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Does a Clean Development Mechanism Facilitate International Environmental Agreements?

Kai A. Konrad* and Marcel Thum†

February 2, 2015

Abstract

When politicians negotiate in international climate conventions they may suffer from incomplete information about each other's preferences about reaching an agreement. As is known, this may cause failure to reach an efficient cooperative agreement. We study the role of the clean development mechanism (CDM) for the likelihood of such failure. The CDM has been introduced in the context of the Kyoto Protocol to allow countries to make efficiency enhancing use of cross-country low-cost mitigation opportunities. We use a simple bargaining framework to uncover why this mechanism may reduce the likelihood for reaching an efficient cooperative climate agreement.

JEL classification code: Q54, Q58, F53, H41

Keywords: clean development mechanism, international climate agreements, bargaining, incomplete information

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1 Introduction

We study arrangements that allow firms in one country to comply with their governmentally imposed emission abatement targets by implementing abatement projects in other countries. In particular, we explore the consequences of this option for the success probability of international climate negotiations.

The use of cross-border abatement opportunities is the core characteristic of what is called the Clean Development Mechanism (CDM).¹ Article 12 of the Kyoto protocol introduced the principle that signatory states can fulfill part of their commitments towards greenhouse gas reductions by implementing abatement projects in developing countries that have ratified the protocol but have made no commitment. In our context we distinguish only two regions: one region is the set of industrialized countries, who act as a uniform player. They are seen as the main polluters and as causing the global climate change. The other region consists of a set of less developed countries. This bipolar set-up may reasonably well map a negotiation pattern in a series of climate change conferences.²

With the risk of stretching this comparison, we consider two regimes. We refer to the regime with strictly nationally confined abatement projects in the fallback as "the regime without a CDM" and the regime that allows to use all available abatement opportunities internationally as "the regime with a CDM". Of course, by its very nature of being a model, this mapping eliminates potentially important aspects from the picture, but it provides a qualitative insight which we consider as important. We identify a major potential drawback of the CDM: in the absence of a global cooperative agreement, the availability to the CDM changes the cost and benefit of such a cooperation agreement in climate negotiations. As it turns out, the

¹For a comprehensive survey on the CDM literature, see Paulsson (2009). The objectives of this Clean Development Mechanism (CDM) were twofold: On the one hand, developing countries should benefit from technology transfers and achieve a sustainable development. On the other hand, the industrialized countries should be able to minimize their abatement costs. It is this latter objective of the CDM our paper focuses on. The industrialized countries will benefit if some abatement projects can be carried out at lower costs in high polluting industries abroad. Due to the lower cost, the industrialized countries may even find it optimal to increase their commitment towards abatement compared to a scenario without CDM.

²According to observers, the policy controversy and the distributional conflict shifted slightly. At the 2014 UN Climate Change Conference in Lima, for instance, question about how to treat the economically strong and fast growing emerging countries (see, e.g., Endres 2014) who formerly did, but do no longer belong to the group of less developed victims moved to the forefront.

agreement has lower benefits This will lead to more aggressive bargaining and will ultimately reduce the probability for an international agreement on climate policy.

We employ a formal ultimatum bargaining framework with two players that may be thought of as two countries comprising the global economy, or groups of countries if these groups coordinate internally and bargain as single strategic players. Taking up the traditional distributional conflict between the group of industrialized countries and the group of less developed countries we assume that only one of the players is a major polluter. For global efficiency reasons in the context of climate change, this polluter should reduce climate gas emissions. The two players are in conflict with each other and negotiate about how to allocate the cost of this emission reduction. One of the countries is allowed to make a take-it-or-leave-it offer. The other country accepts or rejects. We allow for a random mechanism that determines the roles as proposer or responder. We fix the emission reduction offer to the reduction size that would be efficient from a global perspective.

Both players may have incomplete information about relevant aspects of the responder's payoff function. As is well-known, in the context of ultimatum bargaining this may lead to bargaining failure. We consider a specific type of incomplete information that was discussed in Konrad and Thum (2014): politicians represent their countries and take the roles as negotiators in the climate conventions. Politicians may have their own objective functions. They may care more or less strongly about negotiation success. And politicians can be imperfectly informed about their negotiation partner's political benefits or costs of reaching an environmental treaty. This may lead to a failure to reach a cooperative agreement, even if such an agreement has a positive aggregate surplus. The proposer, being uncertain about parameters of the objective function of the responder politician, may offer too little emission reduction and/or ask for a too large compensation. Hence, the model allows for the possibility of failure in negotiations due to this incomplete information about the negotiating politicians' preferences.³ The probability of failure in negotiations depends on the specific framework and parameters. We compare two frameworks that differ in the availability of cross-border abatement opportunities in the non-cooperative fallback that is reached if negotiations fail. In one framework, the polluting country

³This is in contrast to models of cooperative Nash bargaining or non-cooperative bargaining under complete information where negotiations can never fail. Models that employ Nash bargaining in the context of abatement consider the role of unilateral commitment on abatement (Hoel 1991), commitment on technology choices (Buchholz and Konrad 1994), or investment in R&D (Becherle and Tirole 2011), prior to bargaining.

can implement abatement projects in the non-polluting country only as part of the cooperative agreement. Hence, if the negotiations fail, the domestic firms have to fulfill their obligations in domestic abatement projects. In the other framework, abatement abroad is also available in the non-cooperative fallback that has to be implemented if bargaining fails. Hence, even if the countries act non-cooperatively, the abating country can use the most cost-effective abatement projects that are globally available.

There is an extensive literature on the role of transfers in international environmental agreements. This literature mostly focuses on the question whether side payments can increase the set of signatory countries (see, for instance, Barrett (2001) or Carraro and Siniscalco (1993)). Or it discusses the feedback effects as the anticipation of future transfers might reduce the incentives to commit to cooperation in the first place; see Hoel and Schneider (1997). These papers, however, do not consider the potential failure of international environmental negotiations.

