The Clean Development Mechanism - Welfare and Restrictions on imported Abatement

Inauguraldissertation
zur Erlangung des Grades Doctor oeconomiae publicae
(Dr. oec. publ.)
an der Ludwig-Maximilians-Universität München

vorgelegt von

Sabine Aresin

2015

Referent: Prof. Dr. Kai A. Konrad

Korreferent: Prof. Dr. Florian Englmaier

Promotionsabschlussberatung: 04. November 2015

To Mama, Papa and Maximilian.

Acknowledgments

I am truly grateful that I was given the opportunity to write this thesis at the Department of Public Economics of the Max Planck Institute for Tax Law and Public Finance.

Primarily, my first supervisor, Kai Konrad influenced this work with his ideas, helpful advice and critical comments. I am particularly grateful that he led me in the direction of my thesis topic. Moreover, I would like to thank my second supervisor, Florian Englmaier, for his constant readiness to give valuable advice, provide reassurance in times of struggle and for agreeing to co-supervise this work. I would also like to thank Karen Pittel for allowing me to consult with other environmental economists on the subject of my thesis and for her willingness to complete my thesis committee.

During the last years my work has benefited from many advantageous conversations with colleagues and guests at the Max Planck Institute. I want to express sincere gratitude to my fellow colleagues, in particular to Florian Morath: I could not have finished this thesis without his guidance and his crucial advice. Appreciation is also due to Anne-Kathrin Bronsert, Elias Brumm, Kai Brückerhoff, Thomas Daske, Nadja Dwenger, Aart Gerritsen, Athina Grigoriadou, Erik Hornung, Changxia Ke, Harald Lang, Tim Lohse, Birgit Menzemer, Philipp Meyer-Brauns, Rhea Molato, Salmai Qari, Sven Simon, Tim Stolper and Fangfang Tan for many small and some larger favors: proofreading, encouraging words, and the pleasant working environment at the Max Planck Institute. I would like to also thank May Elsayyad and Luisa Herbst for the aforementioned and beyond, for never ceasing to believe in me and encouraging me with ample pep talks - especially when I was in doubt.

Furthermore, I want to thank Maximilian for his patience, for putting up with me during the more difficult times of this endeavor and for never

hesitating to put my troubles into perspective.

Above all, I am grateful to my parents and my brother who have always generously supported me in every way - no questions asked.

Lastly, I would like to thank the Max Planck Institute for Tax Law and Public Finance and the Ludwig Maximilian University for the financial support.

Munich, June 2015.

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Introduction and Summary

Global warming became a focus of public interest in the early 1970s. Since then, the concern with this topic has constantly grown and spread from the industrialized world to emerging and developing countries. This worldwide spread is understandable, keeping in mind that Stern (2006) predicts a mean global temperature increase of 2-5°C by 2035 in the absence of counter measures. Such an increase is associated with climate change, implying weather extremes, sea level rise and desertification, which may in turn lead to crop failure and forced migration. The consequence of this will be losses in economic output and public welfare, making questions on climate change a topic for economic research. Island states and countries in the southern hemisphere, which are often emerging and developing countries, can be expected to face the majority of the disastrous consequences associated with global warming. This explains their joining in the concern.

While controversial in the past, it is now commonly agreed upon that man-made CO_2-emissions cause the global warming observed today. Acting upon this threat, the industrialized world started to engage in inter country negotiations on emission caps. In 1997, these negotiations led to the Kyoto Protocol. In the Kyoto Protocol, many industrialized countries committed themselves to emission control.[1] Others, mainly the emerging and developing countries did not agree on any commitment, but ratified the protocol.

Even though there is no commitment by emerging and developing countries, the Clean Development Mechanism (CDM) introduced in Article 12 of the Kyoto Protocol manages to include the developing world in global abatement efforts. The CDM enables public or private entities from indus-

[1] These commitments are then passed on to the firms under the jurisdiction of the respective country and constitute the firms' abatement obligations.

trialized countries to set up or invest in abatement projects in the developing world. All projects that bring about emission reductions compared to the counterfactual emission level that occurred in the absence of the CDM are admissible. The reductions associated with a CDM project are then paid out to the investing entity in the form of Certified Emission Reductions (CERs). These CERs can be sold on the market for CERs or used to offset the entities' domestic abatement obligations.

The CDM makes use of the fact that emission abatement is a global public good, i.e. the location where the abatement is realized is irrelevant. Thus, abatement can be carried out wherever it is cheapest. Typically, abatement is cheapest in emerging and developing countries either because production costs are smaller or because abatement opportunities, all ready taken on at home, are still available. Thus, entities from industrialized countries facing an abatement obligation benefit from the CDM.

Therefore, the mechanism has grown to be the largest Green House Gas (GHG) offset mechanism worldwide (Kachi et al. 2014) and is expected to have generated around 3 billion CERs by the end of 2015, since its introduction in 2001.[2]

Despite this frequent use, politicians, interest groups and scholars have raised concerns about the CDM ever since it was introduced in Article 12 of the Kyoto Protocol. The concerns mainly revolve around the environmental integrity of the mechanism. Most prominent in the discussion are the additionality and the low-hanging fruits problem.

Emission reductions generated under the CDM are supposed to be additional. Being additional means that the reductions would not have occurred in the absence of the CDM. To ensure additionality, abating firms have to state the hypothetical baseline emission that would materialize in the absence of the mechanism and to specify how and by how much their abatement project reduces these emissions. The host country's government has to agree to this and a subcontractor working for the UNFCCC's executive board has to verify the emission reduction. Then, CERs are paid out for every metric tonne of CO_2 equivalent reduced. However, despite the ver-

[2]See the CDM statistics on the web-page of the UNFCCC: http://cdm.unfccc.int/Statistics/Public/CDMinsights/index.html.

ification measures, the baseline emissions remain hypothetical. Therefore, it might well be that some of the abatement occurring under the CDM is non-additional. Non-additionality implies that the Kyoto target is diluted. This happens if CERs from non-additional projects are used to offset the domestic abatement obligation and domestic emissions can increase for every CER. Then, overall emissions increase rather than decrease (see Greiner and Michaelowa 2003).

The low-hanging fruits problem arises when CDM abatement crowds out a developing country's own abatement. When developing countries themselves want to commit to abatement obligations in the future, the only abatement options left are the expensive ones. This coincides poorly with the mechanism's goal of supporting clean development. See Rose et al. (1999) and Narain and van't Veld (2008) on the low-hanging fruits problem.

Mainly calling on the concerns mentioned above, some governments discussed and introduced restrictions on the import of CERs. These restrictions can take the form of quantitative limits for CER imports or of discounting CERs compared to domestic emission reductions.

A last note on the relevance of the CDM might be in order. Admittedly, CER prices have plummeted just like the prices for domestic emission certificates did, and there are voices that predict the CDM's fade into irrelevance. However, as long as CO_2-emissions are worryingly high and global warming constitutes a problem, an abatement need will remain. With an abatement need, there will be demand for market mechanisms and for cheap abatement opportunities. Even if this demand should be met by a new mechanism or through bilateral agreements, as is currently the case in Japan (Kachi et al. 2014), the questions I address regarding the CDM, in particular the welfare effects of cross border abatement and the implications of restricting abroad abatement with a quantity limit or an allowability rate or discount, remain relevant and would be worthwhile to consider when designing alternative options.

In the three chapters of this thesis, I formally analyze the implications of the CDM itself and of the import restrictions imposed on CERs. In Chapter 1, I start with a welfare analysis. Chapters 2 and 3 go into more

detail and consider the cause and effect of the observed import restrictions for CERs. In Chapter 2, I consider a monitoring problem as a possible economic explanation for the observed import quota. In Chapter 3, I look into the effects of a CER discount on the equilibrium allocation of domestic and abroad abatement. The following paragraphs provide a more detailed preview of the three chapters.

Chapter 1 analyzes how the CDM affects the international provision equilibrium of GHG abatement and the welfare of the industrialized and developing countries involved. In this chapter, I apply a non-cooperative Nash game in a public goods provision framework. In this framework, an industrialized and a developing country privately contribute to the global public good: emission abatement. While both, the industrialized and the developing country can contribute and are assumed to have a positive valuation for abatement, I assume that this valuation is larger for the industrialized than for the developing country.

