Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Journal of Policy Modeling 28 (2006) 981–994
Journal of Policy Modeling
www.elsevier.com/locate/jpm

The contribution of the clean development mechanism to national climate policies

Thierry Bréchet [a,*], Benoît Lussis [b,1]

[a] *CORE and IAG, Chair Lhoist Berghmans in Environmental Economics and Management, Université catholique de Louvain, 34 voie du Roman Pays, B-1348 Louvain-la-Neuve, Belgium*
[b] *Institute for a Sustainable Development, 7 rue des Fusillés, B-1340 Ottignies, Belgium*

Received 1 March 2005; received in revised form 1 September 2005; accepted 1 January 2006

Abstract

The clean development mechanism (CDM), one of the flexible mechanisms of the Kyoto Protocol, has not received noticeable attention in the applied modeling literature. In this paper we develop a policy-oriented trading model explicitly including the key features likely to influence the supply and demand of CDM projects. This model allows us to evaluate the contribution of the CDM to climate policies at the national level. With an application to Belgium we show that the CDM could reduce the cost of the Kyoto Protocol by a factor 10. Policy analyses reveal that some features (e.g. the market share) have much more influence on this result than others (notably the transaction costs). Moreover, equilibrium effects can sometimes exceed direct effects so that, all in all, a larger domestic abatement could be justified by the desire to reduce what we call carbon dependence. Policy implications and perspectives for the CDM are discussed.

JEL classification: Q28; Q48; Q25; Q43

Keywords: Clean development mechanism; Carbon market modeling; Emission trading

1. Introduction

The Kyoto Protocol allows industrialized countries (referred to as Annex 1 countries) to finance investment projects for greenhouse gases emission abatement in developing countries so as to

* Corresponding author. Tel.: +32 10 47 43 40/81 86; fax: +32 10 47 43 41.
E-mail addresses: brechet@core.ucl.ac.be (T. Bréchet), idd.mdp@skynet.be (B. Lussis).
[1] Tel.: +32 10 47 73 41.

0161-8938/$ – see front matter © 2006 Society for Policy Modeling. Published by Elsevier Inc. All rights reserved.
doi:10.1016/j.jpolmod.2006.01.006

generate credits which can be used to meet their own commitment. This instrument is known as the Clean Development Mechanism (hereafter, CDM) and is expected to raise a twin benefit. On the one hand, the industrialized countries abate carbon emissions at a lower marginal cost than domestically and, on the other hand, developing countries have the opportunity of accelerate technological transfers and to benefit from positive spin-offs in terms of development. In the literature, the CDM is always analyzed within the global carbon market and rarely as an instrument for climate policies in industrialized countries (see Zhang, 2004 in this journal). The objective of this article is to evaluate the potential contribution of this instrument at the national level, with a numerical application to Belgium. This evaluation raises specific modeling questions so as to provide insights for climate policy.

In contrast with emission trading, the CDM has not received noticeable attention from the economists' community, particularly in applied modeling in support for decision-making. Early theoretical discussions were provided by Bollen, Gielen, and Timmer, (1999) but the institutional context has considerably evolved since then, in particular after the Conference of the Parties held in Marrakech in 2001 where guidelines were edicted.[2] In this context Jotzo and Michaelowa (2002) provide an analysis of the carbon market and discuss the contribution of the CDM at the global level. A more recent contribution is the one by Pan (2005), who focuses on the implications of such sector-limited projects on efficiency with a computable general equilibrium world model GEM-E3, or the one by Kallbekken and Westskog (2005) who explore some carbon market outcomes but model the CDM as equivalent to emission trading. Böhringer, Conrad, and Loschel (2003) consider CDM projects in the power sector between Germany and India by coupling a national German CGE model with an Indian Markal model for determining the supply of CDM projects within this sector. In the meantime, reduced-form partial equilibrium models originating from Ellerman and Decaux (1998) were developed. These trading models, based on marginal abatement cost curves, calculate least-cost abatement strategies. Even though our model is close, for example, to the CERT model used by Sager (2003), which is included in the Stanford Energy Modeling Forum, it departs from all the existing tools in that it provides an in-depth description of the institutional features of the CDM at the international and national levels. To date, the literature has neglected two of the keystones of the CDM: (i) it is a project-based instrument, (ii) it involves bi-lateral carbon credits exchange between a single couple of buyer and seller partners. This article tackles these two key issues within a simple and transparent modeling framework and highlights policy implications of the CDM for Belgium.[3]

The paper is organized as follows. The next section provides an overview of the institutional dimensions of the CDM, its design and implementation under the Climate Convention. Section 3 briefly describes our modeling framework and a reference scenario for the carbon market is presented is Section 4. The potential contribution of the CDM to the Annex I and Belgian climate policies is discussed in Section 5 with adequate policy scenarios and the implications for policy are drawn in Section 6. The last section concludes.

[2] A set of projects is now to be submitted to the Convention for accreditation. The list of the projects approved is continuously updated on the UNFCCC website or on http://www.cdmwatch.org.