With respect to CDM, there is an extensive literature on whether the proposed objectives are achieved (see Paulsson 2009). In particular, the question of additionality has received quite some attention in the literature. These considerations are largely orthogonal to the question of whether or not a CDM makes bargaining failure more or less likely.⁴

Our paper is closely related to Harstad (2007) as well as Konrad and Thum (2014). Both papers allow for negotiation failures. Harstad shows that side payments can be detrimental to successful bargaining. In Konrad and Thum (2014), we analyze the role of unilateral commitment on advances in greenhouse-gas abatement as in Hoel (1991). We consider ultimatum bargaining allowing for a source of incomplete information that can lead to equilibrium bargaining failure. This previous paper shows that bargaining is less likely to yield an efficient outcome if the offer-making player is committed to high abatement when entering into the bargaining game. The current paper borrows the assumption about the source of incomplete information in the context of ultimatum bargaining as a technical tool. Its policy question differs. This current paper assesses the likelihood of an ef-

⁴Abatement projects that are carried out within the CDM are desired to be additional to what the host country would have undertaken anyhow. Additionality is hard to verify as the counterfactual is not observable. To focus on the CDM-bargaining nexus, we eliminate this aspect by assuming that only the Annex 1 countries abate in *laissez-faire*. Aresin (2013) focuses on the strategic interaction between countries. Her analysis is constrained to a fully non-cooperative framework. She analyses the welfare effects of the CDM, depending on whether low cost abatement opportunities in the Annex 2 countries are allocated to firms from this country.

efficient bargaining outcome for two alternative non-cooperative fallbacks. In one case, the firms from one country can use abatement facilities in the other country, also if bargaining does not yield an agreement. In the other case, the firms have to abate in their country of residence only, when fulfilling the governmentally set abatement levels. Taken in isolation, the use of abatement opportunities in other countries is efficiency enhancing. If this efficiency gain is available in case of bargaining failure, however, the availability of such abatement opportunities makes bargaining success less likely. It offers a further environmental application of the 'topsy-turvy' principle. This more general principle has been explored in many variants in industrial economics and suggests that improvements in the non-cooperative outcome tend to reduce the scope for cooperation.

Ultimatum bargaining under incomplete information is a simple and prominent analytical tool that can be used to reveal, assess and compare the possibility for bargaining to reach an inefficient outcome in a context of incomplete information. As is known from Myerson and Satterthwaite (1983) and Chatterjee and Samuelson (1983), the inefficiency in the context of incomplete information is generic, and not due to the specific type of bargaining set-up.⁵ The ultimatum bargaining process is admittedly simple. As described in Barrett (1998), climate negotiations are a much more complex matter that has further dynamics, other important elements and relevant dimensions, and the theory of bargaining provides a large set of richer structures. However, simple ultimatum bargaining highlights most clearly the economic rationale behind failed negotiations in the context of incomplete information and the simple bargaining framework applied here reveals a strong intuition which should also be relevant in more complex frameworks.

2 The formal framework

Overview In short, we consider a world with two (groups of) countries A and B that suffer from global warming, derive benefits from global green-

⁵A different approach on negotiations that can be applied to climate negotiations is by Martimort and Sand-Zantman (2013) and Helm and Wirl (2014). They consider a richer contractual framework. Such a richer contractual framework may, but need not exist. If, as in Helm and Wirl (2014), one side can commit and offer a whole menu of price-quantity contracts, then our research question would have to be redefined. It would no longer be a question on whether or not a cooperative agreement is found, but the question would be how the efficiency properties of the principal-agent contract that is reached in the equilibrium depends on the availability of a CDM in case of non-cooperation.

house gas emission reduction and negotiate about a global agreement. We may think of A as a rich country (or the industrialized hemisphere) with high emissions and few unexploited cost-effective emission reduction opportunities at home, and of B as a less wealthy country (or less developed hemisphere) that contributes little to global emissions but provides considerable opportunity for cost effective emission reductions. Politicians who represent these countries appear at the negotiation table of a climate convention. With a slight abuse of notation, we denote them as politicians A and B .

The negotiations for a climate agreement take place as an ultimatum offer game. A random mechanism determines which player A or B is the proposer. The other player is the responder. The offer consists of two components. First, an efficient total quantity of emission abatement is offered. Second, the offer consists of a monetary compensation, defined as a payment t from B to A . If the negotiations lead to agreement, this agreement will be implemented. If negotiations fail, each country will non-cooperatively implement the country's own non-cooperative optimum. A crucial aspect for this choice is whether A has the option to mitigate using mitigation opportunities in country A only, or whether A is allowed to use abatement opportunities in country B to fulfill A 's abatement goals in the non-cooperative equilibrium.

The motivation for this institutional framework is what is called the Clean Development Mechanism (CDM) in the context of the Kyoto protocol, that has been described briefly in the introduction. Admittedly, the CDM context is much more complex than our institutional framework, as the current CDM operates as an element of an environmental agreement among a subset of countries. However, to a large extent, this subset of countries could be seen as representing player A : the polluting hemisphere, and the Kyoto protocol provided this group with rules about how they could use abatement projects in the non-signatory country group B in the absence of a truly global environmental agreement.

Mitigation technology First we characterize the technological opportunities for climate preserving emission mitigation and their costs. For simplicity, let the industry with climate relevant emissions be the firms in A , and let A regulate the mitigation of these firms. We assume that all emission decisions are made in A . This disregards the possible regulatory/pollution problems that may emerge in country B . But this is a useful simplification. In particular, it removes the problem of 'additionality', the problem that may otherwise occur in the context of cross-border abatement

arrangements.⁶ The assumption allows us to focus on the bargaining inefficiency. The choice variable is emission reduction. Such emission reduction can occur domestically in A or in country B . The quantities of emission reduction that use mitigation opportunities in A and B are denoted by m_A and m_B respectively. They sum up to total global emission reductions $m = m_A + m_B$. Emission reductions in country A have a cost $c_A(m_A)$ and mitigation that is carried out in country B has a cost $c_B(m_B)$. These cost functions are twice continuously differentiable and convex, with $c'_I > 0$, $c''_I > 0$ and $c_I(0) = c'_I(0) = 0$ for $I \in \{A, B\}$.

Note that the total cost of aggregate mitigation m that is implemented by the government of country A depends on the use of mitigation opportunities in A and B . In the absence of cross-border abatement opportunities in the default, firms in country A can make use of mitigation opportunities in country A only. Accordingly, $m_A = m$, and the mitigation cost is $c_A(m)$.

If cross-border abatement opportunities are available in the default, then the firms can make use of the mitigation opportunities in country B , too. A cost-minimizing mitigation program with aggregate mitigation $m = m_A + m_B$ uses mitigation opportunities in both countries as a solution of

$$\min_{m_A} \{c_A(m_A) + c_B(m - m_A)\} \equiv c(m).$$

For any given aggregate amount of mitigation, $c(m)$ is the cost as a function of m . A key assumption in what follows is that

$$c(m) < c_A(m) \text{ for all } m > 0. \tag{M}$$

This is a mild assumption. It basically states that the availability of mitigation opportunities in B is economically relevant. If Assumption (M) does not hold, cross-border abatement opportunities are essentially meaningless in this economy and the question we address also becomes irrelevant. If Assumption (M) holds, then the use of cross-border abatement can reduce total mitigation costs compared to using mitigation opportunities only in country A .

