Conditional commitment devices to achieve efficient participation and compliance with international environmental agreements

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Abstract

The literature on international agreements typically finds that the free-riding incentive makes it impossible to obtain efficient participation and compliance with international environmental agreements where pollution abatement takes the form of a global public good. This paper presents a potential solution to this problem for environmental problems that can be addressed through a system of tradable permits. In our model, governments use conditional financial option contracts as commitment devices to commit themselves both to respect the agreement if it comes into force and to a retaliation strategy if due to attempts to free-ride it does not. The conditional nature of the commitment and the possibility to commit to a retaliation strategy allows supporting any individually rational agreement as a Nash equilibrium, including efficient agreements. If they can be implemented, those conditional option contracts would therefore have major implications for the negotiation of international agreements, in particular agreements to tackle the problem of climate change.

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1. INTRODUCTION

Some of the most important environmental problems we face today are global in nature, and addressing them therefore requires international cooperation through the signature of treaties. However, the literature on international agreements typically finds that in a contexts where countries are sovereign, the free-riding incentive makes it impossible to obtain efficient participation and compliance with international environmental agreements where pollution abatement takes the form of a global public good.

Many papers have studied the problem of participation to international agreements. Chander and Tulkens (1995) take a cooperative game theory approach to the problem and proposes to use financial transfers to share abatement cost in a way that makes an efficient agreement individually rational for all countries. Further, the cost-sharing rule they propose ensures that no group of countries could do better by departing from the agreement and cooperating only among each other.

This approach yields very optimistic results, as it suggests that financial transfers can be used to induce efficient participation in the agreement. The problem is that this result rest on the assumption that, should a single country refuse to participate in the proposed agreement, no agreement will be signed in that period, so all countries will behave noncooperatively, playing the Nash equilibrium of the emission game. Yet Scott Barrett (2001) and others argue that this is a *noncredible threat*. If a country leaves the coalition, other countries have an incentive to *renegotiate* the agreement with one fewer member rather than letting the agreement collapse since the former would give them a higher payoff.

In contrast, S. Barrett (1994) proposes a noncooperative solution concept that is immune to such criticism, which he calls self-enforcing agreements. He considers only individual deviation and assumes that whenever a country enters or exits the agreement, the agreement is "renegotiated" to maximize the payoff of the cooperating coalition. An equilibrium agreement in his framework is one in which no member of the agreement has an incentive to exit, and no nonsignatory has an incentive to join.

This solution concept is very robust, and for this reason it is the dominant approach in the literature. It provides an answer not only to the participation but also to the compliance problem as it is built such that any country signing the agreement has no incentive to leave the coalition. The results, unfortunately, are very pessimistic. When potential gains from cooperation are high, only a few countries sign, and they reduce pollution only slightly below the Nash equilibrium level. Efficient cooperation is possible only when the potential gains from cooperation are very low, that is when cooperation is least needed.

Carraro, Marchiori, and Oreffice (2009) offer a more optimistic perspective by showing that, within a noncooperative framework, better or even efficient outcomes can be achieved by specifying a minimum participation threshold within the agreement. However, this approach again uses a noncredible threat to behave noncooperatively should the threshold not be met. Once again, the countries would have an incentive to renegotiate the agreement should the participation threshold not be met.

What emerges from this literature, therefore, is that obtaining high levels of cooperation would require making the threat of noncooperation credible and removing the incentive to renegotiate the agreement following deviations. The goal of this paper is to do precisely this.

What the notion of self-enforcing agreement makes clear, however, is that, if an more ambitious agreement is signed, there will be a strong temptation for countries to renege these obligations – again, to free-ride. A treaty aiming to achieve more than a self-enforcing agreement therefore needs a mechanism to enforce compliance. One immediately thinks of trade sanctions, however those are costly not only for the defectors but also for the country imposing them, and hence are often considered to be a noncredible threat in any environmental problem where compliance costs are high.

