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The Clean Development Mechanism in a Global Carbon Market *

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Abstract

This paper discusses the role of the Clean Development Mechanism (CDM) on the market for carbon quotas and countries' commitments to reduce their carbon emission levels. We show that the CDM contributes to an efficient funding of clean technology investments in least developed countries. However, the CDM is not neutral on the global level of carbon emissions as it entices countries to raise their emission caps. The CDM may also make inappropriate the inclusion of any country that takes no emission abatement commitment. It can even make inefficient a country's decision to commit to an emission target.

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1 Introduction

The Article 12 of the Kyoto Protocol presents the Clean Development Mechanism (CDM) as a means to simultaneously stimulate a sustainable economic development and emission reductions in least industrialized countries, while giving the industrialized more flexibility to meet their emission reduction commitments. Accordingly, a country that commits to an emission-reduction target by signing the Annex B of the protocol (Annex B country) can partly fulfill its commitment by implementing emission-reduction projects in any developing country that has ratified the protocol but made no commitment (non-Annex B countries). CDM projects earn Certified Emission Reductions (CERs) which, after certification by the United Nations, can be sold in the carbon market and counted towards meeting Kyoto targets. CDM projects involve investments in solar panels, carbon capture, energy-efficient boilers, hydropower, deforestation, etc. CDM is expected to play an important role in reducing the amount of global carbon emission, improving the cost-effectiveness of mitigation policies in developed countries and reducing carbon leakage of emissions from developed to developing countries (Burniaux et al. 2009). The actual share of CDM in the global carbon market is significant. According to the Work Bank's *State and Trends of the Carbon Market (2010)* CDM projects account for 8.4 % of the global carbon market. The CDM can be considered to have a stronger role in the carbon market given the fact that the Kyoto carbon market itself is quite narrow at the current stage.[1]

At the last Conference of the Parties (Durban, December 2011), 190 countries involved in the UNFCCC agreed on a new Kyoto commitment period beyond 2012, on a new agreement with legal status, and on maintaining the CDM in this architecture. It is thus important to study the impact of CDM on climate change from a past and future perspective. On the one hand, during the last era of the Kyoto protocol, many industrialized countries have made use of the CDM to curb their effective emission targets. However, climate change observers and researchers raise doubts about any positive impact of the Kyoto protocol on curbing the growth of global carbon emissions (see Gupta *et al.*, 2007). The CDM might be part of the causes of such a failure. On the other hand, there exists a debate about the inclusion or removal of the CDM in the convention that will follow the Kyoto protocol. For instance, in the "Washington Declaration" (16 February 2007), influential countries including the U.S.A. proposed to remove this mechanism and impose carbon caps to all countries while, in 2009, the United Nations Climate Change Conference ("Copenhagen Summit") simply suggested a reform of the CDM. Most of the

[1]The total value of the global carbon market was US$135 billion in 2008 and US$144 in 2009. During these two years, 4.8 $GtCO_2$-eq and 8.7 $GtCO_2$-eq changed hands worldwide, respectively. The total amount of CERs traded in 2008 was 404 Mt, to be compared to the volume of 3,278 Mt traded in the market for allowances (trading among Annex B countries and the EU-ETS market). It may be noticed that the EU-ETS represented more than 94 pc of the trading of allowances. This suggests that the Kyoto market itself is quite narrow at this stage, which actually strengthens the role of the CDM in the carbon market.

criticisms to CDM are related to the transaction costs incurred by the registration procedure of projects (see e.g. Michaelowa and Jotzo, 2005), or to the capacity of CDM to promote a clean or sustainable development in developing countries (see e.g. Pearson, 2007, Olsen, 2007, Fankhauser and Martin, 2010). A global discussion of the instrument and its weaknesses is available in Lecocq and Ambrosi (2007). Strikingly this literature offers no formal discussion on the role the CDM in the global market and on the countries' commitment to reduce their carbon emissions.[2] This paper attempts to fill this gap by studying how the CDM affects the equilibrium in this global carbon market in a framework that is similar to Helm's (2003).

This paper discusses the impact of the CDM on global carbon emissions. We abstract from the well documented issues of the additionality and transaction costs of CDM projects, the ratchet effect in implementing firms and countries and the certification backlog in the UN organization. We rather focus on the rent redistribution and on the institutional framework between industrialized and less industrialized countries.

The institutional framework of the CDM requires that each project involves both a firm located in an Annex B country and a local firm that implements the project in the non-Annex B country. The Annex B firm supports part of the costs (equipment, plant, infrastructure, etc.) and receives as a counterpart the carbon credits (emission reductions) generated by the project. In practice, the investment cost of CDM projects in Africa are almost fully supported by firms located in OECD countries. In contrast, investment costs in China are many times borne by Chinese investors themselves. Yet, the important aspect of CDM projects lies in the way the CDM rents are shared between supporting and implementing firms. Although the carbon credit are formally granted to the supporting firm, the CDM rent shifts from the supporting to the implementing firm as the former is asked to bear a larger share of the investment physical cost. When the supporting firm do not bear any investment costs, it may be asked to make cash transfers to the implementing firm or country.

The revenues of the CDM constitute a large source of mitigation funding for developing countries. The redistribution of CDM project rents is negotiated at the outset of the project between the local firms that implement the project and their partners in Annex B countries. In practice some least developed countries (*e.g.* the poorest African countries) suffer from a lack of bargaining power in benefiting from the rents of clean technology transfers whereas others seem to be much stronger and more organized to get those rents (*e.g.* Asian countries). The public opinion complains that CDM may be another form of exploitation of the least developed countries and that it should warrantee a sufficient share of the rents to those countries.

In this paper we answer the following four questions. First, is it true that allowing for CDM projects has no impact on global emission levels? In other words,

[2] Bréchet and Lussis (2006), Timilsinaa and Shrestha (2006) present numerical assessments.

is the CDM prone to carbon leakage from developed to developing countries? Second, is it good to increase the bargaining power of the firms in countries receiving CDM project? This amounts to assess whether redistributive concerns are aligned with reductions in global carbon emissions. The third and fourth questions relate to the organization and commitments of members joining a Kyoto-type protocol or the potential following international convention. On the one hand, is it good for global carbon emissions to accept in the protocol a country that makes no commitment; in other words, is it appropriate to let countries not be signing the Annex B? Historically, the Kyoto protocol has included all countries whatever their commitments. Most least developed countries have ratified the protocol with no abatement commitment. On the other hand, what is the impact of a country's commitment on global emissions? In other words, what would happen if a country like China decided to make abatement commitments and to join the Annex B of the protocol? These latter questions echo Helm's (2003) analysis of the effect of international carbon trading on countries non-cooperative choices of emission allowances. However, they extend his approach to a more sophisticated institutional framework, wherein the CDM enables countries that do not commit to emission abatement to take part to the international carbon trading

We can preview the results of our analysis as it follows. First, we show that the common view that CDM does not alter global emissions holds only under the assumption that countries's carbon emission targets are exogenous (Proposition 1). Under this "accounting" view, the carbon emission reductions implemented under CDM are equal to the additional carbon emissions that the United Nations permit to the industrialized countries implementing the CDM projects. However, in practice, countries endogenously set their carbon emission targets during the protocol's negotiation period and therefore anticipate the benefits of CDM projects. They balance the cost of emission abatement to their industries, the cost of purchasing carbon emission quotas in the carbon market against the benefit of implementing CDM project in least developed countries.