[3] This papers focuses on policy discussions and voluntarily minimizes technical issues: a detailed description of the model is available in Bréchet and Lussis (2005).

2. The clean development mechanism: design and implementation

2.1. The procedure for accreditation

The advantage of the CDM for industrialized countries is having access to low-cost emission reductions. Nonetheless, the Kyoto Protocol states that CDM projects must contribute to the sustainable development of their host countries. This twin objective was explicitly confirmed in article 12 of the Protocol that introduced the concept of the CDM (UNFCCC, 1997).

The contribution to sustainable development is assessed by the host countries. These indeed have the right to determine whether a project contributes or not to their sustainable development prior to the implementation of the project. However, despite the efforts of the developing countries and the scientific community there is not yet a common accepted methodology to assess the projects' impacts on sustainable development. On this issue see e.g. Winkler and Thorne (2002), Heuberger, Sutter, and Imboden (2003) or Gold Standard (2004).

A CDM project must also comply with other requirements set by the UNFCCC in the Marrakech Accords (UNFCCC, 2001), which are verified by an Executive Board composed of representatives of countries that ratified the Kyoto Protocol. Beyond the quantity of GHG reduction, these requirements deal with the voluntary participation of the involved countries, the project's environmental impacts and the stakeholders' participation, among others issues. The question of GHG emission reduction, known as the additionality issue (see below), is probably the most controversial and the most difficult condition to demonstrate for a project developer. In order to comply with the UNFCCC requirements a CDM project will have to follow several steps before generating any credits (UNFCCC, 2001) that are sources of additional costs (transaction costs) which may be rather significant regarding to the credit value obtained.

It is worth noting that, with the notable exception of nuclear power, no technology or type of project can be excluded a priori. Hence, afforestation or reforestation projects, which allow for carbon storage in plants, are also eligible for the first commitment period, even if they are subject to special procedures and incur only temporary credits.

The Marrakech Accords made way for different CDM structures. A project can be financed by a partner from an industrialized country, by a funding that gathers financial contributions from different partners from industrial countries or by a single partner from a developing country. These three structures have different impacts on transaction costs, profits gained by developing countries and technology transfer (see Baumert & Kete, 2000; Jahn, Michaelowa, Raubenheimer, & Litow, 2003).

A CDM project has a life-cycle, called *crediting period*, of 10 years (non-renewable) or 7 years (renewable twice). This period, which cannot be shortened, was introduced in order to allow host countries to benefit from spin-offs of projects for a relatively long time-scale (i.e. beyond the 5-year period of the first Kyoto commitment period). In addition, CDM projects are allowed to generate credits from 1st January 2000. This specification has been set in order to promote a prompt start of the CDM and is referred to as the *early crediting* issue in the literature.

2.2. The measurement of GHG emission abatement

The issue of assessing emission reductions is not only crucial for the environmental integrity of the instrument, but also controversial from a methodological viewpoint within Framework Convention institutions and the scientific community. This problem is known under the name of *additionality*. The credits resulting from a CDM project are calculated according to the difference between the emissions which would have occurred without the project (the business-as-usual scenario, or baseline) and the emissions observed in the project's actual conditions. The measurement of the baseline in this calculation constitutes the main source of uncertainty since, by definition, these emissions will never take place. It has been decided that baselines and emission reductions are to be calculated for each project with methodologies suitable for a kind of projects and approved by the UNFCCC. These methodologies have to produce the means to determine whether the project would have been carried out without the CDM. If this is the case, the project will be ineligible. A project does not constitute a BAU scenario if there is at least one barrier to its implementation and if this barrier can be overcome because of the CDM nature of the project. Different kinds of barriers can prevent the implementation of the most effective technologies: financial (profitability, capital resources), technological, cultural and institutional barriers, etc (CDM Executive Board, 2004).

Ideally, all emissions affected by the project should be accounted for and integrated into the calculation of emission credits. However, listing all emissions involved in a project can be a difficult procedure because that would include emissions on the project site (technology change) but also all direct and indirect off-site emissions (the emissions of the inputs' life-cycle and effects on fuel demand, for example). In practice, the project boundary is defined as the area within which the emissions in the business-as-usual scenario and with the project are measured. Emissions outside boundaries should also be integrated into the calculation of emission credits, but their measurement may be rougher and, consequently, requires a less strict monitoring procedure (see Geres & Michaelowa, 2002; Lazarus, Kartha, & Bernow, 2001).

3. Modeling the CDM within the carbon market

Our model consists of two nested models: a world model of the carbon market and a single-nation partial equilibrium model of optimal climate strategy. Modeling the world market allows us to determine the equilibrium price for carbon whereas the single nation market model sets the optimal strategy for a given country in terms of domestic abatement, purchase of permits, funding of Joint Implementation projects in other industrialized countries and funding CDM projects in developing countries.[4]

3.1. The technology and abatement costs

We consider macroeconomic carbon abatement costs for any country $i \in I$, the set I standing for the set of the world economies. Let first consider the business-as-usual (BAU) scenario and describe the economy i in the reference year (say in 2010). The expected carbon emissions level is e_i^{BAU} be (in tonnes) and pollution abatement, noted a_i is the difference between actual emissions and the BAU emissions level, $a_i = e_i^{\text{BAU}} - e_i$. Let $c_i(a_i)$ be the abatement cost function of country i. This function satisfies the usual properties (twice continuously differentiable, strictly increasing and strictly convex[5]). Each country is committed with an emission target e_i^{KYOTO} corresponding to its assigned amount of emission credits (called assigned amount units). Those emission credits can be exchanged on the world carbon market, whether they result from the funding of CDM or Joint

[4] The model is available online at: http://www.iddweb.be.