This "compliance problem" has received much less attention in the theoretical literature than the participation problem. Gerber and Wichardt (2009) propose a deposit-refund mechanism in which countries only get their deposit back if they have complied with the agreement. The amount of the deposits required is proportional to compliance costs, making the scheme an unlikely solution to ensure compliance with treaties with very high compliance costs such as climate change.

Laffont and Tirole (1996) use options on the price of pollution permits in the context of a Cap&Trade system to go around a government's impossibility to commit to how many permits they will emit in the future. There however the goal is internal, not external : the government is trying to guarantee to "clean technology" firms a return on their investment.

Ismer and Neuhoff (2009) propose to apply a similar idea to commit governments to an international agreement. The commitment device is an option to sell pollution permits (i.e. a put option on the permit price) to the government. This paper adopts their approach as our solution for the compliance problem, which we present briefly in section 2. In section 3, the core of this paper, we show how using a modified version of these commitment devices makes the efficient level of global abatement achievable as an equilibrium of the emission game. This equilibrium is immune to renegotiation and uses only threats that are fully credible. Finally, we discuss how financial transfers might be incorporated in such a scheme to address considerations regarding fairness.

2. Enforcing compliance

2.1. Model

Following Ismer and Neuhoff (2009) we assume that the agreement is implemented by having all countries set up a Cap & Trade system in which firms are required to buy pollution permits in order to be allowed to emit greenhouse gases. Permits are initially distributed by the government, then firms can exchange them through a dedicated market. For concreteness we are taking in this section the example of a carbon market to tackle climate change, but the scheme is applicable to any global pollution problem.

We consider a group of *S* countries that decides to sign an agreement specifying for each member a maximum level of emissions for each of *T* periods. They agree to implement the treaty by emitting the corresponding number of emission permits per country per period. Emission permits are emitted at each period for one period only and are only valid within the emitting country. Let $\{e_{it}\}_{t=1}^{T}$ and $\{p_{it}\}_{t=1}^{T}$ denote the time path of the quantity and real price of emission permits respectively entailed by the agreement for country *i*. *Assuming perfect information*, the number of permits specified in the agreement directly determines the price, as illustrated in figure 1. Therefore, in this setting, committing to a time path for the number of emission permits is equivalent to committing to a time path for the carbon price. As this direct correspondence greatly simplifies the exposition, we maintain the perfect information assumption throughout this paper.

In this setting free-riding is represented by the temptation to distribute more permits than promised. Such an increase in the supply of permits would reduce their price, perhaps down to zero, thereby reducing the cost of compliance for the country's firms. Our goal is thus to find a way to commit countries to emitting no more than the number of permits specified in the agreement.

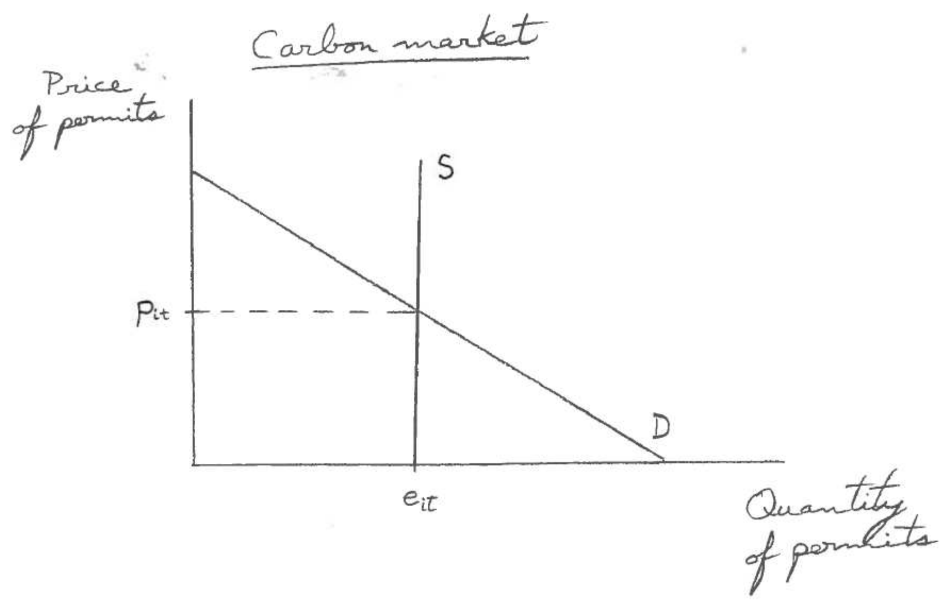

Figure 1 : Correspondence between the number of emission permits and the carbon price