Second, we show that global carbon emissions tend to increase with the bargaining power of implementing firms and (by extension) of non-Annex B countries (Proposition 2). This results from an externality between Annex B and non-Annex B countries. Annex B countries do not fully internalize the effect of CDM and tend to diminish their abatement targets when a share of the CDM rents flows to non-Annex B countries. As a result, CDM generates a new source for carbon leakages and has a negative impact on climate change, unless firms in non-Annex B countries get no bargaining power. Redistribution towards least developed countries is therefore (and unfortunately) not aligned with an efficient climate change policy.

Our analysis also provides innovative results about the rules of the protocol. Actually, countries are free to choose between *(i)* committing to a carbon emission abatement target (i.e. Annex B), *(ii)* joining the protocol without commitment (i.e. non-Annex B) or, *(iii)*, not joining (ratifying) the protocol at all, and thereby waiving the possibility to host CDM projects.

On the one hand, we show that adding a new non-Annex B to the protocol country reduces global emissions if this country has no bargaining power and/or if it generates a small share of certified emission reductions at the global level (Proposition 3). This result runs against the idea of promoting stronger power and rent to the least developed countries that host CDM projects. It also qualifies the inclusion of countries with large potential for CDM projects, like China or India. On the other hand, we show that a country's decision to commit to an emission target may not necessarily reduce global emissions. By joining the Annex B, such a country foregoes the rents of CDM programs but benefits from an access to the global carbon market where it can sell carbon quotas at the carbon price. Then, all depends on whether this country is willing to adopt a sufficiently stringent emission target, or not. If it is so, this country is likely to become a net buyer of carbon quotas. Otherwise the country may adopt lax carbon emission targets and use its access to the carbon market to increase its revenues. In this paper we show a means to assess this effect. We show that global emission will fall if the country that shifts to Annex B becomes a net buyer of carbon quotas (when it has no bargaining power) or if its supply of quotas does not exceed its previous supply of CERs (when it has full bargaining power). In short, global emissions will fall if this country makes the carbon market shorter.

These results have major implications for Kyoto-type protocol or for a post-Kyoto perspective. They firstly imply that letting large countries join the protocol as non-Annex B members may actually increase world emissions, all the more so as they succeed to appropriate a large share of CDM rents. This clearly puts in question the position of China as (by far) the main current provider of CDM projects. Our results also emphasize that joining Annex B should be motivated by a clear intention to further curb global emission through bearing the cost of incremental reductions. This means, in turn, that countries like China may not necessarily be welcome in Annex B. They should first demonstrate their willingness to contribute to global emission reduction by setting domestic emission targets that go beyond the abatement they would have achieved with CDM projects. We may also use the instance of Africa and China that presumably have respectively low and high bargaining power and respectively low and high CDM project potentials. The shift of an African country into Annex B will be good for climate only if it becomes a net buyer in the carbon market whereas the shift of China into Annex B will be good for climate even if it ultimately sells a not too large amount of carbon quotas.

The paper is organized as follows. Section 2 presents the setting while Section 3 discusses the economics of the CDM when carbon emission quotas are fixed beforehand. Section 4 discusses the setting of the carbon emission quotas in the presence of the CDM. Section 5 provides the analysis of the impact of CDM on global carbon emissions when a new country joins the Protocol without making any carbon emission commitments. Section 6 discusses the case of a member country shifting to Annex B and making commitment about its emissions quotas. Section 7 is the conclusion.

2 The setting

The economy includes three distinct sets of countries. The first one is the set of countries $i \in A$ that ratify the Kyoto Protocol but have no emission abatement commitments. These countries cannot participate to emissions trading but they can host CDM projects. The second set includes the countries $j \in B$ that ratify the Kyoto Protocol and sign binding emission abatement commitments in the so-called "Annex B" of the Protocol. By joining the Annex B, those countries $j \in B$ are allowed to participate to the carbon market and to transfer carbon technologies through CDM projects to the other Kyoto Protocol countries $i \in A$. The third set includes the countries $i \in N$ that do not ratify the Kyoto Protocol. For the sake of convenience we denote the set of countries ratifying the Kyoto Protocol by $K \equiv A \cup B$. To date, amongst the 192 ($= \#(K \cup N)$) countries that belong to the United Nations, 191 ($= \#(K)$) have ratified the Kyoto Protocol. The United States did not.[3] The Annex B countries ($\#(B) = 37$) gathers most industrialized countries (except the US) while developing countries are non-Annex B countries ($\#(A) = 154$).

As in Helm (2003) we consider a representative firm in each country. The representative firm in a country $j \in B$ that operates in the carbon market with a carbon price p has a net profit function given by

$$\pi_j(e_j, I_j) - I_j - p(e_j - \overline{e}_j),$$

where e_j denotes its carbon emission level, $\overline{e}_j$ its carbon quota endowment, I_j its investment level in clean technology and $\pi_j(e_j, I_j)$ its gross profit function. Permits are grandfathered, like in the US SO_2 market, the first phase of the EU-Emission Trading Scheme on carbon dioxide and the Kyoto global carbon market. Hence, the purchase/sale of carbon quotas includes the excess of the carbon tons e_j emitted by the firm on top of the carbon tons $\overline{e}_j$ that the firm is initially endowed with. This excess demand is valorized at p, the carbon price prevailing in the carbon market. #We assume that the gross profit function $\pi_j(e_j, I_j)$ is increasing and concave ($\partial\pi_j/\partial e_j > 0$, $\partial\pi_j/\partial I_j > 0$ while $\partial^2\pi_j/\partial e_j^2 < 0$, $\partial^2\pi_j/\partial I_j^2 < 0$, $\Delta \equiv (\partial^2\pi_j/\partial e_j^2)(\partial^2\pi_j/\partial I_j^2) - (\partial^2\pi_j/\partial e_j\partial I_j)^2 \geq 0$). We also assume that investments in clean technologies diminish the marginal costs of emission abatement, or equivalently, raise the marginal profits of emission abatement ($\partial^2\pi_j/\partial e_j\partial I_j < 0$). Finally, to assure finite and non-zero equilibrium outcomes, we impose that $\partial\pi_j/\partial z_j = \infty$ at $z_j = 0$ and $\partial\pi_j/\partial z_j < 0$ at $z_j = \infty$ for $z_j = e_j, I_j$.#

Each representative firm j trades off between curbing emissions, purchasing or selling carbon emission quotas and investing in clean technologies. The firm chooses the carbon emission e_j and investment levels I_j that maximizes its net profit, taking the carbon price as a given. Given our assumptions on π_j, the following first-order

