

Climate Finance, Carbon Market
Mechanisms and Finance “Blending”
as Instruments to Support NDC
Achievement under the Paris Agreement

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Abstract

This paper considers the impacts of “finance blending” whereby climate finance is added to international carbon markets for offset trading. The paper first discusses climate finance and the carbon market as free-standing finance solutions by high-income countries to increase mitigation in low-income countries. Climate finance solutions have advantages for high-income countries due to their greater flexibility and general efficiency. A favorable aspect of well-functioning offset markets is that all participating countries face a similar and robust carbon price. With finance blending and “all attribution to the carbon market,” the market equilibrium is inefficient, as

mitigation is excessive in low-income countries and too low in high-income countries. Instead, mitigation outcomes in the offset market should be attributed to the two finance types in proportion to their finance shares provided to the low-income countries through this market. When climate finance is added to the carbon market, the ambition level for emissions reductions for donor countries should be raised equivalently; otherwise, the added climate finance leads to no increase in global mitigation. When low-income country market participants have limited access to credit markets, climate finance can increase mitigation by supplying the capital required to implement efficient mitigation projects. .

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Climate Finance, Carbon Market Mechanisms and Finance “Blending” as Instruments to Support NDC Achievement under the Paris Agreement

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1. Introduction

Financial contributions from high-income (or high-ambition; hereafter, H) countries, to countries at lower income, development, and climate policy ambition levels (hereafter, L countries), will be essential for a successful implementation of the Paris Agreement (PA). Such financial contributions can take various forms. This paper focuses on two main forms that together are likely to constitute the two most important sources of such finance. The first, denoted “*climate finance*”, is interpreted as consisting of contributions in the form of grants, provided from H country governments (possibly, via International Financial Institutions, or funds) to support mitigation action in L countries. We will in this paper consider climate finance only in terms of its pure grant equivalent value; external finance which contain lending elements will be kept out of this calculation.² Such contributions may be given unconditionally, but may alternatively be given conditionally, upon particular climate mitigation outcomes in the L countries. Such finance can support projects or programs for greenhouse gas (GHG) mitigation in L countries or affect climate-related policies by L country governments.

The other type of finance to support mitigation action in L countries, discussed in this paper, is finance raised by “*carbon market mechanisms*”.³ This is provided by H countries purchasing “carbon offsets” from L countries, toward fulfilling H countries’ Nationally Determined Contribution (NDC) targets submitted by these countries to the PA.⁴ The L countries in this case provide emissions reductions beyond their own (unconditional) NDC targets, sold in the carbon market and purchased by H countries. Traditionally (as under the Kyoto Protocol, KP), finance from carbon market mechanisms has been provided via offset markets whereby private parties in H countries (who need to comply with their imposed GHG emissions targets) purchase offsets

² Consider the example of an IDA loan from the World Bank of \$10 million, given for climate finance purposes, and has a 50% grant element. This loan will in our context constitute a climate finance contribution of \$5 million.

³ “Carbon markets” and “offset markets” will here be used interchangeably to characterize such markets.

⁴ We will in this presentation generally not use the term “carbon finance”, which is a legacy from the Kyoto Protocol and is confusing under the PA which clearly distinguishes climate finance (Article 9) from market mechanisms (Article 6). The Kyoto Protocol did not make this distinction, and did not use the term climate finance.

from private parties in L countries who generate emissions reductions beyond their respective countries' conditional NDCs. The most important carbon market mechanism has so far been the Clean Development Mechanism (CDM) under the KP (Schneider 2009; Erikson et al 2014). Similar finance mechanisms are likely to become operational also under the PA, through trading of Internationally Traded Mitigation Outcomes (ITMOs) under paragraph 6.2 of the PA, allowing countries to cooperate in various ways that they work out for the transactions. Under paragraph 6.4 of the PA, countries can cooperate directly or involve other entities – including the private sector – in the financing and transfer of mitigation outcomes, subject to governing provisions laid out by the UNFCCC. These modalities are summarized in World Bank, EcoFys and Vivid Economics (2017), chapter 3.

In principle, one may think of carbon market mechanisms as functioning also somewhat differently going forward. One such alternative is that H country governments purchase offsets in the carbon market from L country governments, in return for these governments implementing domestic GHG emissions-reducing policies with observable GHG emissions reductions observed at the macro level; often denoted as “scaled-up crediting”.⁵ While this is a possible and likely future carbon market mechanism, we focus in this presentation on the more traditional carbon market role, as the trading ground for offset demand and supply from individual offset sellers and buyers.

We will as noted not discuss private-sector funding on commercial terms as part of climate finance. This is not to say that such finance is unimportant. To the contrary, the private sector will likely supply most of the financing needs for future climate action in L countries. This overall financing need over the next 10-30 years is huge and in the order of \$10 trillion or more, several times what can reasonably be raised through the carbon markets and regular climate finance from donors. Private sector funding through international credit and capital markets, and its relationship to climate finance, will however be discussed in sub-section 3.4 below.

Carbon market funds and climate finance can be “blended” in the sense that the carbon market or offset payments can contain elements provided by climate finance from other sources. Consider mitigation projects implemented by carbon market participants in the L country, where achieved mitigation outcomes (in terms of ITMOs) are bought in the carbon market by H country market

⁵ The World Bank's Transformative Carbon Asset Facility (TCAF) is designed to support exactly this type of carbon market crediting.

participants for compliance purposes. “Climate finance” can be supplied to this market, in the form of donor-based financial support to implement relevant L country mitigation projects; for example, to support L country actors’ investment costs, or MRV activity. An important issue to be discussed in the following is the principle for “attribution”, or in other words crediting, of mitigation outcomes to suppliers of each of the two financing types, climate finance, and funds supplied by offset purchasers in the carbon market.

We will in the following present a simple analytical model to illuminate key issues related to climate finance and carbon market mechanisms as free-standing financing instruments, and when they are “blended”. Some key questions which we will attempt to answer are:

1. What are the impacts of alternative rules for attributing or crediting mitigation outcomes from relevant L country projects to the two types of finance?
2. Is there an optimal rule for such attribution, and which rule is this? More specifically, is it efficient to award the entire credit or attribution to the carbon market participants, or all the climate finance suppliers; or should attribution be shared according to the finance provided, proportionally or according to a different formula?
3. Do there exist efficiency or other arguments in favor of adding climate finance to the carbon market?
4. What does the addition of climate finance to the carbon market imply for the “ambition” of participating (H and L) countries, in terms of setting their NDC targets?
5. Should the use of blended finance in the carbon market focus mainly on programs with aggregate (sector-based or economy-wide) GHG emissions reduction targets, or on solutions that only consider specific projects, as has been virtually the only application until now?
6. How does uncertainty affect the effectiveness and preference of carbon market versus climate finance solutions, or mixes of the two? How does one most effectively and efficiently deal with uncertainty about outcomes of mitigation activities under different blending approaches? Can finance blending help to manage some of the potential problems with uncertainty?

Some of these issues have already been addressed in recent consultant reports, including Broekhoff et al (2017), Schneider et al (2017a, b), and Theuer et al (2017). This literature has however a more

specific approach, as it focuses on administrative, definitional, accounting, and other technical issues; and does not go deeply into economic mechanisms or incentives created for various participants, nor analytical arguments; and does less to consider efficiency aspects.

A particularly important technical issue in this paper is the impact of alternative rules for attributing mitigation outcomes to regular carbon market participants, and to climate finance supplied to the carbon market. We demonstrate that proportional attribution of mitigation outcomes to the respective finance shares leads to an efficient carbon market solution. Our analysis also addresses several other issues from an analytical point of view. We address whether climate finance can play additional facilitating or enabling roles for the carbon market. We also study whether increased “ambition” (among H countries) is a natural policy change accompanying finance blending. We find that climate finance can indeed play important facilitating and efficiency-enhancing roles; in particular when implementation of mitigation projects, at efficient scales, requires adequate credit market access, and credit markets are imperfect. We also conclude that climate finance supplied as “blending”, and with proportional attribution, should naturally lead to increased ambition of the respective donor countries; otherwise this blended finance does not lead to higher global mitigation and is effectively wasted.