2.2. Financial option committing countries to pollution abatement

Define $\omega_{it}(p_{it})$ as an option to sell a pollution permit to the government of country *i* at price p_{it} at any time during period *t*. In other words, $\omega_{it}(p_{it})$ represents a put option of which the government is the writer. Such an option should be considered a form of government debt, hence the government would have a strong incentive to honour this commitment. Failure to do so would be considered a sovereign default, and recent history has proven that governments are willing to go to great lengths to avoid such a situation.

In order to commit to emitting no more than e_{it} permits at period *t*, the government emits a quantity o_{it} of options $\omega_{it}(p_{it})$, with $o_{it} >> e_{it}$. If price falls below p_{it} at time *t*, options will be exerted until the price rises back to p_{it}. The government will fail in his attempt *and* incur a loss. As long as there are enough of these options to make the cost of noncompliance prohibitively high, the commitment is effective and the government will comply.

To show this, consider what happens if the government issues $e'_{it} > e_{it}$ permits, driving the price down to p'_{it} as illustrated in figure 2. A speculator holding an option can then buy a permit in the market at price p'_{it} and sell it to the government at price p_{it}, thus making a profit $p'_{it} - p_{it}$. This profit for speculators translates one-to-one into a loss to the government, which sold the marginal permit in the market at price p'_{it} but was forced to buy it back at price p_{it}.

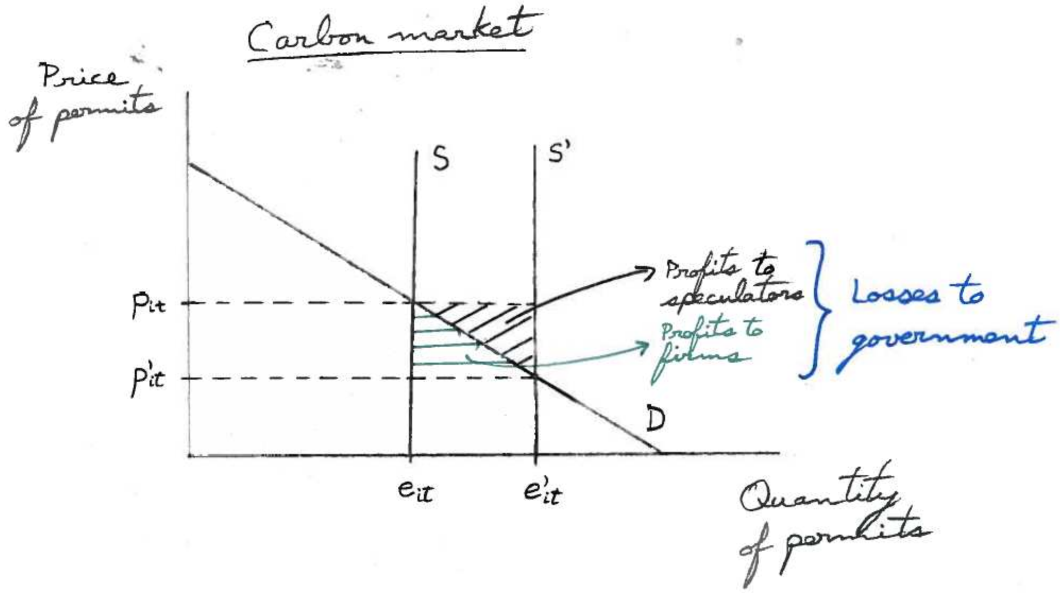

Figure 2 : Attempt by the government to emit too many permits

2.3. Other possible uses of commitment options

Above we used a put option (option to *sell* permits) to commit to a *price floor*, but we can similarly design call options (options to *buy* permits) to commit the government to a *price ceiling*. Further, even though the commitment afforded by these two options is one-sided, the combination of various put and call options allows much more general possibilities, as the government can then commit to both a specific price or a price bracket.

