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Decentralized enforcement, sequential bargaining, and the Clean Development Mechanism

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Sammendrag:. Selv om det eksisterer en omfattende litteratur både om internasjonale forhandlinger og om hvordan internasjonale avtaler kan håndheves, er det hittil gjort lite forskning om hvordan forhandlinger og håndhevingsmekanismer påvirker hverandre gjensidig. Et viktig unntak er Fearon (1998), som modellerer internasjonalt samarbeid som en to-trinnsprosess, der partenes atferd i forhandlingsprosessen påvirkes av vissheten om at avtalen må håndheves av partene selv. I dette notatet utvikles en alternativ modell for denne typen interaksjon, med den grønne utviklings-mekanismen som eksempel. Som hos Fearon modelleres håndhevingsfasen som et uendelig gjentatt Fangens dilemma-spill. Men mens Fearon betrakter forhandlingsfasen som et utmattelsesspill, modelleres denne fasen her som et sekvensielt forhandlingsspill av typen Ståhl-Rubinstein. Modellens implikasjoner sammenlignes med resultatene fra Ståhl-Rubinstein-modellen og også med resultatene fra Fearons modell. En noe overraskende konklusjon er at det forhold at partene selv må håndheve avtalen bidrar til å gjøre utfallet av forhandlingene mer symmetrisk enn det ellers ville være. Forhandlingsstyrke er således mindre viktig hvis partene er overlatt til seg selv enn det er hvis det finnes en tredjepart (f.eks. en domstol) som sørger for å håndheve avtalen.

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Abstract: While there is a vast literature both on international bargaining and on how international agreements can be enforced, very little work has been done on how bargaining and enforcement *interact*. An important exception is Fearon (1998), who models international cooperation as a two-stage process in which the bargaining process is constrained by a need for decentralized enforcement (meaning that the agreement must be enforced by the parties themselves rather than a third party, such as a court). Using the Clean Development Mechanism as an example, the present paper proposes a different model of this kind of interaction. The model follows Fearon's in so far as we both use the infinitely repeated Prisoners' Dilemma to capture the enforcement phase of the game. However, while Fearon depicts the bargaining stage as a War of Attrition, the present model sees that stage as a sequential bargaining game of the Ståhl-Rubinstein type. The implications of the present model are compared both to those of the Ståhl-Rubinstein model and to those of the Fearon model. A surprising conclusion is that a need for decentralized enforcement tends to make the bargaining outcome more symmetrical than otherwise. Thus, the impact of bargaining power is actually smaller when the resulting agreement must be enforced by the parties themselves than it is if enforcement is taken care of by a third party.

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1 Introduction

Much of the literature on international cooperation can be placed in two main categories. One focuses on bargaining – the process of reaching agreement. Scholars working in this field tend to ask if certain bargaining outcomes are more likely than others, given a particular setting. After the fact, they ask why the solution actually reached in a specific context came to be chosen over other potential outcomes.[1] The second category investigates the conditions under which international agreements can be enforced, given the anarchic character of the international system. Work of this kind typically focuses on the means by which states try to sustain the outcome of a bargaining process.[2]

Although there is a vast body of literature in either of these two categories, very little work exists on how bargaining and enforcement *interact*. A notable exception is Fearon (1998), who studies how the need for enforcement might constrain the outcome of a bargaining process. For this purpose, Fearon uses the repeated Prisoners' Dilemma to model the enforcement stage, portraying the bargaining stage as a War of Attrition.

The present paper proposes a different model of the interaction between enforcement and bargaining. The model resembles Fearon's in so far as they both use the infinitely repeated Prisoners' Dilemma to model the enforcement stage. However, the bargaining stage is modeled in a different way. Instead of using the War of Attrition to portray this stage, the Ståhl-Rubinstein (S-R) sequential bargaining model is used.[3] The question posed is similar to that of Fearon: How do the restrictions imposed by the enforcement stage affect the bargaining outcome? In particular, I ask how the need for decentralized enforcement influences the distribution of the fruits of cooperation. The surprising answer is that it makes the bargaining outcome more symmetrical than it is in the S-R model. In other words, the impact of bargaining power turns out to be *smaller* if the parties must enforce the agreement themselves than it is if the agreement is enforced by a third party.

Even if the basic idea is quite general, I find it convenient to present the model in terms of a concrete example, namely the Clean Development Mechanism (CDM).[4] It is not yet clear to what extent CDM projects will have to be enforced in a decentralized manner.[5] The model presented here suggests that this decision is likely to have a bearing on how the gains from CDM projects are distributed between the parties. Surprisingly, decentralized enforcement tends to induce a more symmetric division of the gains than does centralized enforcement. In other words, there is less room for bargaining power if the parties must enforce CDM

1 For a brief review of the literature on international bargaining, see Hopmann (1996, ch. 3).

2 This literature includes parts of the neo-neo-debate, e.g., Baldwin (1993), Grieco (1990, 1993), Morrow (1997), Powell (1991, 1993, 1994) and Snidal (1991a, 1991b, 1993), as well as the huge amount of work on cooperation under anarchy. Classics in the latter literature are Axelrod (1984), Kreps et. al. (1982), Oye (1986), Taylor (1976, 1987) and Shubik (1970).

3 This model has been extremely popular in economic applications of bargaining theory. Applications to international relations include Fearon (1995), Powell (1996) and Wagner (1996).

4 A potential problem with this example is that many CDM projects are one-off rather than repeated in nature. This makes the assumption of depicting the enforcement stage as an infinitely repeated game problematic. In practice, however, decentralized enforcement may involve punishment on other issues as well. Hence, it may be useful to think of the parties' moves in the enforcement stage as a choice between cooperation and non-cooperation that is not necessarily limited to CDM projects.