Mitigation benefits Next we consider countries' payoffs. Global mitigation affects climate change, but the geographical origin of emission re-

⁶If both A and B can use abatement opportunities in B , then abatement by A in B may replace abatement by B that would have been undertaken by B otherwise. Also, if B may also abate in B , this causes an assignment problem: who can benefit from the least expensive abatement opportunities in B ? These issues are important, but they are somewhat unrelated to the bargaining issue we study.

ductions does not matter for the impact of greenhouse gas emissions. Accordingly, countries have benefits from global mitigation m . The countries' benefits from mitigation m are defined as functions $b_A(m)$ and $b_B(m)$. These gross benefits can be understood as the aggregate rent emerging in the respective country if the aggregate mitigation is m , notwithstanding the cost of mitigation. For welfare comparisons these benefits will be compared with the mitigation costs.⁷ The two countries may have the same or different benefit functions; the only requirement is that these functions are both twice continuously differentiable and concave, with $b'_i > 0$ and $b''_i < 0$ for $i \in \{A, B\}$ with $b'_i(0)$ being sufficiently large.

Politicians' agenda – the source of incomplete information We assume that all cost and benefit functions introduced so far are common knowledge. This may be reasonable, given that mitigation technology is not top secret and also what can be found out about the mitigation benefits in one country relies on sources that are typically openly accessible, at least to experts and specialists.

In addition to these technologically determined costs and benefits, the politicians A and B who negotiate may receive political benefits or costs of size α and β if bargaining leads to a global environmental agreement, compared to bargaining failure. For instance, successful negotiations may be considered an indicator for the politician's general ability, may be interpreted as a diplomatic success and may help being reelected or gaining support from environmental groups at home. These values may be large and positive or small or even negative, for instance, if the politician cares particularly about voters who fear job losses from additional mitigation effort, or cares about the support from an industry lobby that suffers from an implementation of high mitigation effort. Formally, α and β are draws from random distributions with cumulative distribution functions $G(\alpha)$ and $F(\beta)$ with supports $[\underline{\alpha}, \bar{\alpha}]$ and $[\underline{\beta}, \bar{\beta}]$. Throughout we assume that these cumulative distribution functions are continuous everywhere, continuously differentiable on the supports and have hazard rates that are non-increasing,⁸ i.e.,

$$\frac{d}{dx} ([1 - H(x)]/H'(x)) \leq 0 \text{ for } H \in \{F, G\}. \quad (\text{HR})$$

⁷Benefits of mitigation can be expected to be unevenly distributed in a country, but we disregard such intra-country equity issues and assume that the benefits can be uniquely aggregated and represented by these functions.

⁸Assumption (HR) holds for many commonly considered probability distributions and is a standard regularity assumption in contract theory.

The functions G and F are common knowledge. But politicians know their own cost, i.e., A privately knows α and B knows β .

Non-cooperative and cooperative mitigation outcomes As discussed before, we distinguish two frameworks that differ with respect to the availability of cross-border abatement opportunities in case the bargaining procedure does not yield a cooperative environmental agreement.

Consider first the case in which A cannot use cross-border abatement in B if negotiations fail. Player A chooses the mitigation level that is optimal in autarky, i.e. considering only domestic mitigation projects with marginal costs $c'_A(m)$. The individually optimal choice of $m = m_A$ is the solution of

$$c'_A(m) = b'_A(m). \quad (1)$$

Consider next the case with cross-border abatement being available even if bargaining fails to reach an agreement between A and B . This second framework allows country A 's firms to use the mitigation opportunities in country B . The cost of a given amount of abatement $m = m_A + m_B$ is described by the cost function $c(m)$. The non-cooperative fallback is described by the solution of

$$c'(m) = b'_A(m). \quad (2)$$

Finally, consider the efficient amount of m that emerges if both countries' benefits of abatement m are taken into account. Efficiency also implies that the low-cost abatement opportunities in country B are used. Accordingly, the efficient amount of abatement is determined by the condition

$$c'(m) = b'_A(m) + b'_B(m). \quad (3)$$

The choice of m and the availability of cross-border abatement in the fallback determines the environmental cost and benefits from mitigation for the two countries. Recall that, given the availability of information about technologies and their costs, the functions $c_A(m)$, $c(m)$, $b_A(m)$ and $b_B(m)$ are common knowledge. This makes also the solutions to (1), (2) and (3) common knowledge. We denote the solutions to these equations as m_1 , m_2 and m_3 . And, as is clear from these marginal conditions, the assumptions about the cost and benefit functions and the assumption about the economic relevance of cross-border abatement opportunities, we have

$$m_3 > m_2 > m_1.$$

Intuitively, accounting only for country A 's benefits, the emission reduction that is optimal for A is higher if – due to the cross-border abatement opportunities – the cost of emission reduction is lower: $m_2 > m_1$. Given these lower costs, optimal emission reduction is even higher if one accounts for both countries' benefits.

Countries' rents in the three outcomes These mitigation levels lead to different mitigation benefits b_i in countries $i = A, B$, and to mitigation costs in country A . We can determine the net benefits that emerge in the two countries for each of the three outcomes in the absence of transfers between the two countries. These are

$$\begin{aligned} b_A(m_1) - c_A(m_1) &\equiv \theta_1 \\ b_A(m_2) - c(m_2) &\equiv \theta_2 \\ b_A(m_3) - c(m_3) &\equiv \theta_3, \end{aligned} \tag{4}$$

and the net benefits for country B are equal to their gross benefits $b_B(m_1)$, $b_B(m_2)$ and $b_B(m_3)$. The following properties are straightforward to show: First,

$$\theta_1 < \theta_2 \text{ and } b_B(m_1) < b_B(m_2).$$

If the non-cooperative outcome emerges, both countries are better-off if cross-border abatement exists in the fallback. Second,

$$\theta_3 < \theta_2 \text{ but } \theta_3 + b_B(m_3) > \theta_2 + b_B(m_2).$$

Essentially, country A prefers outcome m_2 to m_3 in the absence of transfers, but the sum of rents in both countries is higher for m_3 than for m_2 . This follows by construction, as m_3 maximizes this sum for all possible m .

3 Ultimatum bargaining

The two countries can bargain over the total amount of emissions and over a side payment. The proposer country/politician can make a take-it-or-leave-it offer to the responder. This offer states the total emission reduction m that A will have to implement through regulation of its domestic firms and a transfer t which is a (possibly negative) payment from country B to country A . The responder decides about whether to accept or reject this offer. If the responder accepts, this offer is implemented. If the responder rejects the offer, then country A implements the domestically optimal mitigation level. First we consider the case with A as the proposer.

