Title

EU-California Environmental Agreements: The Role of Trade in Emissions Permits and Escape Clauses

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EU - California Environmental Agreements: the role of trade in emissions permits and escape clauses.

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Abstract

Game theory helps to explain the relation between the structure of multi-national or multi-regional environmental agreements and the success of those agreements. Trade in emissions permits has ambiguous and in some cases surprising effects on both the equilibrium level of abatement, and on the ability to persuade nations or regions to participate in environmental agreements. An escape clause can promote the success of such an agreement, by reducing risk, easing enforcement problems, and most significantly, by providing leverage that encourages participation in the agreement.

Keywords: Kyoto Protocol, escape clause, emissions trade, cost uncertainty, participation game, International Environmental Agreement,.

JEL classification numbers C72, H4, Q54

1 Introduction

California and the EU are considering ways that they might cooperate to reduce aggregate emissions of greenhouse gasses. An agreement between these two regions would have many of the characteristics – and many of the obstacles – of International Environmental Agreements (IEAs) amongst nations. Many papers apply game theory to study the formation of IEAs. We extend this theory in an effort to understand better how California and the EU can improve the chance of cooperation, and the outcome if that cooperation occurs.

In Section 2 we review the workhorse of the economic theory of IEAs. This theory is useful because it identifies in a simple manner the obstacles to cooperation, thereby helping to understand how the structure of an IEA alters those obstacles. In particular, we discuss the effect of a regional agreement, such as that between California and the EU, on attempts to achieve broader cooperation across the world. The remaining two sections discuss modifications to the simple IEA.

Section 3 examines the role of emissions trading. This trade can have quite different effects in a partial equilibrium and a general equilibrium setting. Although trade in emissions permits reduces the aggregate cost of achieving any level of abatement, trade might nonetheless either increase or decrease the equilibrium level of abatement. Trade in permits can promote IEA membership, by using the endowment of permits to provide an implicit side-payment to induce nations to join. However, trade can also reduce equilibrium membership, and possibly reduce welfare. Thus, even though trade in permits sounds like it should be a good idea, we show that several of its effects are ambiguous.

Section 4, which examines the use of escapes clauses, provides a more promising set of conclusions. Escape clauses allow a signatory to an IEA to honor its commitment by paying a fine rather than achieving its target level of abatement. We show that escape clauses reduce risk, simplify the enforcement problem, and most importantly provide leverage that induces a high degree of participation in the IEA. We also show how alternatives, using either trade policy or broadening the legal standing of NGOs, can be used together with escape clauses.

We emphasize the strategic elements involved in the formation of IEAs. In the final section, we recognize that there are several important benefits of IEAs unrelated to strategic considerations.

2 Review of "standard model" of IEAs

In the "standard model" of IEAs, countries first decide whether to join the agreement. Conditional on the number and characteristics of members, the IEA chooses the level of abatement to maximize members' joint welfare. This model is useful for identifying the obstacles to cooperation and shows how various policy changes might magnify or reduce those obstacles. We begin with the simplest version in which countries are identical, there is no uncertainty, and the countries play a one-shot game. We then relax some of these assumptions as we consider different types of agreements.

Since GHGs are a global pollutant, abatement is a global public good. In the symmetric setting, all countries benefit equally from a unit of abatement. In the special case that we consider, marginal benefits of abatement are constant, normalized to 1. Each country can produce at most one unit of abatement at constant marginal costs θ, with $\theta > 1$. This inequality means that it is a dominant strategy for a single country not to abate. There are a total of N countries, where $N > \theta$, so increased abatement always increases aggregate welfare. If M of these countries join an IEA, the IEA chooses the per country level of abatement $a \leq 1$ to maximize members' joint welfare:

$$\max_{a \leq 1} M (M - \theta) a.$$

Define $h(x)$ as the smallest integer not less than x. The linearity of the maximand means that the IEA sets $a = 0$ if $M < h(\theta)$ and it sets $a = 1$ if $M \geq h(\theta)$.

At the participation stage of the game each country makes a binary choice: it either joins the IEA or stays out of it. At the abatement stage, nonmembers use their dominant strategy of not abating, and members follow the IEA's instructions. A non-cooperative Nash equilibrium to this game is both "internally stable" (no member wants to leave the agreement) and "externally stable" (no non-member wants to join it), taking as given other countries' participation decisions. There are two Nash equilibria: $M = 0$ and $M = h(\theta)$. Hereafter we consider only the second of these. To verify that $h(\theta)$ is a Nash equilibrium, note that each signatory's payoff is non-negative; no signatory wants to defect, because the resulting IEA would choose not to abate, leaving the defector with a zero payoff. No non-signatory wants to join, because the additional cost exceeds the additional benefit: $\theta > 1$.

This model implies that IEAs are effective only when they are unimportant; they achieve a substantial fraction of potential gains from cooperation only when potential gains are small. A reduction of abatement costs, θ need not increase welfare. More formally, we see:

1. The level of membership, $h(\theta)$, weakly increases with the membership cost, defined as the abatement cost minus the benefit of increased abatement, $\theta - 1$.

