies an emission reduction of CFCs and halons by 20%, by 1998, based on 1986 emission levels. The industrialized countries that agreed to the Montreal Protocol set up the Multilateral Fund in 1990 to help developing countries cover their incremental costs of compliance. We focus on uniform agreements with transfer payments because, as Luken and Grof (2006) have pointed out, it is because there were transfers that the Montreal Protocol worked. The Stockholm Convention on Persistent Organic Pollutants, signed in 2001, is another example of a UT.

Secondly, we investigate an agreement based on differentiated standards without transfers (D). While most transboundary pollution problems are characterized by uniform standards, some negotiations are in fact based on differentiated standards. These agreements specify differentiated percentage reduction rates of the emissions in a base year for different countries. A good example of this is the Oslo Protocol

on Further Reduction of Sulphur Emissions (1994).¹ It is an extension of the 1979 Convention on Long-Range Transboundary Air Pollution. Differentiated standards in this Protocol are indirectly represented by different sulphur emission ceilings (in kt per year) for the year 2010 for different countries: e.g., France, 737 kt; United Kingdom, 980 kt; Bulgaria, 1127 kt.

Many studies have already been carried out to investigate the decision to invest in environmentally-friendly technology at the national level (Arguedas and Hamoudi (2004), Bansal and Gangopadhyay (2005)). Jaffe et al. (2002) have provided a survey of all the literature. More recently, further investigations have been carried out at the international level to focus on either technological change or adoption (Buchholz and Konrad (1994), Golombek and Hoel (2006), Muuls (2004)). Buchholz and Konrad (1994) have studied the choice between two abatement technologies in a two-stage game for two countries.² To our knowledge only Golombek and Hoel (2006) have analyzed the impact of the design of IEAs on the investment in technological change. The authors consider the case of (n) identical countries having (m) number of identical firms each. They mainly compare two types of IEA in the presence of technology spillovers across countries: a tax agreement and a quota agreement. They show that, given the tax agreement, the outcome cannot be a first-best optimum because the level of the technology subsidy for investment in R&D is low. Countries

¹The Kyoto Protocol on Climate Change also includes differentiated standards, however, there is a debate over whether or not it is solely a D or otherwise DT agreement. Chander et al. (2002, p.113) have pointed out that the system of marketable emission permits and the clean development mechanism may very well constitute the equivalent of monetary transfers.

²Buchholz and Konrad (1994) show that it is individually rational for a country to choose a costly abatement technology to increase its bargaining position. This manifests via an increase in the payoff of the country at the threat point. This result arises from two assumptions. First, the investing firm and the government which conducts negotiations are considered as a sole identity. Secondly, the negotiating countries are assumed to be identical. Contrary to that approach, in our model, the country and the firm are decentralized agents in the economy, the choice of abatement technology by firms is endogenous, and the objective of a firm is to minimize its abatement costs. Therefore, in our case, firms always have an incentive to select the technology which reduces its future marginal abatement costs.

have an interest in selecting a low level of subsidy to reduce abatement. Given a quota agreement, this incentive is absent, so that social costs are lower. Contrary to Golombek and Hoel (2006), we do not assume the possibility of technological spillovers across countries. Of greater importance, we do not focus on technological change, but on technological adoption.

Muuls (2004) has studied the dynamic effects of irreversible investment on the bargaining position of countries in global negotiations on climate change. Her study sheds light on the hold-up problem in industrial organization.³ A hold-up problem is a situation where the agent (the firm) must make an initial investment before coming in contact with the principal (the country). The reason behind this situation is that the agent and the principal might only meet once the investment is made (Laffont and Martimort (2002)). In the case of IEAs, a hold-up problem may occur if countries are willing to capture the benefits of their firms—which undertake an investment in new abatement technology—by imposing more stringent international abatement standards on them. By anticipating this, the firms could prefer not to make the initial investment. Given the assumptions made by Muuls (2004), that (i) the governments can commit to issue marketable permits and (ii) there is a single Nash bargained agreement, the hold-up problem does not appear.

In this paper, we investigate what would happen if countries were able to choose the design of their agreements and under which conditions the hold-up problem would appear. To do so, we use a two-stage game with two highly asymmetric countries in terms of their benefits from global abatement: one environmentally-conscious country (ENCC) and a less environmentally-conscious country (LENCC). This terminology is adopted from Petrakis and Xepapadeas (1996). For the sake of simplicity, we assume

³For seminal papers on the hold-up problem, see Klein et al.(1978) and Grossman and Hart (1986). See McLaren (1997) for negotiations on free trade, see Wallner (2003) for an enlarged EU and Gersbach and Glazer (1999) for marketable emission permits.