[5] Futhermore, there is no free lunch ($c_i(0) = 0$) and it is infinitely costly to abate the last unit of emissions ($\lim_{a_i \to e_i^{\text{BAU}}} c_i'(a_i) = +\infty$).

Implementation projects, the selling of tradable permits or domestic abatement.[6] For developing countries this target coincides with the BAU emissions level since they are not committed to emission abatement under the Kyoto protocol. Hence, while committed to the Kyoto protocol the GDP of country i in 2010 is given by its GDP level in the BAU scenario less the abatement cost and the purchase (or the selling) of permits valued at the market price. It is assumed that each country maximizes its GDP level choosing the optimal abatement level, given its assigned amount of emission credits. Under perfect competition[7] the first-order condition for this maximization problem is that emissions abatement be such that the marginal abatement cost be equal to the market price for credits, or $c_i'(a_i) = p$. The inverse of this optimality condition allows us to define the net demand function for carbon credits of country i as a function of the carbon price p. Considering the value of e_i^{KYOTO} and e_i^{BAU} as given the net demand for carbon credits may be either positive, negative or nul, depending on p. Under the Kyoto protocol the world is split into two sets of countries: Annex 1 countries (A1) and developing countries, referred to as non-Annex 1 countries (NA1).[8] The supply of CDM projects comes from *NA1* countries and is given by the inverse net demand function as defined above, where $e_i^{\mathrm{KYOTO}} - e_i^{\mathrm{BAU}} + a_i$ is always positive since $e_i^{\mathrm{KYOTO}} = e_i^{\mathrm{BAU}}$ for this set of countries.

3.2. The key features of the clean development mechanism

The project-based nature of the CDM results in three key features. First, the presence of transaction costs constitutes a major issue for which Michaelowa and Jotzo (2005) provide an in-depth analysis. Transactions costs may result from many reasons, starting from the project research and design to registration, certification and monitoring with the Executive Board. These costs have long been considered as strongly reducing the attractiveness of CDM projects and it is of particular interest to quantitatively check this issue. Secondly, it is widely acknowledged that all the projects that could theoretically be accepted as CDM projects by the Executive Board could not be implemented practically. Reasons range from failures in local infrastructures or local administrations to risk analysis. Introducing an accessibility rate on the projects supplied by developing countries shrinks the amount supplied for a given carbon price. Thirdly, the so-called early crediting opportunity is introduced as the ratio between the actual length of crediting period of the projects and the length of the Kyoto first commitment period (5 years). Hence, taking into account the early crediting increases the supply of carbon reductions through CDM projects. The demand for CDM projects comes from Annex 1 countries, considering the existence of carbon sinks. As it is now established from the literature we acknowledge the fact that sinks have negligible marginal costs.

The nation-based model determines the optimal cost-minimization strategy for a given Annex 1 country operating as price taker on the carbon market. In this paper, Belgium is to be considered. The Belgian abatement cost curve represents its own demand for foreign abatement, i.e. the net purchase of permits and Joint Implementation projects to other Annex 1 countries and the funding of CDM projects. The former is naturally given by the international carbon price set across Annex 1 countries under their Kyoto commitment while the latter requires defining the supply of CDM

[6] In the UNFCCC literature, this is referred to as the fungibility assumption.

[7] We assume that there exists no quantitative constraint on trading volumes, which will be the case under the Kyoto protocol in most countries. The market power of Russia on this market will be considered later on in the article.

[8] Note that $\mathrm{A1} \cap \mathrm{NA1} = \emptyset$ and $\mathrm{A1} \cup \mathrm{NA1} = 1$.

projects addressed to Belgium. We consider here that the global CDM market is exogenously shared among all the Annex 1 countries.

3.3. Market equilibrium

Given the properties of the cost functions $c_i(\cdot)$ the supply and demand functions are well-behaved, continuous, increasing and concave. For every country, and for a given positive carbon price we define the excess supply for carbon credits as a function of this price. A country or set of countries is a net seller (resp. a net buyer) of credits when this function is strictly positive (resp. strictly negative) for a given price. The equilibrium is defined as the market price p^* such that the market clears, i.e. such that the sum of the excess supplies equals zero. Given the properties of the abatement cost functions this equilibrium exists and is unique.

3.4. Calibration and assumptions

We first build a reference scenario for the carbon market in 2010. This scenario is based on three sets of assumptions: (i) the calibration of the marginal abatement cost functions, (ii) the worldwide and Belgian business-as-usual profile for carbon emissions and (iii) an institutional scenario for the first Kyoto commitment period. The first set is technical in its nature and will not be discussed with much detail. We will rather focus on the two others as they raise many policy issues.