The results from the public goods game suggest that the CDM, i.e. allowing the industrialized and the developing country to abate on the developing country's soil, increases the welfare of them both. However, whose welfare experiences the larger increase crucially depends on which of the two countries has access to the least expensive abatement opportunities in the developing country (i.e. it depends on whether or not the additionality principle is fulfilled). Not having access to the least expensive abatement opportunities in the developing country allows each country to commit to little abatement. Hence, given a choice, each country would choose to allot this access to the other country.

As mentioned above, the idea behind the CDM was not only to generate low cost abatement options for industrialized countries, but also to include the developing countries in worldwide abatement efforts and to channel investment into abatement from the industrialized to the developing world. However, the results in Chapter 1 suggest that both goals, spurring abatement efforts by developing countries and investment flows from the industrialized world into developing country abatement, might be difficult to reach at the same time. Which of the two is more likely to be realized depends, like the size of the welfare effect mentioned above, on who

has access to the least expensive abatement opportunities in the developing country: the developing country itself or the industrialized country.

In Chapters 2 and 3, I turn to the question of restricting the use of CERs and analyze the implications of such restrictions. From an economic view point, it is a priori unclear why the restrictions on CERs should be suitable measures to deal with the additionality or the low-hanging fruits problem. At first glance, they simply make the CDM that was intended to be an efficiency increasing market mechanism less efficient.

Yet there might be an economic explanation for imposing restrictions on the use of CERs. For the industrialized country's government, abroad abatement is less observable than domestic abatement. This generates a monitoring problem for the government when the CDM is used. Chapter 2 analyzes whether or not the observed discrimination of abroad abatement by means of a quota can be explained with this monitoring problem regarding abroad abatement. I use a classical monitoring framework with one government and one firm, building on Becker (1968). This classical model, I extend by a cost minimization problem subject to a minimum abatement constraint and introduce heterogeneous observability for abatement generated in different regions. Furthermore, I allow the government to introduce a quantitative limit on the use of abroad abatement certificates.

Chapter 2 finds that the government can implement the first best abatement allocation even under incomplete information regarding abroad abatement. However, it shows that, starting from a scenario without any quota, welfare increases when a strictly positive quota is introduced, shifting some abroad abatement home compared to the first best allocation. This shift reduces the efficiency of the allocation but, at the same time, increases the firm's incentive to comply, thereby reducing the monitoring cost.

Whether the government wants to shift all of the abroad abatement home or wants to allow for some abroad abatement depends on the monitoring cost, the fine, the abatement obligation and the cost of the last domestic and the first foreign unit of abatement. The smaller the monitoring cost, the larger the fine and the abatement obligation, the higher the cost for the last unit of domestic and the lower the cost for the first unit of abroad abatement, the more likely is it that the government allows abroad abatement.

The use of a quota for CERs can, evidently, be justified by the existence of a monitoring problem regarding abroad abatement. But what about a discount/an allowability reduction? The literature commonly finds that quantity and price instruments are equivalent. In this context Weitzman (1974) considers the effect of emission standards versus pollution taxes and Pizer (1997) looks into the effect of taxes on emissions versus permits for emissions. Both claim that for every quantity instrument there is a price instrument inducing the same results, unless there exists, for example, uncertainty over costs.

Likewise, in my case, for a discount/an allowability reduction, there is a corresponding reduction in the total abatement obligation such that the combined policy (allowability reduction plus reduction in abatement obligation) leads to an equivalent outcome as a given quota. However, politicians never considered decreasing the abatement obligation along with the allowability of abroad abatement. This implies that in the scenario at hand, opposing effects on the abatement allocation resulting from discount/allowability rate and quota can not be ruled out. Therefore, Chapter 3 analyzes how an allowability reduction for abroad abatement certificates affects the allocation equilibrium of domestic and abroad abatement. It further asks whether or not abroad abatement necessarily decreases following the allowability reduction and, if not, under which condition the allowability reduction might actually increase abroad abatement. Moreover, Chapter 3 studies whether or not reduced allowability of CERs can address the additionality and the low-hanging fruits problem. Chapter 3 employs a cost minimization framework with a representative firm facing a minimum abatement constraint. Comparative statics with respect to the allowability rate show that both the effect on domestic abatement and the effect on abroad abatement can be decomposed into a substitution and a quantity effect. While the substitution effect measures the change stemming from the compensated relative decrease in allowability, the quantity effect measures the change resulting from the increased need for abatement when previously used CERs are less allowable.

For domestic abatement, both substitution and quantity effects work towards an increase, such that domestic abatement increases as allowability

decreases. The effect on abroad abatement, however, is ambiguous. While the quantity effect again works towards an increase, the substitution effect points towards a decrease. Which of the two dominates the other, and therefore the direction of the overall effect, depends on the policy advantage at home weighted with domestic relative to abroad equilibrium abatement and the abatement elasticity of marginal domestic abatement costs. Chapter 3 shows that, under plausible assumptions, abroad abatement can increase following a relative decrease in the allowability of CERs. The results are robust to the introduction of a secondary market for emission certificates as long as the price is endogenous, i.e. it reacts to changes in the allowability of CERs.

As mentioned above, restrictions on CERs are commonly justified with the additionality problem and the low-hanging fruits issue. Regarding the goal of weakening the additionality problem, my results are in line with the policy maker's intention. Effective emission reductions increase with an allowability reduction and the CDM moves from pure offsetting to actual GHG abatement. However, the low-hanging fruits issue might become more severe as allowability is reduced. I find that abroad abatement does not necessarily decrease reacting to an allowability reduction, but might also increase. When crowding out is an issue, it worsens with increasing abroad abatement.

Furthermore, as foreign abatement does not necessarily decrease following an allowability reduction, my results suggest that a quota on abroad abatement, as employed in Chapter 2, is (weakly) superior to an allowability or discount rate when it comes to addressing the monitoring problem regarding abroad abatement.

Chapter 1.

Cross Border Abatement and its Welfare Effects

1.1. Introduction

In international climate policy, the Kyoto Protocol marks a milestone for the global coordination on fighting Green House Gas (GHG)-induced climate change. This chapter analyzes a special feature of the Kyoto Protocol, the Clean Development Mechanism (CDM).[3] After the European Union Emission Trading System, the CDM is the world's second largest market for emission permits, both with respect to usage and issuance of emission permits.[4] The CDM enables industrialized countries to offset Green House Gas emissions, not only at home but also in developing or emerging countries, abroad. Emission credits, which industrialized countries earn for their abatement abroad, can be counted against the countries' national emission reduction obligations. This chapter provides a detailed description of the Clean Development Mechanism and of how it works before it examines how the CDM affects the international provision equilibrium of GHG abatement and the welfare of the countries involved.

To model the strategic interaction between an industrialized and a developing country and to derive the abatement equilibrium, I use a non-cooperative Nash game in a public goods provision framework. In this

[3] This chapter is based on Aresin (2013), Max Planck Institute for Tax Law and Public Finance Working Paper No. 2013-04.

[4] See Newell et al. (2013).

analysis, environmental protection in the form of emission reduction is seen as a global public good that is privately provided by, both the industrialized and developing/emerging country. Both countries can contribute to global abatement, and both countries are assumed to value abatement positively, but the industrialized country assigns a higher value to emission reduction than does the developing country.

The results from the public good game show that both the industrialized and the developing country have greater welfare with the CDM than without it. In addition, I find that under the CDM, i.e. for cases in which the industrialized and the developing countries can each abate on the developing country's soil, the equilibrium results strongly depend on which of the two countries has access to the least expensive abatement opportunities in the developing country. Given a choice, each country would prefer for the other to have access to the least expensive abatement opportunities because this allows them to commit to low emission reductions.

The parties to the Climate Convention, which issued the Kyoto Protocol, pursue several goals. Amongst these goals is not only worldwide commitment to emission reduction, but also the flow of support from rich, industrialized countries to poor, developing ones. Both these objectives shall be supported by the Clean Development Mechanism. This chapter suggests that reaching both goals at the same time might be difficult and whether the first or the second goal is realized depends entirely on who has access to the least expensive abatement opportunities in the developing country: the developing country itself or the industrialized country.

Methodologically, this chapter is closest to the literature on the private provision of public goods. Major contributions to this literature were made by Cornes and Sandler (1985) and Bergstrom et al. (1986). Hoel (1991) applied the Cornes and Sandler model to environmental public goods. He showed that uncoordinated unilateral action taken to reduce GHG emissions can negatively affect a country's negotiating position. Further, unilateral action might even lead to more global emissions than self-interested actions by all countries.