This paper says less about whether international carbon markets with offset trading are required for implementation of optimal or efficient global GHG mitigation. In particular, we do little to compare carbon tax solutions to cap-and-trade (c-a-t) arrangements of which carbon markets constitute an important category. Several authors have questioned the efficiency and usefulness of international c-a-t solutions based on offset markets, when compared to carbon tax solutions. See the survey by Goulder and Schein (2013); and contributions by Hoel and Karp (2001; 2002), Helm (2003), Holtmark and Sommervoll (2012), MacKenzie (2011), Strand (2013), Weitzman (2017), and Weitzman and Holtmark (2018) for critical views of c-a-t solutions when compared to tax solutions; and Newell and Pizer (2003), Karp and Zhang (2005; 2012), and Karp and Traeger (2018) for more positive views of c-a-t solutions.

In the continuation, section 2 discusses and compares the two finance types as stand-alone finance mechanisms for GHG mitigation. Section 3 considers “blending” of offset payments with climate finance. We there focus on two alternative attribution principles: “all to the carbon market”; and attribution which is proportional to the respective finance shares. We there also discuss alternatives

regarding donor countries' ambition when climate finance is added to an existing offset market: either no increase in ambition; or increased ambition in proportion to the mitigation share attributed to climate finance. Our final case discusses different market structures for emissions-reducing investments financed through the offset market, with both finance types supplied to offset markets mitigation programs in L countries implemented through the carbon market. We show that when the respective GHG-mitigating investments require credit market access for project hosts, and credit markets are imperfect, an offset market solution with no additional supply of climate finance may be inefficient as the credit then obtained may be too small to implement an efficient project, or credit may be unobtainable. In such cases, climate finance has clear efficiency-enhancing roles by facilitating credit market access and projects closer to optimal sizes.

2. Climate finance and carbon market mechanisms as separate policy instruments

2.1 Climate finance only

Our first case to consider is “pure climate finance”, assuming that international carbon markets are absent. Support to mitigation in L countries is provided on a free basis by H countries, and with a high degree of flexibility.

There is little we can say at a very general level about the impacts, effectiveness and efficiency of such financing. This depends to a large extent on the more specific form the climate finance takes, what conditions are put on outcomes, and other features to be discussed.

We first present a simple model where a given H country provides GHG mitigation support to L countries on the basis of climate finance. Climate finance can take many forms, one of which is up-front finance payments by an H country to (fully or partly) finance projects or investments aimed at climate mitigation in an L country, and where the supply of finance is not made to depend on the mitigation outcomes. Climate finance can however also be applied as a more conditional instrument (supplied only when certain targets are reached).

Denote the marginal mitigation value for H countries by c_H , and the similar value for L countries by $c_L < c_H$, where both c_L and c_H are constant parameters (over the ranges considered here). c_H represents the marginal value of global GHG mitigation as considered by H countries, independent of where mitigation is carried out. It represents the value of additional mitigation effort for an H country or a bloc of such countries, regardless of who exerts this effort (thus regardless of where

mitigation takes place). With this interpretation, c_H does not include “co-benefits” or any other domestic benefits to H countries. We will not try to “explain” the level of c_H : It is considered exogenous and may take either low or high values (when the relevant H country or bloc has “low climate ambition”, or “high ambition”). It could in principle represent the “global cost of carbon” (for a “highly altruistic” bloc of H countries); a lower value, possibly the climate-induced marginal damage cost of GHG emissions for the H bloc itself; or a value in between these two cases. For L countries, by contrast, $c_L (\geq 0)$ is assumed to represent only “co-benefits” of domestic mitigation action for the individual country or region. Individual L countries are assumed to act selfishly, and place no value on mitigation carried out for the sake of reducing global GHG emissions (at home or abroad).⁶ The higher value of c_H relative to c_L makes it efficient for H countries to support additional mitigation in L countries. I assume that c_L and c_H are stable over the period of concern (the PA implementation period).

Assume that marginal mitigation costs in the L country increase linearly in the amount of mitigation it undertakes. The benefit function from GHG emissions for market participants in the L country is

$$(1) \quad W(L) = \alpha E - \frac{1}{2} \beta E^2 - tE - qE .$$

Equation (1) has a simple quadratic form, derived from a macro production function where fossil energy is a production factor with decreasing marginal productivity. E is the fossil-fuel consumption, and emissions level, of the L country, q = the market price of fossil fuels, t = a carbon price or tax imposed by the L country’s government (or a domestic carbon trading price in the L country given a domestic carbon market), while α and β are coefficients in the L country’s emissions benefit function. Maximizing (1) with respect to E yields:

⁶ This is an extreme position as it assumes that individual L countries, acting non-cooperatively in setting their NDC targets, put no value on the global climate implications of their own climate action. For example, this case would hardly fit for China which has a large fraction of global GHG emissions and is at the same time subject to substantial damage due to climate change. Note however that for most small L countries this value is likely to be very small. Alternatively, one might here have assumed a more cooperative climate policy stance by L countries, by assuming that they also consider global climate outcomes as part of c_L . This would however not change any fundamentals of the following analysis.

$$(2) \quad \frac{dW(L)}{dE} = \alpha - \beta E - t - q = 0 \Leftrightarrow E_0(L) = \frac{\alpha - t - q}{\beta}.$$

$E_0(L)$ is the GHG emission rate in the L country in the case of a comprehensive domestic carbon tax t , no outside support from climate finance, and no accessible international carbon market.

Assume that the L country's government determines its unconditional nationally determined contribution (NDC) to the PA by setting a comprehensive national carbon tax, t . One easily finds that the optimal domestic carbon tax is $t = c_L$, which is the purely domestic marginal value of mitigation action for the L country itself. Inserted into (2), this gives a solution for $E = E_L$:

$$(2a) \quad E_L = \frac{\alpha - c_L - q}{\beta}.$$

E_L is here the L country's unconditionally optimal emissions level, which we assume corresponds to the L country's NDC emissions level under the PA.⁷

α is assumed to represent the ex-ante expectation of a parameter determining the L country's optimal emissions level, which can be subject to uncertainty (while β will be considered unaltered). Assume for simplicity that each relevant L country executes its mitigation effort efficiently (and is relatively small).

Consider next an H country (or cooperating bloc of such countries), which provides climate finance to incentivize additional mitigation in the L country, given no international carbon market. The H country's mitigation activity has two parts: domestic mitigation; and climate finance to support L country mitigation. Define the domestic benefit function of the H country by

$$(3) \quad W(H) = aE - \frac{1}{2}bE^2 - c_H E - qE,$$

where E is GHG emissions in the H country. Consider mitigation to be carried out by the H country domestically, assuming that no carbon market is available, so that offset markets cannot be used. In (3), c_H represents the marginal value of mitigation for country (or bloc) H, where (as discussed)

⁷ This concept of conditional NDC corresponds to that of Spalding-Fecher et al (2017): "business as usual with new policies but without crediting".

c_H represents the H bloc's incorporation of the marginal, global, carbon externality in its own utility function. The H country or bloc maximizes (3) with respect to its domestic GHG emissions, E , yielding

$$(4) \quad \frac{dW(H)}{dE} = a - bE - c_H - q = 0 \Leftrightarrow E(H) = \frac{a - c_H - q}{b}.$$

The initial E level in the H country, set by its private market participants (before any climate policy is applied) is assumed to equal

$$(5) \quad E(0) = \frac{a - q}{b}.$$

In a similar way as for L countries, (4) is assumed to be implemented by the H country government imposing a domestic, uniform and comprehensive, carbon tax equal to its marginal damage related to own GHG emissions, c_H . Domestic mitigation in the H country is then

$$(6) \quad M(c_H) = \frac{c_H}{b}.$$

The welfare gain to the H country from its optimal domestic climate policy is

$$(7) \quad \Delta W(H) = W(H) - W(0) = \frac{1}{2b}(a - c_H - q)^2 - \frac{a - q}{2b}(a - q - 2c_H) = \frac{c_H^2}{2b}.$$

The H country provides a given amount of climate finance to support additional mitigation in the L country. When this climate finance is used to provide a positive support price for each additional unit of emissions mitigated in the L country, at least some mitigation beyond its unconditional NDC target, determined from (2) is then carried out in the L country. We here say nothing specific about how such mitigation is actually implemented other than that it is conducted efficiently.