the existence of a single firm in each country. We first identify the effects of the future (negotiated) levels of abatement standards on the current irreversible investment decisions of firms. Then, we investigate the conditions under which it is beneficial for all countries to implement one of the agreements in order to obtain a higher level of welfare. We show that in the presence of a country which is not very environmentally conscious (LENCC)—which would agree on a very low abatement standard in the negotiations of a differentiated agreement—it is Pareto-improving for the countries to implement a uniform agreement with transfers in the future. In fact, in this case the firm of the LENCC would anticipate such an abatement standard (higher than the one which would prevail in the negotiation of differentiated standards), that it would prefer to invest. This result arises, however, when this technology's level of the sunk cost of investment in new abatement technology is low. In the presence of a high level of sunk cost, the implementation of the uniform agreement removes the incentives to invest both in the LENCC and in the ENCC. The idea is the following: given that the firms have invested in new abatement technology, the negotiated level of the uniform standard will be higher, which is more costly for the firms. By anticipating this, the firms prefer not to invest. It is the fear that the countries will create a hold-up problem that induces the firms not to invest in costly abatement technology. Hence, we show that, contrary to the findings of Muuls (2004), some Nash bargained agreements cannot solve the problems of absence of investment by the private sector.

The article proceeds as follows: section 2 details the model and the timing of the game; section 3 provides the description and the principal results of the game, section 4 sets out some extensions of the model, and section 5 offers some concluding remarks.

2 The model

We posit the context of two countries facing a transboundary pollution problem. To mitigate this pollution problem, these two countries cooperate by taking into account the welfare functions of both. The countries are assumed to be asymmetric in terms of their benefits from global abatement or their degree of exposure to global pollution. We consider an environmentally-conscious country (*ENCC*) (or a country very sensitive to global pollution), and a less environmentally-conscious country (*LENCC*) (or a country less sensitive to global pollution). There is a single firm in each country.⁴ The endogenous choice of the type of agreement by each country results from the outcome of negotiations on different agreements. The negotiated levels of abatement standards are determined by the use of the Nash bargaining solution (Nash (1950)). The comparison of IEAs is carried out on the basis of Pareto criteria. The endogenous choice of abatement technology by firms is determined by the comparison of the abatement costs associated with two different technologies.

Note that this model, with no uncertainty, is one of perfect expectations. This assumption is similar to the rational expectations hypothesis which assumes “that (i) all economic decision units refer to the same image of the future and (ii) the common image of the future is the true image” (Guesnerie (1993), p. 243). In the model developed here, when firms anticipate that a UT agreement will be negotiated in the future, they invest accordingly. Because firms invest as such that their governments negotiate a UT agreement. This is a Pareto optimal solution. When firms anticipate

⁴This assumption, as simple as it is, illustrates the idea that the country and the firm are decentralized agents in the economy. Within our framework, the single firm affects the result of the negotiations by means of its investment decision. The single firm could be thought of as an industrial or agricultural lobby. If we considered the case of multiple firms in a country, we would take into account the market structure of the economy. In addition, for heterogeneous firms, another question could emerge, that is to know which firm(s) in a given country would invest first, and thus pay the sunk cost of investment.

that a D agreement will be negotiated in the future, the firm of the LENCC prefers not to invest. Then, the governments negotiate a D agreement, which is also a Pareto optimal solution. We do not deal with the question entailing the analysis of the formation of anticipations for each firm, as it is well beyond the scope of this paper. We just aim to highlight that the anticipation of the type of agreement leads to investment behavior by firms, which in turn affects the type of the agreement which will be effectively negotiated in the future.

2.1 Agents in the Economy

There are two countries and two firms in this economy, with a single firm in each country.

2.1.1 Countries

The two countries negotiate two agreements: an agreement on a uniform standard with transfers (UT) or an agreement on differentiated standards without transfers (D). More specifically, they bargain over the levels of standards and transfers (A and A^* in agreement D, \bar{A} and t in agreement UT).

The payoff functions (net benefit) of the ENCC and the LENCC are written, respectively, as follows:

$$\begin{aligned} NB(x) &= B(A + A^*) - C(A, x) - t \\ NB^*(x^*) &= \alpha B(A + A^*) - C(A^*, x^*) + t \end{aligned} \quad (1)$$

where A (*resp.* A^*) represents the negotiated level of the abatement standard of the ENCC (*resp.* LENCC) with $A \leq 1$ (*resp.* $A^* \leq 1$), x (*resp.* x^*) is the firm's decision to invest in the ENCC (*resp.* LENCC), expressed in a binary way

$x \in \{0,1\}$, and t are transfer payments between the two countries. The function $C(A,x)$ represents the abatement cost function of the firm in the ENCC, which depends on the negotiated level of the abatement standard, A , and its own decision to invest in new abatement technology, x . The function $B(\cdot)$ is the benefit function from global abatement, with $B'(\cdot) > 0$ and $B''(\cdot) < 0$. The parameter α represents the asymmetry across the countries. Let $0 < \alpha < 1$ such that the LENCC has lower benefits from global abatement than the ENCC. The function $B(\cdot)$ could also be interpreted as a damage function from global pollution, in which case the parameter α would refer to different degrees of damage in the two countries. We use the following quadratic benefit function from global abatement:

$$B(A + A^*) = b(A + A^*) - \frac{d}{2}(A + A^*)^2$$

where $b > 0$, $d > 0$.