[3] Information about the ratification is available on the UNFCCC website: *www.unfccc.int.*

conditions are necessary and sufficient:

$$\frac{\partial \pi_j}{\partial e_j} = p \quad \text{and} \quad \frac{\partial \pi_j}{\partial I_j} = 1, \quad \forall j \in B. \tag{1}$$

Those simultaneous equations solve for the optimal carbon emission and investment levels (e_j^*, I_j^*). Total differentiating those expressions, one can show that the firm's optimal investment level $I_j^*(p)$ increases in the carbon price p whereas its optimal emission level $e_j^*(p)$ is a decreasing function of it: $e_j^{*\prime}(p) \equiv de_j^*/dp < 0$.[4] In other words, higher carbon prices entice the firm to invest more in clean technologies and to exert more effort in carbon emission reductions. In the absence of a carbon market, carbon emission is equal to $e_i^o \equiv e_i^*(0)$ and is larger than $e_i^*(p)$ for any $p > 0$ while clean technology investment is equal to $I_i^o \equiv I_i^*(0)$ and is smaller than $I_i^*(p)$ for any $p > 0$.

The *net demand for emission quotas by country* $j \in B$ is given by the net demand of its representative firm, $e_j^*(p) - \overline{e}_j$, which decreases with carbon price. Aggregating all net demand functions yields the market clearing condition, $\sum_{j \in B} e_j^*(p) = \overline{e}$, where $\overline{e}$ is the total emission quota admitted by the Protocol. By the Inada conditions, there exists a unique non negative equilibrium price p^* that satisfies this condition. Inverting this last relationship yields

$$p^* \equiv p_B(\overline{e}),$$

where $p_B(\overline{e})$ is the inverse demand function of global carbon demand, which depends on the set B of Annex B countries. Under the above assumptions, we have that $dp_B/d\overline{e} < 0$. The equilibrium price in the carbon market falls as the total endowment of carbon emission quotas in the economy rises.

The countries $i \in A \cup N$ do not commit to emission reductions and have no (access to) carbon market. Their representative firms choose their "business-as-usual" levels of emission and investment (e_i^o, I_i^o). Those levels are the solutions of the first order conditions (1) applied at $p = 0$ and $j = i$. So, emission levels are larger in the business-as-usual situation than in the context of a carbon market.[5]

Within this setting we are now able to introduce the key features of the CDM as an instrument in firms' strategy and countries' climate policy.

3 The Clean Development Mechanism

The key feature of the CDM is to address individual firm's investment projects and contribute to national climate strategies. Thanks to the CDM, a firm located in

[4] Indeed, under the above assumptions, $de_j^*/dp = (\partial^2 \pi_j / \partial^2 I_j)/\Delta < 0$ and $dI_j^*/dp = (\partial^2 \pi_j / \partial e_j \partial I_j)/\Delta > 0$.

[5] In this paper the business-as-usual situation may involve taxes on carbon emissions. The only restriction is that those taxes also apply in the contexts where firms access to carbon market and/or where they make use of CDM projects.

an Annex B country is given the opportunity to transfer its clean technology to a firm located in a non-Annex B country. By doing this, the firm is allowed to claim a number of so-called *Certified Emission Reductions* (CERs) that is equal to the carbon emissions saved through the implementation of its clean technology in the host country. The CDM Executive Board of the United Nations is in charge of the careful assessment of such carbon emission savings over a business-as-usual benchmark for each project. When this evaluation is successful, the Executive Board grants the certified emission reductions that can be supplied and sold on the carbon market at the same market value as carbon permits that prevails among Annex B countries.[6]

3.1 Rent sharing

In this section, we discuss the distribution of CDM projects' rents between two firms belonging each to a Annex B and non-Annex B country. Given our setup in terms of representative firms, those rents are also those applying at a country level. ##

CDM projects allow countries that do not belong to Annex B to benefit from carbon reduction opportunities. To obtain certified emission reductions, they must find a partner in a country that belongs to Annex B and file a joint project at the United Nation. So, the rent here lies in the legal requirement of partnership. It is shared between two firms, one that belongs to countries that have signed Annex B and the other that does not. Although the origin of CDM rents has no importance in the present analysis, it is important to distinguish the two types of countries in which firms operate.

Let us first describe the investment and the rents of a CDM project. Each CDM project matches an "implementing" firm i that belongs to a non-Annex B country ($i \in A$) and a "supporting" firm j that belongs to an Annex B country ($j \in B$). Without loss of generality, we consider the implementing firm as the country i's representative firm that is responsible for the country's carbon emissions. By contrast, the supporting firm in country j is typically a (consortium of) firm(s) that designs, produces, sells and offers finacal support for clean technology equipment. The project is rewarded by a transfer of carbon emission rights that corresponds to the reduction of carbon emission and that is certified by the United Nations. It can be also accompanied with an investment commitment by the supporting firm according to the institutional framework of CDM project. Therefore, each CDM project is characterized by four items: an investment level I_i in the implementing firm $i \in A$, a reduction of carbon emission $e_i^o - e_i$ in this firm, a share $\beta \in [0, 1]$

[6] There obviously exists an informational issue in the United Nation's assessment of equivalent carbon emission quotas, an issue that merits dedicated attention. This is referred to as the *additionality* issue in the relevant literature. However, since our focus is on the general equilibrium properties of the CDM we deliberately avoid this informational issue by assuming that the Executive Board of United Nations makes a perfect assessment of each project additionality. On that informational issue, see Millock (2002).

of additional investment that it bears, and a share $x_i \in [0, 1]$ of the revenue from emission reductions.

At a carbon price of p, the certified emission reductions are worth $p\left(e_i^o - e_i\right)$. On the one hand, the net profit of the implementing firm is therefore equal to

$$\pi_i(e_i, I_i) + x_i p\left(e_i^o - e_i\right) - I_i^o - \beta\left(I_i - I_i^o\right).$$

This includes its gross profit after emission abatement plus its share in the proceeds of the sales of the certified emission reductions generated by the project minus its business-as-usual investment cost and its share in the additional investment in carbon reduction. On the other hand, the net profit by the supporting firm is equal to

$$(1 - x_i)\, p\left(e_i^o - e_i\right) - (1 - \beta)\left(I_i - I_i^o\right),$$

which includes its share $(1 - x_i)$ of the **revenue from sales of** certified emission reductions and its share $(1 - \beta)$ of the additional investment cost.

The parameter β is a measure of the (unilateral or bilateral) institutional framework of CDM projects. Under unilateral CDM projects, the implementing firm bears the full investment cost I_i if $\beta = 1$ whereas it bears only the business-as-usual investment cost I_i^o if $\beta = 0$. The former framework is likely to apply for CDM projects in China where the Chinese investors take over the cost of the investment. The latter is more likely to apply for CDM project in Africa where local firms are not able to fund the investment costs of their projects and where the supporting firm supplies the required capital. Under bilateral CDM projects, the cost increment is supported by both parties: $\beta \in (0, 1)$.