2. Global welfare is non-monotonic in abatement costs, θ. When $N \geq h(\theta)$, global welfare, the sum of members' and non-members' welfare, in the Nash equilibrium is $(N - \theta) h(\bar{\theta})$. As θ increases between integers abatement costs increase but there is no

change in membership, so welfare falls; welfare has an upward jump as θ passes through an integer value, since this change leads to a discrete increase in membership and an infinitesimal increase in costs.

3. If all nations were compelled to join the IEA, global welfare (the "potential gain" from cooperation) is $(N - \theta) N$. Relative to this grand IEA, the fraction of potential welfare achieved in equilibrium is $\frac{h(\bar{\theta})}{N}$, a non-decreasing function of costs.

4. The equilibrium membership does not depend on the number of potential members.

2.1 Dynamics

The game described above uses a static setting, in which nations decide only one time whether to participate in the IEA and then whether to abate. If the game lasts many periods and if agents care about the future, a higher level of participation can be sustained as a subgame perfect noncooperative Nash equilibrium. This more favorable outcome uses a "threat" to revert to the equilibrium in which no nation abates, following any defection. A defection occurs if any agent deviates from equilibrium play. One type of defection is for an agent not to abate when the equilibrium action is to abate. Although the "good equilibria" – those with many abaters – are indeed subgame perfect, they are not, in general, "renegotiation proof" unless the number of members is quite small. Renegotiation proofness requires that all IEA participants would actually want to punish a defector.

More formally, suppose that there are M IEA participants and that each has the discount factor $0 < \delta < 1$. Suppose that an equilibrium strategy requires that non-defectors punish a defector by not abating for a single period, during which time the defector must abate in order for cooperation to resume in the next period. (It is clear from the following that requiring punishment to last more than a single period further reduces the equilibrium number of participants.) A non-defecting IEA member prefers to carry out this punishment rather than resuming cooperation immediately if and only if

$$1 + \frac{\delta}{1-\delta}(M - \theta) \geq \frac{1}{1-\delta}(M - \theta).$$

The left side of this inequality is the payoff in equilibrium (a single period of punishment followed by cooperation) and the right side is the payoff if cooperation resumes immediately. This inequality requires $M \leq 1+\theta$ in a renegotiation-proof equilibrium. Since $1+h(\theta) \geq 1+\theta$, we see that membership in a renegotiation-proof equilibrium to the dynamic game exceeds the equilibrium in the static game by at most one country. This result highlights the fact that the pessimistic conclusions of the standard model reflect the intrinsic difficulty of getting sovereign nations to provide public goods, together with the limitations inherent in the structure of the IEA as described by this game. The pessimistic conclusions are not due to the unrealistic assumption that the game lasts a single period. Hereafter, we use the single period setting, because its simplicity promotes clarity.

2.2 Regional agreements

It might seem that an agreement between California and the EU would undermine the prospects for a broader agreement amongst many nations. The regional agreement imposes abatement costs on its participants, without exerting any leverage over non-participants. If the members' abatement capacity is constrained, as in our model, or if there are increasing marginal abatement costs, the regional agreement might make it more difficult for the members to entice non-members into joining a broader agreement.

The model above shows why regional agreement can actually promote greater global cooperation. This conclusion is a consequence of Result 4 above. For example, suppose that $h(\theta) < \frac{N}{2}$.. In this case, if there are two participation games, each with $\frac{N}{2}$ potential IEA members, then the equilibrium size of each IEA is still $h(\theta)$. In this case, the combined number of abaters is $2h(\theta)$ Here, it is possible to achieve nearly complete cooperation simply by splitting up the pool of participants. This result shows that an agreement between California and EU need not decrease the incentives of other countries to abate (i.e. to form other agreements).

3 The effect of emissions trade in IEAs

There are potential gains from trade in permits when IEA members have different marginal abatement costs. Those differences might be predetermined, or they might emerge endogenously; for example, investment decisions that affect abatement costs may depend on the anticipation of an emissions ceiling and on whether trade in permits is allowed. In addition, for a given level of membership, the effect of trade in permits may differ in a general equilibrium and a partial equilibrium setting. Finally, the anticipation that an IEA will allow trade in permits can have surprising effects on the equilibrium number of IEA members. Except were we note otherwise, this section drops the assumption that countries are identical and that they have constant marginal abatement costs.

3.1 Partial versus general equilibrium effects of trade in permits

Here we take the number of members in the IEA, and each member's abatement costs, as given, and discuss the differences between general and partial equilibrium settings. The partial equilibrium setting is obvious; there, whenever countries have different marginal abatement costs, the ability to trade permits reduces aggregate abatement costs, yielding efficiencies. Moreover, provided that members actually trade in equilibrium, this trade reduces each member's total abatement costs, thus increasing their welfare.

There are other interesting possibilities in the general equilibrium setting. If the conditions of the Factor Price Equalization (FPE) theorem hold, trade in emissions permits is not needed in order to achieve a cost-minimizing outcome. Under FPE, trade in commodities is a perfect substitute for trade in inputs; permits are just a particular kind of input. Although an interesting theoretical possibility, factor price equalization is an extreme outcome, and unlikely to hold. However, FPE is likely to be more closely approximated amongst more similar countries, e.g. those with similar relative factor endowments; it is also likely to be more closely approximated where other factors, such as capital and labor, are more mobile across countries, e.g. where there are fewer restrictions on foreign investment or labor migration. Thus, trade in permits may yield smaller efficiency gains when IEA members are more similar and allow greater factor mobility.