Assume first that there are no constraints on the amount of climate finance available for the H country to implement this solution. The optimal emissions rate in the L country as viewed by the

H country (denoted $E_H(L)$) is found from simply replacing t with c_H in the utility function from mitigation among L country market participants, (1). This yields:⁸

$$(8) \quad E_H(L) = \frac{\alpha - c_H - q}{\beta}.$$

The optimal additional mitigation induced in the L country, resulting from the H country's provision of climate finance to the L country at a rate $c_H - c_L$ per mitigated unit, is then

$$(9) \quad M_H(L) = \frac{c_H - c_L}{\beta}.$$

This amount of mitigation is added to the L country's own mitigation via its carbon tax c_L which implements the L country's unconditional NDC. Support payments to the L country, $G_H(L)$, are then the unit support payment, $(c_H - c_L)$, times the amount of mitigation induced, from (9):

$$(10) \quad G_H(L) = \frac{(c_H - c_L)^2}{\beta}.$$

This same mitigation solution can however be implemented at lower cost for the H country, through more efficient provisioning of results-based climate finance (RBCF). This lowest payment to induce the mitigation solution (8) in the L country is found by providing a total utility for the L country equal to (or "epsilon" higher than) the utility level the L country achieves from the initially maximizing solution, (2) with t replaced by c_L . To find the minimum necessary support to the L country, one needs to calculate the welfare level for the L country given its own optimal carbon price, c_L , and its welfare level given the carbon price c_H . The difference between these two expressions is⁹

$$(11) \quad G_{H0}(L) = \frac{(c_H - c_L)^2}{2\beta}.$$

⁸ The H country can here be considered to provide a subsidy $c_H - c_L$ per unit of additional mitigation $E_L - E_H(L)$, as the L country is assumed to maintain its carbon tax of c_L per unit of GHG emissions.

⁹ See Strand (2018) for the analytical derivation.

This amount is exactly half of $G_H(L)$ from (10), when a fixed per-unit support payment per emission unit mitigated in the L country is provided by the H country.¹⁰ When the L country faces a subsidy $c_H - c_L$ to each of its mitigated carbon units (beyond its unconditional NDC), it achieves a net surplus as inframarginal mitigation costs to the L country are below $c_H - c_L$. When the H country instead provides a subsidy to the L country government equal to $G_{H0}(L)$, the L country's government is exactly compensated for this welfare loss, and not given any inframarginal surplus. If paid $G_{H0}(L) (+\varepsilon)$, the L country government will be (slightly) more than compensated and itself willing to impose c_H as a domestic tax.

It is in this case “optimal” for the H country to separate its own country's domestic climate policy from its policies toward the relevant L countries. The H country should carry out domestic mitigation using a uniform domestic carbon tax at level c_H , equal to the H country's own negative externality from its own GHG emissions.¹¹

We conclude that when the H country provides climate finance to the L country, and is free to structure this finance supply optimally (by holding the L country's utility at its reservation level), the finance cost to the H country can be reduced to half of the cost represented by a simple per-unit mitigation support of $c_H - c_L$. This makes it attractive for H countries to supply such climate finance, instead of using carbon market mechanisms of the offset type provided as fixed per-unit payments to additional mitigation.

2.2 Carbon market only

We will now consider a “pure carbon market” solution where mitigation induced in L countries relies fully on the offset market and with financial resources supplied from H to L countries through this market. We abstract from implementation problems, missing additionality, and leakage, and assume participation by all potential market participants from both the H and L

¹⁰ That this share is exactly half follows from the linear-quadratic structure of benefit and cost functions of the H and L countries. With other functional forms this share would be different, but always “close” to half given that $c_H - c_L$ is small.

¹¹ Calling this an “optimal” strategy for an H country or country bloc is of course questionable. It depends on the H country or bloc not engaging itself in more comprehensive climate treaties with other partners, that would involve GHG mitigation that is more ambitious and more aligned with a globally optimal mitigation solution. The scope for implementing such more efficient global mitigation solutions is widely studied and will not be discussed here; see Finus (2001), Barrett (2003), Nordhaus (2015), Cramton, Ockenfels and Stoft (2017), and Harstad (2018).

country. We develop a canonical model for the carbon market that can be used also to study blending cases to be discussed in section 3.

All financial support from the H country to mitigation in L countries is now provided through the carbon market. This support takes the form of offset payments from H country market participants to L country participants. We make the following assumptions:

- a) There exists an international, comprehensive, carbon market which comprises the entire economies of both the H and L countries.
- b) All GHG emitters in both the H and L countries are active carbon market participants.
- c) The emissions targets of the H and L countries are (in our main alternative) fixed, equal to E_H for the H country (set freely), and E_L for the L country.

E_H can be set either lower (tighter) or higher (slacker) than $E(H)$ from (4). E_H corresponds to the sum of allowable emissions quotas across all carbon market participants from the H country; assuming here that all emissions in the H country are embedded in the carbon market and subject to trading in that market. We will assume that the equilibrium carbon price in the carbon market, p , exceeds c_L , so that carbon market participants from the L country will sell and participants from the H country purchase “offsets”.

When relying completely on the carbon market with all GHG emissions in both the H and L countries subject to the carbon market rules and restrictions, the international carbon market solution and domestic climate policy will be integrated and both determined by the domestic climate policy of both country groups, and by the targets set by the two countries (or country groups), E_H and E_L , and the mitigation solution chosen by both the H and L countries fully market-determined.¹² H country market participants are net purchasers of offsets, and all L country participants sellers, at the carbon price p , and all participants consider this price to be exogenous. The domestic emissions level in the H country is determined by market participants maximizing the following function (which takes the same basic shape as (3)):

¹² There is here however nothing to prevent the H government from imposing a domestic carbon tax in addition to letting its domestic firms face a carbon price p in the carbon market (although this is not advisable; see Gollier and Tirole 2017). This will be ignored here. Note however again that the L country is assumed to impose a comprehensive carbon tax, c_L , for implementation of its unconditional NDC.

$$(12) \quad W_o(H) = aE - \frac{1}{2}bE^2 - qE - p(E - E_H).$$

(12) represents the preferences of H country market participants subject to a given emissions constraint E_H , but their emissions demand is $E > E_H$, so that $E - E_H$ needs to be purchased as offsets from L country participants, at the equilibrium offset price p . Maximizing (12) with respect to E , the emissions demand by the H country's carbon market participants is

$$(13) \quad \frac{dW_o(H)}{dE} = a - bE - p - q = 0 \Leftrightarrow E(H) = \frac{a - p - q}{b}.$$

p can here be lower or higher than c_H , although a typical case is $p < c_H$, as the H countries' emission targets (including offset purchases), E_H , can often be assumed to be set in such a way. If E_H is sufficiently small (the emissions constraint for the H country sufficiently tight), however, $p > c_H$.

The benefit function for L country participants takes the same basic form as (1), and is written as

$$(14) \quad W(L) = \alpha E - \frac{1}{2}\beta E^2 - c_L E - qE + p(E_L - E),$$

where E_L is the L country's unconditional NDC emissions level, considered as exogenous when setting E , with the domestic carbon tax imposed by the L country government equal to c_L . We assume as noted no carbon tax in the H country. Maximizing (14) with respect to E yields the emissions level in the L country:

$$(15) \quad \frac{dW(L)}{dE} = \alpha - \beta E - c_L - q - p = 0 \Leftrightarrow E(L) = \frac{\alpha - c_L - q - p}{\beta}.$$

Assume that the NDC emissions targets for L and H countries equal E_L and E_H , respectively. E_H is assumed to be set exogenously reflecting the H country's "ambition". E_L is by contrast endogenous, as the expected emissions level of the L country given a domestic carbon tax c_L , although it is set at an "ex ante" stage before the realization of certain short-run variables. Assume that the demand parameters α (for the L country) and a (for the H country) are uncertain when the NDCs are set, and have expectations $E\alpha$ and Ea respectively when E_L is set, and that similarly the fossil fuel price q is also uncertain at that time, with expectation Eq . E_L is then considered to be set by a rule somewhat modified relative to (2a), namely

$$(16) \quad E_L = \frac{E\alpha - c_L - Eq}{\beta}.$$

The H country's NDC target equals E_H which is generally below the emissions rate of the country $E(H)$ (from (13)) for any relevant carbon emissions price p ; and corresponds to the sum of the target emissions rates for all the individual market participants.