In this chapter the equilibrium outcome of the public good game changes due to a changed institutional framework. Likewise, Konrad (1994), Buch-

holz and Konrad (1994), Buchholz and Konrad (1995), Ihori (1996) and Morath (2010) consider institutional change and analyze its implications. Konrad (1994) introduces a period previous to the public good game, in which players can determine which fraction of their endowment shall be disposable income in the public goods game. He finds that this generates an incentive to strongly reduce disposable income and free-ride on richer individuals' contributions in the public good game.

In Buchholz and Konrad (1994), players simultaneously choose their production technologies prior to a simultaneous emission reduction game. Players have the incentive to choose a production technology that leads to high opportunity costs for abatement and therefore makes free-riding, in the second stage of the game, credible. Buchholz and Konrad (1995) and Ihori (1996) look at two-country models, in which the two players have different contribution productivities and therefore different contribution costs. Previous to the public good provision game, players can simultaneously choose to make an income transfer to the other player. Both papers find that the less productive agent has an incentive to transfer income to the more productive one, committing itself to low contributions in the public good provision game.

In Morath (2010) the players do not know the value of emission reduction. They can, however, publicly acquire information on the abatement value previous to a public good game of abatement. Morath finds that players can have an incentive to abstain from information acquisition. The reason being that information acquisition, which positively affects own contributions, can in return decrease other countries' contributions if the own benefits from abatement are publicly learned to be large. This strategic information acquisition can have a negative effect on GHG abatement and efficiency.

All authors mentioned above deal with voluntary public good provision and most of them look at an environmental public good. They do, however, only consider domestic abatement and do not address public good contributions that a player carries out abroad, which is the case for the Clean Development Mechanism. In this chapter, in contrast, I abstract from the strategic interaction that occurs between countries that contribute to the global public good, emission reduction, by abating domestically and fo-

cus on the strategic interaction that occurs when a country abates abroad (i.e. when a country contributes to the public good, emission reduction, by abating in another country).

As I do in this chapter, Bréchet et al. (2012) analyze the Clean Development Mechanism, though not in a public good game. They use a bargaining model to study the implications of the CDM on global emissions. Firms from an industrialized and a developing country join together for a CDM project. They bargain over each other's optimal investment level in clean technology, their carbon emission level and their respective shares of emission credits which they receive from the CDM project. The authors find that, when the firm from the developing country has a positive bargaining power, the CDM leads to an emission increase. Furthermore, the authors examine the effect of adding a new country that does not commit to any abatement target to the Kyoto Protocol. They find that global emission reductions only occur if this new developing country has no bargaining power. In contrast to Bréchet et al. (2012), my focus is not on the interaction of firms that jointly engage in an abatement project nor on the effect the CDM has on global emissions. I concentrate on both the strategic interaction between two GHG abating countries when, under the CDM, firms of the industrialized country can engage in abatement projects in the developing country, and on the welfare implications of this strategic interaction.

Other literature on the CDM deals predominantly with optimizing the Clean Development Mechanism. A recurring concern is to preserve the environmental integrity of the mechanism. The authors of the Kyoto Protocol intended for CDM projects to be additional to low-cost abatement projects, which are cost-efficient on their own and do not require the payment of emission credits, in the form of Certified Emission Reductions (CERs), to become economical.[5]Many authors claim that this additionality is not warranted for a large proportion of CDM projects. Extra emission credits, which are paid out for abatement that is not truly additional but

[5]The literature distinguishes between additionality of emissions and financial additionality. The first measures whether or not emissions will be reduced compared to the counterfactual, the latter whether or not the CDM project would occur if not for the profits from CER sales. Both should be fulfilled to secure the integrity of the mechanism, see Paulsson (2009).

would have also occurred in the absence of the CDM, might be created as the host countries do not have an emission restriction. Therefore, the CDM might lead to an increase in Green House Gas emissions instead of an emission reduction due to the mechanism. Intending to provide a solution to this problem, a number of authors assess new ways to measure the counterfactual to which the abatement under the CDM shall add (Paulsson 2009). With this chapter, I do not attempt to solve the additionality problem, but take the fact that not all CDM projects are additional as given and focus on how additional versus non-additional CDM abatement affects the strategic interaction between industrialized and developing countries. The aspect of additionality enters my framework via the question of who has access to the least expensive abatement opportunities in the developing country: the developing country itself (additional) or the industrialized country (non-additional).

The following section provides a broad illustration of the Clean Development Mechanism. Section 3 deals with the formal analysis of the CDM. It starts with a benchmark case and then considers two cases with the CDM under different cost regimes. Section 4 compares the model results in the different cases under normative aspects. Section 5 concludes the chapter.

1.2. The Institution CDM

The description of the Clean Development Mechanism can be found in Article 12 of the Kyoto Protocol.[6] This article makes clear that the CDM is intended to allow industrialized (Annex I) countries to reach their abatement obligations at the lowest possible cost, and developing or emerging (Non-Annex I) countries to profit from foreign investment and technology spill-overs. Annex I countries to the United Nations Framework Convention on Climate Change from 1992 (UNFCCC) are for the most part developed countries and to a lesser extent additional countries who likewise committed themselves to reducing their GHG emissions.[7] When the Annex I coun-

[6] Article 12 is provided in Appendix A.

[7] Annex I countries are all OECD countries in the year 2013 less Chile, Israel, Korea and Mexico and plus Belarus, Bulgaria, Croatia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Russian Federation and Ukraine.

tries committed themselves to emission reductions in 1992, their intention was to return to 1990-emission levels by the year 2000 (UNFCCC 1992). The UNFCCC stipulates no emission reductions for Non-Annex I countries. These countries are all the countries which have ratified the Kyoto Protocol but have not agreed to a GHG emission reduction target (see Appendix A, "Modalities and Procedures for a Clean Development Mechanism".).[8]

With the CDM, Annex I countries, self-committed to a GHG emission cap, can take on abatement projects in Non-Annex I countries whose emissions are unbounded. Public or private entities from an Annex I country can initiate and/or invest in GHG abatement projects abroad. For each metric tonne of CO_2 equivalent induced by the investments, the investing entity gains one so called Certified Emission Reduction (CER).[9] These CERs are emission rights which the investor can sell or use to count against its own commitment (Paulsson 2009).

Ordinary production plants as well as hydro power stations or photovoltaic parks can qualify as CDM projects. Generally, any project is admissible as long as it generates an emission reduction compared to the respective business-as-usual scenario. The counterfactual business-as-usual scenario is what would happen in the absence of the CDM, either due to actions taken by entities from the developing country itself, actions taken by foreign investors or actions taken by both of the above working together.[10] These three are also the constellations in which CDM projects can be carried out.

In a business-as-usual scenario, an ordinary production plant could make use of antiquated and high-emission technology. In case of hydro power or photovoltaic stations, the business-as-usual scenario could be electricity generation by way of a coal power station. The counterfactual emissions

[8] Non-Annex I countries are predominantly developing and emerging countries. For a detailed list, see the web page of the United Nations Framework Convention on Climate Change.

[9] See Appendix A, "Modalities and Procedures for a Clean Development Mechanism". Relevant passages are highlighted

[10] The entity which proposes the CDM project - either a developing or an industrialized country entity - has to state the amount of counterfactual GHG emissions and an explanation of how it calculated this number in the Project Design Document. This document is then reviewed by a Designated Operational Entity, for example a German TÜV, and submitted to the CDM executive board that is in charge of overseeing the CDM.

in the business-as-usual scenario mark the baseline to which emissions of CDM projects are compared. The units mitigated compared to the baseline give the number of Certified Emission Reductions which are granted to the parties involved in the project (Greiner and Michaelowa 2003).