In a general equilibrium setting, trade in permits can have more subtle effects. First, trade in emissions permits alters production costs and changes the supply of commodities, thus changing the commodity prices. If emissions trade leads to a sufficiently large fall in the price of a country's exports, or a rise in its imports, the welfare loss resulting from the deterioration in the terms of trade might more than offset the direct welfare gain from trade in permits. In this case, trade in permits harms an IEA member. Of course, if the price of exports rises (or the price of imports fall) due to trade in permits, the country certainly benefits from emissions trade.

Finally, if there are distortions in the economy, the theory of the second best alerts us to the possibility that trade in permits has ambiguous welfare effects. This observation is useful only if we have a reasonable idea of which existing distortions are likely to be altered by trade in permits.

3.2 The effect of trade on equilibrium abatement, given membership

This sub-section considers the effect of permit trade on the equilibrium level of abatement, given IEA membership. Here we use a partial equilibrium setting. As noted above, in this setting trade makes it cheaper to achieve any level of abatement, when the countries have different marginal abatement cost functions. This observation might make it appear that trade in permits promotes a greater level of abatement; in that sense, trade appears to be "environmentally friendly". This conjecture need not be true. If the IEA's objective is to maximize the amount of GHG reduction (= abatement) subject to a ceiling on total costs, then trade would certainly be environmentally friendly. However, if the IEA objective is to maximize welfare, then the optimal level of abatement depends on marginal, not on average abatement costs. Even though trade reduces average abatement costs, it need not reduce marginal abatement costs. Therefore, trade can increase the equilibrium level of abatement. When that occurs, trade in permits is "environmentally unfriendly". The importance of this observation is that trade in permits should be defended on the ground that it reduces aggregate abatement costs, not that it promotes increased abatement.

We illustrate this claim in two settings. In the first, we take the marginal abatement cost curves as given, and in the second we allow them to depend on investment. The investment depends on the anticipated allocation of emissions permits, and on whether trade in these permits is allowed.

3.2.1 Abatement cost curves exogenous

Figure 1 illustrates a situation where trade increases the equilibrium level of emissions; in this example, trade in not "environmentally friendly".

There are two countries, each of which receives an emissions allowance of e. The dashed line, $1 - e$, shows the marginal benefit of emissions (equal to the marginal cost of abatement) for the high cost country, and the dotted line, $1 - be$ with $b > 1$ shows the marginal benefit of emissions for the low cost country. The kinked curve, labelled "social MB w/out trade" shows the average of the two marginal benefit curves; this curve gives social marginal benefits (MB) without trade. At points along this curve, the vertical distance between curve and the dotted and dashed lines – the low and high marginal costs – are equal, reflecting the fact that this curve shows average marginal costs. The line labelled "social MB with trade" shows social marginal benefits of emissions when the countries are allowed to trade. At points along this curve, the horizontal distances between this curve and the dotted and the dashed lines are equal; this distance equals the amount of trade in permits, for a given allocation e, needed to equate marginal abatement costs in the two countries.

The equilibrium levels of emissions with and without trade are shown by the small circles where the marginal damage curve intersects the marginal benefits curves. In this example, the marginal damage of emissions lies above the intersection of the two marginal benefit curves – those with and without trade – so trade in permits increases the equilibrium level of emissions.

3.2.2 Abatement costs endogenous

Now we consider the case where there are many small firms in both countries, all of which are initially identical. A firm can reduce its marginal benefit of emissions (equal to its marginal