5 At the earliest, agreement on a binding enforcement regime will be adopted at the first Meeting of the Parties following the entering into force of the Kyoto Protocol. Relatively optimistic observers expect this to happen some time in 2002.

agreements themselves, than if enforcement is ensured by a third party such as the enforcement branch of the climate regime's compliance mechanism. Assuming that the bargaining advantage will typically rest with the industrial country, this may be seen as good news from the point of view of developing countries.

The present model has at least two distinct advantages over Fearon's model. First, while Fearon construes the bargaining process as a struggle over just two competing proposals, the S-R model allows for a continuum of bargaining outcomes. When, as in this paper, the main purpose is to analyze the distribution of the benefits of cooperation, the latter is clearly the preferable solution. Second, another unsatisfactory feature of Fearon's model is that it uses continuous time in the bargaining stage, but discrete time in the enforcement stage. This problem is avoided in the present model, as both stages are pictured in discrete time.

These two advantages do have a price, however. A counterintuitive feature of the S-R model is that agreement is always achieved instantaneously. Although the (potential) length of the bargaining process is nevertheless a central parameter in the model and an important determinant of the predicted bargaining outcome, the assumption that in equilibrium agreement is always reached immediately makes the model unfit to study a contest of nerves of the type that is sometimes characteristic of the final stages of international bargaining processes. At that point, it is indeed often the case that two proposals confront each other, threatening a breakdown unless one of the parties backs down.

These observations suggest that the two models have different applications and are therefore best seen as complementary rather than competing. Fearon's model is more appropriate for the purpose of deciding which side is likely to prevail in a contest of nerves. The present model is likely to be more useful if the aim is to predict which party will be able to claim the larger share of the fruits of cooperation, or how particular parameters tend to influence the parties' payoffs. Used together, the two models offer a better and fuller understanding of the impact of anarchy on bargaining outcomes than either of the two models used alone.

The main parts of this paper focus on a version of the model that assumes complete information. Some may object that some of the model's parameters (notably the parties' discount factors) are unlikely to be common knowledge, meaning that a model based on incomplete information would be more appropriate. I agree. However, as I need to compare my results to those of the S-R and Fearon models, it is only sensible to retain as much as possible from those models and vary only the factors of principal interest. These factors are the means of enforcement (vis-à-vis the S-R model) and the structure of the bargaining stage (vis-à-vis Fearon). As the assumption of complete information is made both in the S-R model and in Fearon's model,[6] the bulk of the present paper relies on that assumption as well. However, Appendix C indicates how incomplete information can be incorporated into the model, and shows how this affects some of the model's implications.

The paper is organized as follows. The Clean Development Mechanism is briefly explained in section two. Section three presents the model, portraying international cooperation as a two-stage process. It begins with a bargaining stage, where the parties determine the terms of cooperation. Once an agreement is reached, the parties move on to the enforcement stage, where they seek to implement and sustain that agreement. In the fourth section, I solve the model and explore how the need for enforcement affects the bargaining outcome in

6 Fearon makes a brief note on incomplete information, but the bulk of his article is based on a complete information model.

9 See Hagem (1997:433ff.) for a more thorough discussion of the first three problems mentioned here.

equilibrium. Finally, the fifth section discusses some of the model's main implications and compares the results to those of the S-R and Fearon models.

2 Example: the Clean Development Mechanism of the Kyoto Protocol

Although the relevance of the present model is quite general, it is convenient to have a specific application in mind. The example chosen here is the Clean Development Mechanism (CDM) of the Kyoto Protocol. The purpose of this mechanism is to allow countries listed in Annex I of the Protocol (i.e., industrial countries) to obtain additional emission quotas by financing specific measures that reduce emissions of greenhouse gases in developing countries (which are not included in Annex I). The principal legal basis for the CDM is found in Article 12 of the Kyoto Protocol. The first three sections of the Article state that:

> 1. A clean development mechanism is hereby defined.
>
> 2. The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.
>
> 3. Under the clean development mechanism:
>
> Parties not included in Annex I will benefit from project activities resulting in certified emission reductions; and
>
> Parties included in Annex I may use the certified emission reductions accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, as determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

Arrangements of this kind are often portrayed as having a number of advantages (Bohm 1994b:5). First, they enhance efficiency by allowing a given amount of resources to produce a larger reduction of carbon emissions than otherwise. Conversely, a given reduction of emissions may be obtained at a lower cost. Thus, for a given overall emission level, the CDM can make each party better off than it would have been if all emission-reducing projects were implemented individually. Second, since abatement is generally less costly with joint than with individual implementation, the CDM makes it easier for individual countries to accept more ambitious targets for abatement. Finally, it has been argued that, for the above reasons, the CDM is likely to enhance the chances of more general agreements on abatement.

However, agreements based on the CDM are not without difficulties. At least four problems may be distinguished.[9] First, it may be difficult to estimate the net effect of a CDM project. Emissions are constantly changing, meaning that an estimate is needed of a baseline for emissions in the host country in the absence of the CDM project. A second problem is that potential host firms might be induced to act strategically. The hope of being offered a profitable CDM contract might cause them to postpone investments in less polluting technology, causing adverse effects on global emissions. Third, transaction costs connected with negotiation, implementation and monitoring of CDM agreements may be considerable. As a consequence, potential gains from cooperation may be seriously reduced or even completely offset. Finally, it is far from obvious how schemes of joint implementation can be enforced. It may be tempting for a developing country to try to cash in a side payment without delivering (in full) the promised investment. Conversely, an industrialized country might be tempted to hold back (part of) the agreed-upon side payment, hoping that the developing country might nevertheless deliver the agreed-upon investment. In addition, there is the possibility that the parties might join forces to make imaginary contracts that seemingly satisfy the industrialized country's obligations under the Kyoto protocol, while actually achieving nothing in terms of reducing carbon emissions. Avoiding this type of cheating could require vast resources being used for monitoring.