For illustration purposes, the CDM shall be explained by a real life example. The German RWE AG, one of Europe's largest electric utilities companies, frequently uses the CDM to abate in China. One of its abatement projects is the "Coke Dry Quenching Waste Heat Recovery for Power Generation" project in the Chinese city of Laiwu. In May 2004 a Chinese firm, Laiwu Iron & Steel Group Corp., decided to build a power generation plant with turbines that run on steam, heated by hot inert gas.[11] However, the internal rate of return for the project was viewed as too low, so Laiwu Iron & Steel decided to register their undertaking as a CDM project. At first, the Chinese company had to find an Annex I entity willing to abate in China, which would invest in the project and receive the CERs the project generated in return. They found RWE AG. To participate in the CDM project, both companies had to get authorization from their respective government bodies: the German Federal Environmental Agency's Emission Trading Authority in Germany and, in China, the National Development and Reform Commission of the Peoples Republic of China. With the application, Laiwu Iron & Steel submitted a comprehensive Project Design Document explaining the planned activity and stating a detailed operating plan and the expected emission reduction compared to the business-as-usual scenario. The document describes in great detail how the business-as-usual scenario comes about and why the emission reduction by the project is truly additional to the counterfactual one. The CDM executive board is the UNFCCC's entity in charge of all CDM projects. For monitoring purposes, however, the executive board hires private contractors: the so called Designated Operational Entities. One Designated Operational Entity revises the project, based on its Project Design Document, and recommends the approval to the CDM executive board. This was TÜV NORD CERT GmbH in the example. A different Designated Operational Entity oversees

[11] The hot inert gas is a byproduct of the coke dry quenching. Cold inert gas enters the dry quenching oven but is not consumed. The hot inert gas then exits the oven, heats a boiler for the steam production, cools down and again enters the dry quenching oven.

the project, visits the project site and validates the actual emission reductions. In the example, this Designated Operational Entity was TÜV SÜD Industrie Service GmbH. Therefore, TÜV SÜD is also the entity which certifies the emission reductions that are generated. The project is expected to generate emission reductions of 326.309 metric tons of carbon dioxide equivalent per annum (CDM Project no. 1656: Coke Dry Quenching Waste Heat Recovery for Power Generation Project of Laiwu Iron & Steel Group Corp.).

The majority of CDM projects are similar to this example. An entity from a developing country wants to carry out a CDM project and finds itself an industrialized partner that invests money and receives Certified Emission Reductions. However, other projects exist in which the industrialized partner invests not only money but also know-how.

The intention of the Kyoto authors was that only additional abatement, which adds to the counterfactual, should occur as CDM abatement, where Annex I countries invest and receive CERs in return. That is, only high cost abatement projects should be registered with the UNFCCC. However, empirical evidence suggests that the additionality principle is often violated and that CDM projects are often low cost projects.[12] Therefore, I will not only consider the intended case, where CDM projects are the high cost projects, but also the reversed case, where CDM projects are the low cost projects.

In the following, projects carried out by the industrialized country in the developing country are CDM projects where the industrialized country invests money and/or technology in projects abroad and receives CERs in return. Projects carried out by the developing country itself are projects that are efficient on their own, without the payment of CERs, but also lead to emission reductions. That is, the former should be high cost projects, while the latter should be low cost projects. When the industrialized country takes on low cost projects that are efficient without the payment of CERs as CDM projects and receives CERs for them, then the additionality principle is violated.

[12] See for example Haya (2009). She surveys the general use of the CDM in India and specific abatement projects in India and China and finds that the majority of the examined CDM projects are not additional.

1.3. Formal Analysis

Consider a game with two players, countries H and F. H is an industrialized (Annex I) country and F a developing (Non-Annex I) country.[13] Each of the two players, H and F, simultaneously chooses its amount of emission reduction. For simplicity, I assume that country H can abate in both H and F while country F can only abate in F.[14] Player $H's$ set of possible actions is to choose $x_{HH} \in [0, \infty)$ and $x_{HF} \in [0, \infty)$. The variable x_{HH} denotes the amount of emission reduction country H realizes at home, and x_{HF} denotes the emission reduction country H realizes in country F. Player $F's$ set of possible actions is to choose $x_{FF} \in [0, \infty)$, the amount of emission reduction country F realizes at home. This model explains all types of CDM projects mentioned in Section 2. It is applicable to projects where money is transferred from the industrialized to the developing country to finance abatement there, as well as to projects where physical labor and/or know-how is transferred from the industrialized to the developing country for abatement purposes.

Emission reductions by countries H and F are contributions to a global public good. The payoff function from these public good contributions is the welfare function of country H for player H and the welfare function of country F for player F. Player $H's$ payoff is

$$W_H = v_H \left(x_{HH} + x_{HF} + x_{FF} \right) - c_H \left(x_{HH}, x_{HF}, x_{FF} \right),$$

and player $F's$ payoff is

$$W_F = v_F \left(x_{HH} + x_{HF} + x_{FF} \right) - c_F \left(x_{HF}, x_{FF} \right).$$

The parameters v_H and v_F are player $H's$ and $F's$ respective marginal willingnesses to pay for abatement. I assume that the players' marginal

[13] Strictly speaking, firms are the ones making the abatement decisions. However, the countries determine the amount of emission allowances the firms receive and firms can trade these allowances. So, in the end, the amount of abatement is determined by the emission quotas set by the Annex I countries and the market mechanism. Here, for simplicity and as is common in the literature (see for example Hoel (1991)), I let the countries make the abatement decision.

[14] $F's$ not abating in H reproduces the Clean Development Mechanism and would also be the equilibrium outcome of a model in which F can abate in H.

willingnesses to pay for abatement are constant and that both countries H and F attribute a positive value to GHG reduction, but country H has a higher marginal willingness to pay for abatement than country F, $v_H > v_F > 0$.[15] Further, I do not model Certified Emission Reductions (CERs) explicitly, because they do not change the game. They are captured in $H's$ marginal willingness to pay for abatement, v_H. I assume complete information.

The players have to exert abatement costs for each unit of emission reduction. The higher the amount of abatement that was already carried out in a country, the higher are the abatement costs for one additional unit of abatement in that country. That is, the abatement cost function in country H must be increasing and convex in x_{HH}, and the abatement cost function in F must be increasing and convex in x_{HF} and x_{FF}. For simplicity, I assume quadratic cost functions for the two countries and that these functions are symmetric. For convex costs, one can think of a variety of abatement projects ordered by abatement efficiency. That is, when little abatement has occurred so far, the efficient projects are still available for implementation. Large amounts of GHG reduction can be carried out at low costs. The more abatement has already occurred, the smaller the efficiency of the abatement projects that are still available. That is, high costs have to be paid for little amounts of GHG reduction.

In the absence of the Clean Development Mechanism, cross border abatement does not occur. That is, $x_{HF} = 0$. I assume abatement costs in country H, then, to be a quadratic function of x_{HH} and abatement costs in country F to be a quadratic function of x_{FF}.

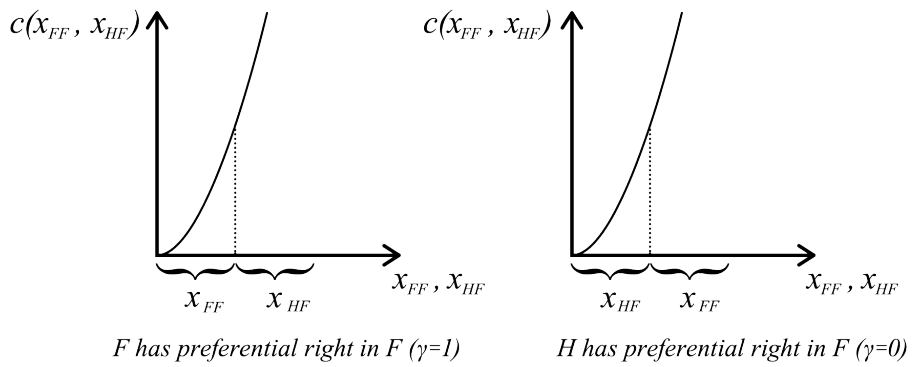
With the CDM, however, both countries can abate in F, while only H is able to abate in H. That is, $x_{HF} \in [0, \infty)$. Furthermore, the cost functions that the countries face in F then depend on which of the two has access to the least expensive abatement opportunities. In the following, having access to the least expensive abatement opportunities will be called having

[15] I deliberately use constant marginal benefits of abatement to abstain from modeling the strategic effects of country $H's$ and country $F's$ global abatement decisions, which of course exist when two parties contribute to the same global public good, and to focus on the strategic interaction that takes place under the CDM between countries H and F in country F.

a preferential right for abatement in F, see Figure 1.1.