Our model uses marginal abatement cost functions which represent the macroeconomic marginal cost of abatement in any country or group of countries for the year 2010. These functions are calibrated on data coming from the computable general equilibrium GEM-E3 model (see Eyckmans, Van Regemorter, & van Steenberghe, 2002) and following the methodology originated by Ellerman and Decaux (1998). Technical details and a discussion on the limitations of this approach are considered in Bréchet and Lussis (2005).

The business-as-usual scenario consists in the time profile of carbon emissions over the period between the last available data and the middle of the first Kyoto commitment period, 2010. It is based on the BAU scenario of the GEM-E3 model and the World Energy Outlook of the International Energy Agency. For Belgium we considered the latest medium term forecast provided by the Federal Planning Bureau (Bossier, Bracke, & Vanhorebeek, 2004).

The institutional scenario consists in assigning values to the parameters defined above. First, let consider transaction costs. Michaelowa and Jotzo (2005) compare several kinds of CDM projects. They suggest a benchmark transaction cost of 0.75\$/tCO_2. Considering the 'hot air', two intrinsically related questions arise: what will be the Russia's strategy and what amount of 'hot air' will be supplied on the carbon market? We assume that Russia will act as a rational monopsoner and supply the carbon quantity which maximizes its return (74.6% of the available hot air would be sold on the carbon market). The accessibility rate of CDM projects is rather tricky to assess at the aggregate level and we retain the conservative value of 33% as Eyckmans et al. (2002). Sinks within the Annex 1 countries (including Belgium) would be fully exploited. The early crediting parameter is set at 9/5, which means that we assume that crediting for CDM projects will start from 2004. This value is consistent with the evidence to date, since only a few projects are to fully benefit from this rule. For the Belgian market share, we assumed that this share corresponds to the share of the Belgian abatement in the Annex 1 countries emission abatement, i.e. 0.7%. This assumption boils down to admitting that no country has a proactive strategy on the

Table 1
Optimal carbon abatement strategies in the reference scenario

	Annex I countries		Belgium	
	$MtCO_2$	%	$MtCO_2$	%
CDM projects	434	21.0	3.0	20.3
JI projects			9.3	62.8
Purchase of permits	547	26.5		
Domestic measures			1.2	8.1
Sinks	370	17.9	1.3	8.7
Hot air	715	34.6		
Total abatement	2067	100	14.8	100
Carbon price (US$/$tCO_2$)	6.9			

CDM market.[9] An alternative assumption would be to consider the share of Belgium in foreign direct investment in developing countries.

One must keep in mind that the results strongly depend on the methodology and the assumptions made. So, their predictive value must not be overestimated. Yet, this model can provide fruitfully policy insights and the rest of the paper will focus on them. After having presented the results of the reference scenario we shall pay a special attention to policy issues by implementing a set of sensitivity analyses.

4. The carbon market in our reference scenario

Table 1 displays the optimal mix of policy measures for Annex 1 countries and for Belgium in the international context defined previously. Under this reference scenario carbon would be priced at \$6.9 per tonne of CO_2 in 2010. The CDM would contribute to 21% of the carbon abatement in Annex 1 countries. This figure differs from the ones provided in the literature to date. The reason for this is that those studies generally neglected the empirical evidence showing that not all of the projects that may be eligible are realizable in practice, which we represent with our accessibility rate parameter. This feature affects not only the supply of CDM projects but also the equilibrium on the carbon market. Assuming that only one third of the projects are technically feasible, as we do, reconciliates our result with those of previous studies, in particular Zhang (2004) who evaluates the share of CDM projects in Annex 1 reduction at 47%. What is more important, however, is the impact of this assumption on the equilibrium price: shrinking the supply of low-cost CDM projects increases the carbon price at equilibrium. This clearly impacts on the optimal abatement strategy within industrialized countries in favour of domestic abatement.

The most salient feature is the prominent role played by tradable permits and Joint Implementation, i.e. carbon transfers within Annex 1 countries. Belgium would be a net buyer of credits and these would contribute up to 63% of the Belgian carbon abatement in 2010. The CDM would contribute up to 20%. This contribution is far from being quantitatively negligible and flows from the fact that, despite a reduced accessibility rate, many CDM projects are supplied at very low marginal prices. Indeed, the higher the price of permits, the higher this contribution. Tradable permits, JI and CDM considered jointly would represent 83% of the carbon abatement, thus showing

[9] We already know that it is far from being the case in reality and that some countries are already leaders on this market: this will be discussed in detailed later on in the paper.