This implies that the marginal damage constantly decreases with the level of the total pollution. The use of a quadratic benefit function allows us to take into account the interaction between countries suffering from a global pollutant.

2.1.2 Firms

The firms decide to invest ($x = 1$) or not ($x = 0$) in new abatement technology. Consider a situation where national firms already have access to an old abatement technology which allows them to reduce their pollution. However, the marginal abatement costs associated with this technology are high. These firms also have the possibility of investing in alternative technology which is associated with lower marginal abatement costs. But this initial investment represents some sunk cost. We assume that the firms of both countries have access to the same set of possible abatement

technology.⁵

Concerning the functional forms, we assume that the abatement cost function is increasing and convex in the case of investment in new technology, i.e., $C'(A |_{x=1}) > 0$ and $C''(A |_{x=1}) > 0$. For the sake of simplicity, we use a linear abatement cost function in the case of non-investment, i.e., $C''(A |_{x=0}) = 0$. We could think that early emissions are abated with the conventional technology associated with constant returns to scale in abatement. To further reduce emissions, at a reasonable cost, requires the adoption of the new technology by paying a sunk cost. The existence of a sunk cost in abatement first leads to increasing returns to scale, because of the decrease in the burden of the sunk cost in total costs as long as abatement takes place. After a certain level of abatement, returns to scale become diminishing, as the abatement of the last unit of emissions costs more than that of early units of emissions.

In order to capture this idea, we choose a simple specification for abatement cost functions:

$$\begin{aligned} C(A) &= \frac{A^2}{2} + F & \text{if } x = 1 \\ C(A) &= A & \text{if } x = 0 \end{aligned} \tag{2}$$

where $x = 1$ (*resp.* $x = 0$) represents the decision (*resp.* the absence) of investment

⁵The results of our model do not change if we consider different quadratic and linear abatement cost functions for both firms. In fact, we focus on the situations “incentive uniform standard” and “disincentive uniform standard” in terms of the decisions by the private sector to invest (see Section 3.2). In this case, the only change is that the negotiated uniform standards when only the firm of the ENCC or the LENCC invests are no longer identical. This implies that we should add an additional condition to the conditions of emergence of the two situations “incentive uniform standard” and “disincentive uniform standard.” This will only change the interval of the values of F in which these two situations occur.

in a new abatement technology and F , with $F > 0$, represents the sunk cost of installation of the new technology. These costs can include the acquisition of a new plant and new machines (setup costs), or the hiring and training new engineers. We assume that the marginal abatement costs in the case of investment are lower than those in the absence of investment. This implies that the levels of the abatement standards are lower or equal to 1, $A \leq 1$. This trait is in line with the definition of standards in IEAs as percentage emission reduction rates based on the emission levels in a base year.

2.2 Timing of the Game

A two-stage game within a perfect information environment has been conceived.

Stage 1: The single firm in each country decides whether or not to invest in new abatement technology. There is a time lag between the decision to invest by firms and the negotiation process of governments which is justified by the time it takes to invest in abatement activities that require the training of new engineers, the buying of new machines, and the constructing of new plants.

Stage 2: The countries bargain over the levels of standards and transfers. If this is a D agreement, they negotiate the levels of differentiated standards (A and A^*). If this is a UT agreement, they negotiate the levels of the uniform standard (\bar{A}) and the transfer (t).

Finally, the single firm in each country abates according to the abatement burden imposed by the agreement (i.e., according to what has been negotiated at stage 2 of the game). We implicitly assume that the firm in each country completely complies with these regulations.⁶ This requires the assumption that the governments

⁶Concerning Clean Water Act regulations, Shimshack and Ward (2005) report that 98 % of plants comply with total suspended solids and biochemical oxygen demand regulations during an average

are able to commit to the stringency of a penalty for the firm which does not respect standards.⁷ If the governments could not enforce the abatement standard, the best response of a cost minimizing firm would be not to abate at all, and *ex ante*, not to invest in new abatement technology.

It is worthwhile noting that there is an interaction between stages 1 and 2. The current decisions to invest by the firms affect the levels of abatement standards and transfers that will be negotiated in the future. Likewise, the anticipated levels of abatement standards and transfers that will be negotiated in the future have an impact on the current investment decisions of the firms. This timing of the game leaves the possibility of the emergence of a situation where no firms invest because they anticipate high (future) levels of negotiated abatement standards (a hold-up problem).