2.4. Implementation issues

There are many considerations relating to the implementation of such a commitment device to ensure compliance. As many are discussed at length in Ismer and Neuhoff (2009) we will cover them only briefly here.

First, being committed to a high carbon price, governments will tempted to reduce the burden of this commitment by reducing the size of the carbon market. Various industries, activities or specific plants could be granted exceptions. Going even further, a government could try to render the options inapplicable by abolishing the carbon market. The option should therefore include a provision to remove any incentive to do so. For instance, it could specify that, should the market for permits be abolished, or should its scope be reduced below a fixed percentage of the country's emission, the permit price is assumed to be zero. Alternatively, it could specify that under those circumstances the government must buy back all options at a fixed price $\pi \in (0, p_{it}]$, with π large enough for his option to be prohibitively costly to the government.

Second, if the scheme is properly set up, a rational government will always ensure to maintain the price above the threshold, hence the options will likely never be exerted. Foreseeing this, investors would value the commitment options at zero under perfect information. This raises the question of whether investors would want to hold these options. We must remember however that we have here worked with perfect information solely to simplify the analysis. Accounting for uncertainty would introduce the possibility that the price drop below the threshold, thereby granting the options a positive albeit small value. Further, the mere fact of being able to force the government to keep its commitment would be of value to some groups of investors, including clean technology firms, environmentalists, and foreign governments. There is thus no doubt that there would be a demand for these options.

Another danger of the expected low market price for these options is that a government desiring to free itself from the commitment could try to stealthily buy back all the options at the very low market price to withdraw them from circulation. There should therefore be a clause in the option specifying that they cannot be held directly or indirectly by the government that has issued them.

Admittedly, the many clauses and provisions needed to address the above considerations make this option an unusually complicated one – and the next section will only deepen this problem. For this reason we shall hereafter refer to those devices as "option contracts" to emphasize that they are more complex than a standard put or call option. Still, nothing in principle prevents such option contracts from being issued. Further, readers uncomfortable with thinking of those complex devices as financial options may regard them simply as contracts that the government offers to sign with anyone interested in doing so. As contracts are protected by constitutions, they cannot be overturned even by the vote of a national government, and like option they therefore constitute a binding financial obligation for governments.

3. PARTICIPATION : REACHING AN EFFICIENT AGREEMENT

3.1. Achieving efficiency in the Prisoner's dilemma with contracts

Having now reviewed a solution to the problem of compliance, we now turn to the problem of participation. In order to introduce the solution we wish to propose, let's first consider the simplest possible game theoretic representation of the problem we are facing, a two-player prisoner's dilemma, and see how efficiency could be attained in this very simple example. Figure 3 illustrates this game applied to our emission game context, where F is the free-rider's payoff, E the efficient payoff, NC the non-cooperative payoff and S the sucker's payoff. We assume F > E > NC > S.

	Cooperate	**Defect**
Cooperate	E, E	S, F
Defect	F, S	NC, NC

Figure 3 : Two-player emission game

Myerson (1991) proposes an original way of obtaining cooperation in the prisoner's dilemma by considering what he calls "games with contracts". Contracts in our societies are a coordination tool : they bind two or more parties to a mutually beneficial agreement that otherwise might not be possible. Using them to improve the outcome in a game is therefore natural. A difficulty is that the process of negotiating such contracts would typically be too complicated to be modeled explicitly. Therefore, Myerson instead proposes to model them implicitly by adding them as separate strategies in the game's normal form representation.

In the prisoner's dilemma example, suppose a neutral third party with enforcement power proposes the following contract to the countries, which choose whether to sign it :

> "We, the undersigned, promise to cooperate (by choosing high abatement) if this contract is signed by both countries and to defect (select low abatement) otherwise."