Offer making by A Proposer/politician A makes a take-it-or-leave-it offer to politician B . The offer states the efficient amount m_3 of mitigation country A promises to impose on its firms and a transfer t that is paid to country A by country B . Country B needs to decide whether to accept this offer or to reject it. Note that the restriction to offers with $m = m_3$ limits the set of possible offers that can be made to the set of efficient outcomes.⁹

If the offer is accepted, then m_3 is implemented and country B pays t to country A . If the offer is rejected, then this ends the bargaining stage. Country A then chooses the amount of mitigation that maximize A 's rents and no transfers are paid. In the non-cooperative fallback, this amount of mitigation is $m_A = m = m_1$ if no cross-border abatement is available and it is $m_A + m_B = m_2$ if cross-border abatement is available. Hence, the fallback of ultimatum bargaining is the non-cooperative equilibrium without or with cross-border abatement, respectively.

Turn now to A 's offer. Politician A chooses t , and this choice depends on the fallback position. A successful climate agreement changes mitigation from the fallback m_i to m_3 , where $i \in \{1, 2\}$ for the two possible fallback outcomes. The net benefits for the proposer A is $\theta_3 + t + \alpha$ rather than θ_i and benefits for the politician in B rise from $b_B(m_i)$ to $b_B(m_3) + \beta - t$. Player B accepts the offer if $b_B(m_3) + \beta - t - b_B(m_i) \geq 0$, or, solving for β , if

$$\beta \geq b_B(m_i) - b_B(m_3) + t. \quad (5)$$

This inequality describes a one-to-one relationship between t and the critical β such that B accepts a transfer t that is at most equal to the t that solves (5) with equality for given regime i . This critical β_i is

$$\beta_i(t) = b_B(m_i) - b_B(m_3) + t, \quad (6)$$

and is a linear function in t with slope 1.

Due to (6) the bargaining-success probability is $1 - F(b_B(m_i) - b_B(m_3) +$

⁹The limitation to a fixed m is important as this limitation allows us to study bargaining failure and whether cross-border abatement opportunities in the fallback increase or decrease its likelihood. A more sophisticated bargaining framework in the spirit of Martimort and Sand-Zantman (2013) or Helm and Wirl (2014) could allow A to offer a menu of possible contracts (m, t) . Player A could then typically implement the optimal principal-agent contract. In this case, the inefficiency from bargaining failure is replaced by an inefficient size of m for all contracts with agent types, except 'at the top'. In such a principal-agent framework, an analogous question to ours would be whether cross-border abatement in the default state increases or decreases the expected inefficiency that emerges in the principal-agent contract.

t). The proposer A chooses t to maximize

$$E\pi_{A,i} = (\theta_3 - \theta_i + t + \alpha)(1 - F(b_B(m_i) - b_B(m_3) + t)). \quad (7)$$

This expected payoff is the product of A 's actual gain in case of success compared to the fallback i , times the probability for acceptance of the proposal. Player A knows the true value α of his own willingness to pay for a positive bargaining outcome. Differentiating (7) with respect to t yields a first-order condition which can be re-written as

$$\frac{1 - F(b_B(m_i) - b_B(m_3) + t)}{F'(b_B(m_i) - b_B(m_3) + t)} = \theta_3 + t + \alpha - \theta_i. \quad (8)$$

Interior solutions Let $t_i(\alpha)$ denote the interior solution to (8) where it exists. Note that the left-hand side of (8) is weakly decreasing in t (due to Assumption (HR) of a non-increasing hazard rate), and the right-hand side is strictly monotonically increasing in t . Accordingly, there is at most one solution for $t_i(\alpha)$. This transfer demanded by A is a monotonically decreasing function in the politician A 's own private benefit of reaching an agreement.

We observe a one-to-one correspondence between t and a value of β_i such that responder B accepts the transfer offer t if $\beta > \beta_i(t)$ and rejects the transfer offer if B 's true value of β is smaller than $\beta_i(t)$ in the interior range of $(\underline{\beta}, \bar{\beta})$. As shown by (5), the respective functions $\beta_i(t)$ are linear and have slope 1 for $\beta_i(t) \in [\underline{\beta}, \bar{\beta}]$ and a zero slope outside this interval. Further, $\beta_2(t) - \beta_1(t) = b_B(m_2) - b_B(m_1) > 0$.

We can now compare the likelihood for a cooperative outcome.

Proposition 1 *Let $t_1(\alpha)$ and $t_2(\alpha)$ be interior solutions to (8). They describe A 's demands without and with cross-border abatement opportunities in the non-cooperative fallback for a given α . The probability for a bargaining failure is higher if cross-border abatement opportunities are available in the non-cooperative fallback.*

Proof. Condition (6) can be used to rewrite the first-order condition in terms of β as

$$\frac{1 - F(\beta)}{F'(\beta)} = [\theta_3 + b_B(m_3)] - [\theta_i + b_B(m_1)] + \alpha + \beta. \quad (9)$$

The solutions are denoted as β_1 and β_2 for $i \in \{1, 2\}$. Figure 1 plots the right-hand sides and left-hand sides of (9) as functions of the political benefits $\beta \in (\underline{\beta}, \bar{\beta})$ on the horizontal axis. The left-hand side of the equilibrium

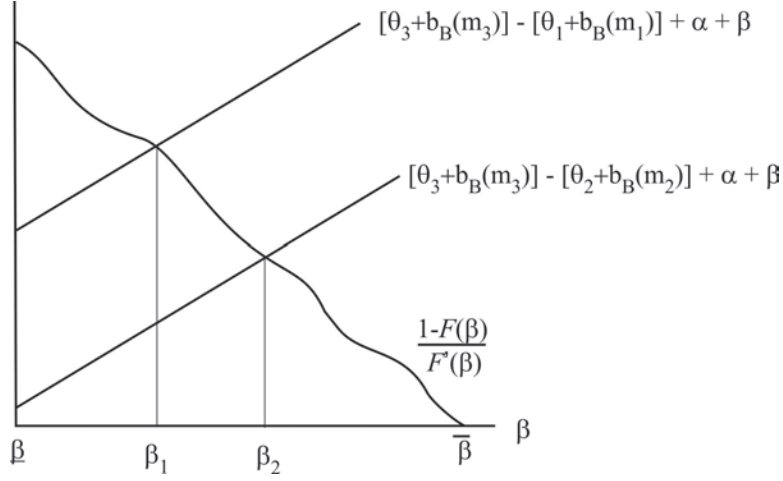


Figure 1: Interior Solution

conditions above is non-increasing due to the monotone-hazard-rate condition. For $\beta \geq \bar{\beta}$, the left-hand side becomes zero. The right-hand sides are straight lines with slope 1. Note that $[\theta_1 + b_B(m_1)] < [\theta_2 + b_B(m_2)]$, which implies that $\beta_2 > \beta_1$. This, in turn, implies that $1 - F(\beta_1)$, which is the probability for success in case $i = 1$, is higher than $1 - F(\beta_2)$, which is the success probability in case $i = 2$. Putting it differently, the chances that the offer is accepted is smaller if cross-border abatement options are available than without it. ■