For simplicity, we assume that both firms have no outside opportunities. So, the implementing firm has a gain after the CDM project that is equal to

$$v_i\left(e_i, I_i, x_i\right) \equiv \pi_i(e_i, I_i) - \pi_i(e_i^o, I_i^o) + x_i p\left(e_i^o - e_i\right) - \beta\left(I_i - I_i^o\right).$$

This includes a change in gross profit plus the firm's share in the revenue from certified emission reduction minus the cost increase associated with the clean technology investment. The supporting firm has a gain equal to

$$v_j\left(e_i, I_i, x_i\right) \equiv (1 - x_i)\, p\left(e_i^o - e_i\right) - (1 - \beta)\left(I_i - I_i^o\right),$$

which includes its shares of the proceeds from emission reduction and in the additional investment cost. The total rent of the CDM project is thus given by

$$R_{ij}\left(e_i, I_i\right) \equiv v_i\left(e_i, I_i, x_i\right) + v_j\left(e_i, I_i, x_i\right) = \pi_i(e_i, I_i) - \pi_i(e_i^o, I_i^o) + p\left(e_i^o - e_i\right) - \left(I_i - I_i^o\right).$$

We assume a bargaining process where the implementing and supporting firms negotiate about the optimal investment and emission levels and about their share of certified emission reductions. Let α and $1 - \alpha$ be the *bargaining power of the implementing firm $i \in A$ and the supporting firm $j \in B$*, respectively. The optimal emission, investment and revenue share of the CDM project is given by the maximization of the Nash product $\mathcal{N} = v_i^{\alpha} v_j^{1-\alpha}$. Restricting our study to interior solutions (in particular, $x_i \in (0, 1)$), we find that the optimal investment level I_i^*, emission level e_i^* and share x_i^* are given by the following first-order conditions:#[7]#

$$\frac{\partial \pi_j}{\partial e} = p, \quad \frac{\partial \pi_j}{\partial I} = 1 \quad \text{and} \quad \frac{v_i}{v_j} = \frac{\alpha}{1-\alpha}. \tag{2}$$

Those first-order conditions show that the investment and emission levels are efficient under CDM. They are independent of the bargaining power, α, and the institutional framework, β. Also, the total rent $v_i + v_j$ is shared in the same proportion as the bargaining power.

Using those equilibrium values, the rent of the CDM project is given by $R_{ij}(e_i^*, I_i^*)$, which increases with higher carbon price. Indeed, R_{ij} is a convex and increasing function of the carbon price because, by the envelop theorem, $dR_{ij}(e_i^*, I_i^*)/dp = e_i^o - e_i^* > 0$ and $de_i^*/dp < 0$. The gain of the supporting firm in country j is given by

$$(1-\alpha) R_{ij}(e_i^*, I_i^*).$$

The implementing firm i has a gain $\alpha R_{ij}(e_i^*, I_i^*)$ and bears the cost of carbon emissions reduction. Its net profit thus writes as

$$\pi_i(e_i^*, I_i^*) - I_i^* + p(e_i^o - e_i^*) - (1-\alpha) R_{ij}(e_i^*, I_i^*).$$

In this expression, the first three terms represent the minimal cost borne by the implementing firm if it does not share any rent with the supporting firm. The last term represents the rent left to the supporting firm. The supporting firm thus has a gain that is equal to a share of the rent generated by the CDM project, which directly accrued to the implementing firm. Note that, again, the rents and costs do not depend on the institutional framework, β. This is because the supporting firm recoups its share of investment cost through its shared in CERs.

3.2 Carbon market equilibrium

We can now discuss the carbon market from an aggregate viewpoint and establish the condition under which CDM is neutral from a global emission viewpoint. On the one hand, when CDM projects are not allowed, the global emission level of the member countries of the Kyoto Protocol is given by the sum of the national emission quotas and the business-as-usual emissions of non-Annex B countries:

$$e_K \equiv \sum_{i \in A} e_i^o + \sum_{j \in B} \bar{e}_j. \tag{3}$$

[7]The partial differentiation of $\ln \mathcal{N} = \alpha \ln v_i + (1-\alpha) \ln v_j$ with respect to e_i, I_i and x_i yields the respective first order conditions: $\alpha v_i^{-1} (\partial \pi_i / \partial e_i - x_i p) = (1-\alpha) v_j^{-1} (1 - x_i) p$, $\alpha v_i^{-1} (\partial \pi_i / \partial I_i - \beta) = (1-\alpha) v_j^{-1} (1-\beta)$ and $\alpha v_i^{-1} p (e_i^o - e_i) = (1-\alpha) v_j^{-1} p (e_i^o - e_i)$. Simple algebraic manipulation yield the conditions (2).

The world emission level is given by $e \equiv e_K + e_N$ where $e_N \equiv \sum_{i \in N} e_i^o$ is the global emission level of the countries that have not ratified the Kyoto Protocol. On the other hand, when CDM projects are allowed, the implementing and supporting firms are able to generate an amount of $e_i^o - e_i^*(p)$ of certified emission reductions in each country i that does not belong to Annex B. After certification by the United Nations those amounts are introduced as an additional supply in the carbon market. Hence, when the carbon market clears, the demand for carbon permits by firms located in Annex B countries must be equal to the sum of the certified emission reductions and Annex B countries' emission caps. That is,

$$\sum_{j \in B} e_j^*(p) = \sum_{i \in A} [e_i^o - e_i^*(p)] + \sum_{j \in B} \overline{e}_j.$$

Reshuffling this equation we get the global emission level of countries that are parties of the Kyoto Protocol:

$$\sum_{i \in K} e_i^*(p) = \sum_{i \in A} e_i^o + \sum_{j \in B} \overline{e}_j, \tag{4}$$

which is equal to e_K, the global emission level of Annex B countries without CDM. This proves that the CDM is neutral from the global emission viewpoint. Although not novel, this statement is highlighted in the following proposition.

Proposition 1 *With given national emission quotas, allowing for CDM projects does not change the global carbon emission level.*

Under CDM, the carbon price reflects the balance between the global demand for carbon permits and the supply of Annex B countries' carbon emission quotas and business-as-usual emission levels in other countries. Once national emission quotas are set, carbon reductions by non-Annex B countries are exactly offset by carbon increases in the Annex B countries. As a consequence, the introduction of the CDM does not change the global emission level. This result is key for the political and environmental credibility of CDM. Unfortunately, as it will be shown in the next section, it only holds when national emission quotas are given beforehand. If one accepts that countries are likely to anticipate the investments and rents generated by the CDM projects, then the countries will adapt their own abatement commitment. This leads us to discuss the strategic choice of their emission quotas by countries.