It is also important to note that we implicitly assume that the abatement decision of a firm is independent of its decision on production. This property holds for a specific class of clean-up technology called “end-of-pipe” which represents the majority of all abatement technology currently used by firms.⁸

month.

⁷For instance, participating in the system of emissions trading in the European Union is mandatory for some sectors. The system charges 40 euros per tonne of CO₂ for the emissions in excess of the amount stipulated in permits.

⁸Skea (2000) reports that the proportion of end-of-pipe technology in pollution control investment is 80% in Belgium, 82% in Germany and 87% in France.

3 Description and Results of the Game

3.1 Stage 2: Negotiation of the effective levels of abatement standards

At this stage of the game, the two countries negotiate the effective levels of abatement standards and transfers according to the type of IEA. Here, we take into account cooperative behavior between governments in the sense that countries may prefer to improve their payoffs via a cooperative agreement. To analyze the outcome of negotiations, we thus use the Nash bargaining solution as equilibrium. We assume that the two countries have the same negotiation power.⁹

There are three possible situations of investment¹⁰:

- Only the firm of the ENCC invests: $x = 1$ and $x^* = 0$,
- Both firms invest: $x = x^* = 1$, or
- No firm invests: $x = x^* = 0$.

In order to calculate the outcome of negotiations, we must first define the payoff levels at the threat point.

⁹In fact, this assumption does not affect our results. If we posit that each country has a different negotiation power defined by the parameter γ for the ENCC and $(1 - \gamma)$ for the LENCC, the first-order conditions of the programs corresponding to different negotiation situations would not differ. This implies that the expressions of the negotiated abatement standards would be the same as those in the initial case. The only change concerns the share of the gains of cooperation between the two countries, weighted by the value of the parameter γ . But, since the relative negotiation powers of the countries are the same for agreements UT and D, this does not modify the comparison of these agreements.

¹⁰The fourth situation in which only the firm of the LENCC invests, $x = 0$ and $x^* = 1$, is highly impossible. We show this impossibility for a small value of α , in the neighborhood of $\alpha = 0$ (*available on the author's website: Appendix A4*).

3.1.1 Nash Equilibrium

We assume that the countries choose Nash equilibrium strategies when they do not cooperate. At the Nash equilibrium, we implicitly assume that the investment is determined prior to abatement. The objective of the ENCC is to maximize its payoffs, taking the abatement level of the LENCC, A^* , as follows:

$$\begin{aligned} & \underset{A}{Max} [B(A + A^*) - C(A, x)] & (3) \\ & w.r. A \leq 1; A^* \leq 1 \end{aligned}$$

where $B(A + A^*) = b(A + A^*) - \frac{d}{2}(A + A^*)^2$ and, $C(A |_{x=1}) = (\frac{A^2}{2} + F)$ and $C(A |_{x=0}) = A$.

The program of the LENCC is written in a similar way, only its benefit function differs. The first-order condition for the ENCC is: $b - d(A + A^*) > Ax + (1 - x)$. This means that the individual marginal benefits from global abatement exceed the individual marginal abatement costs. In the case where only the firm of the ENCC invests, the levels of abatement at the Nash equilibrium are defined as follows: $\hat{A} = 1$ and $\hat{A}^* = \frac{b}{d} - 1 - \frac{1}{\alpha d}$, because the countries are asymmetric $0 < \alpha < 1$ and the levels of abatement cannot exceed 1. These abatement levels at the Nash equilibrium give us the payoff levels \hat{NB} and \hat{NB}^* at the threat point of the negotiation.

Once the payoffs at the Nash equilibrium are calculated¹¹, we can in turn calculate the outcome of negotiations for the two types of IEAs (an agreement based on differentiated standards without transfers and an agreement based on a uniform standard with transfers) and compare the negotiated abatement levels.

¹¹See Appendix C: *available on the author's website.*

3.1.2 Negotiation

We call A, A^* and \bar{A} respectively the differentiated standard of the ENCC, the differentiated standard of the LENCC, and the uniform standard.

The Nash bargaining solution is as follows:

$$\begin{aligned} & \text{Max}_{A, A^*, t} \left[b(A + A^*) - \frac{d}{2}(A + A^*)^2 - x\left(\frac{A^2}{2} + F\right) - (1 - x)A - t - \hat{N}B \right] \quad (\text{A}) \\ & \left[\alpha b(A + A^*) - \frac{\alpha d}{2}(A + A^*)^2 - x^*\left(\frac{A^{*2}}{2} + F\right) - (1 - x^*)A^* + t - \hat{N}B^* \right] \\ & A \leq 1; A^* \leq 1 \end{aligned}$$

Note that the payoff of each country at the Nash equilibrium depends on the decisions by firms to invest in new abatement technology. This program corresponds to the agreement on differentiated standards with transfers (DT), with the largest number of negotiation variables A, A^*, t .¹² The given agreements, agreements UT and D, imply the following constraints:

Agreement UT: $A = A^* = \bar{A}$.