3 The Model

The model consists of two stages. At the first stage, the parties bargain in order to set the terms of agreement. At the second, they implement that agreement and select strategies to enforce it.

Consider a project designed to reduce carbon emissions that, if implemented, would meet part of country C's emission reduction target under the Kyoto protocol. The project can be implemented by country C itself, at cost C_C, but it may also be implemented by another country I, at cost C_I, where $C_C > C_I$.[10] This means that both countries benefit if they are able to reach (and enforce) an agreement whereby, first, the project is implemented by I, and, second, I receives a side payment X from C. Country C would then gain C_C - X, while country I would gain X - C_I, compared to a situation where the relevant project is implemented by country C itself and no side payment is made.

In the bargaining stage, the parties determine the size of the side payment X. Clearly, any candidate for a final agreement has to satisfy $C_C \geq X \geq C_I$, since a proposal outside this range would make one of the parties worse off with an agreement than without it. Thus that party would rationally choose not to consent to it. In other words, only agreements satisfying this requirement belong to the bargaining set.

The bargaining stage will here be depicted as a sequential bargaining game of the Ståhl-Rubinstein type (Ståhl 1972, Rubinstein 1982).[11] In this model, two parties get to share a pie if they are able to agree on how to share it. In the present context, the "pie" corresponds to $C_C - C_I$. At date 0, one of the countries proposes a side payment x_0 in [C_I, C_C], and the other party either accepts or refuses. For the sake of comparability, I suppose throughout that country I makes the first proposal. If country C accepts, it obtains $C_C - x_0$, leaving $x_0 - C_I$ for country I. If country C refuses, it makes a new proposal x_1 at date 1, in which country I gets $x_1 - C_I$ if it accepts. If country I refuses, it gets to make yet another proposal x_2 at date 2, and so forth. In this manner, the countries alternate making offers until either one of them accepts the opponent's proposal or the time available for bargaining runs out. In the S-R model, the payoffs are $\delta_I^t (x_t - C_I)$ for country I and $\delta_C^t (C_C - x_t)$ for country C if the parties

10 It may be useful to think of country C ("Compensator") as an industrialized country, and country I ("Implementor") as a developing country.

11 The following exposition is based on Hovi (1992:162-163), which in turn draws heavily on Sutton (1986:710-712) and Tirole (1988:430).

agree at date t on a side payment of x_t. If no agreement is reached, both sides receive a zero payoff. The discount factors δ_j (j=C,I) apply to the bargaining stage only, and are assumed to satisfy $0<\delta_j<1$. It may be noted that the bargaining stage is not only a game of complete information, but also one of perfect information.

Once the parties have reached an agreement, they enter the second stage of the game: the enforcement stage.[12] In other words, the sooner they reach an agreement, the sooner they can begin to enjoy the fruits of cooperation.[13] Implicitly, the S-R model assumes that any agreement is enforced automatically and without cost. This could mean, for example, that there is an institution such as a court that can be relied upon to automatically enforce any agreement the parties might reach, free of charge. Of course, this is usually unrealistic even in a national setting, as not all disputes can be brought before a court, and legal proceedings are typically costly. Assuming that the parties are states, however, the assumption of automatic and costless enforcement is even more unrealistic. Granted, even at the international level, the parties can in theory often refer a dispute to a third party, either a permanent court or an institution established by the parties themselves to ensure compliance. For example, the climate regime will include a compliance mechanism for this purpose. In practice, however, international institutions rarely have the power to enforce their decisions. And even if they do, it is not always credible that they are prepared to use them. Among other things, this could cause the relevant party to exit the agreement. In the case of CDM, the compliance mechanism of the emerging regime on climate change is primarily designed to enforce emission quotas. It is less clear if it can also be used to enforce the terms of CDM contracts. It is not unrealistic, therefore, to assume that such contracts must be enforced by the signatories themselves. I shall call this decentralized enforcement, whereas enforcement by an institution (or another third party) will be referred to as centralized.

The enforcement stage of the model consists of an infinite number of periods. In each period country I decides whether to implement a project and country C decides whether to make the side payment that was agreed upon in the bargaining stage. The periodic payoffs in the enforcement stage are shown in Figure 1. All payoffs represent gains and losses compared to a situation where the project is implemented individually by country C (and no side payment is therefore made). It is assumed that each project is “small”, in the sense that it affects global warming only marginally. Ecological benefits are therefore negligible compared to monetary payoffs, and may be ignored.

[12] Throughout this paper, I only consider agreements characterized by “constant” distributions of the pie, meaning that each party gets the same payoff in every period of the enforcement stage (as long as both parties abide by the agreement). This means imposing a restriction on the bargaining set, since in practice, the parties might also consider “variable” distributions. It is obvious that this restriction might influence the bargaining solution, regardless of whether or not the agreement is enforced by the parties themselves. If the parties’ discount factors differ, both sides may benefit if a “constant” distribution is replaced with a “variable” one, which gives more to the relatively impatient party in early phases of the enforcement stage, and more to the relatively patient party in later phases. However, whether restricting the bargaining set to “constant” distributions has an impact on the effect of decentralized enforcement remains to be determined.

[13] As future benefits are being discounted, the parties can therefore be said to bargain over a shrinking pie.

12 The countries have “almost perfect” information because both of them know the game’s history up to the current period, but neither country can observe the opponent’s move in the current period before it has to make his own decision.

The game in Figure 1 obeys the definitional criteria of a Prisoners' Dilemma game. That the time horizon of the enforcement stage is infinite means that no matter how many times the game has already been played, there is always a positive probability that the game continues at least one more period. The game in Figure 1 is the constituent game of the larger, repeated game that makes up the enforcement stage.