Table 2
Policy analyses: parameters value

	Reference values	Rule	Alternative values
S1. Abatement effort ($MtCO_2$)	14.8	–	26
S2. Hot air ($MtCO_2$)	716	−50%	358
S3. Accessibility rate (%)	1/3	+50%	1/2
S4. Transaction cost (US$/$tCO_2$)	0.75	+50%	1.125
S5. Belgian market share (%)	0.7	+50%	1.05

the dependence of a country like Belgium to the Kyoto flexible mechanisms. The macroeconomic cost of the Kyoto commitment for Belgium would represent only 0.03% of its expected GDP in 2010, which is quite low from a macroeconomic viewpoint. Interestingly we can calculate that, without these flexible mechanisms, this cost would reach 0.3% of the GDP: even if this remains rather low, it reveals that the Kyoto flexible mechanisms allow to reduce this cost by a factor 10 in Belgium.[10]

5. Policy scenarios

The objective of this paper is to discuss the potential contribution of the CDM to national climate policies by testing and analysing key policy issues. We shall focus on a set of alternative scenarios regarded as the most meaningful from a policy viewpoint. Some scenarios will consider national policy instruments (e.g. transaction costs, market share, etc.) while others will consider parameters that are taken as exogenous at the national level (e.g. Russia's strategy, emissions profiles, etc.). The scenarios considered are the following: (1) Belgium experiences a higher business-as-usual CO_2 emissions profile, (2) Russia supplies a lower quantity of hot air, (3) the accessibility rate for CDM projects is increased, (4) the transaction costs are higher than expected and (5) Belgium adopts a proactive strategy so as to enhance its market share on the CDM market. Table 2 displays the numerical values of the parameters and the simulations results are gathered in Table 3.

5.1. Scenario 1: a higher CO_2 business-as-usual scenario for Belgium

To date, some uncertainties still exist on the time profile of carbon emissions to 2010, as for any medium term forecast. The question here is to assess the impact of these uncertainties on the expected contribution of the CDM in Belgium and on the cost of the protocol in Belgium. Let assume that the profile of emissions under the business-as-usual scenario is higher than in the reference. The alternative comes from the GEM-E3 model (Eyckmans et al., 2002) and results in a higher abatement effort in 2010, or 26 $MtCO_2$ instead of 14.8 Mt. Belgium being a small country, this does not affect the equilibrium of the world carbon market. The equilibrium price of carbon remains unchanged and so do the domestic abatement efforts in Annex I countries and in Belgium. Hence, an increase of the abatement effort in a single (small) country induces a higher purchase of permits in that country and, but to a lesser extent, more CDM projects.[11] Numerically,

[10] Although the redistributive impacts cannot be captured with our model, it is now well established that such impacts may be significant and play a crucial role from a political point of view. See Bossier and Bréchet (1995) on that point.
[11] In this simulation we assume that the budget share of Belgium in the CDM market is unchanged.

this shows that an increase of the abatement effort in Belgium by 1 $MtCO_2$ in 2010 would raise the overall compliance cost by 6 million Euros. The policy implication is that the cost of domestic economic growth in terms of Kyoto-compliance remains very limited as long as low-cost carbon credits are available on the world market. In our simulation this average cost is 6$/$tCO_2$ and the marginal one is the price of the permits (6.9$/$tCO_2$). In such a context more growth is profitable.

5.2. Scenario 2: a lower supply of hot air from Russia and Ukraine

We assume here that the amount of hot air supplied is 50% smaller than the optimal one (as considered in the reference case). The rationale behind this may be, for example, a wrong expectation about the carbon price or successful market reforms inducing more economic growth in these countries (see Golub & Strukova, 2004 for further analyses on that issue). As shown in Table 3, this unambiguously raises the world carbon price at equilibrium. Starting from $6.9 in the reference scenario, it would reach $10.6. This alters the overall picture on the carbon market and also the optimal climate policy in Belgium. The share of the CDM and domestic measures increases while the purchase of permits drops. Hence, the higher the price of the permits, the more appealing CDM projects and domestic abatement become. Considering the large contribution of the purchase of permits in Belgium, this scenario results in a significantly higher macroeconomic compliance cost. This cost is very sensitive to the price of permits since a 54% increase of the carbon price raises the macroeconomic cost by 41%. This result will be discussed below as an argument for reducing the share of permits in the Belgian climate strategy.

5.3. Scenario 3: an increase of the accessibility rate of CDM projects

The value of the accessibility rate of CDM projects is subject to many debates. Any improvement in the capacity of developing countries to host projects would have a major impact on the supply of low-cost abatement projects, upsetting the world carbon market and lowering the price of carbon. The industrialized countries themselves may contribute to that by building capacities in host countries and, in that sense, this parameter should also be considered as a policy instrument. We assume that the accessibility rate is now 50% higher than in our reference scenario. The supply