Agreement D: $t = 0$.

3.1.3 Comparison of the Levels of Negotiated Standards

We compare the negotiated levels of differentiated standards with the negotiated level of the uniform standard.¹³

¹²We study, in an extension, the implications of this agreement (see Section 4).

¹³The first-order conditions indicate that the negotiated abatement levels are independent of the level of sunk cost F . Even though the level of sunk cost has a crucial role in the investment decision of the firms, it does not affect the negotiated abatement levels because, in the timing of the game, the levels of abatement standards and transfers are negotiated after the investment decision of the private sector, and the abatement cost function is additively separable.

Lemma *For very asymmetric countries (a small value of α , in the neighborhood of 0), the ranking of the negotiated levels of abatement standards is the following: $A^* < \bar{A} < A$.*

This lemma¹⁴ shows that for every possible configuration of the choice of investment of the two firms, the level of the uniform standard is situated between the two differentiated standards when the countries are very asymmetric. This result confirms the intuition that the LENCC abates less than the ENCC under the differentiated agreement when the firm of the former does not invest and the firm of the latter invests. Since the uniform standard reflects the preferences of both countries, its level is situated between the two levels of differentiated standards.

The comparison of the levels of the uniform standard obtained from different configurations of investment reveals that $\bar{A}(x = x^* = 1) \geq \bar{A}(x = 1; x^* = 0) \geq \bar{A}(x = x^* = 0)$.¹⁵ This indicates that the uniform standard, when all the firms invest, is superior to or equal to that obtained when only the firm of the ENCC invests and to that obtained when no firm invests. The investment of the firm contributes to an increase in the uniform standard.

3.2 Stage 1: Decision of investment of the firms

The investment choice of the firms is analyzed according to the type of IEA.

3.2.1 Cost condition

The threshold abatement level for which the abatement cost of the firm in the case of investment is identical to the one in the case of non-investment is as follows:

¹⁴The proof of this lemma is available on the author's website: *Appendices A1, A2 and A3*. When no firms invest, $x = x^* = 0$, this result always holds for every value of the parameter α , due to the form of the benefit function assumption.

¹⁵This proof is available on the author's website: *Appendix B*.

$$C(A |_{x=1}) = C(A |_{x=0}) \iff \frac{A^2}{2} + F = A \iff \tilde{A} = 1 - \sqrt{1 - 2F} \quad (5)$$

with $\tilde{A} \leq 1$ and $1 - 2F \geq 0 \iff F \leq \frac{1}{2}$.

Note that the threshold abatement is an increasing and convex function of F . A firm has an interest in investing if the level of sunk cost is sufficiently low ($F \leq 1/2$). More precisely, a firm will have the right incentives to invest in new technology if the *cost condition* is satisfied: $C(A |_{x=1}) < C(A |_{x=0})$. The arguments in this cost condition are the equilibrium values of the abatement standards.

Thus, a firm does not invest if its costs when it invests (with an implied level of the abatement standard) exceed those when it does not invest (with another implied level of the abatement standard). This situation could illustrate the hold-up problem: given that the firms have invested in new abatement technology, the countries agree on higher levels of abatement standards. These high-level standards could make firms worse off compared to a situation of non-investment. Hence the firms might decide not to invest.

3.2.2 Two decision-making situations: “*incentive uniform standard*” and “*disincentive uniform standard*”

We focus on two situations for which the equilibrium is unique. The first situation is the “*incentive uniform standard*” and the second one is the “*disincentive uniform standard*.”

We define an incentive uniform standard (*resp.* a disincentive uniform standard) as the situation in which all the firms first invest (*resp.* no firms invest) because they correctly anticipate that an agreement based on a uniform standard with transfers will be negotiated in the future. Then, the countries negotiate the levels of the uniform

standard and the transfer. Finally, the firms abate according to the obligations of the agreement.

The “incentive uniform standard” (*resp.* “disincentive uniform standard”) is a situation where the implementation of the uniform agreement with transfers gives an incentive (*resp.* takes away the incentive of) to both countries to invest, whereas the implementation of the differentiated agreement without transfers would induce only the ENCC to invest, in which case the implementation of the uniform standard has a higher (*resp.* lower) incentive effect ($x = x^* = 1$) (*resp.* $x = x^* = 0$) than those of differentiated standards ($x = 1$ and $x^* = 0$).

The conditions of existence of the **incentive uniform standard** are the following:

1) The firm in the LENCC does not invest in the agreement based on differentiated standards without transfers. This requires a condition which ensures that it is not beneficial for the firm in the LENCC to deviate, i.e., that it is beneficial for this firm to stick to the decision of non-investment: $C(A^* |_{x=1, x^*=0}) < C(A^* |_{x=x^*=1})$.