For simplicity, I assume that in each period of the enforcement stage, each side makes its move in ignorance of the decision made by the opponent. However, at the beginning of each period, the parties are assumed to know the history of the game up to that point. Moreover, payoffs and strategy sets are assumed to be common knowledge. The enforcement stage is, therefore, a game of complete and "almost perfect" information.[15]

Some may object that for many types of CDM projects, it is more realistic to assume that the parties make their moves sequentially, rather than simultaneously. For example, the project may not be started until the payment has been made. In this case, only country I has a real chance of cheating, since if country C does not make the payment, it is unequivocally in country I's best interest not to complete the project. Similarly, if the payment is not due until the project has been completed, only country C has a real chance of cheating. The implications of introducing sequential moves turns out to be straightforward, and will be briefly reviewed in the final section.

As the constituent game of the enforcement stage is a Prisoners' Dilemma, it follows that in the one-shot version of the game, it is a dominant strategy for each side to defect from the agreement. However, it is well known that in the infinitely repeated version of the game, compliance can be sustained if the parties apply appropriate strategies for the repeated game (e.g., Axelrod 1984, Shubik 1970, Taylor 1976, Taylor 1987).[16] The question that concerns us here is what impact the enforcement stage has on the outcome of the bargaining stage.

Figure 1: Payoff matrix for the enforcement stage

		Country C: Pay	Country C: Not pay
Country I	Implement	X-C_I, C_C-X	-C_I, C_C
	Not implement	X,-X	0,0

4 Equilibrium

The game can be solved by backwards induction. I therefore begin with the enforcement stage and then turn to the bargaining stage.

4.1 The enforcement stage

In the enforcement stage, the countries are simply assumed to use "grim" trigger strategies to punish a defection. As a consequence, any defection causes the agreement to be terminated. Let ω_j (j=I,C) be the parties' discount factors for the enforcement stage. These discount

13 With a small amount of the "right" sort of incomplete information, compliance can also be sustained in the finitely repeated game (Kreps et. al. 1982).

factors are assumed to satisfy 0< ω_j <1.[17] The motivation for introducing separate discount factors for the enforcement stage and for the bargaining stage is that the effect of discounting turns out to be different in the two stages (see below).

It is straightforward to show that for compliance to be sustained, the following two conditions must be satisfied (see Appendix A for details):[18]

(1a) $\omega_I \geq \frac{C_I}{X}$

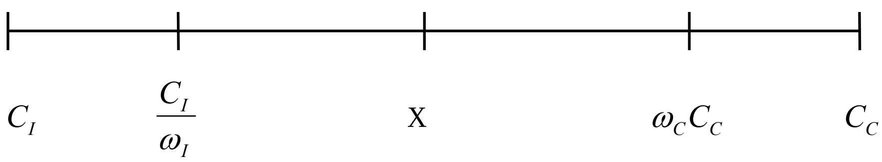
(1b) $\omega_C \geq \frac{X}{C_C}$

Conditions (1a) and (1b) can be combined and re-written as

(2) $\omega_C C_C \geq X \geq \frac{C_I}{\omega_I}$

Since $C_I < \frac{C_I}{\omega_I}$ and $\omega_C C_C < C_C$ (see Figure 2), condition (2) places real constraints on the size of the side payment X. It says that for compliance to be enforceable, the bargaining outcome must be better for each side than some minimum threshold. If the side payment is too small, then country I will not be induced to implement the project. If it is too large, then country C will decline to pay the side payment. Note that the smaller the discount factors of the parties, the more severe the constraints. Conversely, as the discount factors tend to one, condition (2) simply reduces to a requirement that both sides must be better off with than without the agreement, i.e., the agreement must be an element in the bargaining set. In short, the more patient the parties, the more room there is for negotiation about the size of the side payment.

Figure 2. The bargaining set



At this point, one might intuitively expect that if the S-R solution lies *outside* the interval $\left[\frac{C_I}{\omega_I}, \omega_C C_C\right]$, then the need for decentralized enforcement will bring the outcome inside that interval (if only just). A second hypothesis that may seem intuitively reasonable is that if the S-R solution lies *inside* that interval, then the outcomes of the two models will be identical. It turns out that only the former intuition is correct. To see why, let us now turn to the bargaining stage.

14 Note that if a period in the enforcement stage is longer than a period in the bargaining stage (which is usually a reasonable assumption), then $\delta_j > \omega_j$ (j=I,C).

15 In other words, if these conditions are satisfied, then, in subgame perfect equilibrium, the parties comply in every period of the enforcement stage.

4.2 The bargaining stage

I shall mainly consider two cases, which differ only in the time available for bargaining. I begin with the single-period case, and then proceed to the infinite-horizon case. Intermediate cases will also be mentioned briefly.

4.2.1 Single-period bargaining

In the single-period case, the entire process of "bargaining" is reduced to a simple ultimatum game. Country I offers a contract and country C must simply accept or reject country I's proposal. If country C rejects, both sides receive a zero payoff, and there is no agreement to enforce. The solution of the single-period S-R model is that country I proposes $x_0 = C_C$, and that country C accepts.[19] In other words, country I is able to secure (virtually) all of the gains from cooperation for itself. Hence, the game has a strong first-mover advantage.

If, on the other hand, the contract must be enforced by the countries themselves, country I knows that even if country C were to *consent* to any side payment smaller than or equal to C_C, it would not *comply* unless the agreement satisfies inequality (1b). Accordingly, country I rationally offers an agreement which only just passes this test. Assuming that inequalities (1a) and (1b) are satisfied, then, the solution of the game may be described as follows:

I. At date 0, country I proposes $x_0 = \omega_C C_C$.

II. Country C accepts this proposal.

III. Both countries comply indefinitely.

This equilibrium gives country C a payoff of V_C:

(3) $V_C = C_C - x_0 = C_C - \omega_C C_C$

Similarly, country I obtains a payoff of V_I :

(4) $V_I = x_0 - C_I = \omega_C C_C - C_I$

Note that in the case of single-period bargaining, the inclusion of an enforcement stage provides country C (the second mover) with a larger share of the pie. There is still a first-mover advantage in the model (provided that country C's discount factor is sufficiently large),[20] but the need for decentralized enforcement makes this advantage smaller than it is in the case with centralized enforcement.