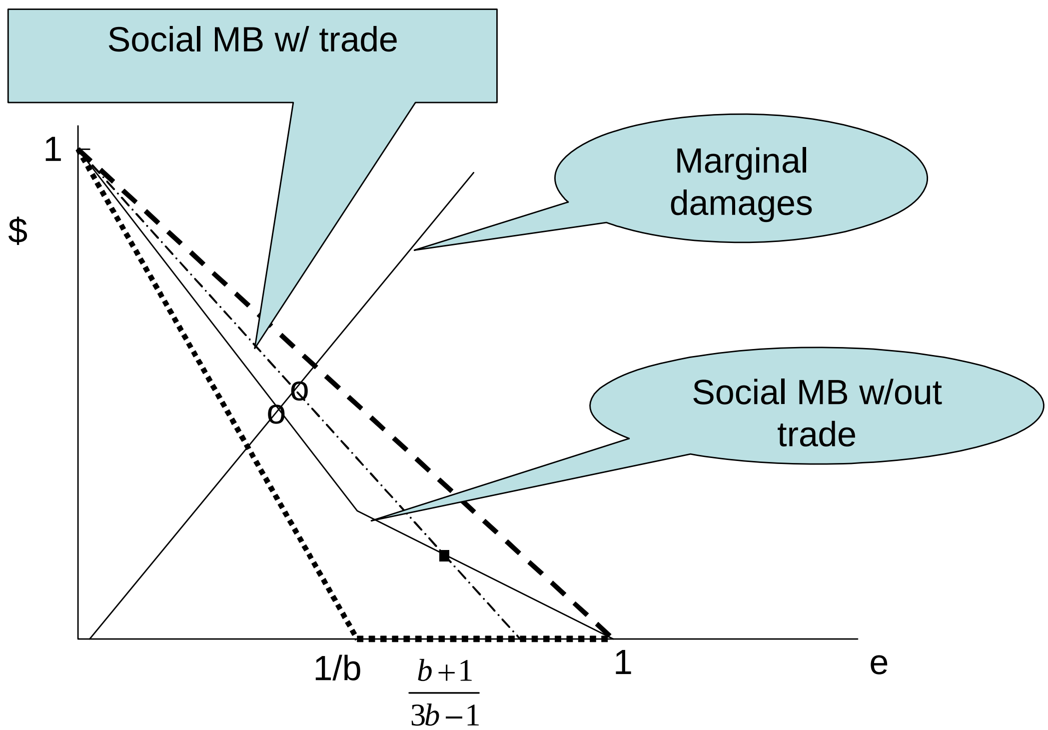

Figure 1: Example showing that trade in permits can increase equilibrium level of emissions.

abatement cost) from $1 - e$ to $1 - 1.5e$ by investing in a new technology. The investment costs the firm ϕ. Marginal damages equal e in this example. Figure 2 shows the graph of the equilibrium level of emissions, as a function of investment costs ϕ, in two scenarios. The continuous dashed curve shows the equilibrium level of emissions under trade: the level of aggregate investment falls continuously with higher investment costs, leading to higher industry-wide marginal abatement costs and a lower equilibrium level of abatement, and a higher level of emissions. The solid step function shows the equilibrium level of emissions without trade. For low investment costs all firms invest, leading to a low industry-wide marginal abatement cost curve and a low level of emissions. When investment costs pass a critical level, no firm invests. In that case, abatement costs are high, so the equilibrium level of emissions is high. The example assumes that the social planner can announce the level of permits before investment takes place.

When trade is permitted, in equilibrium only a fraction of firms make the investment; the equilibrium fraction depends on the investment cost, ϕ. In the absence of trade, either all firms or no firms invest, depending on whether ϕ exceeds a critical value. This example illustrates two important points, which hold much more generally. The first is that for moderately low investment costs, trade is likely to increase equilibrium emissions, but for moderately high investment costs, trade is likely to reduce these emissions. Of course, for very low or very high

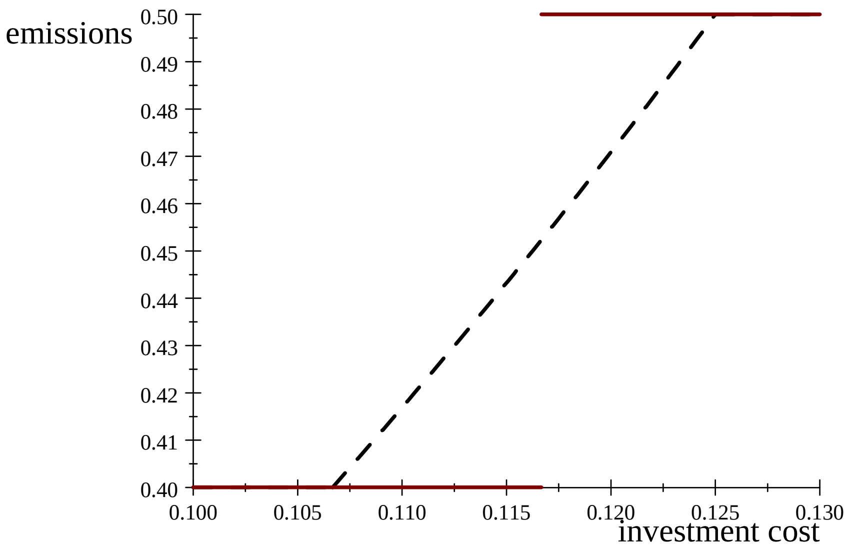

Figure 2: Dashed curve: Equilibrium emissions with trade. Solid step function: Equilibrium emissions without trade when regulator announces emissions before investment.

investment costs, the equilibrium is the same with and without trade, because in these extreme cases either all firms or no firms invest, regardless of the trade regime. The second point is that the anticipation of permit trade induces firms to make different investment decisions, thereby creating or increasing heterogeneity of abatement costs, and thus increasing the gains from trade. In contrast, the anticipation that trade in permits will not be allowed causes firms to make the same investment decisions, thereby maintaining or increasing firm homogeneity, and thus reducing the gains from trade. In other words, realizing the full gains from trade requires not only that trade is permitted, but also that firms understand that trade will be permitted at the time they make their investment decisions.

3.3 The effect of trade on membership: ex ante heterogenous countries

Previous subsections examined the effect of permit trade when IEA membership was taken as given. Now we turn to the question of how trade affects the incentives to join an IEA. We first consider the case where countries have known differences in abatement costs at the time they decide whether to join the IEA. In this case, the potential gains from trade are known. Allowing trade, together with a judicious distribution of permits, makes it possible to increase membership. The distribution of permits provides a way to make side-payments which induce countries to join the IEA.