A crucial assumption is that, if a contract is signed, there is a prohibitively high cost to breaking it. In essence, the contract represents a *conditional commitment* : players are committed to cooperating only if both sign

The game with contract is represented in figure 4 and best responses are underlined. One can easily see that (Defect, Defect) is still an equilibrium, but now (Sign, Sign) is also an equilibrium, it yields the efficient payoff and it is an equilibrium in weakly dominant strategies. Therefore the efficient outcome is the only equilibrium in weakly dominant strategies.

	Cooperate	**Defect**	**Sign**
Cooperate	E, E	S, <u>F</u>	S, <u>F</u>
Defect	<u>F</u>, S	<u>NC</u>, <u>NC</u>	NC, <u>NC</u>
Sign	<u>F</u>, S	<u>NC</u>, NC	<u>E</u>, <u>E</u>

Figure 4 : Prisoner's dilemma with contracts. Best responses of the players are underlined and Nash equilibria are shaded

The major difficulty in applying the concept of a game with contract to international agreement is that whereas contracts can be enforced *within* countries, where the role of the neutral third party enforcer is played by courts of law, contracts cannot be so easily enforced *among* countries. For the above situation to be consistent with the status of international politics, therefore, we need an alternative way of achieving conditional commitment.

3.2. Achieving efficiency with conditional options

3.2.1. A conditional commitment device

A conditional commitment device can be obtained simply by including a clause in the options described in section 2 so that they become valid only when certain conditions are met. To reproduce the example of the prisoner's dilemma above we in fact need two commitments at once : (i) a commitment to cooperate conditional on other countries committing to cooperate and (ii) a commitment *not* to cooperate otherwise. The latter, as we will see, is crucial to rule out incentives to renegotiate the agreement in case of defection, an incentive which according to the reasoning of Scott Barrett (2001) would cause a collapse of the agreement as in the approaches of Chander and Tulkens (1995) and Carraro et al. (2009).

In keeping with section 2, a conditional commitment to cooperate can be made by issuing put options with a clause specifying that they become valid only once other countries have emitted equivalent options in sufficient quantity, that is when other countries have also made a conditional commitment to cooperate. The commitment is triggered as soon as the last country emits these options, which is equivalent in our model to the "signing" of an environmental agreement – although no actual signature of a joint treaty is involved nor needed. Similarly, a commitment not to cooperate otherwise can be made by issuing call options that becomes valid only if the condition for the put option has not been met, that is if one of the countries has failed to conditionally commit to cooperate. For simplicity we will assume that the put and call options are integrated into a single conditional option contract.

One might ask why contracts in the form of options would be enforceable while contracts like those of section 3.1 are not. The key difference is that the option contracts proposed here apply not among but rather within countries, where courts of law do have an enforceable purview protected by constitutions. The commitment is not made directly towards other countries, but rather towards domestic and foreign investors. Further, as these options are a form of sovereign debt, failure to respect them could be considered as sovereign default, something governments seek to avoid at almost any cost.

3.2.2. An international agreement through conditional commitment

Let us now formalize the conditional commitment device proposed in the previous section and apply it to the case where a subset S of the set of all countries N want to negotiate and commit to an international agreement. We use $\mathbf{p}_t^A = (p_{1t}, ..., p_{St})$ to denote the minimum carbon price in countries 1 to S if an "agreement" is reached, that is if commitment is triggered. Let $\Omega_{it}(S, p_{it}^A, p_{it}^F, \mathbf{o}_{-i,t}, \mathbf{p}_{-i,t}^A)$ denote a conditional option contract written by country i to *either*

1. Sell a local permit at an agreement price p_{it}^A in period t conditional on all other countries $j \in S$ issuing at least a quantity o_{jt} of options $\Omega_{jt}(S, p_{jt}^A, \bullet, \mathbf{o}_{-j,t}, \mathbf{p}_{-j,t}^A)$.[1]

or

2. Buy a permit of country i at a fallback price p_{it}^F in period t conditional on some other country *not* issuing at least a quantity o_{jt} of options $\Omega_{jt}(S, p_{jt}^A, \bullet, \mathbf{o}_{-j,t}, \mathbf{p}_{-j,t}^A)$.