Figure 3 gives the solutions of the one- two-, three-, four- and five-period cases. For easy comparison, the corresponding equilibrium outcomes for the S-R model are given in Figure 4.

16 In fact, to ensure a strict preference for country C, the side payment must be infinitesimally smaller than C_C.. For simplicity, differences of this kind will be ignored throughout.

17 A first-mover advantage requires that country I's payoff is larger than country C's. In the single-period bargaining case, this condition is satisfied if $\omega_C C_C - C_I > C_C - \omega_C C_C$, i.e. if $\omega_C > \frac{C_C + C_I}{2C_C}$

.

Figure 3: Equilibrium bargaining outcomes with decentralized enforcement

No. of periods.	Payoff for country I
1	$\omega_C C_C - C_I$
2	$(C_C - C_I) - \delta_C \left[C_C - \frac{C_I}{\omega_I} \right]$
3	$(C_C - C_I) - \delta_C (C_C - C_I) + \delta_C \delta_I (\omega_C C_C - C_I)$
4	$(C_C - C_I) - \delta_C (C_C - C_I) + \delta_C \delta_I (C_C - C_I) - \delta_C^2 \delta_I \left[C_C - \frac{C_I}{\omega_I} \right]$
5	$(C_C - C_I) - \delta_C (C_C - C_I) + \delta_C \delta_I (C_C - C_I) - \delta_C^2 \delta_I (C_C - C_I) + \delta_C^2 \delta_I^2 (\omega_C C_C - C_I)$
.....	.....
∞	$\frac{1-\delta_C}{1-\delta_C \delta_I} \ (C_C - C_I)$

Figure 4: Equilibrium Bargaining Outcomes in the S-R model

No. of periods.	Payoff for country I
1	$C_C - C_I$
2	$(C_C - C_I) - \delta_C (C_C - C_I)$
3	$(C_C - C_I) - \delta_C (C_C - C_I) + \delta_C \delta_I (C_C - C_I)$
4	$(C_C - C_I) - \delta_C (C_C - C_I) + \delta_C \delta_I (C_C - C_I) - \delta_C^2 \delta_I \ (C_C - C_I)$
5	$(C_C - C_I) - \delta_C (C_C - C_I) + \delta_C \delta_I (C_C - C_I) - \delta_C^2 \delta_I (C_C - C_I) + \delta_C^2 \delta_I^2 (C_C - C_I)$
....	....
∞	$\frac{1-\delta_C}{1-\delta_C \delta_I} \ (C_C - C_I)$

4.2.2 Infinite-horizon bargaining

Proofs for the two-period and three-period solutions in Figure 4 are given in Appendix B.[21] Here, I concentrate on the infinite-horizon case. Figure 5 shows the difference between the solutions of the two models for up to five periods in the bargaining game.

18 The results of the S-R model are assumed to be well known. Interested readers are referred to Rubinstein (1982), Tirole (1988:430-431) or Fudenberg & Tirole (1991:113-117).

19 If country C moves first in the enforcement stage, it is the other way around.

Figure 5: Difference in equilibrium bargaining outcome with and without decentralized enforcement

No. of periods	Payoff Difference for Country I
1	$\omega_C C_C - C_C$
2	$\delta_C \left[\frac{C_I}{\omega_I} - C_I \right]$
3	$\delta_C \delta_I (\omega_C C_C - C_C)$
4	$\delta_C^2 \delta_I \left[\frac{C_I}{\omega_I} - C_I \right]$
5	$\delta_C^2 \delta_I^2 (\omega_C C_C - C_C)$

Let V_I^{PM} denote the payoff to country I provided by the solution of the present model. Similarly, let V_I^{SR} denote the payoff to country I provided by the S-R model. In general, we may then write the difference between the two solutions, in terms of country I's payoff, as follows:

k=uneven: $V_I^{PM} - V_I^{SR} = \delta_C^{\frac{k-1}{2}} \delta_I^{\frac{k-1}{2}} (\omega_C C_C - C_C) < 0$

k=even: $V_I^{PM} - V_I^{SR} = \delta_C^{\frac{k}{2}} \delta_I^{\frac{k}{2}} \left[\frac{C_I}{\omega_I} - C_I \right] > 0$

Here *k* equals the number of periods in the bargaining stage. Notice that, as *k* becomes large, the right-hand side of (5) tends to zero. The same is true for the right-hand side of (6). In other words, *as* k *tends to infinity, the bargaining solution in the case with decentralized enforcement converges to that of the S-R model*. As indicated by Figures 3-4, this solution gives country I a payoff of $\frac{1-\delta_C}{1-\delta_C\delta_I} (C_C - C_I)$, which leaves $\frac{\delta_I(1-\delta_C)}{1-\delta_C\delta_I}(C_C - C_I)$ for country C.

Before I turn to the discussion, one further comment is in order. So far, I have assumed that in the enforcement stage, the parties make their moves simultaneously in each period. As already noted, this assumption is not always realistic. It turns out, however, that the implications of relaxing this assumption are straightforward. With sequential moves in the enforcement stage, only the second mover has a real chance of cheating. The reason is that if the first mover cheats (does not pay or does not complete the project, depending on who the first mover is), then the second mover has no incentive to cooperate either. In this case, therefore, the enforcement stage no longer places *two* restrictions on the bargaining set (cf. figure 1), but only *one*. If country C moves last in the enforcement stage, then only the lower restriction is effective. If country I moves last, then only the upper restriction is effective. It can be shown that in the latter case, for k=even, the solution of the game with decentralized enforcement is the same as in the simultaneous move version of the game with decentralized enforcement. In contrast, when k is uneven, the solution is the same as in the S-R model.[23] As the solutions with and without decentralized enforcement have already been shown to be identical if there are infinitely many rounds in the bargaining stage, it follows that this is also true in the case with sequential moves in the bargaining stage.