The intuition of using side-payments to increase membership is quite obvious, but a brief consideration of the formal explanation is nevertheless useful. The requirement that no participant of the IEA wants to abandon the agreement – the "internal stability" requirement – states that for each participant, the payoff that the country receives in the IEA is at least as large as the payoff that it would receive if it were to abandon the IEA, holding fixed all other countries' participation decisions, but taking into account how their abatement decisions might change. (Recall that the level of abatement that the IEA chooses typically depends on the number and characteristics of its members.) When side-payments are possible, these individual participation constraints are replaced by a single constraint that requires the aggregate payoff to members to be greater than the sum of members' payoffs if they individually defect from the agreement.

Although trade in permits increases the potential size of IEA membership, it has two important limitations. First, trade typically does not lead to the grand IEA, where all countries join. This result follows from the fact that the amount of the transfers is limited by the magnitude of the gains from trade. For example, if countries are fairly similar, then the gains from trade are small, so the "budget" for the implicit side-payments arising from the allocation of permits is also small. In this case, trade in permits can create only small increases in membership. The second limitation is that to the extent that the allocation of permits, together with trade, succeeds in inducing membership, it does so by creating large implicit transfers across countries. These transfers might encounter political opposition.

In Section 2.2 we noted that using regional agreements to "split up" the grand participation game into smaller games has the potential to increase aggregate abatement. However, if these regional agreements lead to groups with relatively homogenous countries, i.e. those with similar marginal abatement costs, the agreement decreases the scope for using trade to induce participation. For example, suppose that two regions with high abatement cost, such as California and the EU, form an IEA. If this agreement causes these two regions to no longer be part of the participation game played by other countries (as assumed in Section 2.2) the regional agreement reduces the potential gains from trade among the remaining countries. In that case, the regional agreement might jeopardize the prospects for the remaining countries to form an IEA. This observation suggests that there should be some mechanism that enables regional IEAs to interact amongst each other. The optimal form of interaction (trade?) should be investigated.

3.4 The effect of trade on membership: ex ante homogenous countries

Section 3.3 examines the effect of trade on membership when countries know at the participation stage that they have different abatement costs. Trade is also potentially important when countries face random abatement costs, which they learn only once they actually begin reducing emissions, i.e. after the participation stage. In order to study the effect of this kind of uncertainty and country heterogeneity, we consider the simplest case where, at the participation stage countries face the same distribution of abatement costs: countries are "ex ante homogeneous". Moreover, for simplicity we again assume, as in Section 2, that the country's abatement cost is constant up to a maximum level of abatement equal to 1, and the marginal benefit of abatement is 1 for each country. Here, however, country i's abatement cost, θ_i is the realization of a random variable. Denote the expectation of this random variable as θ.

The country's abatement cost, θ_i is private information, or in any case is not verifiable by the IEA. Therefore, the IEA cannot give different countries different abatement targets. If the IEA were to condition a country's abatement target on its announcement of its costs, the country would like to exaggerate its abatement costs. The assumption that abatement costs are non-verifiable means that the IEA discards any information the country might provide. Therefore the country has no incentive to misrepresent its costs. Each country receives the same required level of abatement, which depends on the number of signatories of the IEA..

In the absence of trade, each country must abate at the level determined by the IEA. Since each country's expected marginal abatement cost is θ for abatement $a \leq 1$, and since the marginal benefit of abatement for the IEA as a whole is M (the number of IEA members), the optimal level of abatement in the absence of trade is the same as in Section 2. For $M < \theta$ the IEA sets $a = 0$ and for $M \geq \theta$ the IEA sets $a = 1$. The solid step function in Figure 3 graphs the equilibrium level of per country abatement in this situation, where trade in permits is not allowed.

With trade, the expected marginal cost of abatement varies with the level of abatement, a. For low levels of abatement, the expected marginal cost is strictly less than the expected marginal costs without trade, θ. For example, consider the case where there are 5 members, and suppose that $a = 0.2$. In this case, with trade, all of the abatement will be done by the country with the lowest abatement cost. The expected value of the lowest cost among the five draws is less than the expected cost of the average of the five draws. Therefore, with trade, the expected marginal cost of abatement at $a = 0.2$ – denote it as θ'– is strictly less than θ. A similar argument shows that at large values of a, the expected marginal costs of abatement exceeds θ. For example, when $M = 5$, if $a > 0.8$ it will be necessary for the highest cost country to produce some abatement. The expected value of the highest of five draws exceeds the expected value of the average of the five draws.

Now return to the example where for $a = 0.2$ the expected marginal abatement cost is $\theta' < \theta$. It is certainly possible that $\theta' < 5 < \theta$. If this inequality holds, then an IEA with 5 members would instruct no member to abate if trade is prohibited, but it would instruct each member to abate at a positive level (not less than 0.2) if trade is permitted. As M increases, the expected marginal cost of a (weakly) decreases for $a < 1$; with larger M there is a higher