2) The firm in the ENCC invests in the agreement on differentiated standards without transfers. This requires a condition which ensures that it is not beneficial for the firm in the ENCC to deviate, i.e., that it is beneficial for this firm to stick to the decision of investment: $C(A |_{x=1, x^*=0}) < C(A |_{x=x^*=0})$.

3) The firms in the ENCC and the LENCC invest in the agreement based on a uniform standard with transfers: $C(\bar{A} |_{x=x^*=1}) < C(\bar{A} |_{x=0, x^*=1})$ for the ENCC, $C(\bar{A} |_{x=x^*=1}) < C(\bar{A} |_{x=1, x^*=0})$ for the LENCC.

The first two conditions of existence of the incentive uniform standard case also hold for the **disincentive uniform standard case**. The following condition allows us to distinguish between the two cases:

3bis) The firms in the ENCC and the LENCC do not invest in the agreement

based on a uniform standard with transfers: $C(\bar{A} |_{x=x^*=0}) < C(\bar{A} |_{x=1, x^*=0})$ for the ENCC, $C(\bar{A} |_{x=x^*=0}) < C(\bar{A} |_{x=0, x^*=1})$ for the LENCC.

In Appendix C, we first define the negotiated levels of standards regarding the investment decisions of firms, when $\alpha = 0$. By continuity, the results still hold in the neighborhood of $\alpha = 0$. We then characterize the conditions of existence of the incentive uniform standard and disincentive uniform standard situations in the case where the parameter α is small, in the neighborhood of 0.¹⁶

3.3 Welfare of Countries

The countries optimally choose the type of IEA. Optimality is defined according to the Pareto concept. This means that the individual welfare of a country in the optimal agreement must exceed the one in the alternative agreement, and the other country must obtain at least the same amount of individual welfare as in the alternative agreement.¹⁷

Proposition *In the case of very asymmetric countries (small α), the implementation of the agreement on a uniform standard with transfers is either:*

A) optimal for each country if the level of sunk cost is sufficiently low (F low) and if the marginal benefits from global abatement are sufficiently high (b high), in which case it is the incentive uniform standard; or

B) not optimal for a higher level of sunk cost (F high), in which case it is the disincentive uniform standard.

¹⁶When the countries are identical ($\alpha = 1$), in fact, the type of IEA does not affect the decisions of the firms to invest, because the levels of differentiated standards are the same, thus the standard is uniform. Furthermore, we know that the national firms have, by definition, the same set of possible abatement technology. Under these givens, the implementation of standards (no matter whether differentiated or uniform) leads either to the absence of investment or to full investment by all the firms, according to the level of sunk cost of investment.

¹⁷Proof is available on the author's website: *Appendix D*.

The proposition of optimal welfare (A) can be explained as follows. In the presence of a low sunk cost of investment, the implementation of the uniform agreement with transfers induces all the firms to invest in new abatement technology, whereas that of the differentiated agreement without transfers induces only the firm of the ENCC to invest. In the presence of a high marginal benefit from global abatement, the implementation of the uniform agreement with transfers, when the two firms invest, provides better levels of gain from cooperation than that of the differentiated agreement without transfers, where only the firm of the ENCC invests. In fact, the existence of a side payment scheme compensates for the additional abatement efforts in the LENCC in the uniform agreement and therefore induces the country to participate in the cooperative agreement.

The proposition of non-optimal welfare (B) can be explained as follows. In the presence of very asymmetric countries, the implementation of the uniform agreement with transfers is not optimal if the level of sunk cost is sufficiently high. For such a level of sunk cost, the implementation of the uniform agreement takes away the incentives of the firm in the ENCC to invest. Moreover, the implementation of this agreement, in the case where no firm invests, is not able to generate positive gains for either country through cooperation.

Our findings as regards Proposition A might at first seem counter intuitive. It is beneficial for very asymmetric countries to implement a UT agreement, if the level of sunk cost is sufficiently low and the level of the marginal benefit from global abatement is sufficiently high. In this case, the implementation of a UT agreement induces the two firms to invest in new abatement technology. Moreover, this agreement is the only one which generates positive gains for each country through cooperation. The Montreal Protocol on Substances that Deplete the Ozone Layer (1987) could, in some ways, illustrate this situation. We could argue that many industrialized coun-

tries which agreed to the protocol invested in new abatement technology¹⁸ because the cost of installation of this technology was lower than the benefit of acceding to the Montreal Protocol.¹⁹ Among other things, these benefits included an increase in the number of newly created jobs and a decrease in the number of deaths due to cancer as well as in the number of both local pollution and global warming problems. Furthermore, the Multilateral Fund covered the incremental costs of developing countries for the implementation of the protocol which induced these countries to abate their emissions.