Table 3
Results of policy analyses for Belgium

	Ref.	S1	S2	S3	S4	S5
CDM projects						
$MtCO_2$	3.0	3.0	4.1	3.7	3.0	4.5
Percentage w.r.t. Ref.		+0.0	+36.7	+23.3	+0.0	+50.0
Purchase of permits						
$MtCO_2$	9.2	20.4	7.7	8.8	9.2	7.7
Percentage w.r.t. Ref.		+121.7	−16.3	−4.3	+0.0	−16.3
Total cost						
$M€_{95}$	76.7	153.5	107.9	57.5	79.3	71.0
Percentage w.r.t. Ref.		+100.1	+40.7	−25.0	+3.4	−7.4
Carbon price						
$/$tCO_2$	6.9	6.9	10.6	5.2	7.0	6.9
Percentage w.r.t. Ref.		+0.0	+53.6	−24.6	+1.4	+0.0

curve of CDM projects becomes less steep and more low-cost projects are supplied, leading to decrease of the carbon price at equilibrium from \$6.9 to \$5.2 tCO_2. The national strategies being revised, the purchase of permits drops (−4.3%), less domestic measures are implemented and the share of CDM projects sharply increases (+23.3%). All in all, the cost of compliance decreases by 25% in Belgium. What is particularly appealing here is that a substitution occurs between the CDM and the purchase of permits, depending on the decrease of the carbon price. If the decrease of the carbon price is strong enough when the accessibility rate increases, then the share of CDM projects decreases. In other words, the higher the demand elasticity for CDM projects on the carbon market, the less the developing countries would benefit from an increase of the supply of CDM projects at equilibrium. Yet, naturally, it is always beneficial for industrialized countries.

5.4. Scenario 4: an increase of transaction costs

We consider here an increase of the transaction costs by 50%. This renders the CDM less attractive and the carbon price at equilibrium increases, but only slightly: \$7.0 instead of \$6.9. This limited impact comes from the fact that CDM supply 'only' counts for 21% of the global carbon reduction in the reference equilibrium. These two effects (the shrink of supply and the slight increase of carbon price at equilibrium) result in a decrease in the share of CDM projects in Belgian abatement and a small increase in the share of tradable permits and JI projects. Similarly, due to the increase of the carbon price, the share of domestic measures also slightly increases. This scenario highlights the fact that (i) transaction costs have minor impacts on the optimal mix between abatement opportunities at the national level, and that (ii) equilibrium effects (through the adjustment of the carbon price) also contribute to the final outcome. Overall, the raise of the cost of compliance is limited to 3.4% in Belgium, showing that transaction costs are far from being that crucial as far as national strategies are concerned, although they directly affect the amount of CDM projects implemented.

5.5. Scenario 5: an increase in Belgium's market share

What would happen if a country adopts a proactive strategy in favour of CDM projects? It is obvious that some countries are more involved in this market than others and the market shares are probably different from one country to another. The policy question addressed here is to know whether a country has a strong incentive to increase its share on the CDM market. Let us assume that Belgium implement a proactive strategy so as to increase its market share on the CDM market by 50% in 2010, the market share of all other countries being reduced proportionally.[12] Since global supply and demand remain unchanged the carbon price at equilibrium remains the same. Hence, only direct effects play a role in this scenario and the contribution of the CDM is raised mechanically by 50% in Belgium at the expense of the purchase of permits, while domestic abatement remains the same. Overall, the cost of compliance is only reduced by 7%.

6. Policy discussion on the potential use of CDM

Many policy discussions emerge from the previous analyses about the potential contribution of the CDM to national climate policies in industrialised countries. This contribution will intrinsically

[12] Because the weight of Belgium in the world carbon market is marginal, the decrease of the market share of the other countries is quantitatively negligible.

depend on the financial and institutional attractiveness of this instrument, but also on the strategies followed by competitors on the CDM market, the outcome of that game being reflected by the carbon market outcome. Most of the studies undergone to date neglect the impact of national strategies (either from industrialised or developing countries) on the market equilibrium and, consequently, the way they interplay. In our framework we highlight the fact that, for some policy options, indirect impacts (i.e. through the equilibrium) may be more important than direct impacts (i.e. as considered ex ante). Relating this property with the specific institutional features of the CDM allows us to address the four following key policy issues.

Firstly, it must be recognised that the CDM was designed as a 'safety valve' for industrialised countries expected to be committed to a strong carbon constraint when the Kyoto protocol was negotiated. Our analyses show that the CDM is all the more appealing as the carbon price within industrialised countries is high, this price intrinsically depending on the profile of carbon emissions in industrialised countries with respect to the Kyoto commitment. The most recent carbon forecasts suggest that industrialized countries already engaged themselves in climate policies, thus curbing their carbon profile. Lower economic growth, moreover, increases the amount of hot air available in Russia and Ukraine. Our simulations show that the combination if these two effects lead to a sharp decrease in the carbon price at equilibrium, thus strongly reducing the attractiveness of the CDM. In other words, the window for the CDM seems to be quite narrow, at least in the short or medium terms.

Secondly, the fact that the CDM cannot be considered as a substitute for traditional official development assistance (ODA), as stated in the Marrakech Accords, raises many issues. It is clear that CDM projects interact with ODA and, if one wants to maximise the impact of these projects on human development, she has to consider that both are complementary. This issue of the potential synergy between ODA and CDM still remains to be addressed within the Climate Convention and this does question both the attractiveness of the CDM for industrialized countries (missing this complementarity rises the cost of the project) and its contribution to human development in developing countries.