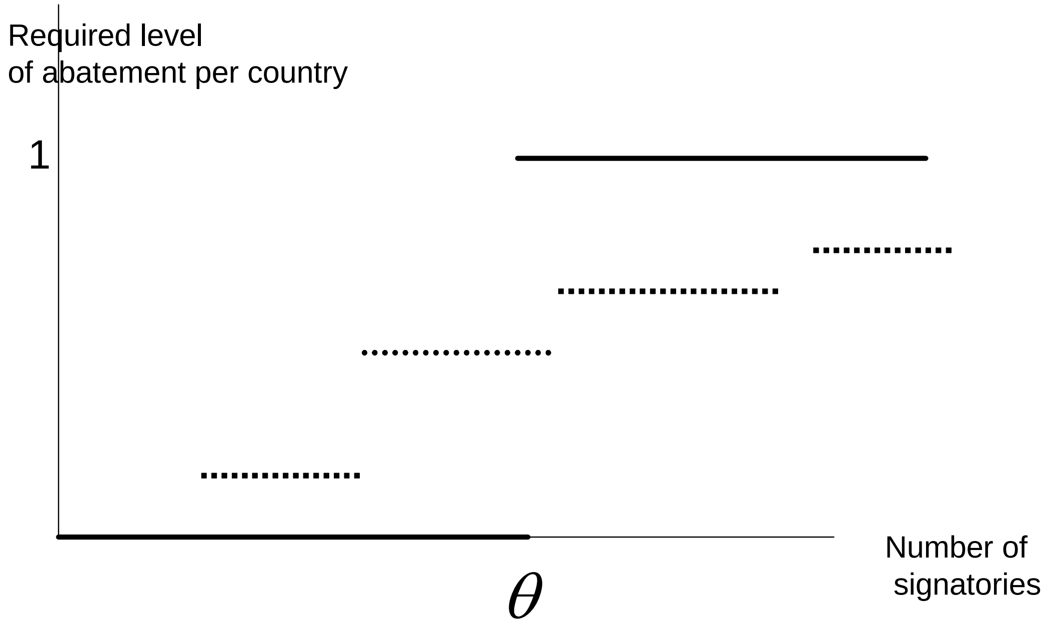

Figure 3: Equilibrium abatement level without trade (solid step function) and with trade (dotted step function) as a function of number of IEA members

chance of having enough low cost countries to take care of the abatement. Therefore, with trade, the equilibrium required level of abatement, per country, "resembles" the dotted step function in Figure 3. For very low levels of participation the per country required level of abatement is 0 with or without trade. For somewhat higher levels of participation, the required level of abatement is strictly positive with trade, and 0 without trade. However, for participation levels $M \geq h(\theta)$, trade reduces the equilibrium level of per country abatement. This example provides another case where trade in permits can either increase or reduce the level of abatement.

The effect of trade on equilibrium participation is a bit more subtle. Without trade, equilibrium participation is $h(\theta)$, so the equilibrium amount of abatement without trade is also $h(\theta)$. With trade, equilibrium participation might be either greater or less than $h(\theta)$, but per firm abatement is always strictly less than 1. Thus, a sufficient, but not necessary condition for trade to reduce aggregate abatement, is that equilibrium membership is less than $h(\theta)$. In this case, trade is clearly not "environmentally friendly". Even if this circumstance occurs, trade might still increase welfare, because it decreases average abatement costs.

4 The role of escape clauses

An escape clause can improve the success of an IEA. The major insight from the model described in Section 2 is that sovereign countries willingly join an IEA in order to exert leverage on other countries. In the standard model, each member of the IEA knows that if it were to defect, the IEA would reduce abatement to 0. By joining the IEA, each country recognizes that it increases the equilibrium level of abatement from 0 to $M = h(\theta)$ (the number of members). However, this leverage is quite limited, so the IEA that arises in equilibrium is quite small. There are a number of ways in which a re-designed IEA increases each country's leverage and thereby increases the size of the IEA.

Here we discuss the role of an escape clause, which links an environmental commitment to a financial commitment. In addition to increasing a country's leverage, and the resulting size of the IEA, the escape clause has two other benefits. It reduces the risk of joining the IEA when abatement costs are uncertain, and it simplifies the enforcement problem. Moreover, the escape clause requires a simple contract.

Our proposal is that at the negotiation stage, potential IEA members choose a target level of abatement, possibly different for different countries if there is ex ante heterogeneity, and a monetary cost (a fine) of exercising the escape clause. A country that joins the IEA must either achieve its target level of abatement, or exercise the escape clause. In the latter case, it pays the contracted fine to a central agency which then distributes the aggregate fine collections to all members. All members, regardless of whether they reached their target level of abatement or exercised the escape clause, receive a share of this "distribution".

In the interest of simplicity, we assume now that countries are ex ante identical, so they are given the same target level of abatement, the same cost for exercising the escape clause, and an equal distribution of aggregate fines. We also assume that there is no trade in emissions permits. (The inclusion of trade is a subject of current research.)

4.1 Risk reduction

Risk reduction is important when the country does not know the cost of achieving a given level of abatement at the time it agrees to participate in the IEA. The escape clause creates an upper limit on the country/region's financial liability. This liability equals the minimum of the fine less the distribution, and the cost of abatement.

We could extend the proposal to allow "partial escapes", under which the country can achieve a portion of its abatement commitment, and then pay a fine that depends on the gap between its target and its achievement. Depending on how this partial escape is constructed, it puts a ceiling on the marginal cost of abatement. Our simple proposal that allows only a "total escape" puts a ceiling on aggregate abatement costs.

4.2 The enforcement problem

The escape clause changes the nature of the enforcement problem, by requiring debt payment rather than environmental performance.. Instead of having to somehow compel a signatory to achieve the level of abatement, the organization "merely" has to compel the country to pay its debt – the fine. We think that this is a simpler enforcement problem, because the process of sovereign debt collection is better developed, and certainly has a longer history, compared to the process of enforcing sovereign compliance with environmental agreements.