An unfamiliar aspect of this solution may be that the “effective carbon price” facing L country participants is $c_L + p$, while the carbon price facing H country participants is only p and thus lower. This has here a natural explanation: the L country is considered to experience “co-benefits” of climate policy at the average rate c_L per unit of GHG mitigation, while H countries experience no such co-benefits. The “correct” carbon price in a given country, from a global perspective, is the sum of the global carbon climate externality plus the marginal co-benefit (Cramton, Ockenfels and Stoft 2017), which are the “effective carbon prices” for H and L countries applied here.

Equilibrium in the carbon market implies that demand for offsets from H, equaling $E(H) - E_H$, equals supply of offsets from L, $E_L - E(L)$, at the clearing price p , found using (13) and (15):

$$(17) \quad \frac{1}{b}(a - q - p) - E_H = E_L - \frac{\alpha - c_L - q - p}{\beta} = \frac{p + (q - Eq) - (\alpha - E\alpha)}{\beta}.$$

The solution for the offset price p , in terms of parameters in (17), is found as, expressed now more conveniently in terms of the two countries' NDC emissions levels, E_H and E_L :

$$(18) \quad p = \frac{1}{b + \beta} [b(\alpha - c_L) + \beta a - b\beta(E_L + E_H)] - q.$$

To interpret some important factors that influence the equilibrium offset price, p , in (18), consider a and α as positive parameters in the respective emissions demand functions of the H and L countries. Shifts in a and α can be considered to represent (positive) shifts in the fossil fuel (and GHG emissions) demands of respectively the L and H countries. The anticipated solution for the equilibrium carbon price p is seen to be influenced by the expected levels of a and α ; while the actual, realized offset price is influenced by the realized values of a and α . When either of these parameters increases, emissions increase for a given carbon price, leading to a higher p . (18) also

shows that when the emissions target for either of the H and L countries becomes tighter, so that E_H and/or E_L are reduced, p also increases.

The global emission level, $E(G)$, is given by

$$(19) \quad E(G) = E(L) + E(H) = E_L + E_H,$$

“Global” emissions (here, involving only the L and H countries in question) simply equals the sum of the (exogenously set) emissions target for the H country, E_H , and the unconditional NDC emissions interpreted as the target for the L country.

The volume of offsets traded in the offset market, Q_0 , is found from (16) and (18) as

$$(20) \quad Q_0 = \frac{1}{\beta(b + \beta)} [\beta a + b(\alpha - c_L) - b\beta(E_L + E_H)] - \frac{q}{\beta}.$$

(20) holds as long as the H and L countries’ emissions targets, E_H and E_L , are set sufficiently tight to make $Q_0 > 0$ (which is the same as the condition for $p > 0$).

When comparing this solution to the same solution in the climate finance case (in section 2.1), we find that there could here be a welfare loss due to the H country not being “allowed” to conduct its domestic climate policy optimally. Optimality for the H country requires that the carbon price facing H country market participants should equal c_H , which requires a very specific NDC target level E_H , for this solution for p to hold in (18).

Fourthly, the amount of finance transferred from H to L countries via the carbon market is given by the product of the carbon price for the L country, p , multiplied by the amount of emissions reductions traded. In carbon markets to date, notably the CDM under the KP, such trading has taken place between individual (private) market participants on both sides of the carbon market, to reduce emissions from individual projects in L countries, with transfers from private parties in H countries to parties in L countries. A limitation is that transfer occurs between private agents and not between governments. A question is then whether the costs are charged to, and go to, the “right” parties; and whether the funds are provided in the best way.

The way carbon markets have traditionally operated may change as the PA is being implemented. Governments may come to play larger roles in offset markets as offsets are generated in more

varied and flexible ways, possibly on a sector- or economy-wide basis, and funding to a larger extent flows directly between governments. Such carbon markets are however not yet in operation. It thus appears natural and prudent for us, at this point, to view carbon markets as similar to the CDM and how this mechanism has traditionally been operating, for our present discussion.

There are several well-known reasons why project-based carbon markets were inefficient under the KP. Some of these inefficiencies are likely to persist under the PA, albeit perhaps in less serious forms. Problems with the CDM have included lack of additionality, leakage, and manipulation of baselines including the possibility of so-called “hot air” (transacted offset units are virtual and not real); see Rosendahl and Strand (2011), Strand and Rosendahl (2012). These problems led to increased transaction costs and infested the market as required MRV activity, and other activity to ensure the integrity of mitigation projects, became more complicated, and more costly.

A further complicating feature, not addressed in detail here, is that the offset price in carbon markets for individual mitigation project implementation is not uniform but often set in individual bilateral bargains between host and acquiring party. Such bargaining can reduce carbon prices below the levels derived here, as H country parties are often able to capture part of the matching surplus through individual project bargaining, for projects with low implementation costs. This implies that carbon prices differ between projects. See Liski (2001), Liski and Virrankoski (2014), Strand (2016b), and Harstad (2018).

2.3 Digression: Impacts of uncertainty

We will now, briefly, discuss how carbon (and offset) market outcomes differ from market outcomes under carbon taxes under uncertainty. Two major “result variables” can here be uncertain. The first is *the amount of mitigation induced* in each country bloc (H, and L) and in aggregate. The second is *the carbon price, p*. Weitzman (1974) and Roberts and Spence (1976) have argued that when carbon emissions demand is uncertain, and the marginal benefit function related to the global benefit from GHG mitigation is (much) more stable than the marginal cost function in the short run (for society, for implementing a given mitigation policy), the carbon price should be kept stable, and emissions variable, in the short or intermediate run (5-10 years, or longer). Most of the literature, including Pizer (2002), Kollenberg and Taschini (2016), Abrell and Rausch (2017), and Weitzman (2017), tends to concur. The global marginal cost of carbon emissions (the “global cost of carbon”) is relatively stable in the short and medium run, as it

depends largely on long-run global economic development and growth conditions which change little in the short run. The global or regional cost of mitigation policy has for most regions, over the past two decades, been quite volatile. Individual decision makers also tend to strongly prefer a stable carbon price for their long-term planning purposes.

In section 2.2, uncertainty can (as already indicated) be represented by (short-term) shifts in α and a for the two countries, and in the fossil-fuel price q , holding all other parameters and NDC emissions targets, E_L and E_H , constant (when shifts occur after E_L and E_H have been set). From (19), global mitigation will not be affected. With fixed emissions targets for all parties, carbon trading cannot affect global mitigation; it only shifts mitigation between the H and L countries.

The offset price p is by contrast impacted by both targets E_L and E_H ; and the parameters considered to shift L and H country emissions, α and a ; and the fossil fuel price, q .

The carbon trading price, p , could be quite volatile in particular when both α and a shift at the same time and in the same direction. This would be a typical outcome with global business cycles. When instead a and α are negatively correlated (a business downturn in one bloc goes together with an upturn in the other bloc), the change in p could be small, or even zero given perfect negative correlation.

Volatility of the carbon price facing mitigating agents is here undesirable as the price signal from the market is distorted or blurred. Higher market efficiency (with smaller or no carbon price fluctuations) would then require that the emissions targets, E_H and E_L , be altered at the same time.

A much more likely situation under offset market solutions is that countries (in the relatively short run) keep their emissions targets as given. It is unrealistic to assume that both H and L country governments are capable and willing to implement efficient (unconditional) mitigation solutions when offset markets are subject to global demand fluctuations.

We have so far ignored the possibility of splitting the two countries' economies into two separate parts where one (internationally-oriented) part participates in the carbon (offset) market, and the other (domestically-oriented) part does not, as has so far been the case under the EU-ETS. The governments might then impose carbon taxes (c_H in H countries, and c_L in L countries) on the parts

of their economies that do not participate in the carbon market. Only the internationally-oriented sector would then experience inefficiency in the form of fluctuating carbon prices.

3. Blending solutions

3.1 Carbon market subsidized by climate finance: “All to the carbon market”

Based on the carbon market model just presented, this section will add publicly funded financial resources to carbon market outcomes. Climate finance then “subsidizes” the carbon market. As before, p is the price paid by H country participants per unit of offsets generated for them by L country market participants. L country participants receive a higher carbon price, $p+s$, where s is the subsidy supplied via climate finance. We here focus on cases under certainty which are central for explaining the key features here. Brief discussions of finance blending under uncertainty are included in sub-sections 3.2 and 3.5.