4 Strategic choices of emission quotas

Only Annex B countries participate in the setting of the carbon emissions cap. Each Annex B country, $j \in B$, is committed to a binding emission cap, $\overline{e}_j$, which corresponds to its endowment in carbon emission quotas, as negotiated under the Kyoto Protocol. By contrast, non-Annex B countries, $i \in A$, make no commitment under the Kyoto Protocol, set no cap and are allowed to follow their business-as-usual carbon emission level, e_i^o.

Annex B countries balance the cost of their local strategies to curb their emissions, the avoided local damages due to climate change mitigation, and the benefit of their potential rents accruing from CDM projects. To establish each country's cost function we need to specify the country's damage from carbon emissions and its share in the CDM projects. Hence, we assume that every country suffers from a local damage due to climate change, $D_i(e)$, where e stands for global carbon emissions ($e = e_K + e_N^o$). Each damage function D_i is assumed to be strictly increasing and convex ($D_j' > 0$ and $D_j'' > 0$). We also define σ_{ij} as the share of the rent accrued to the supporting firms located in country $j \in B$ that transfer CDM projects to firms in the non-annex B country $i \in A$. This share is nil if there is no CDM project involving firms in countries i and j. It is equal to one if all CDM projects in country i involve firms located in country j. The share can take any value between zero and one if CDM projects are realized by a consortium of firms located in different countries. Such shares naturally aggregate so that $\sum_{j \in B} \sigma_{ij} = 1$.

Using those definitions, an Annex B country, $j \in B$, has a welfare objective function given by

$$\mathcal{W}_j(\overline{e}_j, e, p) \equiv \pi_j\left(e_j^*, I_j^*\right) - I_j^* - p\left(e_j^* - \overline{e}_j\right) + \sum_{i \in A} (1-\alpha)\,\sigma_{ij} R_{ij}(e_i^*, I_i^*) - D_j(e),$$

where the first three terms represent the net profit of the local firm, including the costs of its investments and carbon purchases, while the fourth term is the net profit of the local firm that acts as supporting firm and the last term the country's damage function. This welfare function depends on the country j's emission cap, $\overline{e}_j$, on the global emission level e and on the carbon price p. The emission and investment levels in country j and CDM recipient countries, $(e_j^*, I_j^*, \{e_i^*, I_i^*\}_{i \in A})$, are the equilibrium values that vary with the carbon price p. By (3), the global emission level $e = e_K + e_N^o$ is a linear function of $\sum_{j \in B} \overline{e}_j$, the sum of countries' emission caps.

As in Helm (2003) we assume that each Annex B country j decides uncooperatively on its own national carbon emission quota $\overline{e}_j$. The Nash equilibrium is defined as the set of national quotas $\{\overline{e}_j\}_{j \in B}$ such that for all $j \in B$

$$\overline{e}_j^* \in \arg\max_{\overline{e}_j, e, p} \mathcal{W}_j(\overline{e}_j, e, p)$$

subject to

$$e = \sum_{k \in K} e_k^*(p) + e_N^o = \sum_{i \in A} e_i^o + \overline{e}_j + \sum_{k \in B \backslash \{j\}} \overline{e}_k^* + e_N^o$$

where the other countries' carbon emission quotas $\overline{e}_k^*$, $k \in B \backslash \{j\}$, are taken as given. The two equality constraints respectively express that global emissions are equal to the demand of emission quotas and to their supply. The first constraint can be written as the equality $\sum_{k \in K} e_k^*(p) = e - e_N^o$ and be inverted as the price function $p = p_K(e - e_N^o)$. This price function p_K depends on the set of Kyoto member countries, K, and decreases with the global emission level ($p'_K \equiv dp_K/de < 0$). Using the second constraint we get $p = p_K(e_K)$ where $e_K = \sum_{i\in A} e_i^o + \sum_{k\in B} \overline{e}_k$. Substituting this price and the second constraint in the above objective and using the envelop theorem, we get the following first order conditions:

$$\frac{d\mathcal{W}_j}{d\overline{e}_j} = p_K(e_K) - \left(e_j^* - \overline{e}_j\right) p'_K(e_K) + \sum_{i\in A} (1-\alpha)\,\sigma_{ij}\left(e_i^o - e_i^*\right) p'_K(e_K) - D'_j(e) = 0,$$

$\forall j \in B$. This condition is sufficient if the damage cost D_j is sufficiently convex, which we assume for simplicity.

We further define *the amount of certified emission reductions initiated by all the supporting firms located in country $j \in B$ through CDM projects* as

$$H_j^* \equiv \sum_{i\in A} \sigma_{ij}(e_{ij}^o - e_{ij}^*) > 0,$$

and the (positive) *elasticity of the world carbon emission* as

$$\eta_K^* \equiv -\frac{p_K}{p'_K e_K} = -p\frac{\sum_{i\in K} e_i^{*\prime}}{\sum_{i\in K} e_i^*},$$

which are both evaluated at the equilibrium price p^*.[8] So the equilibrium conditions can be rewritten as

$$D'_j(e^*) = p^*\left[1 + \frac{\left(e_j^* - \overline{e}_j^*\right) - (1-\alpha)\,H_j^*}{\eta_K^* e_K^*}\right], \forall j \in B, \tag{5}$$

where the superscript asterisk * denotes equilibrium values.

So, each Annex B country sets its carbon emission quota $\overline{e}_j^*$ so as to equate its marginal damage to the carbon price, with a positive correction for its net demand for carbon emission quotas and a negative correction for its rent in CDM projects. In the absence of CDM projects and strategic behaviors, the square bracket term vanishes so that a higher carbon price makes local emission more costly and entices the country to weaken its commitment on emission reductions (that is, to increase its carbon emission quota). This is the standard property of carbon pricing theory. However, when countries are strategic in setting their quotas, they relax their commitment when they expect to have a positive demand of carbon quotas. The novel point in this paper is that *Annex B countries also strengthen their individual commitments when they anticipate positive rents from CDM projects.*

Note at this stage that, if all Annex B countries had the same damage function, $D_j(e) = D(e)$, $\forall j \in B$, then each country would set its carbon emission quota $\overline{e}_j^*$ such that $\left(e_j^* - \overline{e}_j^*\right) - (1-\alpha)\,H_j^*$ takes the same value for all countries. So, a

[8]Note that the above elasticity aggregates the emission of all countries in the Kyoto Protocol ($i \in K = A \cup B$) but not the emission of countries outside the Kyoto Protocol ($i \in C$).