The enforcement aspect is particularly important when actual abatement costs are not known at the time a nation decides to participate in the IEA. In the simple model set out in Section 2, the agreement is always self-enforcing, because each participant knows that its defection causes the IEA to reduce per member emissions from 1 to 0, and the resulting welfare loss from the reduced aggregate abatement effort exceeds the country's own net cost of abatement. When costs are uncertain at the participation stage, this type of self-enforcement does not arise. In equilibrium, when θ is the ex ante expected cost of abatement, a participant has total benefits of $h(\theta)$. When costs are random, some countries face costs strictly less than θ, but others have higher costs. If a country has costs $\theta_i > h(\theta)$ its ex post welfare from being a member is negative. That country would like to withdraw from the IEA, even if its withdrawal precipitates a collapse of the IEA. When costs cannot be verified, ex post renegotiation of abatement targets is not practical, because each country has an incentive to exaggerate its owns costs.

In short, under random costs, the IEA in the standard model is not self-enforcing. There therefore must be some mechanism to induce countries to abide by their participation decision. Our point here is simply that it is easier to enforce payment of a monetary debt, rather than enforcement of an environmental outcome.

4.3 Increased leverage

The previous two subsections considered the case where there is cost uncertainty. In order to make our point about the increased leverage arising from the escape clause, we can use a simpler model with no cost uncertainty. Suppose then that abatement cost is θ, known. The terms of the IEA require each country to abate one unit or pay the fine F to exercise the escape clause. The optimal decision for an IEA member depends on F and M, the total number of members, but not on the actions of other members; that is, the IEA member has a dominant strategy at the abatement stage of the game. Its cost of abating, less the additional benefit of abatement, is $\theta - 1$. The cost of exercising the escape clause, net of the amount returned in

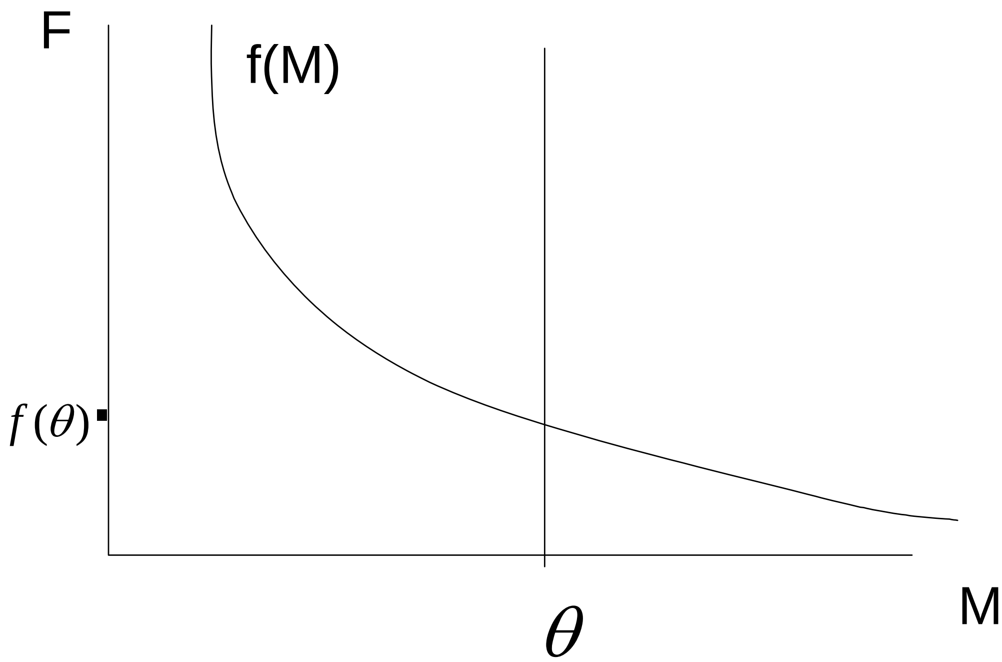

Figure 4: The graph of $f(M)$

distribution payment, is $\frac{M-1}{M}F$. The country prefers to abate if and only if the latter is at least as great as the former, i.e. if

$$F > \frac{(\theta - 1)\,M}{M-1} \equiv f(M).$$

The function $f\,(M)$ approaches its lower bound $\theta - 1$ as M becomes large, so any fine must be greater than $\theta - 1$, i.e. it is likely to be large.

The negatively sloped function $f(M)$ divides $F - M$ space into two regions. For $F < f\,(M)$ each country prefers to exercise the escape clause. In that case, every country's total revenue from distributions of the receipts from the fine just equals the cost of the fine, so each country receives welfare 0. For $F \geq f\,(M)$ a country's welfare is higher if it abates, so all members abate. For any F, $M = 0$ remains an equilibrium to the participation game. The other equilibrium must satisfy $M = h\,(f^{-1}\,(F))$, i.e. the smallest integer to the right of the graph of $f(M)$; a value of M greater than $h\,(f^{-1}\,(F))$ is not internally stable.