The climate finance-based subsidy to carbon market outcomes can in practice be provided in several alternative forms instead of as a direct financial disbursement: as a subsidy to MRV activity; as subsidized loans, as financing of investments components for L country project hosts; or as subsidies to particular inputs involved in realizing the offset solution. This can without loss of generality be represented by climate finance subsidies to the offset price, leaving the host’s project costs unaltered. Nothing will be said about the specific form that a subsidy may take. Neither will we offer any particular reason(s) to warrant or justify such finance.

The subsidy is assumed to be applied uniformly to all mitigation activity induced by the offset market. A potential issue, here ignored, is that the subsidy rate may (and most likely will) in reality vary across offset projects.

We will now study how such subsidies affect the carbon market, including the equilibrium carbon price and mitigation in both the L and H country. Assume that the H country carbon market participants are awarded full attribution in terms of credited offset units, for their offset purchases. An “all to carbon markets” attribution principle is then applied. The offset price paid to L countries is now $p+s$, while offset buyers from the H country pay p . The amount of additional mitigation carried out in the L country, beyond the country’s unconditional NDC, is now:

$$(21) \quad E_L - E(L; s) = E_L - \frac{\alpha - c_L - q - p - s}{\beta} = \frac{p + s}{\beta}.$$

Emissions in the H country, given that H country market participants face the offset price p , are still given by (13). Equilibrium in the offset market now requires:

$$(22) \quad \frac{1}{b}(a - q - p) - E_H = \frac{p + s}{\beta}.$$

Offset prices p and $p + s$, facing H and L country market participants, can then be expressed as:

$$(23) \quad p = \frac{1}{b + \beta}[\beta a + b(\alpha - c_L) - b\beta(E_L + E_H)] - q - \frac{b}{b + \beta}s$$

$$(24) \quad p + s = \frac{1}{b + \beta}[\beta a + b(\alpha - c_L) - b\beta(E_L + E_H)] - q + \frac{\beta}{b + \beta}s.$$

The amount of offset trading is given by

$$(25) \quad Q(s) = \frac{p + s}{\beta} = \frac{1}{\beta(b + \beta)}[\beta(a + s) + b(\alpha - c_L) - b\beta(E_L + E_H)] - \frac{q}{\beta}.$$

Comparing (23)-(24) to (18), we find that p in (23) (the offset price facing the H country) is now reduced by $[b/(b + \beta)]s$, while $p + s$ in (24) (the offset price facing the L country) is increased by $[\beta/(b + \beta)]s$. Global emissions are unaltered, because the emissions targets of both countries are kept fixed, and these targets together determine global mitigation and emissions.

From (25), carbon offset trading is increased when s is increased. The L country's emissions are reduced, while the H country's emissions are increased by the same amount. When ambition of all parties is unaltered, increased offset trading in the carbon market here only shifts mitigation from buyers to sellers of offsets, and does not increase overall mitigation.¹³

To sum up, such “blending” (“combining carbon market solutions and climate finance in one solution”), with an attribution principle of “all to the carbon market”, implies that the carbon price

¹³ Remember here also that when there are problems with leakage, baseline endogeneity, and not full additionality for carbon market-induced mitigation, a higher level of offset transactions will lead to *reduced* global mitigation, as these problems are then worsened. See, e.g., Rosendahl and Strand (2011), Strand and Rosendahl (2012).

facing L country market participants, and the level of mitigation in the L country, are both higher than with no climate finance support. But the carbon (or offset) price facing H country market participants is reduced, and less mitigation takes place in the H country. A clear result is that as long as the emissions targets E_H and E_L for the H and L countries (or country groups) are kept fixed, global emissions will be unaffected. Mitigation increases in the L country, but diminishes by exactly the same amount in the H country. Offset purchases, by H country from L country market participants, increase to exactly compensate for the reduced mitigation in the H country as the carbon price facing that country falls. H country participants in the carbon market gain by paying less per unit of mitigation purchased from L country participants, and by mitigating less, while L country actors gain by mitigating more, due to higher offset prices and greater amount of credited offsets. When climate finance is supplied by the H country's public sector, part of the finance burden for the H country is shifted from the private to the public sector. The total finance burden is also increased, as the increased burden on the public sector is greater than the reduced burden for the private sector.

Since global mitigation is unaltered, using climate finance to subsidize the carbon market in this way largely represents a waste of precious public finance resources.

It is interesting to note that such a scheme is in certain ways diametrically opposite to “carbon credit discounting” proposed by some researchers (Castro and Michaelowa 2010; Klemick 2012; Lazarus et al 2013); and which can lead to “increased net mitigation” (Strand 2016a). Carbon credit discounting would imply that host country participants are paid *less* per unit of mitigation than the quota trading price within the H country or bloc. The intention of “net mitigation” schemes is to increase global mitigation under a climate finance constraint for support to mitigation in L countries, and for given mitigation targets in the H countries. Instead, using climate finance resources to subsidize carbon market outcomes has the opposite result relative to the intention of carbon credit discounting schemes: offset prices facing L countries are artificially *increased*. This leads to increased spending on climate finance resources by donor countries, but with no impact on global mitigation outcomes.

3.2 Proportional attribution with fixed H country mitigation target

A natural attribution alternative, instead of “all to the carbon market”, is to attribute the mitigation outcome to climate finance and the carbon market in proportion to the finance shares provided by

the two finance types. In our model above, the attribution share to carbon market participants would then be $p/(p+s)$, while the attribution share to climate finance would be $s/(p+s)$. Another way to express this is that, when considering the total volume of offsets, carbon market participants would be given an attribution share of $p/(p+s)$ per unit of total offsets, while climate finance would be given an attribution share of $s/(p+s)$ per same unit. A main purpose of this section is to study the efficiency properties of such a market solution, using the same analytical framework as applied above. This analysis in this sub-section will rest on the following assumptions:

- a) The emissions target of the H country, E_H , is fixed and not affected by the attribution share to climate finance.
- b) The climate finance and carbon market payments in question are supplied from the same source (a given H country or bloc of H countries).
- c) When emissions reductions in an L country below its NDC are attributed to climate finance from a given H country, this attribution counts toward the H country's aggregate (unaltered) emissions target, E_H .

These three assumptions together imply that the amount of offsets needed for the H country's carbon market participants, to fulfill their aggregate emissions targets, is reduced by climate finance, by the same amount as the attribution to climate finance.

The share of mitigation outcomes in the L country attributed to carbon market participants, for each offset purchase in the offset market, now equals $p/(p+s)$. The price per offset unit received by L country participants in the carbon market is $p+s$. The price paid by H country participants in the carbon market, for each offset unit, is now $[p/(p+s)](p+s)$, while the climate finance contribution pays for $[s/(p+s)](p+s)$ per offset unit. The price paid by carbon market participants in the H country per offset unit attributed to these participants is then $\frac{p/(p+s)}{p/(p+s)}(p+s) = p+s$.

This implies no subsidy to offsets in this market.

Climate finance "takes over" a fraction $s/(s+p) = 1-\lambda$ of the carbon market, while the regular carbon market participants contribute a share $p/(s+p) = \lambda$ of the offset costs in the market, and also receive the same share of attributed offset credits.

Note our assumptions that the “overall ambition” of the H country is not affected; and that climate finance comes from the same H country as the carbon market payments. The emissions targets for carbon market participants can now be considered as “relaxed” by this share, for participants on both sides of the regular carbon market. Otherwise the market can be considered to function in the same way as in the case of only carbon market payments, in section 2.2.

To derive the offset price p in this case, recognize that $E(L; s)$ is still given by (21), while $E(H)$ is given by (13) only replacing p by $p+s$. The solution for $p+s$ is identical to the solution for p from (18); so that the solution for p is found as:

$$(26) \quad p = \frac{1}{b + \beta} [b(\alpha - c_L) + \beta a - b\beta(E_L + E_H)] - q - s.$$

The subsidy from climate finance to the carbon market here has one single effect, namely to subsidize the offset price to market participants, in such a way that the offset price including the subsidy equals the original (unsubsidized) offset price. The offset price is then reduced by the subsidy rate s . No real variables are affected, when comparing to the pure carbon market case in section 2.2. In particular, overall mitigation, and mitigation by each of L and H country participants, are all unaltered. A fraction $s/(p+s)$ of the attribution of mitigation outcomes is shifted from H country participants in the carbon market, to climate finance. This is done by reducing the target for mitigation for H country participants in the carbon market, by exactly the same amount as the mitigation outcomes now attributed to climate finance.