country would set a lower $\overline{e}_j^*$ if it expects a larger share and/or a larger size of CDM rents. The presence of CDM rents and the importance of bargaining power in favor of supporting firms entices Annex B countries to be more stringent on their commitment on carbon emission quotas. This argument can be generalized in the following way. In the carbon market equilibrium, the net demand for certified emission reductions by Annex B countries must be equal to its supply by non-Annex B countries; that is,

$$\sum_{j\in B}(e_j^* - \overline{e}_j^*) = \sum_{i\in A}(e_i^o - e_i^*).$$

Because we successively have

$$\sum_{i\in A}(e_i^o - e_i^*) = \sum_{i\in A}\sum_{j\in B}\sigma_{ij}(e_i^o - e_i^*) = \sum_{j\in B}H_j^*,$$

it must be that the carbon market clearing occurs if

$$\sum_{j\in B}\left(e_j^* - \overline{e}_j^*\right) = \sum_{j\in B}H_j^*.$$

Let the *total amount of certified emission reductions* initiated under CDM projects among the set of Kyoto member countries K be defined as

$$H_K^* \equiv \sum_{j\in B}H_j^*.$$

It represents the volume of the CDM market under the Kyoto Protocol, which can be valued at the market price p^*. Using the latter definition and summing up conditions (5) for all Annex B countries we can write

$$\sum_{j\in B}D_j'(e^*) = p_K(e_K^*)\left(b + \frac{\alpha H_K^*}{\eta_K^* e_K^*}\right), \tag{6}$$

where b is the number of Annex B countries (i.e. $b = \#(B)$). On the one hand, the LHS of this expression increases in e_K^* because $e^* = e_K^* + e_N^o$. On the other hand, the RHS increases with larger α and H_K^*; it falls with e_K^* if $p_K(e_K)/\eta_K e_K$ falls with e_K, which is the case if the carbon demand is not concave (so it can be iso-elastic or linear). Such a condition is standard in the economic literature on carbon markets. Under this condition, the global emission level e^* increases with α and H_K^*. Thus, *ceteris paribus*, the effect of CDM on global emissions increases for any rise in the share of certified emission reductions in the global carbon market, H_K^*/e_K^*. In other words, the amount of certified emission reductions matters. The effect also increases if the price elasticity of carbon (η_K^*) falls. Note that this equilibrium condition is independent of the institutional framework of CDM projects, β.

We summarize the above discussion in the following proposition.

Proposition 2 *(i) Global emissions are invariant to the institutional framework of CDM projects (β). (ii) Provided that the carbon demand function is not concave, global emissions rise as non-Annex B countries get stronger bargaining power and CDM project potentials (larger α and H_K^*).*

The first part of the proposition states that global emissions are not affected by the Partie that bears the investment costs. These investment costs can equivalently been borne by the supporting firm or by the implementing firm. This result stems from the fact that investment costs can be recouped with certified emission credits. The result hinges on our assumption of efficient bargaining. Asymmetric information about CDM project costs and benefits might distort investment levels and is likely to alter this result. Nevertheless, the result provides an interesting benchmark in the discussion of the share of investment responsibilities and costs in CDM projects. It further simplifies the subsequent analysis of the effect of non-Annex B bargaining power on impact of global emissions.

The second part of the proposition tells that the redistribution of the CDM projects' rent towards the implementing firms and thus non-Annex B countries does have a positive impact on global emissions. Allowing for CDM projects is therefore not neutral on the carbon market outcome and on the global level of emissions. When an Annex B country gets a larger share of the certified emission reductions in CDM projects, its trade deficit in the carbon market diminishes. This country is therefore willing to commit to a stronger emission reduction, so that it diminishes further its carbon emission quota. This conclusion unfortunately runs against the redistributive argument in favor of a shift of CDM rents towards the less developed countries.

It is important to note that the CDM does not help the carbon market to reach the socially optimal level of emission abatement. An optimal carbon market would require the last term in bracket of the RHS term of (6) to disappear. But because the climate benefits of emission abatement are public good, and because the burden sharing among Annex B countries is strategic, the CDM market leads to an under-provision of emission abatement. The CDM market would be Pareto efficient only if the reference carbon price provided by Annex B countries were the optimal one. Nevertheless, under strategic setting of country emission caps among Annex B countries, the global cap is too high and, consequently, the carbon price is too low.

This analysis allows us to answer two additional questions about countries' participation to non-Annex B: what is the impact of the inclusion of a new country in non-Annex B, and, what is the impact of the shift of a country from Annex B to non-Annex B? We shall start with the former question.

5 Ratifying the Protocol without commitment

In this section we discuss the case of a country that ratifies the Protocol without committing to any emission abatement. This means that this country becomes a non-Annex B country. What is the effect of this enlargement of the Kyoto agreement on the carbon market and global emissions? Such a discussion illustrates the dilemma faced by developing countries during the negotiation process of the Kyoto Protocol and in the future international negotiations. If they join the Annex B, those countries have to accept binding emission commitments. By not joining the Annex B they avoid such an emission constraint but, because they ratify the Protocol, they are allowed to host CDM projects.

Suppose that country z comes to ratify the Kyoto Protocol but refuses any emission commitment. It thus becomes a non-Annex B country. We consider the following notation. The set of non-Annex B countries welcomes a new member, so that it grows from A to $A \cup \{z\}$. The set of countries that ratify the Protocol changes from $K = A \cup B$ to $L \equiv A \cup B \cup \{z\}$. The set of countries that do not ratify the Kyoto Protocol changes from N to $N \backslash \{z\}$. Variables are indexed accordingly. As an example, the global equilibrium emission level of the Kyoto countries will change from e_K^* to e_L^*.

We now check under which conditions global carbon emissions fall after the inclusion of the new member z; that is, whether $e_K^* \geq e_L^*$. Note that since the set B of Annex B countries remains the same, the LHS of condition (6) remains the same function of e^*. Therefore, the global carbon emission e^* falls after the new membership only if the RHS of condition (6) decreases. That is, if

$$p_K\left(e_K^*\right) + \frac{\alpha}{b}\frac{p_K\left(e_K^*\right)}{\eta_K^*}\frac{H_K^*}{e_K^*} \geq p_L\left(e_L^*\right) + \frac{\alpha}{b}\frac{p_L(e_L^*)}{\eta_L^*}\frac{H_L^*}{e_L^*}. \tag{7}$$

The most direct result is obtained when **implementing** firms have no bargaining power ($\alpha = 0$). In this case, the inclusion of country z into the Kyoto Protocol, but not in the Annex B, decreases global carbon emissions if $p_K(e_K^*) \geq p_L(e_L^*)$. That is, if the carbon price falls. This is indeed the case because, with the new membership, the market clearing condition becomes

$$\sum_{k \in L} e_k^*(p) = \sum_{i \in A \cup \{z\}} e_i^o + \sum_{j \in B} \overline{e}_j,$$

which is equivalent to

$$\sum_{k \in K} e_k^*(p) = \sum_{i \in A} e_j^o + \sum_{j \in B} \overline{e}_j + \left[e_z^o - e_z^*(p)\right],$$

where the squared bracket term is positive and induces the fall in price. Put differently, the fall in carbon price makes the commitment of Annex B countries less costly so that they can commit to stronger emission abatements, which pushes the global emission level down. This result reflects the common argument for inviting the largest number of countries to adopt the Protocol, even without making any carbon emission commitment. The inclusion of new countries into the Protocol indeed brings carbon reduction opportunities that have lower implementation costs than the last opportunities available within Annex B countries. Countries that join Annex B fully internalize the effect of CDM on their own emissions because they receive the full proceeds of the rents raised by these projects.