The country emitting those options is committed to a *price floor* of p_{it}^A if other countries in the proposed coalition S make a similar commitment and to a *price ceiling* of p_{it}^F otherwise. Therefore the arguments p_{it}^A and p_{it}^F represent the commitments of country i while $\mathbf{o}_{-i,t}$ and $\mathbf{p}_{-i,t}^A$ represent the conditioning on similar commitment by other countries.

For now, we take the strategy space to be as follows. Each country may choose to emit any positive number of conditional option contracts $\Omega_{it}(S, p_{it}^A, p_{it}^F, \mathbf{o}_{-i,t}, \mathbf{p}_{-i,t}^A)$ with any parameters as long as all prices and quantities are positive and $S \subseteq N$. We later discuss how that space may be

[1] We use the $\bullet$ to indicate that the device does not condition on the fallback price p_{jt}^F used by their peers.

expanded. A strategy for country i is the choice of a set of options to issue. We also assume for the time being that each country individually gains from cooperation. Cases where this assumption might not hold are dealt with in the next subsection.

In order to discuss the efficient equilibrium, we define

$\mathbf{p}_t^* = (p_t^*, ..., p_t^*)$ the vector of efficient prices (notice that permit prices are equalized across countries, a necessary condition for efficiency)

$\mathbf{p}_t^{nc} = (p_{1t}^{nc}, ..., p_{St}^{nc})$ the vector of noncooperative prices, where p_{it}^{nc} is the carbon price that country *i* would choose to set in Nash equilibrium

$\mathbf{e}_t^* = (e_{1t}^*, ..., e_{St}^*)$ the corresponding number of permits emitted by each country, where e_{it}^* is the number of permit yielding an equilibrium price of p_t^* in country *i*

$\bar{\mathbf{o}} = (\bar{o}_{1t}, ..., \bar{o}_{St})$ a vector of minimal issuance levels where $\bar{o}_{it}$ is sufficient to effectively commit country *i* to maintaining a minimum price of p_t^* for all *i*.

We can then establish the following result :

Result 1 :

Every country *i* issuing a quantity $\overline{o}_{it}$ of options $\Omega_{it}(N, p^*, p_{it}^{nc}, \bar{\mathbf{o}}_{-i,t}, \mathbf{p}_{-i,t}^*)$ is an efficient Nash equilibrium. In this equilibrium commitment is triggered and, in keeping with this commitment, all countries issue e_{it}^* pollution permits resulting in a carbon price $p_{it} = p_t^*$

Proof :

Given the Nash equilibrium strategies described, the fact that commitment is triggered and that an issuance of e_{it}^* permits is realized follows from the definition of the option and the definition of $\bar{\mathbf{o}}$ as sufficient to effectively commit each country. It thus remains to demonstrate that that those strategies are indeed a Nash equilibrium, for which it suffices to show that no country has an incentive to deviate individually.

Take any country *i*. On the one hand, choosing to emit a quantity $\overline{o}_{it}$ of options $\Omega_{it}(N, p^*, p_{it}^{nc}, \overline{\mathbf{o}}_{-i,t}, \mathbf{p}_{-i,t}^*)$ will give this country the payoff of full cooperation. On the other hand, choosing to emit any different number of options $\Omega_{it}(N, p^*, p_{it}^{nc}, \overline{\mathbf{o}}_{-i,t}, \mathbf{p}_{-i,t}^*)$, as well as choosing to instead emit options with different parameters, would result in committing all other countries to the behaviour of the noncooperative outcome. Yet, by assumption of a global public good, this can only provide country *i* with a lower payoff than full cooperation. Therefore country *i* has no incentive to deviate, and the same is true for all other countries. Q.E.D.