In the countries' cost functions, the parameter $\gamma \in \{0, 1\}$ indicates who holds the preferential right. If country H has the preferential right, $\gamma = 0$, if country F has it, $\gamma = 1$.[16]

Figure 1.1.: Cost function in country F with CDM



The general cost function for player H is

$$c_H\left(x_{HH}, x_{HF}, x_{FF}\right) = x_{HH}^2 + \left(x_{HF} + \gamma x_{FF}\right)^2 - \gamma^2 x_{FF}^2. \tag{1.1}$$

That is, player $H's$ abatement costs are quadratic in $H's$ domestic abatement x_{HH} and in $H's$ abatement abroad x_{HF} but increase linearly in country $F's$ abatement x_{FF}. This implies that, with every additional unit of abatement by F, country $H's$ marginal costs for abatement in F increase.

Player $F's$ cost function is

$$c_F\left(x_{FF}, x_{HF}\right) = \left(x_{FF} + (1-\gamma)\, x_{HF}\right)^2 - (1-\gamma)^2\, x_{HF}^2. \tag{1.2}$$

Player $F's$ abatement costs are quadratic in its own abatement x_{FF} and linearly increasing in country $H's$ abatement in F, x_{HF}. That is, with every additional unit of abatement by H in F, country $F's$ marginal abatement costs increase.

[16] Abatement by countries H and F in F are substitutes. To illustrate this with an example, one can think of solar panels, being installed on house tops. Once every roof is filled with solar panels, this technology is exhausted.

In the following, I derive the Nash equilibrium outcomes for three different cases and compare these outcomes to each other. I start with the Benchmark Case without CDM, where both countries can only abate domestically. The other two cases are with CDM. In one of these cases, F has a preferential right with regards to emission abatement in country F ($\gamma = 1$). In the other one, H enjoys a preferential right for its abatement in F ($\gamma = 0$).[17]

With the two CDM cases, I look at borderline cases. There also exists a variety of cases in between the two with all sorts of alignments of country $H's$ and country $F's$ respective abatement projects on the cost function in F.

1.3.1. Benchmark Case without CDM

Suppose both countries H and F can only abate at home; that is, $x_{HF} = 0$. In that case, player $H's$ objective function reduces to

$$\max_{x_{HH}} W_H = v_H \left(x_{HH} + x_{FF}\right) - x_{HH}^2,$$

and player $F's$ to

$$\max_{x_{FF}} W_F = v_F \left(x_{HH} + x_{FF}\right) - x_{FF}^2.$$

It follows directly that optimal contributions are

$$x_{HH}^* = \frac{v_H}{2} \text{ and } x_{FF}^* = \frac{v_F}{2}.$$

Due to the constant marginal benefit of abatement, optimal abatement choices do not depend on the other country's abatement level. The resulting

[17] When H has the preferential right, additionality of CDM projects is violated. When F has the preferential right, additionality of CDM projects is warranted. The cases where one or the other player has a preferential right are not to be mistaken for cases with sequential moves. The contribution of the other country is unknown when countries decide on their own contribution. The preferential right is not a right to move first, but one which ensures a country to have lower marginal abatement costs in F than the other country. The first mover in the sequential case would, to the contrary, not use its first mover advantage to secure the relatively lower marginal abatement costs for itself.

payoffs are

$$W_H^* = \frac{v_H^2}{4} + \frac{v_H v_F}{2} \tag{1.3}$$

and

$$W_F^* = \frac{v_F^2}{4} + \frac{v_H v_F}{2}. \tag{1.4}$$

Both players contribute to the public good and both abate up to the point where the marginal costs of abatement match the respective player's marginal willingness to pay, v_H and v_F. While the players' abatement costs are symmetric, player $H's$ optimal amount of abatement is larger than player $F's$ as, by assumption, H has a higher marginal benefit from GHG reduction than F does.

1.3.2. Effect of the Clean Development Mechanism

In the following, I consider the optimal abatement choices if the Clean Development Mechanism is implemented and cross border abatement is possible for player H. Therefore, player H faces abatement opportunities in countries H and F, while player F still only abates in F. That is, $x_{HF} \in [0, \infty)$.

1.3.2.1. Preferential right for country F

Suppose country F enjoys a preferential right with respect to emission reduction. Intuitively, this means that F is allowed to invest in the least expensive abatement opportunities in F, while H is only allowed to abate in excess of player $F's$ abatement. This is the scenario which corresponds to the one intended by the Kyoto authors. Abatement under the CDM is additional in this case.

In the case where F has a preferential right, the assumptions on the cost functions are such that player H has higher marginal costs than player F when abating in country F. That is, $\gamma = 1$. So player $H's$ and $F's$ objective functions are

$$W_H = v_H\left(x_{HH} + x_{HF} + x_{FF}\right) - x_{HH}^2 - \left(x_{HF} + x_{FF}\right)^2 + x_{FF}^2$$

and

$$W_F = v_F\left(x_{HH} + x_{HF} + x_{FF}\right) - x_{FF}^2.$$

From the first order conditions for H, $v_H = 2x_{HH}$ and $v_H = 2(x_{HF} + x_{FF})$, and for F, $v_F = 2x_{FF}$, the following equilibrium contributions are derived:

$$x_{HH}^* = \frac{v_H}{2},\ x_{HF}^* = \frac{v_H - v_F}{2} \text{ and } x_{FF}^* = \frac{v_F}{2}.$$

These abatement choices constitute a unique Nash equilibrium. The equilibrium welfare for players H and F is,

$$W_H^* = \frac{v_H^2}{2} + \frac{v_F^2}{4} \tag{1.5}$$

and

$$W_F^* = v_H v_F - \frac{v_F^2}{4}. \tag{1.6}$$

respectively.

Player F exerts the same amount of abatement as in the Benchmark Case. In country H, player H still simply chooses the amount of abatement that maximizes $H's$ welfare under isolation. In addition, player H adds to $F's$ abatement projects, in country F, up to the point where its own marginal willingness to pay equals the marginal abatement costs in country F. Therefore it is player $H's$ additional abatement that leads to larger global contributions than in the Benchmark Case. The same holds for global welfare.

1.3.2.2. Preferential right for country H

Suppose country H enjoys a preferential right with respect to emission reduction. Intuitively, this means that H is allowed to invest in the least

expensive abatement opportunities in F, while F can only abate in excess of player $H's$ abatement in F. This is the scenario the Kyoto authors intended to prevent but which is nonetheless observed empirically. Abatement under the CDM is non-additional in this case.

In the case where H has a preferential right, the assumptions on the cost functions are such that player F has higher marginal costs than player H when abating in country F. That is, $\gamma = 0$. So player $H's$ and $F's$ objective functions are

$$W_H = v_H \left(x_{HH} + x_{HF} + x_{FF}\right) - x_{HH}^2 - x_{HF}^2$$

and

$$W_F = v_F \left(x_{HH} + x_{HF} + x_{FF}\right) - \left(x_{HF} + x_{FF}\right)^2 + x_{HF}^2.$$

From the first order conditions for H, $v_H = 2x_{HH}$ and $v_H = 2x_{HF}$, and for F, $v_F = 2(x_{HF} + x_{FF})$, the following equilibrium contributions are derived:

$$x_{HH}^* = \frac{v_H}{2},\ x_{HF}^* = \frac{v_H}{2} \text{ and } x_{FF}^* = 0.$$

Player $F's$ optimal abatement choice results in a corner solution as by definition $x_{FF} \in [0, \infty)$. The abatement choices constitute a unique Nash equilibrium and the equilibrium welfare for players H and F is,

$$W_H^* = \frac{v_H^2}{2} \tag{1.7}$$

and

$$W_F^* = v_H v_F. \tag{1.8}$$

respectively.

Player H abates in country F up to the point where his marginal benefits from abatement are equal to his marginal abatement costs in F. As player F has lower marginal benefits from abatement than player H does, F will not choose any abatement at all. That is, player $H's$ GHG reduction in country F fully crowds out player $F's$ abatement. Player F free-rides on

$H's$ emission reductions.

1.4. Welfare Comparison

To assess the Clean Development Mechanism from a welfare perspective, I compare the countries' welfare in the three different cases. Firstly, the welfare in the absence of the mechanism is compared to the welfare under the mechanism. Secondly, I examine how the countries' welfare differs in the cases where country H (country F) enjoys the preferential right regarding GHG abatement in country F.

Proposition 1.1.

a) Country $F's$ welfare is strictly higher under the CDM than without the CDM.

b) If $\gamma = 1$, country $H's$ welfare is strictly higher under the CDM than without the CDM.