At values $M = h\,(f^{-1}\,(F)) < \theta$, members would have negative payoffs. Therefore, any $F > f\,(\theta)$ leads to a unique equilibrium with 0 members. However, any $F \leq f\,(\theta)$ leads to an equilibrium with M participants, where M is the smallest integer on or to the right of the curve $f(M)$.

In short, an IEA that announces a required level of abatement of 1 and cost of exercising the escape clause $F < f\,(\theta)$ induces more members than in the game without the escape clause. By setting F to solve $h\,(f^{-1}\,(F)) = N$ the IEA can attract all members. To confirm this claim, suppose that the IEA chooses this value of F. If $N-1$ countries join, the N'th country knows that if it also joins it will receive a payoff of $N-\theta > 0$, but if it stays out of the IEA all the other members will choose to exercise the escape clause, leaving the outside country with a 0 payoff. Therefore, N participants is a Nash equilibrium. Note that the equilibrium membership size increases as the fine is decreased; however, the smallest fine is strictly greater than $\theta - 1$, the difference between a country's costs of abatement and its private benefits.

This result may suggest that the problem of inducing membership to IEAs is trivial – which is obviously not the case. Our point is much more modest: the escape clause provides another means by which a country that decides to join is able to exercise leverage. Since the escape clause also has the other desirable properties of reducing risk and simplifying enforcement, it should be seriously considered in choosing the architecture of the post-Kyoto IEA.

4.4 Alternatives to the fine

Our proposal uses a monetary fine, which leads to the problem of credible debt collection. That problem would be avoided if instead of the fine, the participants post a bond that is redeemed by achieving the target level of abatement, and forfeited otherwise. (Or perhaps a portion of the bond is forfeited if the target is partially met.) This alternative is not practical, given the size of expenditures likely to be necessary to induce abatement. The fine – or the bond – is always greater than $\theta - 1$.

A second alternative replaces the fine by a "withdrawal of concessions" under WTO. This penalty is currently used when a disputant in a WTO case does not adopt the remedy determined by the WTO dispute resolution panel. This alternative would be consistent with WTO law, since it places constraints on countries that willingly enter the IEA. This use of the WTO is very different from the proposal to apply trade sanctions to countries that refuse to sign the WTO – a proposal that would run afoul of WTO law.

The replacement of the fine with a withdrawal of WTO "concessions" gives rise to the same kind of leverage as does the fine. By joining the IEA a participant increases the actual cost to any country of exercising the escape clause; the additional participant increases the amount of concessions withdrawn from the country exercising the escape clause. This alternative also has the advantage that it does not require that IEA members collect the fine from a member that exercises the escape clause; the IEA members who achieve the target can impose the penalty without the cooperation of the delinquent country. A possible disadvantage of this alternative is that the country that imposes the trade sanctions also suffers diminished gains from trade; however, countries appear willing to suffer those losses: witness the fact that liberalized trade is viewed as a "concession" in WTO-speak, even though it is one that typically benefits the country making the concession. Of course, some countries are reluctant to exercise their rights to withdraw concessions, either because they recognize the resulting costs to themselves, or because they fear some kind of retribution from a more powerful trading partner.

A third alternative is to give NGOs standing in bring a complaint against a signatory that violates its IEA agreement. This type of extension of rights already has precedence in international law. For example, under NAFTA law, groups (other than signatories) are allowed to bring a complaint before a NAFTA tribunal in the event that a country violates its own national environmental law in the pursuit of foreign investment. Also, many investment treaties, including Chapter 11 of NAFTA, give investors the right to bring suit against signatories in the event that the government violates the treaty, e.g. by expropriating investments or failing to honor rights of establishment. These suits can be brought even if the offending government action occurs at a sub-national (e.g. province or state) level. In other words, the investment treaties open the door to investor-to-state disputes, unlike the WTO which permits only state-to-state disputes. This extension is important because a government has to balance many interests, and may not be willing to represent the interests of a particular investor that feels it has been treated illegally. An IEA that gives NGOs legal standing – analogous to that of investors in the investment context – together with a tribunal structure (similar to ICSID) would ease the problem of enforcement.

5 Non-strategic effects of multinational cooperation

Our paper emphasizes strategic issues involving cooperation among nations, or between two regions such as California and the EU. We close by recognizing several non-strategic reasons that this cooperation might promote improved climate change policies.

1. Lower economic costs and lower leakage. Countries/regions are concerned that stricter climate change policies increase costs in their pollution-intensive sectors. If these increased costs cause industries to migrate to low-standard regions, the country imposing the policy suffers job loss, and the migration merely shifts pollution elsewhere (leakage). This migration of industries and the associated leakage is a consequence of cost differences; it is less likely to occur when other countries/regions impose similar restrictions. Therefore, by instituting climate change policies, California (for example) decreases the cost of similar policies in the EU and increases the environmental benefits of those policies, making it more likely that the European policies will be sustained.

2. Learning from Policy experience. A country/region is able to learn from policy experiments elsewhere. International cooperation makes it easier for countries to transfer this

knowledge.

3. Economies of scale. Reducing the costs of GHG abatement is likely to require large fixed costs in R&D and investment. An increase in the scope of regulation, such as occurs when other countries/regions require GHG abatement, increases the demand for the new technology and spreads the fixed costs of its development over more units of abatement, thereby decreasing the average costs of abatement.