The intuition behind this conclusion may be explained as follows. The enforcement stage constrains the advantage of making the proposal in the final bargaining round.[24] The nature of this constraint is to rule out extremely asymmetrical proposals. With sequential moves in the enforcement stage, the constraint is absent for one of the parties, namely the first mover in the enforcement stage. For example, suppose that country C moves first in the enforcement stage. In this case, country I need not worry that a very asymmetrical agreement will lead C to violate the agreement. Therefore the bargaining solution becomes more asymmetrical in country I's favor, compared with the case where the parties move simultaneously in the enforcement stage. However, this is true only when k is uneven, since it is only in these cases that country I gets to make the proposal in the final bargaining round.

5 Discussion and conclusion

This paper has analyzed the impact on inter-state bargaining outcomes of decentralized enforcement, which is often typical for international cooperation. Using the Clean Development Mechanism as an example, I constructed a two-stage model in which a bargaining stage is followed by an enforcement stage once an agreement is concluded. While the enforcement stage was modeled as an infinitely repeated Prisoners' Dilemma, the bargaining stage was pictured as a sequential bargaining game of the Ståhl-Rubinstein type. To study the impact of the enforcement stage, equilibrium bargaining outcomes reached in the two-stage model were compared to those generated by the S-R model. This section elaborates on the differences between the results of the present model, those of the S-R model, and those of the Fearon model.

As the present model is an extension of the S-R model, it is not surprising that there are both similarities and differences between the equilibrium outcomes of the two models. First, in both models it is advantageous to make the *first* proposal, i.e., to have agenda-setting power. This is most easily seen if we concentrate on the single-period case and the infinite-horizon case (where the two solutions converge) and assume that the parties' discount factors for the bargaining stage are identical (i.e., $\delta_C = \delta_I = \delta$). We have already seen that country I (the first mover) gets more than country C in the single-period case, provided that country C's discount factor for the enforcement stage is sufficiently large.[25] And it is easily verified that with an infinite horizon $V_I > V_C$ for $\delta < 1$ (recall that in the above analysis, country I was invariably the party making the first proposal).

However, with an even number of periods in the bargaining stage, country I is unlikely to get a larger payoff than country C, even if country I makes the first proposal. The reason for this is that in both models it is also advantageous to make the *final* proposal.[26] It is intuitively plausible that the party making the final proposal has an advantage in the S-R model, since that party can always threaten to wait until the final period and then claim (virtually) the entire pie for itself. A similar (although generally smaller) advantage exists with decentralized enforcement as well. Consider the two-period case, where country C makes the proposal in

20 This explains why the enforcement stage has no impact on the solution in case with infinitely many rounds in the bargaining stage. The reason is that in this case, there is no final bargaining period.

21Cf. footnote 14. Notice that the smaller the difference between C_c and C_I , the higher ω_c needs to be.

22 Since it is an advantage both to make the first proposal and to make the final proposal, the best thing of all is to make both the first and the last proposal. Of course, this is only possible if the number of periods in the bargaining stage is uneven.

the final period. In the S-R model, the difference between the payoff of country C and that of country I is $2\delta_C(C_C - C_I) - (C_C - C_I)$, which is positive for $\delta_C > 1/2$. With decentralized enforcement, the corresponding difference is $2\delta_C(C_C - \frac{C_I}{\omega_I}) - (C_C - C_I)$. Given that $\delta_C > 1/2$, the latter difference is also positive, but smaller than the former, as long as ω_I is sufficiently high.[27]

A corollary to this result is that in both models it is a disadvantage to have the final *move* (i.e., to be the one who must accept or reject the final proposal). However, in my model, this disadvantage is less pronounced than in the S-R model. The explanation is that when there is a need for decentralized enforcement, the country having the final move can credibly point out that in order to be enforceable, an agreement must offer both sides a certain minimum payoff. Thus, with decentralized enforcement, country C gets a larger share of the pie than in the S-R model if the bargaining stage has an uneven number of periods (since country C is then the final mover). Similarly, country I gets a larger share of the pie with an even number of periods (as country I is then the final mover).

Third, in the S-R model it is advantageous to be *patient* compared to the other party. For example, if in the infinite-horizon case δ_I tends to 1, while δ_C is kept constant between 0 and 1, country I's payoff tends to $C_C - C_I$ (the entire pie). Similarly, if δ_C tends to 1, while δ_I is kept constant between 0 and 1, country I's payoff tends to 0. In short, the more patient country I is, relative to country C, the larger country I's share of the pie. However, an interesting feature of my model is that, while it is an advantage to be patient in the bargaining stage, it is a *disadvantage* to be patient in the enforcement stage. On this point, the present model concurs with Fearon's. However, as Fearon pictures the bargaining stage as a War of Attrition, his model does not enable the analyst to study the impact of discounting on the distribution of the gains from cooperation. In this respect, the present model is richer. From (5) we see that country I's payoff increases (and thus country C's payoff decreases) as ω_C increases. Similarly, we see from (6) that country I's payoff decreases (meaning that country C's payoff increases) as ω_I increases. The intuition behind these results is that the more patient a party is in the enforcement stage, the larger its aggregate discounted payoff becomes. And the larger the aggregate payoff at stake, the more difficult it is to credibly threaten a breakdown of the negotiations. In short, the present model resembles Fearon's in that getting more patient influences a party's payoff in two ways. On the one hand, the payoff is affected *positively* via an increase in the discount factor for the bargaining stage. On the other hand, it is affected *negatively* through an increase in the discount factor for the enforcement stage.