To conclude, adding climate finance to the carbon market leads in this case to no real difference nor improvement in the overall solution; but neither to a deterioration. The “ambition” of each of the H and L countries is unaltered, and global mitigation is unaltered. The only difference is that part of the mitigation “burden” is shifted to climate finance provided centrally by the H country government, while the cost for carbon market participants from the H country is reduced.

Note finally that it may be questionable to consider climate finance resources to be used for compliance purposes as we implicitly assume here, when “overall ambition” is not increased, climate finance is attributed its finance share of all offset units, and climate finance and offset payments coming from the same country. Alternatively, the attributed offset shares to climate finance could be retired and not used for compliance. But this is the same as saying that the “true

overall ambition” (which must include retired offsets) increases with the addition of climate finance. It is simply unrealistic to consider the addition of climate finance without considering a similar increase in “ambition”, as discussed in the next sub-section.

Consider briefly uncertainty in the emissions demand functions for the H and L countries in this case. It is easy to demonstrate that shifts in the parameters a (for the H country), and α (for the L country), have exactly the same effects on p as were found in section 2. A question here is whether it is practical to use a variable climate finance policy to smooth otherwise volatile carbon prices in the international offset market. With proportional attribution, the effective carbon price for both the H and L countries equals $p+s$. Climate finance can then be varied to counteract demand shifts, by changing s in the opposite direction to p . This opens up another constructive role for climate finance in such markets. Applying such a rule may however be difficult. The climate finance subsidy rate would need to be changed in the opposite direction to the short-run shifts in p , which may be difficult as low p values tend to indicate poor general business conditions, and this makes the mobilization of additional climate finance resources problematic.

3.3 Proportional attribution with proportional increase in H country ambition

The blended finance case in the previous section might appear unsatisfactory as adding climate finance to the pure carbon market solution was assumed to not increase the climate policy ambition of the H country. The subsidy coming via climate finance could then be considered as unhelpful. Assume now instead that the H country’s reduction of its GHG emissions target relative to its status quo emissions rate is made more ambitious in proportion to the supply of climate finance relative to the regular carbon market.

The offset price facing carbon market participants in H countries is then impacted in a similar way as was found in sub-section 3.2. In both cases, there is a subsidy element from climate finance while there is a “discounting” of the attribution to carbon market participants at exactly the same rate. Thus, also here, all carbon market participants face the same effective carbon price, $p+s$, per unit of traded offsets. For L market participants, this is the price per unit of offsets sold; for H market participants it is the price per unit of offsets attributed. The difference from section 3.2 is that now there is an increase in the overall mitigation target of the H country, and also as we will see a higher mitigation rate in the L country.

Consider tightening the emissions constraint for both groups, such that mitigation would increase in proportion to the climate finance share of total finance from the carbon market. The initial amount of mitigation is

$$(27) \quad M(1) = \frac{p+s}{\beta} + \frac{p+s}{b} = \frac{(b+\beta)(p+s)}{b\beta}.$$

M(1) here represents “initial” mitigation, to which is added mitigation funded by climate finance, M(2). M(1) will then be a share $p/(p+s)$ of total mitigation M, given by

$$(28) \quad M = \frac{(b+\beta)(p+s)^2}{b\beta p}.$$

It is here not straightforward to find an analytical solution for M, as p and s will both be endogenous and affected by the resulting mitigation. The offset price will need to increase to induce this additional mitigation among both L country and H country participants in the carbon market.

Alternatively, one might here assume that (all or part of) climate finance comes from other countries than the H country bloc that provides the carbon market payments. Part of the mitigation executed in L countries and purchased in the offset market (financed in part by H country carbon market purchases, and in part by climate finance from other countries) will then reasonably be attributed to these other countries and not to the particular H country (or bloc) in question. This will work in exactly the same way as discussed above, with all finance stemming from the same country; and with the same solution.

A conclusion from this section is that adding a climate finance contribution to the carbon market, in the form of a subsidy to offset transactions, can be productive under proportional attribution. Proportional attribution does not by itself cause distortions, and the additional finance leads to increased mitigation in both L and H countries as the carbon price facing all increases. This principle can also be said to imply “fairness” in the allocation of shares of attributed mitigation outcomes to each of the finance sources.

3.4 Investments in renewable power capacity: Adding climate finance to the carbon market under credit market imperfections

We now switch to our second major way to explain roles of climate finance as support to enhance the effectiveness and efficiency of the carbon market. This can often be a more significant impact than for cases considered in previous sections. Climate finance may now have productive “synergies” in overcoming barriers that otherwise hinder the carbon market from functioning effectively. Some of these barriers are discussed as “complementary policies” in World Bank, Ecofys and Vivid Economics (2016, chapter 3). Main issues are:

- 1) Interaction between carbon pricing and climate finance in power markets
- 2) Policies whereby climate finance serves to expand infrastructure provision and access, relative to a pure carbon market solution
- 3) Overcoming non-price barriers to energy efficiency investments in the building and transport sectors, with multiple (climate and other) benefits
- 4) Climate finance serving to improve access to finance, mainly for infrastructure investments, in cases with inefficiently functioning credit and capital markets.

Point 4, inefficient credit and capital markets, is here important and we focus on this issue. Many energy-related investment projects with large mitigating potential imply large up-front investment costs, while variable costs in producing energy, once the capital costs are sunk, can be low. This applies to hydro, wind, solar and geo-thermal power. Many such projects will be highly uncertain for investors. In addition, the creditworthiness of borrowers is often questioned by investors due to problems of moral hazard (Holmström and Tirole 1998) or adverse selection (Stiglitz and Weiss 1981). All these factors make it difficult for private (and sometimes also public-sector) investors to obtain sufficient credit to implement such projects at close to optimal scales, or at all.

This gives new roles to climate finance, to increase the viability of potential carbon market projects by making it possible for entrepreneurs to realize such projects. Uncertainty with respect to other factors than investment costs (such as the electricity price, the fossil fuel price, and the carbon price) enhances this role further.

Assume that the climate finance considered here is in principle infinitely flexible by making it up to the donor/finance provider to define its use. One main advantage of climate finance is that it can be provided up-front and without verification of whether or not any mitigation has taken place

on the basis of the funding. This has impact on the risk profile of this type of finance, as viewed by the finance receiver (the party most likely to be the seller in the carbon market).

We will in the following study two examples of credit market-related climate finance which follow these assumptions, and where the credit market will (often) not provide the entire required finance.

3.4.1 Exogenous credit supply: Variable marginal product of capacity (case 1)

Consider a project to build a power plant (or set of power plants) in an L country based on renewable energy (hydro, wind, solar or geothermal power). Assume no baseline inflation, no leakage, and full additionality. The project size is endogenous and variable. Consider the following investment cost function for the project:

$$(29) \quad K(Z) = \lambda Z + \frac{1}{2} \rho Z^2,$$

where Z is the electricity production capacity of the plant or set of plants, and with λ and ρ both positive.¹⁴ Assume that all costs are investment-related and that there are no variable costs. This relationship can be certain or uncertain at the time of the investment. When it is uncertain, either λ or ρ or both can be uncertain. We will in the following consider only λ to be uncertain (for analytical simplicity).

The problem facing a fully financed investor is to maximize its expected profit function (the investor being risk neutral), as follows:

$$(30) \quad E\Pi(Z) = (EQ)Z - (E\lambda)Z - \frac{1}{2} \rho Z^2,$$

where Q = the electricity price, which is uncertain with expectation EQ at the time of investment. Maximizing $E\Pi$ with respect to capacity, Z , then yields

$$(31) \quad Z_1 = \frac{EQ - E\lambda}{\rho}.$$

¹⁴ When $\rho > 0$, marginal investment costs are increasing in capacity. This is not an obvious assumption for individual projects which may instead experience increasing returns to scale. It is however a more natural assumption when the “project” in consideration is a portfolio of potential investments where one starts with the least cost investment opportunity and goes on to projects with higher costs.

This constitutes the optimal investment rule for this project, given no climate-related costs. (We also for simplicity assume no investment time delays, and that EQ represents the discounted unit value of the resulting electricity output.)