Naturally, the above argument must be qualified to the extent of the bargaining power of non-Annex B countries in CDM projects ($\alpha > 0$). When Annex B countries do not receive the full amount of the certified emission reductions, they do not fully internalize the potential of emission reductions offered by CDM projects and do not appropriately reduce their carbon emission quotas. So, the equilibrium outcome may be different.

As it can be seen from condition (7), the fall in carbon price can be balanced by the rise in certified emission reductions as $H_z^* \geq 0 \iff H_K^* \leq H_L^*$. When more CDM rents from those reductions accrue to the implementing firms (larger α), the global emission level may not decrease with country z's membership. A simple result can be obtained under the assumption of iso-elastic demand for carbon where $\eta = \eta_K^* = \eta_L^*$. In this case, the inclusion of the new member reduces global carbon emissions ($e_K^* \geq e_L^*$) if and only if

$$\frac{p_K\left(e_K^*\right)}{p_L\left(e_L^*\right)} \geq \frac{\eta b/\alpha + H_L^*/e_L^*}{\eta b/\alpha + H_K^*/e_K^*}. \tag{8}$$

Because the carbon price decreases after the inclusion of the new member country ($p_K\left(p_K^*\right) > p_L\left(e_L^*\right)$), this inequality is satisfied if $H_L^*/e_L^* < H_K^*/e_K^*$. This means that global emissions fall if the new member country does not augment the share of certified emission reductions in the global market. Loosely speaking, the new member must bring less certified emission reductions than the other countries do on the average. By contrast, if the new member proportionately brings a large amount of certified emission reductions ($H_L^*/e_L^* >> H_K^*/e_K^*$), then the above inequality is reversed and global carbon emissions will increase. In this scenario, it is easy to show that the ratio in the RHS of the latter condition increases with the bargaining power of non-Annex B countries, α. As a result, a rise in α expands the set of economic parameters for which global carbon emissions increase with the inclusion of a new member country. These results are summarized in the following proposition.

Proposition 3 *(i) The inclusion of a new non-Annex B country to the Kyoto Protocol decreases global emissions if non-Annex B countries have no bargaining power. (ii) Under iso-elastic carbon demands, this inclusion decreases global emissions if the new country does not bring too high a proportion of certified emission reductions compared to other countries and/or if non-Annex B bargaining power is not too high.*

The intuition goes as follows. On the one hand, the new member country brings new carbon reduction opportunities, which reduces the expected carbon price and entices Annex B countries to reduce their own emission quotas. On the other hand, the latter countries do not internalize the full surplus of the emission reduction opportunities and choose their emission target uncooperatively. As a result, they also relax their carbon emission reduction targets; they reduce the latter even further in the presence of an above average potential of certified emission reductions. In the end, they relax their commitments above the new member country's potential of carbon emission reduction. By continuity, this argument holds for a class of carbon emission demand that have no constant elasticity.

6 A new committed comer (shift to Annex B)

We here consider the case of a non-Annex B country that decides to shift to Annex B. A candidate country could be China or India. Therefore, let country a shift from the set A to the set B, so that the Protocol now includes $A\backslash\{a\}$ and $B\cup\{a\}$. Because the set of Kyoto countries remains the same, the net demand for total carbon emission quotas $\sum_{k\in K} e_k^*(p)$ remains the same and can be inverted as the same inverse demand for carbon $p_K(e_K)$. So, if the total emission cap is unchanged, the carbon price should be unchanged, too (see Proposition 1). Country a's shift to Annex B nevertheless implies a basic difference. This country is now asked to commit to an emission quota $\overline{e}_a$ that is below its business-as-usual emission benchmark e_a^o. Doing this, it gets the opportunity to trade carbon permits through the carbon market but looses the opportunity to sell CDM projects.

Here we shall consider that the rents from CDM projects lie in the legal requirement of partnership between Annex B supporting firms and non-Annex B implementing firms. For the sake of simplicity, we shall assume that country a is not the owner of the clean technology in the sense that it hosts implementing firms for CDM projects but no clean technology firms that can transfer their technology to other non-Annex B countries. If country a lies outside Annex B, a implementing firm in country a must find a supporting partner in a country that belongs to Annex B to obtain certified emission reductions. However, if country a joins the Annex B, the same implementing firm is allowed to implement the clean technology without using any specific supporting firm partner in another Annex B country. The clean technology then becomes a local public good in country a and firms do no longer have to share the rents from CDM projects. So, at any carbon price p, the certified emission reductions initiated in the CDM projects shift from

$$H_K^*(p) \equiv \sum_{j\in B} H_j^*(p) = \sum_{i\in A}\sum_{j\in B} \sigma_{ij}\left[e_i^o - e_i^*(p)\right]$$

to the new certified emissions reduction

$$H_K^{**}(p) \equiv \sum_{j\in B\cup\{a\}} H_j^*(p) = \sum_{j\in B} H_j^*(p) = \sum_{i\in A\backslash\{a\}}\sum_{j\in B} \sigma_{ij}\left[e_i^o - e_i^*(p)\right]$$

where we denote the variables for the new situation with a double asterisk ** and where the second identity results from the assumption that country a transfers no CDM projects after its shift (that is, $H_a^*(p) = 0$). One can readily check that

$H_K^{**}(p) \leq H_K^*(p)$. At a given carbon price, country a's shift diminishes the global number of certified emission reductions.

The equilibrium condition (6) after the country a's shift becomes

$$\sum_{j \in B \cup \{a\}} D_j'(e^{**}) = p_K(e_K^{**}) \left(b + 1 + \frac{\alpha}{\eta_K^{**}} \frac{H_K^{**}}{e_K^{**}} \right)$$

where the number of Annex B countries b is changed into $b+1$ and where H_K^{**} and η_K^{**} are evaluated at the new carbon price p^{**}. This equality can be rewritten as

$$\sum_{j \in B} \left[D_j'(e^{**}) - p_K(e_K^{**}) \right] = \alpha H_K^{**} \frac{p_K(e_K^{**})}{\eta_K^{**} e_K^{**}} - \left[D_a'(e^{**}) - p_K(e_K^{**}) \right]. \qquad (9)$$

The latter identity is to be compared with condition (6) before country a's shift, which can also be written as

$$\sum_{j \in B} \left[D_j'(e^*) - p_K(e_K^*) \right] = \alpha H_K^* \frac{p_K(e_K^*)}{\eta_K^* e_K^*}. \qquad (10)$$

Because $e_K^* = e^* - e_N$ and $e_K^{**} = e^{**} - e_N$, the LHS of conditions (9) and (10) includes the same increasing function of the global emissions e^* and e^{**}. As a result, the global carbon emission falls after country a's shift to Annex B ($e^* \geq e^{**}$) if

$$\alpha H_K^* \frac{p_K(e_K^*)}{\eta_K^* e_K^*} \geq \alpha H_K^{**} \frac{p_K(e_K^{**})}{\eta_K^{**} e_K^{**}} - \left[D_a'(e^{**}) - p_K(e_K^{**}) \right].$$

This will occur for two reasons. On the one hand, if $D_a'(e^{**}) \geq p_K(e_K^{**})$, then country a incurs a high marginal damage from global carbon emissions and is eager to reduce them further. It will be the case for a large and/or developed country. A large country will have a large number of people affected by climate damages. A developed country will have a population with a strong willingness-to-pay for climate change mitigation. Such a country indeed adopts stringent abatement commitments that will push the carbon price up. Note that, in reaction to that country's commitment, other Annex B countries will partly relax their own commitment, free-riding on the new comer (the so-called *carbon leakage effect*). Nevertheless, global emissions will fall. Conversely, global carbon emissions will rise if country a has low marginal damages in equilibrium (when $D_a'(e^{**}) \leq p_K(e_K^{**})$). This can be the case of a small and/or poor country whose impact on global warming is small or whose damage valuation is low.