Proposition 1 is the main result of the paper. If the incomplete information about the responder's attitude towards an agreement causes ultimatum bargaining to fail with some probability, this probability is higher if countries can rely on cross-border abatement opportunities in the non-cooperative fallback. The intuition for this result is that the fallback position affects the offers. If there are no cross-border abatement opportunities available in the non-cooperative outcome, the gains from successful negotiations are larger. Therefore, proposer A is more cautious / less aggressive when making its take-it-or-leave-it offer to the responder B .

From a structural point of view, the result is in line with what is known in the context of industrial organization as the topsy-turvy-principle: cooperation works better the less attractive is the non-cooperative outcome. Intuitively, if players can gain a lot by reaching the cooperative outcome,

then they are willing to settle for a smaller share in the cooperation rent if this makes it more likely that they can avoid the non-cooperative outcome.

Let us see how this result applies to global environmental negotiations in the years beyond the Kyoto Protocol. The Kyoto Protocol led to signatory countries, who may prototypically be seen as the more industrialized countries with high emissions, and to a group of non-signatory countries. These may be seen as the less developed countries who also did not contribute much to global emissions. With some risk of oversimplifying the picture, these groups could be seen as the two major parties negotiating at the international climate conventions. The Kyoto Protocol defines the non-cooperative fallback of global climate negotiations for all countries, whereas a global climate agreement represents the possible cooperative outcome. The Kyoto Protocol gives the signatory countries the option to accomplish their target abatements using cross-border abatement through the CDM. This mechanism allows them to achieve their commitment by use of cross-border abatement. Without a CDM, they would have to reach their abatement commitments without use of cross-border abatement. Proposition 1, hence, suggests that the availability of a CDM in the Kyoto Protocol made a global climate agreement less likely.

Corner solutions So far we considered cases in which the optimal offer (both in the regime without and with cross-border abatement opportunities in the non-cooperative fallback) is an 'interior solution' for t_1 and t_2 as solutions to (8) for $i \in \{1, 2\}$, such that the corresponding critical levels are $\beta_i \in (\underline{\beta}, \bar{\beta})$. This means that, for the optimal transfer offers chosen, the responder B has an acceptance probability that is strictly positive, but smaller than 1. An interior solution cannot be taken for granted. This is evident from Figure 1. An interior solution requires that the upward sloping curves $[\theta_3 + b_B(m_3)] - [(\theta_i + b_B(m_k)) + \alpha + \beta]$ intersect $(1 - F(\beta))/F'(\beta)$ for a value of $\beta \in (\underline{\beta}, \bar{\beta})$. In this section, we want to demonstrate that our main result also holds qualitatively for corner solutions.

The optimal choice of the proposer may lead to a 'corner solution', of which two types can emerge. The first, to which we refer as the 'non-cooperative corner solution' in what follows, is simply the non-cooperative outcome, which can be reached by a transfer demand t_i with the corresponding critical $\beta_i(t) \geq \bar{\beta}$ that is so high that B would never accept it for any $\beta \in [\underline{\beta}, \bar{\beta}]$. This leads to an equilibrium payoff for A of θ_i for $i \in \{1, 2\}$. The second, to which we refer to as the 'cooperative corner solution', is a choice of t_i with a corresponding $\beta_i(t) \leq \underline{\beta}$ that is so low that A can be sure that B

accepts. Among the t_i with this property, A prefers to ask for the largest t_i . For $i = 1$, i.e., if cross-border abatement opportunities are not available in the non-cooperative fallback, this largest, always accepted t_1 is determined by

$$t_1 = b_B(m_3) - b_B(m_1) + \underline{\beta}. \quad (10)$$

Similarly, if cross-border abatement is not available in the fallback, then the largest transfer demand that is accepted for all types of responders B is determined by

$$t_2 = b_B(m_3) - b_B(m_2) + \underline{\beta}. \quad (11)$$

The proposer A 's payoff in this corner solution is

$$\theta_i + \alpha + b_B(m_3) - b_B(m_i) + \underline{\beta}, \text{ for } i = 1, 2.$$

Whether a corner solution emerges and, if so, which one, depends on the actual value of α , the range of political benefits $\beta \in [\underline{\beta}, \bar{\beta}]$ and on the function $F(\beta)$. A look at the first derivative of A 's expected profit yields insights into the conditions for the corner solutions. This derivative is

$$\frac{\partial E\pi_{A,i}}{\partial t} = [1 - F(\beta_i(t))] - (\theta_3 - \theta_i + t + \alpha) \cdot F'(\beta_i(t)). \quad (12)$$

The first term $(1 - F)$ is A 's expected benefit from a marginal increase of the transfer t ; A receives the additional transfer with probability $1 - F$. The second term is the expected cost of a marginal increase in the transfer; the probability of receiving the benefit from successful bargaining $(\theta_3 - \theta_i + t + \alpha)$ falls by F' when the transfer is marginally increased. It takes into consideration that $\partial\beta_i/\partial t = 1$ for the range $\beta_i(t) \in (\underline{\beta}, \bar{\beta})$ and $\partial\beta_i/\partial t = 0$ for the range $\beta_i(t) \notin [\underline{\beta}, \bar{\beta}]$.