If $\gamma = 0$, country $H's$ welfare is strictly higher under the CDM than without the CDM, if and only if $v_H > 2v_F$.

Proof.

a) Let F have a preferential right. With the CDM, player $F's$ welfare is strictly higher than without the CDM since the difference between (1.6) and (1.4) is $v_H v_F/2 - v_F^2/2$, which is strictly positive.

Let H have a preferential right. With the CDM, player $F's$ welfare is strictly higher than without the CDM since the difference between (1.8) and (1.4) is $v_H v_F/2 - v_F^2/4$, which is strictly positive.

b) Let F have a preferential right ($\gamma = 1$). With the CDM, player $H's$ welfare is strictly higher than without the CDM since the difference between (1.5) and (1.3) is $(v_H/2 - v_F/2)^2$, which is strictly positive.

Let H have a preferential right ($\gamma = 0$). With the CDM, player $H's$ welfare is strictly higher than without the CDM, if and only if $v_H > 2v_F$ since the difference between (1.7) and (1.3) is $v_H\,(v_H/4 - v_F/2)$, which is strictly positive if and only if $v_H > 2v_F$. □

Proposition 1 implies that, with the CDM, emission reductions in country F increase compared to the Benchmark Case, due to player $H's$ cross border abatement in country F. At the same time, domestic emission reductions by players F and H remain constant compared to the Benchmark Case if F has a preferential right. If, however, H has a preferential right, player F reduces his abatement contributions to zero compared to the Benchmark Case, but player H overcompensates this reduction with his cross border abatement such that overall emission reductions are the same in the two cases with CDM.

In the case where F has the preferential right, abatement costs remain constant with emission reductions for player F, whereas, in the case where H has a preferential right, abatement costs drop to zero together with $F's$ emission reductions. The increase in overall abatement, together with unchanged or decreased abatement costs, compared to the Benchmark Case, leads to greater welfare under the CDM than without the CDM for country F.

Like country F, country H also profits from the increased abatement compared to the Benchmark Case. However, as this abatement increase is due to player $H's$ cross border abatement in country F, player H is the one who has to pay the costs for the increase in emission reductions.

If $\gamma = 1$ (F has a preferential right), domestic abatement by countries F and H remains the same as in the Benchmark Case and $H's$ cross border abatement simply adds to the Benchmark Case abatement. Under the initial assumption that $v_H > v_F$, the additional benefits from this cross border abatement exceed player $H's$ additional abatement costs and country $H's$ welfare is higher under the CDM than without the CDM.

If $\gamma = 0$ (H has a preferential right), domestic abatement by country H remains the same as in the Benchmark Case, but $F's$ emission reductions drop to zero. As player H fully compensates this drop and, further, adds the same amount of abatement as in the "F has a preferential right" case, the additional abatement costs for H are higher in the case where H has a preferential right than in the case where F has a preferential right. Furthermore, the condition under which additional benefits exceed additional costs is stronger in the latter case. That is, country $H's$ welfare is higher

under the CDM than without the CDM only if $v_H > 2v_F$. When this condition is fulfilled, however, the CDM leads to a Pareto improvement.

In turn, if the two countries' respective willingnesses to pay for abatement were quite similar - i.e. $v_H > v_F$, but $v_H < 2v_F$ - cost benefit considerations would keep country H from cross border abatement in the case where H has a preferential right. Country H would then rather leave the abatement in F to country F because the supplementary abatement H could take on in F would not add enough benefits to compensate for the additional costs.

I have now analyzed how the welfare in the two cases with CDM compares to the welfare in the Benchmark Case. What remains to be seen is which of the two cases with CDM the countries F and H prefer.

Proposition 1.2.

a) Country $F's$ welfare is strictly lower in the case where F has a preferential right than in the case where H has a preferential right.

b) Country $H's$ welfare is strictly higher in the case where F has a preferential right than in the case where H has a preferential right.

Proof.

a) Comparing (1.6) and (1.8) shows directly that $F's$ welfare is strictly lower when F has a preferential right than when H has a preferential right. The difference between (1.6) and (1.8) is $-v_F^2/4$, which is strictly negative.

b) Comparing (1.5) and (1.7) shows directly that $H's$ welfare is strictly higher when F has a preferential right than when H has a preferential right. The difference between (1.5) and (1.7) is v_F^2, which is strictly positive. □

Proposition 2 implies that if country F could decide on the allocation of the preferential right, it would always opt for H to have the preferential right. Likewise, when country H could decide on the allocation of the preferential right, it would always opt for F to have the preferential right. That is, both players prefer the case in which they themselves have higher marginal abatement costs in country F than the other player does.

Overall emission reductions and therewith the two countries' benefits from abatement are the same in both cases. Player F abates a positive amount when he has the preferential right but does not abate at all when player H has the preferential right. That is, $F's$ abatement costs are positive in the former and nil in the latter case. With equal benefits from abatement in the two cases, country $F's$ welfare is, therefore, strictly lower when F has the preferential right than when H has the preferential right.

Player H adds to $F's$ abatement when F has the preferential right, but, when H has the preferential right, H not only compensates for $F's$ abatement from the "F has a preferential right" case but also adds the same amount as it itself contributes in the "F has a preferential right" case. That is, H abates more in the "H has a preferential right" case than in the "F has a preferential right" case. Therefore, his abatement costs are higher in the former than the latter case. With equal benefits from abatement in the two cases, country $H's$ welfare is therefore strictly higher when F has the preferential right than when H has the preferential right.

Global welfare is the same in both cases with CDM. That is, when moving from one case to the other, welfare is simply redistributed from one country to the other.

1.5. Conclusion

The analysis of the simultaneous moves game shows that both countries involved in CDM projects have a higher welfare with the Clean Development Mechanism than without it. Also, global abatement is larger with the mechanism than in its absence.[18]Regarding the industrialized country, welfare is only larger for a parameter range where the industrialized country's

[18]I do not consider the possible effect the crowding out in F might have on $H's$ domestic emission reductions. If $H's$ intrinsic will to abate drives $H's$ willingness to pay for abatement, v_H, $H's$ domestic abatement remained unchanged and global abatement was the same for both cases, the one where H has the preferential right and the one where F has the preferential right. If, however, $H's$ abatement obligation drives $H's$ willingness to pay for abatement, v_H, $H's$ domestic abatement differed for the two cases, affecting individual and global welfare and possibly leading to a global emission increase.

willingness to pay for abatement is substantially larger than the developing country's willingness to pay for abatement. With respect to the two different cost scenarios under the CDM, which I have looked at, the two countries have antithetic preferences. Both countries prefer the scenario in which they themselves have higher marginal abatement costs than the other country. Therefore, the industrialized country would pick the "F has a preferential right" case, while the developing country would decide on the "H has a preferential right" case if it had a choice. When the industrialized country has the preferential right, the developing country can fully free-ride on the industrialized country's contributions, and its own abatement drops to zero.

For future climate negotiations, the results indicate that the Clean Development Mechanism should be kept as a GHG offset mechanism, as the developing country always profits from it. The industrialized country profits from the mechanism, especially as long as the additionality principle is fulfilled, but also for some parameter ranges in the absence of additionality. Further, GHG emissions always decrease.

The parties to the climate convention can pursue different goals. They could wish to get every country, including developing ones, to contribute, or they might wish to increase contributions, but spare the developing countries, and have the industrialized countries carry the burden. Depending on the goal, the parties to the convention have two different scenarios to choose from. If they grant a preferential right regarding abatement in the developing country to the developing country (compliance with the additionality principle), both countries will contribute; that is, the developing country carries part of the burden. However, if the preferential right with respect to abatement in the developing country is granted to the industrialized country (violation of the additionality principle), the only country contributing will be the industrialized one. That is, at the same overall amount of global abatement, the industrialized country takes on all the abatement and the developing country is fully unburdened.

Chapter 2.

Monitoring Abatement in the Presence of an Import Quota

2.1. Introduction

The fight against climate change is a global public good. It makes no difference for the CO_2 concentration in the atmosphere at which place on earth pollutants are abated. However, the choice of the place can make a difference for the abatement costs that accrue.