Finally, perhaps the most striking difference between the present model on the one hand, and the S-R model on the other, is that with decentralized enforcement, the bargaining outcome becomes more symmetrical. This is a second point that is overlooked by Fearon's model, since that model admits only two possible agreements. It is also a surprising result. If anything, it would seem intuitively reasonable to expect the opposite effect. If it is entirely up to the parties themselves not only to reach agreement, but also to enforce that agreement, then intuition seems to suggest that bargaining power should play an even bigger role than in the case where any agreement can be costlessly enforced by a third party. However, the present model predicts the exact opposite result. To understand why, recall that the S-R model predicts extremely asymmetrical outcomes when the time available for bargaining is short.

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23 Specifically, ω_I must be larger than $\omega_I^{\min}$, where $\omega_I^{\min}$ is a threshold value that depends on the other parameters in the model. For example, if $\delta_C = 0.9$, $C_C = 2$ and $C_I = 1$, then $\omega_I^{\min} \cong 0.69$.

Consider the case of single-period bargaining. In this case, the S-R model predicts that the party making the proposal gets (virtually) all of the gains from cooperation. However, that is no longer possible when the agreement must be enforced in a decentralized manner. In other words, the need for decentralized enforcement guarantees each side a minimal share of the pie. Granted, even with decentralized enforcement, the other side might *consent* to an extremely asymmetrical offer. However, such an agreement cannot be enforced. Therefore, any proposal must be adjusted so that the other side is induced not only to accept, but to comply as well. To obtain this requires that the proposal is made more symmetrical than it needs to be in the S-R model. In a context such as the CDM, where one would generally expect the industrial country to have a strong bargaining position, this seems to be good news (at least for developing countries). Surprisingly, this advantage is at least partially curbed if the agreement is enforced in a decentralized manner. Although this effect is particularly striking in the single-period bargaining case, it also holds with several periods in the bargaining stage. However, the longer the horizon of that stage, the smaller the impact on the bargaining outcome. As the horizon approaches infinity, the two solutions converge and the effect disappears altogether.

Appendix A

This appendix demonstrates that conditions (1a) and (1b) in the above text hold. Consider the pair of “grim” trigger strategies for the enforcement stage (G_I, G_C), where the subscripts I and C refer to country I and country C, respectively:

G_I: In the first period, implement the project. In any subsequent period, implement the project if the outcome (implement, pay) has been sustained up to that period. Otherwise, do not implement.

G_C: In the first period, pay the agreed-upon sum. In any subsequent period, pay if the outcome (implement, pay) has been sustained up to that period. Otherwise, do not pay.

If these strategies are used, implementation of further CDM projects is out of the question after a violation has occurred. Thus, each country obtains (at best) a zero payoff indefinitely from then on.

Assuming that the parties’ discount factors for the enforcement stage are ω_I and ω_C ($0<\omega_j<1$), respectively, we find that country I’s expected utility from pursuing G_I, given that country C pursues G_C, is as follows:

(A1) $$EU_I(G_I:G_C) = (X - C_I) + \omega_I(X - C_I) + \omega_I^2(X - C_I) + ... = \frac{X - C_I}{1 - \omega_I}$$

Alternatively, country I can choose not to implement at a particular stage. Since this is an infinitely repeated game, it is of no consequence here whether this happens at the first stage or at a later stage. In both cases, the parties would be confronting exactly the same infinite series of stages in the continuation game (i.e., after a violation has occurred).

Note that after country I has chosen “not implement” in a given period, its best option in the continuation game, given that country C pursues G_C, is to choose “not implement” in all subsequent periods as well. Call this strategy D_I.[28] By using D_I, then, country I obtains a payoff of X in the period in which the violation takes place, and then (at best) zero in each subsequent period. Thus, the expected utility of using D_I, given that country C uses G_C, is simply

(A2) $$EU_I(D_I:G_C) = X$$

28 If “not implement” is prescribed already at the first stage, then D_I is equivalent to “Do not implement, regardless of country C’s behavior.

This means that G_I is preferred to D_I (in other words, it pays to implement the project in every period) if

(A3) $\frac{X - C_I}{1-\omega_I} \geq X$

Solving for ω_I gives:

(A4) $\omega_I \geq \frac{C_I}{X}$

Note that condition (A4) is identical to condition (1a) in the main text.

In the same way, we find that the expected utility to country C from following G_C, given that country I pursues G_I, is as follows:

(A5) $EU_C(G_C : G_I) = \frac{C_C - X}{1-\omega_C}$

Moreover, given that country I pursues G_I, not paying provides a payoff of C_C in the period where the defection occurs, and then (at best) zero in each subsequent period. Suppose the defection occurs already in the first period. The above strategy is then equivalent to "Always defect, regardless of Implementor's behavior". Call this strategy D_C. We then have:

(A6) $EU_C(D_C : G_I) = C_C$

Accordingly, country C prefers G_C to D_C (i.e., it prefers to comply rather than to defect) provided that

(A7) $\frac{C_C - X}{1-\omega_C} \geq C_C$

Solving for ω_C gives:

(A8) $\omega_C \geq \frac{X}{C_C}$

Condition (A8) is identical to condition (1b).

If both conditions (A4) and (A8) are fulfilled, then the strategy combination (G_I, G_C) is a Nash equilibrium in the infinitely repeated game. This equilibrium is subgame perfect, as the two strategies are also in equilibrium after a violation has occurred. After a violation, G_I instructs country I to choose “not implement” indefinitely. For country C, it is then a best response to choose “not pay” indefinitely. But this is exactly what G_C instructs country C to do. Conversely, choosing “not implement” indefinitely is a best response for country I, given that country C chooses “not pay” indefinitely after a violation.

Appendix B

This appendix derives the bargaining solutions given in Figure 3 for the two- and three-period cases with decentralized enforcement.