The non-cooperative corner solution emerges if θ_i with probability 1 yields a higher payoff for A than any offer t that would be accepted with positive probability. This requires in particular that $\frac{\partial E\pi_{A,i}}{\partial t} > 0$ at the t_i that makes B just indifferent between acceptance and rejection if $\beta = \bar{\beta}$. I.e., it requires

$$\frac{\partial E\pi_{A,i}}{\partial t} = [1 - F(\bar{\beta})] - ([\theta_3 + b_B(m_3)] - [\theta_i + b_B(m_i)] + \bar{\beta} + \alpha) \cdot F'(\bar{\beta}) > 0 \quad (13)$$

which reduces to

$$[\theta_3 + b_B(m_3)] - [\theta_i + b_B(m_i)] + \alpha < -\bar{\beta}.$$

This necessary condition is also sufficient for ruling out that an interior solution with a threshold $\beta \in (\underline{\beta}, \bar{\beta})$ is optimal. To show this, consider

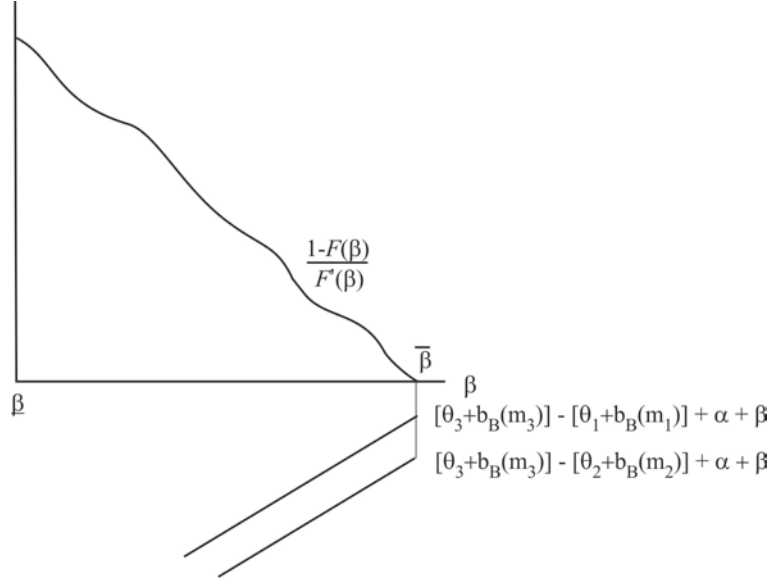


Figure 2: Non-cooperative Corner Solution

transfer demands that yield thresholds $\beta < \bar{\beta}$. Compared to $\beta = \bar{\beta}$, we see that $[1 - F(\beta)]$ will become positive. Further, $([\theta_3 + b_B(m_3)] - [\theta_i + b_B(m_i)] + \beta + \alpha)$ is monotonically increasing in β . Accordingly, if $\frac{\partial E\pi_{A,i}}{\partial t} \geq 0$ holds at $\beta = \bar{\beta}$, then $\frac{\partial E\pi_{A,i}}{\partial t} \geq 0$ in the whole range $\beta \in [\underline{\beta}, \bar{\beta}]$.

Figure 2 illustrates this outcome for a given α . It shows the same curves as Figure 1, but for different intercepts for the upward sloping curves. The downward-sloping curve meets the horizontal axis at $\beta = \bar{\beta}$. If the upward sloping curves end beneath the horizontal axis, country A will choose the non-cooperative solution. Comparing the outcomes without ($i = 1$) and with ($i = 2$) cross border abatement opportunities in the fallback position confirms our earlier result for interior solutions. The chances for successful negotiations cannot be improved by allowing domestic firms to abate abroad. As the upward-sloping line without cross-border abatement ($i = 1$) lies above the line with cross-border abatement ($i = 2$), the chances that a country leaves the non-cooperative solution must be higher when the country does not allow to abate abroad in the fallback position.

A similar line of reasoning can be applied for the other corner solution where country A makes such a cautious proposal that country B will accept

the offer for all β -values. A necessary condition for such a cautious proposal to be optimal for A is

$$\frac{\partial E\pi_{A,i}}{\partial t} = [1 - F(\underline{\beta})] - ([\theta_3 + b_B(m_3)] - [\theta_i + b_B(m_i)] + \underline{\beta} + \alpha) \cdot F'(\underline{\beta}) < 0. \quad (14)$$

The condition describes that a marginal increase in the transfer at \underline{t}_i does not increase A 's expected payoff. This necessary condition is also sufficient. If (14) holds at $t = \underline{t}_i$ then $\frac{\partial E\pi_{A,i}}{\partial t} \leq 0$ holds also for any higher t . To see this, note that the sign of $\frac{\partial E\pi_{A,i}}{\partial t}$ at any t for which $F' > 0$ is the same as the sign of

$$\frac{[1 - F(\beta)]}{F'(\beta)} - ([\theta_3 + b_B(m_3)] - [\theta_i + b_B(m_i)] + \beta + \alpha). \quad (15)$$

The first term in (15) is non-increasing in β (hence, in t) due to Assumption (HR). The second term is negative and strictly decreasing in β . Accordingly, if (15) is non-positive at $\beta = \underline{\beta}$ then it never becomes positive for larger values of β .

The cooperative corner solution is illustrated in Figure 3. If the marginal benefit of an increase in t beyond \underline{t}_i is below the marginal cost, the proposer sets \underline{t}_i and reaches an agreement with probability 1. Again, as the upward-sloping line for $i = 1$ lies above the line for $i = 2$, it is more likely that the cautious solution is chosen when cross-border abatement is not available in the fallback. Put differently, if the distribution of political benefits becomes wider and $\underline{\beta}$ falls, a country will leave its cautious corner solution earlier when cross-border abatement is available in the fallback.

We summarize these findings in

Proposition 2 *For any given distribution $F(\beta)$ with $\beta \in [\underline{\beta}, \bar{\beta}]$ and given value α the following holds: (i) If a cooperative corner solution applies for $i = 2$, then a cooperative corner solution also applies for $i = 1$. (ii) If a non-cooperative corner solution applies for $i = 1$, then a non-cooperative corner solution also applies for $i = 2$.*

Proof. By (14) the proposer in country A prefers the cooperative corner solution if

$$\frac{\partial E\pi_{A,i}}{\partial t} = [1 - F(\underline{\beta})] - ([\theta_3 + b_B(m_3)] - [\theta_i + b_B(m_i)] + \underline{\beta} + \alpha) \cdot F'(\underline{\beta}) < 0.$$