With climate-related costs, the project will yield additional benefits. The degree of uncertainty could also be affected, positively or negatively. Consider a carbon price or tax T in the L country, charged to the initial electricity output (all of which at the outset is produced from fossil fuels), leading to an increase in the electricity price by T . T can also be a priori uncertain for market participants (with expectation ET) due e.g. to policy uncertainty in the L country, or uncertainty about the future “marginal cost of carbon”. The total price of fossil energy is then $Q+T$, where Q is the basic energy price without any carbon tax. Assume that each capacity unit Z of renewable energy faces out one unit of carbon via reduced fossil fuel consumption. This implies that the (expected) benefits of the renewable energy project is (given 100% capacity utilization)

$$(32) \quad E\Pi(Z;T) = (EQ)Z - (E\lambda)Z - \frac{1}{2}\rho Z^2 + (ET)Z .$$

The optimal project capacity is

$$(33) \quad Z_2 = \frac{EQ + ET - E\lambda}{\rho} .$$

The optimal capacity for a renewable power plant is thus larger when the alternative is to produce electricity from coal facing a carbon tax which can be avoided when using renewable energy, and where the carbon tax adds fully to the equilibrium electricity price.

Assume now that (33) is not implementable as competitive creditors refuse to provide the required amount of capital. Several explanations why such credit rationing may occur are offered in the literature. One is in terms of adverse selection, by Stiglitz and Weiss (1981). Creditors then cannot observe the “quality” of individual borrowers, and the loan default probability increases with the interest rate charged, as a higher interest rate attracts a riskier average pool of borrowers. Creditors will then often not increase the interest rate above a certain level but instead select to ration individual creditors.

We will here take a simpler approach by assuming that such rationing occurs, possibly for reasons explained by Stiglitz and Weiss, but without going into its analytical foundations. We assume that a donor (H country) can provide climate finance to help the L country implement the above optimal renewables project when credit rationing occurs.

Assume that the party which develops and later operates the renewables project in the L country has limited ability to raise capital to finance the project. How much if any climate finance will or should be provided? Given that the H country (or bloc) values carbon abatement at a price of $T_H > T$, the H bloc might be willing to put up the entire cost of the project as the marginal benefit to the H bloc exceeds the marginal cost even at the highest level. In practice this contribution will often be less as the financing ability of the donor is limited.

Consider a simple example where the project developer only can obtain finance through capital markets for half of the optimal level of K . From (29) and (33), the optimal cost level is found as

$$(34) \quad K(Z_2) = \lambda Z_2 + \frac{1}{2} \rho Z_2^2 = \frac{(EQ + ET)^2 - (E\lambda)^2}{2\rho}.$$

From the cost function (34), half of the optimal capital cost will finance an electricity capacity level Z_3 , where $Z_2/2 < Z_3 < Z_2$. Z_3 is thus between 50% and 100% of the optimal capacity Z_2 .

With sufficient additional climate finance from credit or capital markets, the optimal solution Z_2 from (33) can be implemented. This leads to added capacity $Z_2 - Z_3$, which is positive but less extra capacity than has already been established.

This argument rests on our assumption that marginal cost per capacity unit related to renewable electricity investments increases with project size. For individual projects, this may not always hold. One way to think of this cost function is however that the “project” investment cost K equals the sum of costs for a number of smaller projects in the L country. Rising marginal costs is then natural as investors will tend to first invest in the lowest-cost projects, and add projects at gradually higher cost per unit of capacity installed.

Consider attribution to the two finance sources. If attribution of mitigation outcomes is proportional to the share of finance raised by carbon and climate finance, it would be natural for each to be attributed half of the overall mitigation.

But it is not immediately obvious that this is the appropriate attribution principle here. With no climate finance, the carbon market would be given the entire attribution H_3 on basis of investing $K(Z_3) = \frac{1}{2} K(Z_2)$, half of the optimal investment cost, which is greater per cost unit than the attribution rate for the entire optimal project. This could speak for carbon market payments to be attributed more than half of the total emissions reduction, even when the capital finance shares from the two finance types are the same.

Note however that such an argument relies on a particular “sequence” of finance provision in the carbon market: that regular offset payments come “first”, and that the capital finance support, by climate finance, is provided “later” (or has lower priority in the case of default). Arguably, it may instead be natural to consider the two finance types as having equal priority, as assumed for other “blending” solutions discussed above. It is thus questionable to argue against a proportional attribution principle in this case.

This example also shows that carbon pricing makes finance of renewable energy projects more attractive for the financial markets, as carbon pricing tends to raise the electricity price, and by a lot when a large part of electricity production is at the outset generated by fossil fuels. In the long run this may change, as renewable energy is likely to take over more of electricity markets. Over time the electricity price will then be subject to a gradually smaller price mark-up by carbon pricing, with a resulting cost advantage to renewable energy projects. When a very large share of the electricity-generating capacity relies on renewable energy, which is clean and with low operating costs, downward pressures on the equilibrium electricity price may increase. This is likely to be recognized in the credit markets, and can imply that credit finance for establishment of clean energy capacity loses some of its attractiveness.

3.4.2 Endogenous credit market supply (case 2)

Consider an alternative explanation of credit market imperfections, which to a larger degree depends on direct rationing of market credit to investments in renewable energy projects in L countries. Assume a simpler investment function with K proportional to capacity Z , so that one can set $K = Z$. Assume that the unit return from investment is R , which is uncertain with expectation $ER > 1$ and standard deviation $\sigma > 0$. Assume that this return includes carbon market benefits (from selling the respective emissions rights in the carbon market at an exogenous and uncertain offset

price p). The investor from the L country is assumed to have no capital to invest, and must borrow all necessary funds in the credit market at (real) interest rate r (above the standard and common discount rate for the project), which reflects the additional returns for the creditor over a “normal” interest rate level. Set $F(R)$ = the cumulative distribution function for R with positive density $f(R)$ on $[0, \infty)$. Assume that the investor must pay back his entire production surplus as long as this is lower than or equal to the borrowed amount plus (above-normal) interest. When the surplus is larger, the investor pays back his borrowed amount plus the contracted interest. The (present value of the) expected amount paid back to the creditor on a unit loan, to be serviced at a break-even rate of unity, is then given by

$$(35) \quad \int_0^{1+r} Rf(R)dR + (1+r)(1 - F(1+r)) \leq 1.$$

With equality in (35), r is endogenous and equals the contracted interest rate that clears the credit market for this type of loans. With inequality in (35), we may think of r as having an exogenous value that is too low to yield full loan service to the creditor.

The expected return for the borrower (or investor) is

$$(36) \quad \int_{1+r}^{\infty} (R - 1 - r)f(R)dR > 0.$$

In this credit market relationship, there is always an interest rate r^* which clears this market by having (35) fulfilled with equality. Consider however cases where r is capped at a lower level $r_l < r^*$. This corresponds to (35) being fulfilled with inequality at its solution.

Creditors will in this case not be willing to finance the investment, since they cannot obtain positive expected returns on provided loans. At least part of any given investment must then be financed from other sources. This conclusion holds independent of the scale of the investment. In case 1, by contrast, credit financing would always be provided except often at sub-optimal project scales.

Set the share of the investment that needs to be financed from other sources than the credit market = θ , between 0 and 1. We may then write (35) as

$$(37) \quad \int_0^{1+r^*} Rf(R)dR + (1+r^*)(1-F(1+r^*)) = 1 - \theta .$$

A minimum fraction θ of investment costs must then be provided by other financing sources than the credit market. Consider climate finance as that alternative source. Climate finance is assumed to be provided on a fully concessional basis and given zero return, which means that the entire project return (on the left-hand side of (36)) is given to the credit finance source.

The analysis in this section has been subject to certain strong qualifications. When a project is affected by informational problems such as moral hazard or adverse selection, these problems will (at least in part) remain even with interference from climate finance which makes the project or projects feasible. The feasible project(s) can then be far away from being first-best. But as long as the project(s) have positive net social value, their implementation will be welfare-enhancing. A further set of problems and issues are then raised for such projects, namely, how to maximally increase their efficiency given that they are implemented. It will go too far to delve seriously into this issue here. We will for further analysis refer to the “mechanism design” literature where this topic is central; see, e.g., Fudenberg and Tirole (1991); Myerson (2008).

3.5 Uncertainty when climate finance relaxes credit market constraints

Uncertainties about returns from these investments, and about carbon market benefits and implementation costs, raise the overall risk level for investors, and are likely to act as additional barriers to credit and finance market access for renewable energy capacity investments. Energy production, the energy price, Q , and the carbon price, T , are all likely to be uncertain.