On the other hand, country a's shift can diminish the global number of certified emissions reductions when $H_K^*(p^*) \geq H_K^{**}(p^{**})$. The shift to Annex B actually reduces the inefficiency stemming from the fact that Annex B countries do not fully internalize the economic potential of emission reduction offered by CDM projects and do not reduce their carbon emission quotas to efficient levels. This effect is strengthened when non-Annex B countries get stronger bargaining power, when country a is endowed with more important and numerous CDM projects, and when the carbon price does not significantly fall after country a's shift.

The above discussion is based on marginal damage functions that are not observable and difficult to quantify. It may be more convenient to discuss the impact of the new comer in Annex B in terms of carbon quotas and CDM certified emissions reductions. Using condition (6) for country a along with $H_a^*(p) = 0$, one can see that global carbon emissions will fall after country a's shift to Annex B ($e^* \geq e^{**}$) if and only if

$$\alpha H_K^* \frac{p_K\left(e_K^*\right)}{\eta_K^* e_K^*} \geq \left[\alpha H_K^{**} - \left(e_a^{**} - \overline{e}_a^{**}\right)\right] \frac{p_K\left(e_K^{**}\right)}{\eta_K^{**} e_K^{**}}. \tag{11}$$

Assume first that the bargaining power of non-Annex B countries is nil ($\alpha = 0$). Then, global carbon emissions will fall after the country a's shift if and only if this country sets its endowment such as to become a net buyer of carbon quotas in equilibrium

$$e_a^{**} > \overline{e}_a^{**}.$$

This is likely to be the case for large and/or rich countries whose population is widely affected by global warming and put high values on damages. Such countries will adopt stringent abatement commitments so that they will become net buyers of carbon quotas and push the carbon price up. By contrast, small and/or poor countries are unlikely to set stringent commitments and their shift into Annex B will raise global emissions.

Assume now that the bargaining power of implementing firms is not nil ($\alpha > 0$). If we assume again that the demand for carbon is not concave, then $p_K\left(e_K\right)/\eta_K e_K$ is a decreasing function of e_K. In such a case it can be shown that inequality (11) implies that $e^* \geq e^{**}$ if and only if $\alpha H_K^* \geq \alpha H_K^{**} - \left(e_a^{**} - \overline{e}_a^{**}\right)$. This means that global emissions will fall if and only if

$$\alpha\left(H_K^* - H_K^{**}\right) \geq \overline{e}_a^{**} - e_a^{**}.$$

To fix ideas, suppose that non-Annex B countries get the full bargaining power ($\alpha = 1$). In this case global emissions fall even if country a becomes a net supplier of a carbon quotas, provided that its net supply of carbon quota (RHS) remains lower than its supply of certified emission reductions before the shift to Annex B (LHS). When country a gets a lower bargaining power ($\alpha < 1$), its net supply in the carbon market must further be constrained to create no adverse effects on global emissions. This leads us to our last proposition.

Proposition 4 *Assume that carbon demand functions are not concave. Then, the shift of a non-Annex B country to the Annex B decreases global emissions if and only if*
(i) the country's net supply of carbon quotas is negative, when the country has no bargaining power ($\alpha = 0$), and

(ii) the country's net supply of quotas is larger than its former supply of certified emissions reductions, when the country has full bargaining power ($\alpha = 1$).

In other words, to induce a fall in global carbon emissions, the shift to Annex B must be driven by a pledge to reduce global carbon emissions through the country's commitment, and not by a will to increase the benefits that this country derives from the carbon market.

7 Conclusion

The Clean Development Mechanism (CDM) is currently part of the global carbon market that is implemented under the auspices of the Kyoto Protocol and that came into force in 2005. Its objective is to jointly stimulate a clean economic development in least industrialized countries and ease industrialized countries to meet their carbon emission commitments. The CDM is however criticized for many problems like its lack of additionality, its transaction costs, the issue of low-hanging fruits, etc. As a result, many countries are challenging the inclusion of CDM into the future convention on climate change. The current paper presents additional arguments that should make those countries even more cautious about the adoption and implementation of such a mechanism.

The starting point of our analysis is that the CDM is fully part of the globalized carbon market. As such, it may alter the carbon market equilibrium, leading to some unexpected outcomes. First, we show that the common view that CDM does not alter global emissions holds only under the assumption that countries's carbon emission targets are given before hand. This contrasts with the reality in which countries have endogenously set their carbon emission targets during the negotiation phase the Kyoto protocol. Similarly, it is also very much likely that countries will understand their benefits from the CDM and will alter their carbon emission commitments in the future international conventions on climate. Then, we show that the bargaining power of receiving firms and (by extension) of least developed countries has a negative effect on climate changes. Annex B countries do not fully internalize the effects of the CDM projects on climate and do not appropriately reduce their abatement targets when some CDM rents flows to non-Annex B countries. As a result, the CDM generates a new kind of carbon leakage and has a negative impact on climate change. Finally, we show that the institutional framework has no impact on the global emission level even when emission targets are endogenously set by countries. Thus, the CDM is a good mechanism for countries that are unable to raise the funds for their clean investments.

We also provide new results that should be of interest for the forthcoming negotiations that seek for an international climate agreement. On the one hand, we show that including a new country that does not commit to carbon emission abatement decreases global carbon emissions only if this country has no bargaining power and/or does not bring too high a proportion of certified emission reductions. This result qualifies the policies that promotes the inclusion of countries with large potential for CDM projects and/or with large bargaining power in the setting up of CDM projects. On the other hand, we show that a country's decision to commit to carbon emission target may not lead to global emission reductions. By joining the Annex B, a country foregoes the rents of CDM programs but benefits from the access to the global carbon market where it can sell carbon quotas. We show that global emission falls if and only if the country that shifts to Annex B becomes a net buyer of carbon quotas (when it has no bargaining power) or if its supply of quotas does not exceed its previous supply of CERs (when it has full bargaining power). All this confirms that the properties and potential of the CDM, as a policy instrument, cannot be considered independently of the global carbon market outcome.

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