As regards Proposition B, our findings indicate that the implementation of a UT agreement is no longer beneficial for the countries if the level of sunk cost is sufficiently high. In this case, the implementation of the uniform agreement takes away the incentives of the two firms to invest. The idea is the following: given that the firms have invested in new abatement technology, the negotiated level of the uniform standard will be higher, which is more costly for the firms. By anticipating this, the firms prefer not to invest. It is the fear that the countries will create a hold-up problem that induces the firms not to invest in costly abatement technology. Moreover, the implementation of this agreement is not able to generate positive gains for each country through cooperation. However, if the sunk of investment in new abatement technology is low, to give incentives to get its firm to invest in this technology, it is better for the *less environmentally-conscious country* to negotiate a future agreement based on a uniform standard with a side payment scheme.

In this model, the firms are the driving force behind the investment in environmentally-friendly technology, pushing governments to design agreements accordingly.

¹⁸Luken and Grof (2006, p.4) report that “*production and consumption of CFC’s, halons and other ozone depleting chemicals has been almost completely phased out in industrialized countries.*”

¹⁹As reported by Barrett (2003, p. 229), according to the US Environment Protection Agency’s calculations, “*even a unilateral implementation of the Montreal controls yields a benefit-cost ratio of 65/1.*”

4 Extensions

(1) What in fact do firms do about investing in environmentally-friendly technology? It has been observed that in most cases, countries have first negotiated and then firms have decided to invest or not. It is generally held that firms do not anticipate their investment. However, there has been a recent shift in this trend. In the United States, some firms have been investing in new technology above and beyond the requirements of the Kyoto Protocol the United States government has not signed, for example the June 2008 announcement by General Motors to invest in hybrid cars. Our initial timing of the game reflects this shift in trend. It is however very worthwhile to discuss the implications of an alternative timing induced by inverting the stages of the game: stage 1: the countries negotiate either the UT or D agreement; stage 2: the single firm in each country decides whether to invest or not in new abatement technology. This would be possible if the process of investment in abatement activities were shorter than the one the previous game involved.

Again, we concentrate our attention on the two situations for which equilibrium is unique: the incentive uniform standard and the disincentive uniform standard. Hence, the same set of values of the parameters for each situation is taken into account. The results are then similar. If the D agreement is negotiated in the first place, then only the firm in the ENCC invests. If the UT agreement is negotiated, then the firm in both the ENCC and the LENCC invest in the new abatement technology, if the sunk cost of investment is sufficiently low (incentive uniform standard). It leads to the absence of investment if the sunk cost of investment is sufficiently high (disincentive uniform standard).²⁰ In this case, what changes is that governments

²⁰We have also verified the renegotiation-proofness of the different negotiations that take place in stage 1 of the game. Thus, individual countries do not have an incentive to deviate from a UT agreement, when both firms invest in new abatement technology (incentive uniform standard).

are the driving force behind the investment in environmentally-friendly technology, pushing firms to invest according to *ex ante* negotiated agreement, given that the sunk cost of investment in abatement is sufficiently low.

(2) Agreements based on differentiated standards with transfers are not frequently observed in reality and there is even a lack of consensus when an agreement is labeled as such, as in the case of the Kyoto Protocol (see footnote 1). However, for the sake of thoroughness, a DT agreement should not be overlooked. How would the implementation of the agreement based on differentiated standards with transfers affect the decisions of the firms to invest?

We again focus on the case of very asymmetric countries.²¹ Our findings imply that this agreement could give incentives to both firms to invest, contrary to the agreement based on differentiated standards without transfers. Transfers compensate the abatement efforts of the LENCC, therefore its negotiated abatement standard is now positive. The anticipation of this level of negotiated abatement standard could incite the firm in the LENCC to invest, if the sunk cost of investment is sufficiently low. This condition is defined in Appendix E. When both firms invest, the negotiated differentiated standards turn out to be uniform, and their level is exactly equal to that of the negotiated uniform standard in agreement UT. Since transfers are defined in the same way in both agreements UT and DT, the gains to cooperation are identical in these agreements, when the firms in the ENCC and the LENCC invest. In this case, agreement DT outperforms agreement D, and it is equivalent, in terms of welfare, to agreement UT when both firms invest in new abatement technology.

²¹The expressions of the negotiated abatement levels in the quadratic case are available on the author's website: *Appendix E*.

5 Conclusion

We have shown that the type of IEA may incite firms to invest in new environmentally-friendly technology. This has been achieved through a two-stage game in which firms first anticipate their irreversible investment before two-government negotiations on the environment take place. We have focused on two situations for which equilibrium is unique: the incentive uniform standard and the disincentive uniform standard. Each of these situations correspond to a set of values of the parameters of the model. If firms anticipate that the D agreement will be negotiated in the future, then only the firm in the environmentally conscious country invests in new abatement technology. If firms anticipate that the UT agreement will be negotiated in the future, then both (*resp.* no) firms invest, provided that the level of the sunk cost of investment is sufficiently low (*resp.* high) (incentive uniform standard *resp.* disincentive uniform standard). In this model, the firms are the driving force behind the investment in environmentally-friendly technology, pushing governments to design agreements accordingly. Their actions can lead to either the negotiation of the uniform or the differentiated agreement. Therefore, countries should first give firms enough time to invest in new technology, and then negotiate the levels of the uniform standard and the transfer, given that the sunk cost of investment is sufficiently low.