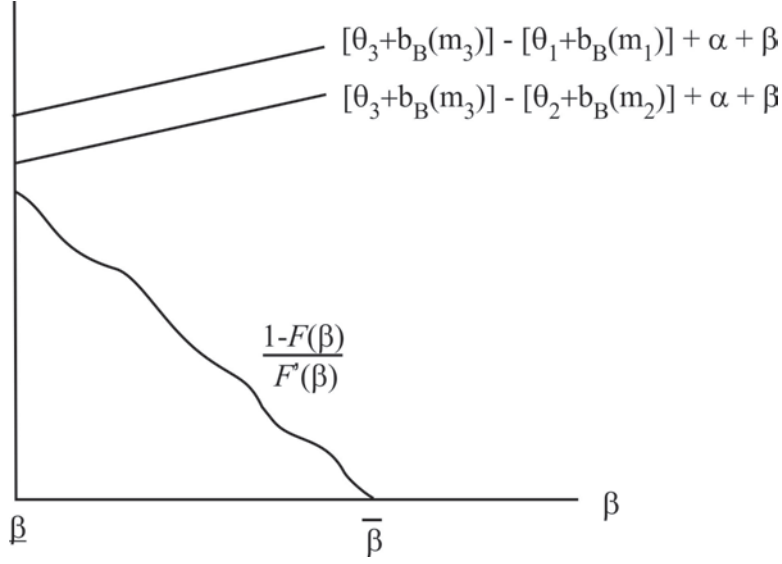


Figure 3: Fully Cooperative Corner Solution

As $\theta_2 + b_B(m_2) > \theta_1 + b_B(m_1)$, for any given β where this condition is fulfilled for $i = 2$ if it is fulfilled for $i = 1$. This establishes (i). Similarly, for (ii), consider the condition (13) which is the sufficient for a non-cooperative corner solution:

$$\frac{\partial E\pi_{A,i}}{\partial t} = [1 - F(\bar{\beta})] - ([\theta_3 + b_B(m_3)] - [\theta_i + b_B(m_i)] + \bar{\beta} + \alpha) \cdot F'(\bar{\beta}) > 0.$$

By $\theta_2 + b_B(m_2) > \theta_1 + b_B(m_1)$ this condition holds for $i = 2$ if it holds for $i = 1$. ■

Proposition 1 showed that reaching an agreement is more likely for $i = 1$ than for $i = 2$ if the proposer A chooses a positive probability smaller than 1 of bargaining failure for both $i = 1$ and $i = 2$. Proposition 2 broadens the scope of Proposition 1 with respect to corner solutions. According to Proposition 2, a non-cooperative corner solution can emerge in the case where cross-border abatement is not available in the fallback only if such a corner solution also occurs when cross-border abatement is available. For the cooperative corner solution we have qualitatively the same outcome: if the cooperative corner solution emerges when cross-border abatement is available in the fallback, this cooperative corner solution will also be chosen without the opportunity of cross-border abatement. Hence, availability of cross-border abatement in the fallback may drive the bargaining

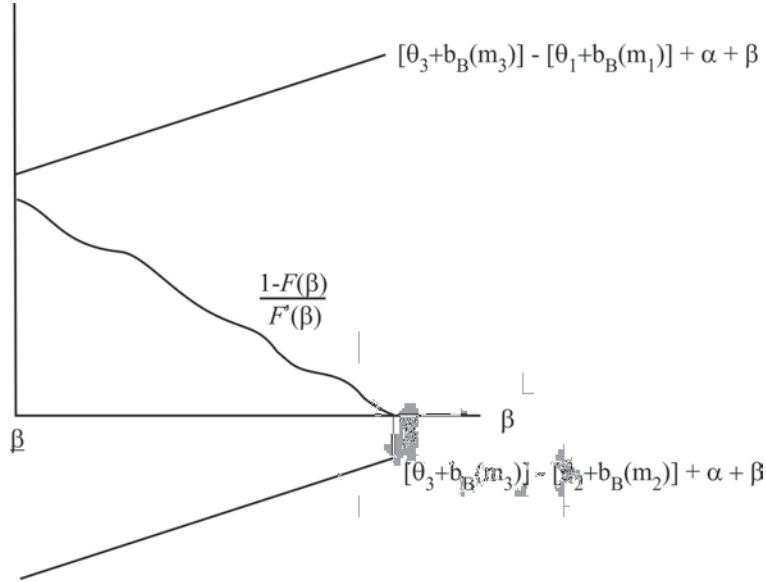


Figure 4: Both Corner Solutions

outcome into a non-cooperative corner solution. Non-availability of cross-border abatement in the fallback can drive the bargaining outcome into full cooperation.

For some distributions $F(\beta)$, the equilibrium leads to the same (non-cooperative or cooperative) corner solution for regimes, as depicted in Figures 2 and 3. For some $F(\beta)$, however, it may happen that the equilibrium is the non-cooperative corner solution for one and a cooperative corner solution for the other regime. Such a case is illustrated in Figure 4. This figure also makes clear that, for such mixed cases, the cooperative corner solution emerges for the case $i = 1$, and the non-cooperative corner solution emerges for the regime $i = 2$. The reverse mixed case is not feasible. Hence, availability of cross-border abatement in the fallback may turn the bargaining equilibrium from reaching a cooperative negotiation outcome with certainty to one in which negotiations fail with probability 1.

If B is the proposer We now turn to the case in which B makes an ultimatum offer to A . This offer consists of a transfer t from B to A as a compensation for A to implement the efficient amount of abatement, m_3 .

The non-cooperative fall-backs remain as in the previous sections. For space considerations we concentrate on the case of interior solutions.

If the offer is rejected, then this ends the bargaining stage. Country A then chooses the amount of mitigation that maximize A 's rents and no transfers are paid. This amount of mitigation is m_1 or m_2 , depending on the regime. If the offer is accepted, then m_3 is implemented and country B pays t to country A . Net benefits for the proposer B change from $b_B(m_i)$ to $b_B(m_3) + \beta - t$ and A 's payoff changes from θ_i to $\theta_3 + t + \alpha$. Player A accepts the offer if $\theta_3 + t + \alpha - \theta_i \geq 0$, or

$$\alpha \geq \theta_i - (\theta_3 + t) \tag{16}$$

for $i \in \{1, 2\}$. This inequality describes a one-to-one relationship between t and the critical α such that A accepts the transfer demanded if the transfer is at least equal to the t that solves (16) with equality. We denote this critical α_i as a function of t as

$$\alpha_i(t) = \theta_i - \theta_3 - t \text{ for } i \in \{1, 2\}. \tag{17}$$

This function is linear in t and has slope -1 .