From an economic view point, CO_2 abatement should be carried out wherever it is cheapest. This consideration was at the heart of the Clean Development Mechanism (CDM) when it was launched as part of the Kyoto Protocol in 1997. The CDM enables firms from industrialized countries to invest in registered CDM abatement projects abroad in developing countries. For each metric tonne of CO_2 abatement enabled by their investment, the firms receive one certified emission reduction (CER) in return. Firms can use the CERs generated by CDM projects to offset their domestic abatement obligation stemming from the negotiated environmental agreement that the Kyoto countries committed themselves to in 1997.[19] CDM projects range from methane avoidance in agriculture and photovoltaic power generation to large hydro power plants. Generally, any project that leads to emission reductions compared to a counterfactual baseline is admissible as

[19] Governments pass the abatement obligations they committed to on to the firms under their jurisdiction.

a CDM project.[20]

The abatement of CO_2 emissions, while generating welfare benefits, accrues costs for the firms carrying out the abatement. Consequently, a government intending to induce abatement by its firms needs to provide incentives for these firms to select into abatement. That is, it needs to demand an amount that is to be abated by each firm and punish shortcomings, both of which is being done in reality.[21] Presumably, while domestic abatement is easily observed by the government, abatement abroad demands some more observation effort. In other words, governments have incomplete information regarding abatement abroad and from this incomplete information arises a monitoring problem for the government. This assessment is backed by Kachi et al. (2014) mentioning that California is prejudiced against the CDM due to the fear of having little control over abatement occurring abroad.

Many governments allow the firms under their jurisdiction to participate in the CDM, but not without imposing some restrictions regarding the use of CERs. While Australia planned to allow 12.5% and South Korea is planning to allow up to 50% of its firms' abatement obligations to be covered by Kyoto abatement units such as CERs (Kachi et al. 2014), the European Union left it up to its member states to impose restrictions.[22] The result was quotas that ranged between 0% and 22%, where Estonia is the strictest and Germany the laxest country. This percentage of allocated emission allowances is admissible in the form of CERs (Vasa 2011). California considered an alternative restriction, a discount for abroad abatement certificates, but this chapter will focus on an import quota.[23]

Keeping in mind that CO_2 abatement is a global public good and that

[20] A broad overview of the workings of the CDM in general can be found in Paulsson (2009), while the course of a CDM project is explicitly explained in Section 1.2 of this thesis.

[21] An example for Germany: According to paragraph 15 of the German legal code on project mechanisms (§15, ProMechG), misreporting in validation or verification reports for emission abatement can be punished with fines of up to 100.000 EUR.

[22] See the Appendix B for the Linking Directive of the European Union. Relevant passages are highlighted

[23] Further restrictions imposed by the EU ETS, such as the exclusion of CERs from nuclear power plants or forestry projects and the restriction of source countries to Least Developed Countries, which have been active since 2012, are also not subject to this analysis.

the efficient allocation of abatement would be one that exploits the lowest cost abatement options worldwide, it is surprising to observe governments discriminating against abatement carried out abroad. The discrimination restricts the firms' options, thereby not only forcing them to meet a specific abatement obligation, but, further, forcing them to choose less cost efficient abatement allocations than are possible in the absence of discrimination.

This chapter adds to the literature on the CDM. More specifically, it adds to the literature on restricting the use of CERs generated under the CDM. Previous papers mainly focused on the fact that restricting the use of CERs breaks the pure offset character of the CDM (i.e. leads to emission reductions that can not be counted against the domestic abatement obligation) and argued that the net atmospheric benefits that arose from this made the governments' failure to prevent non-additionality more acceptable.[24]

Schneider (2009), Alexeew et al. (2010), Bakker et al. (2011) and Francois and Hamaide (2011) make this argument, but focus on restricting the use of CERs by means of a discount. Ranson and Stavins (2012) consider a CER limit and repeat the additionality argument. Also, Castro and Michaelowa (2010), applying a graphic supply and demand analysis of the CER market, and Braun et al. (forthcoming), using an empirical analysis to explain the price spread between CERs and domestic European emission certificates, draw on the same arguments for restricting CER imports and consider quantity restrictions.

The chapter at hand also considers a quantity restriction, but seeks to justify this restriction by the existence of a monitoring problem regarding abatement abroad instead of by additionality concerns.

That is, this chapter examines the following question: Is it possible that the monitoring problem mentioned above can provide a rational explanation for the observed government decision to discriminate between abatement generated at home and abatement generated abroad by means of a quota on abroad abatement? To answer this question, I apply a classical monitoring framework as defined by Becker (1968), extend it by an abatement cost

[24]Non-additional projects are projects that are being carried out under the CDM and generate CERs, although they would have been taken on in the absence of the CDM as well. Hence, those projects fail to offset emissions compared to a counterfactual scenario without the CDM.

minimization problem subject to a minimum abatement constraint and introduce heterogeneous observability for abatement generated in different regions. The analysis reveals that governments can still implement the first best abatement allocation when information on abroad abatement is incomplete. However, it further shows that, while implementable, the first best abatement allocation is not the welfare maximizing one in the presence of incomplete information. Rather, starting from no quota at all, welfare under incomplete information increases when a quota is introduced and some abatement is shifted from abroad to domestic abatement compared to the first best allocation. This shift reduces the efficiency of the allocation, but at the same time increases the firm's incentive to comply, thereby reducing the monitoring cost.

Whether or not the government wants to shift all of the abroad abatement home or wants to allow for some abroad abatement depends on the monitoring cost, the fine, the abatement obligation and the cost of the last domestic and the first foreign unit of abatement. The smaller the monitoring cost, the larger the fine, and the abatement obligation, the higher the cost for the last unit of domestic, and the lower the cost for the first unit of foreign abatement, the more likely is it that the government allows abroad abatement.

To my knowledge I am the first one to consider a monitoring problem in this context. However, there are papers that examine monitoring problems in related environmental contexts. Arguedas (2008, 2013) both consider a framework in which compliance with a general environmental standard can only be observed by means of monitoring and in which monitoring is costly. While Arguedas (2008) is after the socially optimal combination of standard and monitoring policy, Arguedas (2013), in an extension of the 2008 model, considers the optimality of a discount on the fine payable upon noncompliance. His discount depends on the amount a firm invested in abatement technologies. As Arguedas (2013) does, also I consider compliance with an environmental standard, but I model a quota. Furthermore, while the discount in Arguedas (2013) works in favor of the firms that are being granted the discount, my quota applies to abatement generated abroad and penalizes firms that are subject to it. While the two papers

by Arguedas assume all abatement to be equally poorly observable, my essential extension to Becker (1968) is that I introduce heterogeneity regarding the observability of abatement carried out in different regions. A further paper, Arguedas and Rousseau (2015) also considers observability differences, but it introduce the heterogeneity on the side of the observer, as opposed to my heterogeneity on the side of the observed. In Arguedas and Rousseau the national authority that sets the standard is unable to observe the abatement being carried out, but a local agency that enforces the standard can observe the abatement. The chapter at hand, in turn, allows one governmental regulator that takes the emission standard as exogenously given to perfectly observe domestic abatement, but assumes that abroad abatement is not observable free of cost for the regulator.

Stranlund and Chavez (2000) do not model a general environmental standard, but a transferable emissions permit system, with a monitoring problem. They require their firms to self report on their emissions and the permits they hold and find that this self-reporting requirement can be used to reduce monitoring costs. In this chapter, by contrast, the decrease in monitoring probability, and consequently the expected monitoring costs, results from implementing a second best abatement allocation where the use of an import quota shifts some of the abroad abatement home.

The following section presents the theoretical framework. First, the firm's decision is analyzed, then the government's decision, with and without an import quota and under complete and incomplete information. Section 3 concludes this chapter.

2.2. Theoretical Framework

There is one government and one firm and there are two countries, home H and foreign F.[25]

In the first stage, the government seeks to maximize welfare by choosing its monitoring policy. As explained below in more detail, the monitoring policy mainly consists of a monitoring probability $\mu \in [0, 1]$.

[25] This is equivalent to assuming one government and a continuum of homogeneous firms of mass one.

In the second stage the firm chooses its domestic and abroad abatement, $x_H \in [0, \infty)$ and $x_F \in [0, \infty)$, with the intention of minimizing abatement costs, taking an exogenous abatement obligation $x^{min} > 0$ and the government's monitoring probability μ as given. While the government considers both, benefits, $b\left(\sum x_i\right)$ with $b'\left(\sum x_i\right) > 0$, $b''\left(\sum x_i\right) = 0$ and $i \in \{H, F\}$, and costs, $c(x_i)$ with $c'(x_i)$, $c''(x_i) > 0$, $c\left(0\right) = 0$ and $i \in \{H, F\}$, the firm only cares about the cost of abatement. The abatement cost functions are publicly known. Likewise, both the firm and the government can observe domestic abatement. However, the government may not be able to observe the amount of abroad abatement carried out by the firm.