Therefore, unlike S. Barrett (1994) and other papers in the same tradition, cooperation in this framework can be sustained even when the potential gains from cooperation are large. Further, unlike other approaches that allow efficient results (Carraro et al., 2009; Chander & Tulkens, 1995), the threat that sustains the agreement is fully credible because players are committed to executing it. No renegotiation is possible because players are committed not to implement anything but the efficient agreement.

Of course, all individually rational payoffs (i.e. payoffs better than noncooperation payoff) are also a Nash equilibrium. This is because if all other countries in *S* are conditionally committed to an agreement that gives country *i* at least its noncooperative payoff and are committed to noncooperation otherwise, then conditionally committing to this agreement is a best response. This result is in agreement with the findings of Myerson (1991) and with the "commitment folk theorem" presented by Kalai, Kalai, Lehrer, and Samet (2010). The conditional commitment devices therefore create a problem of equilibrium selection, but it is certainly a much better problem to have than the certainty of an outcome close to noncooperation as is the case in the dominant strand of literature.

Finally, the rather restrictive strategy space adopted above to simplify the exposition can be expanded to include any amount of any conditional or unconditional options of any type. These may include options of the type above, or any other kind of option, and the country can emit different types of options simultaneously. A strategy for country i is the choice of a set of options to issue. The only restriction that must be imposed on options is that they condition on the issuances of options by other players (i.e. the conditional commitment devices selected by other players) rather than on the number of permits emitted or the actual pollution levels (i.e. not on the actions that are realized). This restrictions aims at avoiding the circularities that may void the existence of any solution as discussed by Kalai et al. (2010).

3.2.3. Incorporating transfers within the agreement

In what we have done so far the cost of abatement is borne fully by the country in which the abatement takes place. This can lead to two types of problems :

1. It may create "unfair" situations where for instance some developing countries face a disproportionate share of world abatement costs.
2. If some country actually benefit or face very low costs from the environmental "problem" (for instance, Russia might gain from climate change), it will be impossible to induce it to join the agreement even with the threat of noncooperation. However, as they contribute to the problem, these countries must join for efficiency to be achievable.

Both problems can be solved at once if the agreement incorporates financial transfers among nations. Many papers use financial transfers, but the goal is usually to expand cooperation by neutralizing the free-riding incentive. Here this is not necessary, as the conditional commitment devices have already addressed that issue. In case (1) the goal is purely ethical while in case (2) it is to attract participants that otherwise wouldn't even desire an agreement in the first place rather than just free-riders.

A difficulty in the context of the present paper is that receivers of transfers – especially those in situation (2) above – would require a commitment to the transfers from payers before making a commitment of their own to abatement. Similarly, payers of transfers would want this commitment to be conditional on everyone committing to the agreement. A potential way to achieve this would be for payers to give receivers "conditional bonds" that only become valid once commitment has been triggered by all countries emitting their conditional options as required. Once it is, they become national debt like any other government bond. These conditional bonds are therefore the "natural partners" of the conditional option contracts. In this way, transfers now become and integral part of the agreement.

Finally, note that transfers amplify the aforementioned multiplicity of equilibria. There is now many more equilibria, and unlike earlier there is also multiple efficient equilibria. Yet the multiplicity of efficient equilibria could hardly be construed as a problem. The possibility to redistribute wealth is necessary for the second welfare theorem – the ethical justification behind our aim for efficiency – to apply. Further, fairness considerations are necessary to the political acceptability of an agreement and are an important feature of real-world treaties. For instance, the latest blitz of negotiations for a climate treaty in Warsaw have focused on how poor countries should be compensated by rich countries for the climate change damage they will be facing.

4. CONCLUSION

Using climate change as our motivation, we have described a conditional commitment device which simultaneously makes efficient abatement an equilibrium agreement and guarantees compliance with this agreement. Given the very pessimistic trend of the literature on this subject, this is a considerable achievement.

Much remains to be done on this topic. First, before it reaches its final version, the present paper will include a more detailed exposition of the models and a discussion of equilibrium selection. Next, future research should also explore the effects of uncertainty on the scheme, in particular with respect to its efficiency. It is to be expected that there would be some efficiency losses, but that they would be relatively small.

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