The bargaining-success probability as a function of t is $1 - G(\theta_i - \theta_3 - t)$. The proposer B chooses t to maximize

$$E\pi_{B,i} = (b_B(m_3) + \beta - t - b_B(m_i))(1 - G(\theta_i - \theta_3 - t)).$$

This expected payoff is the product of B 's actual gain in case of success compared to the fallback, times the probability for acceptance of the proposal. Differentiating with respect to t yields a first-order condition which can be re-written as

$$\frac{1 - G(\theta_i - \theta_3 - t)}{G'(\theta_i - \theta_3 - t)} = b_B(m_3) + \beta - t - b_B(m_i). \tag{18}$$

If this condition has an interior solution, we denote it by $\hat{t}_i(\beta)$ to distinguish it from the function $t_i(\alpha)$ in the previous section. Note that the left-hand side is weakly increasing in the transfer offered (due to Assumption (HR) of a non-increasing hazard rate), and the right-hand side is strictly monotonically decreasing in the transfer. Accordingly, there is at most one transfer level $\hat{t}_i(\beta)$ that fulfills this first-order condition for each regime i and given β . We further note that

$$\hat{t}_1(\beta) > \hat{t}_2(\beta) \tag{19}$$

Recall the one-to-one correspondence between t and a value of α such that responder A accepts the transfer offer t if $\alpha > \alpha_i(t)$ and rejects the transfer offer if A 's true value of α is smaller than $\alpha_i(t)$ in the interior range of $(\underline{\alpha}, \bar{\alpha})$. With a mild abuse of notation, let $\alpha_i(t)$ denote the political benefit necessary to make country A indifferent between accepting and rejecting the offer t in regime i . As shown by (17), the respective functions $\alpha_i(t)$ are linear and have slope -1. Further, $\alpha_2(t) - \alpha_1(t) = b_B(m_2) - b_B(m_1) > 0$. Together with (19) and (17) this implies

$$\alpha_1(\hat{t}_1(\beta)) < \alpha_2(\hat{t}_2(\beta)).$$

This can be stated as a proposition:

Proposition 3 *Let $\hat{t}_1(\beta)$ and $\hat{t}_2(\beta)$ be interior solutions of (18) for a given β . They describe B 's equilibrium transfer offers without and with cross-border abatement opportunities in the non-cooperative fallback. It holds that $\alpha_1(\hat{t}_1(\beta)) < \alpha_2(\hat{t}_2(\beta))$. The probability for a bargaining failure is weakly higher if such opportunities are available in the fallback.*

Proposition 3 shows that the qualitative result in Proposition 1 does not depend on the allocation of proposer rights. The precise distribution functions F and G as well as the functions describing net benefits and net costs of abatement influence the quantitative outcome. But the result as regards a higher probability of reaching an efficient negotiation outcome holds irrespective of the assignment of the proposer rights.

Welfare A higher probability for a global environmental agreement does not necessarily go along with a higher welfare. As the emission reduction in case of negotiation failure depends on the availability of cross-border abatement opportunities, the welfare effects of cross-border abatement are far from obvious. On the one hand, the CDM increases the abatement level in case of negotiation failure. On the other hand, it reduces the likelihood for achieving a global environmental agreement. We briefly discuss the welfare implications within our framework with country A being the proposer.

For the welfare analysis, we neglect the political benefits α and β as these are the private benefits of the politicians, e.g. the personal gain from winning an election.¹⁰ We can also disregard the transfer t from country

¹⁰Including the political benefits would not alter the overall conclusion. It just makes it even more beneficial to secure a global environmental agreement if the expected political benefit is positive.

B to country A as this transfer will cancel out from a global perspective. Therefore, the welfare analysis can be based on the costs and benefits of abatement. Let $V_i \equiv \theta_i + b_B(m_i)$ denote the global net benefit of both regions from implementing abatement level m_i , $i = 1, 2, 3$. As the success of environmental negotiations ($i = 3$) is uncertain we focus on the expected global welfare $EV_i \equiv [1 - F(\beta_i)]V_3 + F(\beta_i)V_i$ where $i = 1, 2$ denote the cases without and with CDM in the fallback.

A comparison of the expected welfare in the two alternative cases yields

$$EV_1 \leq EV_2 \Leftrightarrow [F(\beta_2) - F(\beta_1)][V_3 - V_2] \leq F(\beta_1)[V_2 - V_1]$$

The availability of the CDM in the fallback increases the probability of negotiation failure by $F(\beta_2) - F(\beta_1)$, which leads to a loss in potential rents of $V_3 - V_2$. The left-hand side measures the welfare cost of a CDM in the fallback. The right-hand side captures the gains: with probability $F(\beta_1)$ the negotiations fail anyhow – even in the absence of a CDM. Then the global economy loses $V_2 - V_1$ in rents.

If there are interior solutions with and without a CDM in the fallback, there is no clear-cut answer to the question whether allowing for cross-border abatement in the absence of global agreements is beneficial.¹¹ Obviously, cross-border abatement is beneficial from a welfare perspective when there is always a non-cooperative corner solution [$F(\beta_1) = F(\beta_2) = 1$]. However, whenever there is a cooperative corner solution in the absence of a CDM [$F(\beta_1) = 0$], introducing a CDM in the fallback position can never be beneficial from a welfare point of view.

4 Conclusions

Our model exploits a simple mechanism to illustrate the feedback effects of the CDM that was established in the context of the Kyoto Protocol on the likelihood of a global environmental agreement in the years after Kyoto. The CDM seems purely beneficial in the first place as it allows for additional abatement at low costs.¹² The implementation of a CDM in the Kyoto Protocol has a severe drawback for future negotiations. It may reduce the chances for successful global international environmental treaties

¹¹The outcome is also ambiguous when there is an interior solution without a CDM [$0 < F(\beta_1) < 1$] and a non-cooperative corner solution with a CDM [$F(\beta_2) = 1$].

¹²Problems that may occur with a CDM in practical applications, such as the problem whether a CDM provides additionality, are absent in our framework. By definition all abatement units are additional here.

in the years after Kyoto. A CDM that is in place already before the global international bargaining starts offers the group of signatory countries of the Kyoto Protocol inexpensive and cost-efficient abatement options even if the negotiations for a truly global treaty fails. This fact improves the payoffs both for the group of signatory countries of the Kyoto Protocol and for the non-signatory countries in the non-cooperative outcome that prevails if negotiations fail. These higher payoffs imply that their gains from successful global negotiations are reduced. This in turn leads to more aggressive bargaining offers from both sides, and, therefore, to higher chances of failed negotiations.

The analytical framework abstracts from many aspects that could be studied. Contract negotiations could take more sophisticated formats. These could include iterated bargaining or bargaining with alternating offers under two-sided incomplete information or negotiations that allow the proposer to offer a more sophisticated menu of contracts. Also, the question emerges how the availability of a CDM affects efficiency in the equilibrium. In particular, using a more differentiated picture of CDMs it would be interesting to compare and weigh the benefits of the CDMs in the non-cooperative outcome against the decrease in likelihood for reaching an efficient and truly global agreement. Our analysis accomplishes to show that this trade-off exists.

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