Thirdly, the CDM is all the more attractive for industrialised countries as they are able to pick up the projects available at the lowest cost (i.e. infra-marginal projects). The first-mover advantage is of key importance here. The CDM is all the more interesting for industrialised countries as they are able to engage themselves in least-cost abatement projects. A waiting strategy will lead to higher marginal costs and, as soon as the market is balanced, there will exist no more opportunities with CDM (in the sense that the marginal project will cost the same price as permits). This does ruin the argument that CDM is cheap. Interestingly, funds may provide appealing solution for such problems and enhance the interest for CDM as they reduce transaction costs and share the risk among the investors.[13]

Finally, the geographical coverage of the supply of CDM projects should give raise to policy debates. As Zhang (2004) showed, the supply of CDM projects would be concentrated in a limited number of countries: 60% of the world supply would come from China, 15% from India, 6% from

[13] Many funds have been created recently, aiming at collecting contributions from corporate and governmental investors to finance CDM projects. The World Bank manages several funds (Prototype Carbon Fund, BioCarbon Fund, Community Development Carbon Fund) that have different objectives regarding to the type of projects, the contribution to sustainable development or the capacity building. Some European governments (the Netherlands, with the CERUPT funds, Denmark, Belgium, Spain and Italy, e.g.) also initiated funds in order to get CDM or JI credits for their own. All these funds account for about 25% of the credits currently claimed by Annex 1 countries for CDM projects. The average abatement cost differs from one fund to another but is generally between 3 and 5/€ tCO_2eq.

emerging Asian countries and 5% from Brazil. African countries would supply only 0.2%. This structure may influence the response of industrialized countries towards the CDM in the sense that they can already have geostrategically oriented relationships towards some of these countries. Moreover, the fact that Africa emits the least carbon gases and offers the fewest opportunities is, if not surprising, at least questionable.[14] The most appealing projects are the one that raise large amounts of carbon credits, i.e. large-scale industrial projects, while the needs for human development essentially focus on small-scale projects close to basic human needs. This really questions the very potential of the CDM as an instrument to alleviate poverty in developing countries.

7. Conclusion

In this paper we analysed the contribution of the Clean Development Mechanism to national climate policies, with an application to Belgium. For this purpose we developed a partial equilibrium model of trading of carbon explicitly including the key features susceptible to influence both the supply and demand for CDM projects. These features encompass the technical characteristics of the CDM (accessibility rate of the projects in developing countries, transaction costs, market share of Belgium in the CDM market, possibility of early crediting), the design of institutional scenarios (Russia's strategy) and assumptions on the business-as-usual profiles for carbon emissions (which imply the abatement effort for each country under the Kyoto protocol).

The main results for climate policy in industrialised countries are the following. First, under a cost minimization strategy the CDM would contribute to 20% of the carbon abatement in 2010 in Belgium. Interestingly, it can be shown that the so-called flexible mechanisms (tradable permits, CDM and joint implementation) contribute to shrink the cost of compliance by a factor 10 in this country. While many in the business community consider the CDM to be excessively bureaucratic and risk-prone,[15] our result shows that a country would largely benefit from investing in capacity building in this field.

Many policy analyses were performed. They revealed that, in Belgium, the macroeconomic cost of compliance is much more influenced by indirect effects (i.e. which originate from the modification of the carbon price in the world market) than by direct effects. This flows from the large contribution of the flexible mechanisms in the Belgian abatement strategy and the slope of supply and demand functions. It provides a rationale for the new concept of carbon dependence, inspired by the one of energy dependence widely advocated in the 80s to motivate ambitious energy policies in the industrialized economies. For a country eager to minimize the costs associated to excessive fluctuations of the world carbon price or the risks associated with supply disruptions, restricting the contribution of foreign reductions may be a suitable strategy.

We stressed out the fact that the predictive value of all these figures must not be overestimated and that the major policy insights stem from the analysis of the economic mechanisms rather than from the figures themselves. Moreover, the domain of reliability of such partial equilibrium models is restricted to small macroeconomic changes, e.g. close enough to the initial equilibrium so that the marginal abatement cost curve can be regarded as stable. Clearly this is the case for the Kyoto protocol under which the global carbon abatement remains quite limited at the global level.

[14] For an application to Senegal and South Africa, see Bréchet and Lussis (2005).

[15] This opinion is reinforced by the continued stalling of the first projects due to be registered by the Executive Committee to date (see http://www.cdmwatch.org).

More ambitious analyses would require using a full general equilibrium modeling framework. Considering explicitly the key features of the CDM, as we did, but within such a model would be of particular interest for policy design and opens the door for further research.

Acknowledgements

This research was funded by the Scientific Support Plan for a Sustainable Development Policy (SPSD II, Belgium), contract CF/F5/261. Detailed results are available in Boulanger et al. (2004). Preliminary results were presented at the Environmental Workshop at CORE. We are grateful to the editor for fruitful suggestions and we thank Paul-Marie Boulanger, Gilles Grandjean, Henry Tulkens, Philippe Tulkens, Vincent van Steenberghe and Véronique Choquette for helpful discussions. The usual disclaimer applies.