In this paper, in the case of highly asymmetric countries, we have focused on two situations in terms of decision to invest. A next step would be to investigate all the outcomes for less heterogenous countries.

References

- [1] **Arguedas, C., Hamoudi, H.** (2004): *Controlling pollution with relaxed regulations*, Journal of Regulatory Economics, vol. 26, no.1, 85-104.
- [2] **Bansal, S., Gangopadhyay, S.** (2005): *Incentives for technological development: BAT is bad*, Environmental and Resource Economics, vol. 30, 345-367.
- [3] **Barrett, S.** (2003): *Environment and Statecraft, The Strategy of Environmental Treaty-Making*, Oxford University Press.
- [4] **Buchholz, W., Konrad, K.A.** (1994): *Global environmental problems and the strategic choice of technology*, Journal of Economics, vol. 60, no.3, 299-321.
- [5] **Chander, P., Tulkens, H., van Ypersele, J-P., Williems, S.** (2002): "The Kyoto Protocol: an economic and game-theoretic interpretation", in B.Kristrom, P. Dasgupta and K-G. Lofgren (eds.), *Economic Theory for the Environment, Essays in Honour of Karl-Goran Maler*, Edward Elgar, Cheltenham.
- [6] **Finus, M.** (2001): *Bargaining over a uniform emission reduction quota and a uniform emission tax*, Game Theory and International Environmental Cooperation, Edward Elgar.
- [7] **de la Fuente, A.** (2000): **Mathematical Methods and Models for Economists**, Cambridge University Press, Cambridge.
- [8] **Gersbach, H., Glazer, A.** (1999): *Markets and regulatory hold-up problems*, Journal of Environmental Economics and Management, vol. 37, 151-164.
- [9] **Golombek, R., Hoel, M.** (2006): *Second-best climate agreements and technology policy*, Advances in Economic Analysis&Policy, vol. 6, issue 1, 1-27.

- [10] **Grossman, S.J., Hart, O.D.** (1986): *The costs and benefits of ownership: a theory of vertical and lateral integration*, Journal of Political Economy, vol. 94, no.4, 692-719.
- [11] **Guesnerie, R.** (1993): *Successes and failures in coordinating expectations*, European Economic Review, vol. 37, 243-268.
- [12] **Hoel, M.** (1991): *Global environmental problems: the effects of unilateral actions taken by one country*, Journal of Environmental Economics and Management, vol. 20, 55-70.
- [13] **Jaffe, A., Newell, R.G., Stavins, R.N.** (2002): *Environmental policy and technological change*, Environmental and Resource Economics, vol. 22, 41-69.
- [14] **Klein, B., Crawford, R.G., Alchian, A.A.** (1978): *Vertical integration, appropriable rents, and the competitive contracting process*, Journal of Law and Economics, vol. 21, no.2, 297-326.
- [15] **Laffont, J-J., Martimort, D.** (2002): *The Theory of Incentives, The Principal-Agent Model*, Princeton University Press, Princeton and Oxford.
- [16] **Luken, R., Grof, T.** (2006): *The Montreal Protocol's multilateral fund and sustainable development*, Ecological Economics, vol.56, issue 2, 241-255.
- [17] **McLaren, J.** (1997): *Size, sunk costs, and Judge Bowker's objection to free trade*, The American Economic Review, vol. 87, no.3, 400-420.
- [18] **Muuls, M.** (2004): *The dynamic effect of investment on bargaining positions. Is there a hold-up problem in international agreements on climate change?*, working paper.

- [19] **Nash, J.F.** (1950): *The bargaining problem*, *Econometrica*, vol. 18, 155-162.
- [20] **OECD Workshop on Multilateral Environmental Agreements and Private Investment** (2005): *Multilateral environmental agreements and private investment: workshop proceedings and key messages*, Helsinki.
- [21] **Petrakis, E., Xepapadeas, A.** (1996): *Environmental consciousness and moral hazard in international agreements to protect the environment*, *Journal of Public Economics*, vol. 60, 95-110.
- [22] **Shimshack, J., Ward, M.B.** (2005): *Regulator reputation, enforcement, and environmental compliance*, *Journal of Environmental Economics and Management*, vol. 50, 519-540.
- [23] **Skea, J.** (2000): *Environmental technology*, in *Principles of Environmental and Resource Economics, A guide for students and decisions makers*, Folmer H. and Gabel H.L., Edward Elgar.
- [24] **Wallner, K.** (2003): *Specific investments and the EU enlargement*, *Journal of Public Economics*, vol. 87, 867-882.