First, consider the case with two periods in the bargaining stage. At date 0 country I proposes a side payment x_0, and country C accepts or rejects that proposal. If the parties are unable to agree at date 0, so that the game proceeds to date 1, then country C makes an offer x_1, whereas Country I accepts or refuses. If date 1 is reached, the remainder of the game is completely analogous to the one-period case, the only difference being that the roles have been switched. Thus, should the bargaining proceed to date 1, then country C suggests x_1 = $\frac{C_I}{\omega_I}$, which is then the smallest acceptable *and* enforceable side payment. If accepted, this proposal would give country C a (periodic) payoff of $C_C - \frac{C_I}{\omega_I}$. Accordingly, country I knows that at date 0, the smallest payoff that country C is going to settle for is $\delta_C\left[C_C - \frac{C_I}{\omega_I}\right]$, which is in effect what country I offers. This means that the agreed-upon side payment is x_0 $= C_C - \delta_C\left[C_C - \frac{C_I}{\omega_I}\right]$. This leaves country I with a payoff of $(C_C - C_I) - \delta_C\left[C_C - \frac{C_I}{\omega_I}\right]$.

I now turn to the three-period game. In this case, country I makes a proposal at date 0, and country C accepts or rejects. If country C rejects, it makes a second proposal at date 1, and country I accepts or rejects. If it rejects, country I gets to make a final proposal at date 2, which country C must then either accept or reject.

Should the final period be reached, the remainder of the game is identical to the single-period case, and thus country I suggests the largest side payment which is both acceptable and possible to enforce. This is $x_2 = \omega_C C_C$.

We already know from the single-period bargaining case that this would give country I a payoff of $C_C - \omega_C C_C$ and country C a payoff of $\omega_C C_C - C_I$. At date 1, country C proposes the smallest enforceable side payment that country I is willing to accept at that time. This is the amount that makes accepting at date 1or waiting until date 2 equally attractive options to country I. In other words, country C sets x_1 so that $V_I(x_1) = \delta_I(\omega_C C_C - C_I)$. If this had been the final agreement, then country C would obtain $(C_C - C_I) - \delta_I(\omega_C C_C - C_I)$. At date 0, the largest enforceable side payment that country C is willing to accept must be the amount that makes accepting or waiting until date 1 equally attractive options to country C. This means that country I rationally determines x_0 so that country C gets a payoff of $\delta_C(C_C - C_I) - \delta_C\delta_I(\omega_C C_C - C_I)$. In turn, this requires that the side payment must be $x_0 = C_C - \delta_C(C_C - C_I) + \delta_C\delta_I(\omega_C C_C - C_I)$, which in effect is what country I proposes. That leaves the payoff $(C_C - C_I) - \delta_C(C_C - C_I) + \delta_C\delta_I(\omega_C C_C - C_I)$ for country I.

Appendix C

This appendix offers a brief description of an incomplete information version of the above model. Assume that when the game starts, country I is uncertain about the true value of country C's discount parameter for the enforcement stage, ω_C. For concreteness, assume that ω_C is either "high" or "low". With probability 1-q, $\omega_C = \omega_C^H$, whereas with probability q, $\omega_C = \omega_C^L$, where $1 > \omega_C^H > \omega_C^L > 0$. As before, all other parameters in the model are assumed to be common knowledge. The question is what impact this type of incomplete information has on the bargaining outcome.

For simplicity, I concentrate on the single-period bargaining case. If country I had been certain that $\omega_C = \omega_C^H$, it would have offered $x_0 = \omega_C^H C_C$, whereas if it had been certain that $\omega_C = \omega_C^L$, it would have offered $x_0 = \omega_C^L C_C$. With incomplete information, however, country I faces a risky choice. On the one hand, country I has the option of proposing $x_0 = \omega_C^L C_C$, which would be accepted with certainty (regardless of the true value of ω_C) and lead to indefinite compliance by both countries. On the other hand, it might propose $x_0 = \omega_C^H C_C$. In this case country C would also accept the offer with certainty, since it has nothing to lose by doing this. However, it would *comply* only if $\omega_C = \omega_C^H$. By contrast, if $\omega_C = \omega_C^L$, country C defects from the first period in the enforcement stage. It follows that the two options generate the following expected utility for country I:

(C1) $EU_I(x_0 = \omega_C^H C_C) = q(-C_I) + (1-q)\left[\omega_C^H C_C - C_I\right] = \omega_C^H C_C (1-q) - C_I$

(C2) $EU_I(x_0 = \omega_C^L C_C) = \omega_C^L C_C - C_I$

Neglecting the special case of indifference, country I rationally proposes the higher side payment, i.e., $x_0 = \omega_C^H C_C$, if and only if the right-hand side of (C1) is larger than the right-hand side of (C2). This condition is satisfied if

(C3) $\frac{\omega_C^H}{\omega_C^L} > \frac{1}{1-q}$

Thus, country I is more likely to propose the higher side payment,

- the larger ω_C^H is, compared to ω_C^L, and
- the larger 1-q is, i.e., the larger the probability that C's true discount parameter for the enforcement stage is ω_C^H.

If (C3) holds, the game has a separating equilibrium in which country I proposes $x_0 = \omega_C^H C_C$ and country C accepts regardless of its type. However, in the enforcement stage both parties comply only if $\omega_C = \omega_C^H$. Otherwise, country C defects in the first period of the enforcement stage, whereas country I complies. From then on, both parties defect indefinitely.

On the other hand, if (C3) does not hold, the game has a pooling equilibrium, in which country I proposes $x_0 = \omega_C^L C_C$. Regardless of its type, country C accepts the proposal, and both sides comply indefinitely.

This model admits the possibility that in equilibrium the parties may renege on a previously reached agreement after some initial compliance. This provides an important difference between the incomplete information version and its complete information counterpart. In the latter model, both parties will always either comply indefinitely or defect from the very first stage in the enforcement stage.

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