When a carbon tax is set at a stable level or predictable path over time, the uncertainty about T will be reduced to investors and could serve as a stabilizing factor in the credit market. With c-a-t schemes, uncertainty about T is likely to be greater and might serve to increase uncertainty for lenders, and reduce the amount of supplied credit.

Uncertainty for creditors can be reduced further if the carbon tax policy is made to vary counter-cyclically with other uncertain variables that affect project returns. One example would be to make the carbon tax negatively correlated with fluctuating cost variables in electricity production. This

may however have downsides, in particular when the electricity price is positively correlated with aggregate demand. This issue requires further analysis in future work.

4. Conclusions and final comments

This paper has discussed analytical aspects of “finance blending” where “climate finance” is added as a finance or subsidy element to international carbon markets where “offsets” are traded by individual buyers and sellers. The main conclusions are as follows.

1. Under “blended finance”, whereby climate finance is injected into the carbon market, attributing all GHG emissions reductions to the carbon market (“all to the carbon market”) implies a distorting subsidy to project hosts in the carbon market, which reduces the carbon price for parties demanding offsets (from H countries), and increases this price for project hosts who sell offsets (from L countries). Mitigation is then distorted and shifted in a non-wanted way from H-country to L-country market participants. Overall, global, mitigation does not change as long as the ambition of both country blocs does not change.
2. Blended finance with proportional attribution to climate finance and the carbon market supplies leads to efficiency in the carbon market as all market participants are then facing the same carbon price per attributed offset unit. But the addition of climate finance does not in itself increase global mitigation. For global mitigation to increase, the mitigation ambition of H countries must increase, preferably in proportion to the finance supplied by climate finance.
3. Climate finance can have constructive additional roles for the carbon market when used to counteract credit and other capital market constraints facing L countries. Such finance may then facilitate the implementation of mitigation projects in L countries that otherwise would materialize at too small scales, or not at all.
4. Climate finance to low-income countries, and finance supplied through carbon market transactions to the same countries, both have advantages and disadvantages. Climate finance can be provided in a less constrained fashion, and give donors higher flexibility to conduct their own domestic climate policy separate from any climate support policy to L countries. On the other hand, global carbon markets may provide a greater incentive and assurance that lower-income countries will be integrated in climate-related market

mechanisms; and might often do more than other policy alternatives to ensure a robust carbon price in these economies.

We have said little about whether international finance support to low-income countries, with a climate policy aim, should be provided through carbon markets (with or without blending of financing sources), or through contributions separate from carbon markets.

Carbon markets have to date had limited reach and application. Their main applications have been the EU-ETS and CDM under the KP. On the host side, only a few major L (or emerging) countries have so far had noticeable benefits from such markets; and even in these countries, carbon markets have played relatively small roles (even for China, which has had a dominating role in the CDM, this role has been small compared to total Chinese emissions). Two sets of problems contribute to this. The first is that in most L countries it has been difficult to reach potential project hosts and connect them with potential market buyers. The second is that many offset projects have been adversely affected by a range of problems affecting the quality of the assets supplied to the market: missing additionality; leakage; manipulated country baselines; and moral hazard and adverse selection, in project selection and implementation. These problems have made implementation of offsets projects, with “true” and verified global mitigation benefits, difficult and expensive, as it has been very difficult to ensure that genuinely additional offsets are delivered. It has led to high costs for project implementers in verifying that the respective problems are (likely to be) overcome; often they have not.

So far carbon market transactions have been fully project-based and not in programmatic form. Could this situation change under PA, and as a result of finance blending? Arguably, some of the problems encountered by offset markets under the KP could be smaller under the PA, as certain informational and technical problems (additionality, baseline endogeneity, and leakage) are likely to be reduced as host countries may view their NDC targets as a new disciplinary force, not existing under the KP. But more important would probably be the application of carbon market trading to the outcome of programs for GHG reductions in L countries, to support the implementation of comprehensive carbon pricing (or tax) solutions, or other policy solutions that go beyond individual mitigation projects. A more robust carbon pricing regime, implemented in or supported by the carbon market, could then catalyze a large mitigation and climate finance activity both within and outside the carbon market. This market could attract supplementary finance for

“blending”, as considered in sub-sections 3.2-3.4, and become the focus for more, perhaps most, of the mitigation activity in lower-income countries. The World Bank’s Transformative Carbon Asset Facility (TCAF) has been set up for such purposes; the future will show what impact this will have on the nature of offset transactions under the PA.

Regardless of this, however, problems will remain for the future of carbon markets.

First, under uncertainty about demand for mitigation quotas, offset markets tend to exhibit (perhaps severe) fluctuations in equilibrium carbon prices, as pointed out in section 3.2 above: an unwanted feature for market participants. Such fluctuations can, in principle, be partly countered by countervailing shifts in the climate finance supply to the carbon market, and by careful banking and other long-term management issues for the markets. Good such management would require mobilizing additional climate finance in global downturn situations, which may be difficult.

Secondly, global carbon markets may, at least gradually over time, lead to carbon prices at similar levels throughout the world economy. This is positive in several respects, but could still have some negative implications, at least when the carbon price in this market remains (substantially) below the “global cost of carbon”. Tying global carbon prices “too much” to the carbon market could make it more difficult to realize certain globally favorable solutions: there may be willingness to increase the carbon price in some markets and regions, which can be held back by a carbon market with a global reach.

Thirdly, while project-based offset markets could provide substantial transfers from H to L countries, these transfers are subject to constraints. First, they cannot be expected to raise revenues close to those raised through global carbon taxation.¹⁵ Secondly, this revenue will go to private parties in L countries, often not those parties which need such funds the most; and nothing will be available as free revenue for governments. “Finance blending” through the offset market could worsen this problem by further diverting valuable public donor country funds away from more important uses.

¹⁵ Considering a “correct” global carbon tax of \$40/ton CO₂; a conservative estimate considering Stiglitz and Stern’s (2017) optimal range \$40-\$80; and a global GHG emissions rate of 40 billion tons CO₂ equivalents, this would correspond to a global annual GHG emissions tax revenue of \$1.6 trillion; perhaps an order of magnitude higher than a realistic transaction level for a global carbon market.

Finally, offset markets which contain a host side selling offsets tied to individual private projects are still likely to face problems experienced with the CDM (and EU-ETS) under the KP. One then has less reason to be optimistic about both overall future participation in offset schemes, and the quality problems such schemes may be facing.

Climate finance instruments (which may include the use of carbon tax instruments) face fewer of these problems due to their greater flexibility, and by being less subject to informational problems. Thus, when programmatic carbon market solutions are infeasible or problematic, free-standing climate finance may be a better option.

Can the problems with carbon and offset markets pointed out here, be relieved or overcome by “blending” climate finance and carbon market payments? Our answer to this question is generally negative. We still however find that blending has potential positive aspects. In certain cases, blending can improve the functioning of carbon markets, perhaps most when project hosts face credit and capital market imperfections. Also, climate finance additions to the carbon market can lead to greater global GHG mitigation (given proportional attribution, and given that donor countries’ mitigation ambitions increase in proportion to the additional finance supplied). But it is less clear whether this leads to improvements relative to alternative mechanisms for the use of climate finance as free-standing finance instruments.

Finally, this analysis has been based on several simplifying assumptions, some of which may need to be altered in future work. We will mention these:

- A) H and L economies are both treated as unitary entities with no separation between sub-sectors. An obvious extension would be to separate the sheltered and exposed sectors, possibly with carbon tax solutions in the sheltered sectors, and carbon market solutions in the exposed sectors.
- B) All sectors and market participants are assumed to be competitive and profit or utility maximizers; there is a unitary carbon price, set exogenously (and not subject to bargaining).
- C) There are no serious “political economy” issues or problems related to implementing the solutions (no protests against private carbon tax payments; complete quota payments).
- D) All possible and viable carbon market projects are offered and contracted.
- E) There is no double-counting of emission rights.

- F) There are no imperfections in carbon markets; in particular, no problems related to missing additionality, baseline manipulation, or leakage.
- G) L countries set their unconditional NDC targets more ambitiously than their BAU emissions; there is no “hot air”. Targets are not set strategically.
- H) All entities are non-corrupt, honest, and all pay their required carbon charges.
- I) We only analyze project finance, and not program finance.

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