References

Baumert, K., & Kete, N. (2000). *Designing the clean development mechanism: Operational and institutional issues*. Paris: Organization for Economic Cooperation and Development.

Böhringer, C., Conrad, K., & Loschel, A. (2003). Carbon taxes and joint implementation. An applied general equilibrium analysis for Germany and India. *Environmental and Resource Economics*, *24*, 49–76.

Bollen, J., Gielen, A., & Timmer, H. (1999). Clubs, ceilings and CDM. *The Energy Journal*, Special Issue, *The costs of the Kyoto Protocol: A Multi-Model Evaluation*, 177-206.

Bossier, F., Bracke, I., & Vanhorebeek F. (2004). Projection des émissions de gaz à effet de serre à l'horizon 2010 pour la Belgique, Federal Planning Bureau, Working Paper 9-04, Brussels.

Bossier, F., & Bréchet, Th. (1995). A fiscal reform for increasing employment and mitigating CO_2 emissions in Europe. *Energy Policy*, *23*, 789–798.

Boulanger, PM, Bréchet, Th., Brismé, Ch., Germain, M., Grandjean, G., Huppen, I., & Lussis B. (2004). *Le Mécanisme pour un Développement Propre: Conception d'outils et mise en oeuvre*. Final Report to the Belgian Scientific Support Plan for a Sustainable Development Policy under SPSD II, Institute for a Sustainable Development, Ottignies (http://www.iddweb.be).

Bréchet, Th., & Lussis, B. (2005). *The contribution of the clean development mechanism to national climate policies: A modeling framework of the carbon market, Environmental Economics and Management Memorandum #28*. CORE, Université catholique de Louvain.

CDM Executive Board. (2004). Draft consolidated tool for demonstrating additionality. In *Annex to the report of the 15th Executive Board meeting*.

Chomitz, K. M. (2002). Baseline, leakage and measurement issues: How do forestry and energy projects compare? *Climate Policy*, *2*, 35–49.

Ellerman, D., Decaux, A. (1998). Analysis of post-Kyoto CO_2 emissions trading using marginal abatement curves, MIT Joint Program on the Science and Policy of Global Change, Report 40, Cambridge, MA.

Eyckmans, J., Van Regemorter, D., & van Steenberghe, V. (2002). Is Kyoto fatally flawed?, FEEM Working Paper 43.

Geres, R., & Michaelowa, A. (2002). A qualitative method to consider leakage effects from CDM and JI projects. *Energy Policy*, *30*, 461–463.

Gold Standard (2004). The Gold Standard Project Design Document: Main Document (available at http://www.cdmgoldstandard.org).

Golub, A., & Strukova, E. (2004). Russia and the GHG market. *Climatic Change*, *63*, 223–243.

Heuberger, R., Sutter, Ch., & Imboden, D. (2003). *CDM Projects under the Kyoto Protocol of the UNFCCC: A methodology for sustainable development assessment and an application in South Africa*. Institute of Environmental Physics, Energy and Climate, Swiss Federal Institute of Technology (ETH).

Jahn, M., Michaelowa, A., Raubenheimer, S., & Litow, H. (2003). *Unilateral CDM Chances and Pitfalls*. Deutsche Gesellschaft für technische Zusammenarbeit (GTZ).

Jotzo, F., & Michaelowa, A. (2002). Estimating the CDM market under the Marrakech Accords. *Climate Policy*, *82*, 1–18.

Kallbekken, S., & Westskog, H. (2005). Should developing countries take on binding commitments in a climate agreement? An assessment of gains and uncertainties. *The Energy Journal*, *26*(3), 41–60.

Laurikka, L. (2002). Absolute or relative baselines for JI/CDM projects in the energy sector? *Climate Policy*, *2*, 19–33.

Lazarus, M., Kartha, S., & Bernow, S. (April 2001). *Project baselines and boundaries for project-based GHG emission reduction trading: A report to the greenhouse gas emission trading pilot program*. Tellus Institute.

Lussis, B. (2004). Le MDP unilatéral, Working paper, Institute for a Sustainable Development, Ottignies.

Michaelowa, A., & Jotzo, F. (2005). Transaction costs, institutional rigidities and the size of the clean development mechanism. *Energy Policy*, *33*(4), 511–523.

Pan, H. (2005). The cost efficiency of Kyoto flexible mechanisms: A top-down study with the GEM-E3 world model. *Environmental Modeling & Software*, *20*(11), 1401–1411.

Sager, J. (2003). An analysis with the CERT model of the FSU market power in the carbon emissions trading market. *Environmental Modeling and Assessment*, *8*(3), 219–238.

UNFCCC (1997). The Kyoto Protocol to the Framework Convention on Climate Change.

UNFCCC. (2001). *The Marrakech Accords and the Marrakech declaration: Decision 17/7*. United Nations Framework Convention on Climate Change.

Winkler, H., Thorne, S. (2002). Baselines for suppressed demand: CDM projects contribution to poverty alleviation, SouthNorth, February.

Zhang, Z. X. (2004). Meeting the Kyoto targets: The importance of developing country participation. *Journal of Policy Modeling*, *26*, 3–19.