The firm complies with government legislation whenever the sum of domestic and abroad abatement matches or exceeds the abatement obligation x^{min}. If the abatement sum falls short of x^{min}, the firm does not comply.In case the firm does not comply and the non-compliance is detected, the firm has to meet its abatement obligation ex post and, in addition, pay a fine $S > 0$. For the government to detect a non-compliant firm it has to monitor, and monitoring produces the monitoring cost $m \geq 0$.

2.2.1. First Best

Under complete information, all abatement is observable for the government and there is no need for monitoring. The firm chooses domestic and abroad abatement x_H and x_F to minimize

$$C\left(x_H, x_F\right) = c\left(x_H\right) + c\left(x_F\right)$$

subject to the condition that the sum of domestic and abroad abatement must not fall short of the abatement obligation: $x_H + x_F \geq x^{min}$.

Lemma 2.1.
Under complete information, the firm chooses the allocation
$x_H^{FB} = x_F^{FB} = {}^{x^{min}}/_{2}$.

Proof.
From the equilibrium condition $c'\left(x_H\right) = c'\left(x_F\right)$ and due to the assump-

tion that $c(\cdot)$ is increasing, convex and the same for both countries follows that $x_H^{FB} = x_F^{FB}$. Together with the other equilibrium condition, $x_H^{FB} + x_F^{FB} = x^{min}$, this implies that $x_H^{FB} = x_F^{FB} = {}^{x^{min}}/_2$. Since the firm has to pay a fine $S > 0$ and fulfill its abatement obligation ex post if it does not comply, it is optimal for the firm to comply. □

As abatement costs increase progressively and are the same at home and abroad, it is cost minimizing for the firm to abate both at home and abroad and to equally distribute abatement between the two.

2.2.2. Second Best

Under incomplete information, the firm's decision is no longer aligned with the government's decision, and the government has to monitor and punish non-compliance to incentivize the firm to comply. For a given monitoring policy, if the firm decides to comply, it will choose x_H^* and x_F^*.[26] Since the cost functions are commonly known, the government anticipates the optimal choice of a compliant firm. Therefore, I assume that the government always monitors the firm, if it observes that the firm's domestic abatement choice deviates from the optimal choice of a compliant firm. Otherwise, the government monitors the firm with probability $\mu \in [0, 1)$.[27] That is, the government's monitoring policy is

$$p(x_H) = \begin{cases} \mu & if\ x_H = x_H^* \\ 1 & if\ x_H \neq x_H^* \end{cases}. \tag{2.1}$$

If the firm does not comply and is detected, in addition to fine $S > 0$, it has to meet its abatement obligation ex post, i.e., choose additional (domestic or abroad) abatement such that total abatement sums up to at least x^{min}. Hence, if the firm initially chooses (x'_H, x'_F) with $x'_H + x'_F < x^{min}$ and is detected, it has to pay S and to chooses additional abatement (x''_H, x''_F) such that $x'_H + x'_F + x''_H + x''_F \geq x^{min}$. I assume for simplicity that the

[26] Optimal choices of a compliant firm are marked with asterisks.

[27] I exclude $\mu = 1$, for this is the less interesting case in which the firm is always monitored.

additional abatement of an initially non-compliant firm has to be disclosed (or can be monitored by the government at no additional cost).

Consequently, if compliant (that is, when $x'_H + x'_F \geq x^{min}$), the firm has abatement cost

$$C\left(x'_H, x'_F\right) = c\left(x'_H\right) + c\left(x'_F\right), \tag{2.2}$$

while, if non-compliant (that is, when $x'_H + x'_F < x^{min}$), the firm has expected abatement cost

$$E\left[C\left(x'_H, x'_F\right)\right] = c\left(x'_H\right) + c\left(x'_F\right) + \mu\left(S + c\left(x''_H\right) + c\left(x''_F\right)\right). \tag{2.3}$$

Moreover, I assume that the government values revenues (the fine) and the firm's profits equally. Therefore, for the government, which receives fine S but at the same time takes into account the firm's costs, the fine is welfare neutral.

In addition to the exogenous minimum abatement obligation x^{min} the government can set a quota caping abroad abatement $x_F \leq x_F^{max}$. Backward induction allows to solve for the firm's equilibrium abatement and the government's policy choices.

2.2.2.1. The Firm's Decision

In the absence of a quota on abroad abatement, the firm chooses its domestic and abroad abatement x_H and x_F in the second stage to minimize the abatement cost in (2.2) and (2.3), taking into account the government's monitoring policy in (2.1).

Lemma 2.2.
a) If compliant, the firm chooses the first best domestic and abroad abatement $x_H^* = x_F^* = {}^{x^{min}}/_2$.

b) If non-compliant, the firm chooses domestic abatement $x_H = {}^{x^{min}}/_2$ *and abroad abatement* $x_F = 0$.

The proof of Lemma 2.2. can be found in Appendix B.

As under complete information, when complying, the firm chooses the smallest abatement sum ensuring compliance, x^{min}, and equally divides abatement between domestic and abroad abatement to minimize the cost. This is due to the fact that the abatement cost functions are convexly increasing and the same in both countries.

Given the firms monitoring strategy, every domestic abatement choice except the compliant firm's optimal choice leads the government to monitor with certainty. With certain monitoring and hence certain punishment, choosing the compliant firm's amount at home generates smaller expected costs than any other choice for all levels of abroad abatement. That is, the firm chooses a compliant firm's level of abatement at home. However, abroad, where abatement is not observable for the government, the expected costs are the smallest when the firm chooses no abatement at all. This is due to the fact that fine S is constant and independent of the amount of foregone abatement.

In the presence of a quota on abroad abatement, the firm chooses its domestic and abroad abatement x_H and x_F in the second stage to minimize the abatement cost in (2.2) and (2.3), taking into account the government's monitoring policy in (2.1) and subject to a binding quota for abroad abatement (i.e., subject to the condition that $x_F \leq x_F^{max} < {}^{x^{min}}/_2$).

Lemma 2.3.
Given that the quota is binding,

a) the firm chooses domestic abatement $x_H^* = x^{min} - x_F^{max}$ *and abroad abatement* $x_F^* = x_F^{max}$ *if it is compliant.*

b) the firm chooses domestic abatement $x_H = x^{min} - x_F^{max}$ *and abroad abatement* $x_F = 0$ *if it is non-compliant, .*[28]

Proof.
a) Given a binding quota $x_F^* = x_F^{max} < {}^{x^{min}}/_2 < x^{min} - x_F^{max} = x_H^*$. There-

[28] Where $x_H^* = x^{min} - x_F^{max}$ and $x_F^* = x_F^{max}$, analogous to Lemma 2.2, also correspond to the first best domestic and abroad abatement choices that would be derived under complete information.

fore, it holds that

$$c'\left(x_F^*\right) < c'\left(x_H^*\right).$$

If the firm chooses $x'_F > x_F^{max}$ the marginal costs are $c'\left(x'_F\right) > c'\left(x_F^*\right)$. But as the government only counts $x_F = x_F^{max}$ towards the firm's abatement obligation, x_H must be $x_H^* = x^{min} - x_F^{max}$ to ensure compliance. With allocation (x_H^*, x'_F) the abatement cost is strictly higher than with (x_H^*, x_F^*), hence $x'_F > x_F^{max}$can not be optimal.

Likewise, the choice $x'_F < x_F^{max}$ (and $x'_H > x^{min} - x_F^{max}$) can not be optimal, as allocation (x'_H, x'_F) would imply $c'\left(x'_F\right) < c'\left(x_F^*\right) < c'\left(x_H^*\right) < c'\left(x'_H\right)$.

b) The proof for the compliant firm, follows the same line of argumentation as the proof of Lemma 2.2. □

Given a binding quota on abroad abatement, it is cheapest for the firm to abate the exact amount of the quota abroad when complying. The reason being that, with a binding quota, the optimal amount of abroad abatement that the firm would choose in the absence of the quota is larger than the amount allowed under that quota. Any allocation deviating from the one that is optimal in the absence of the quota increases the abatement costs, but the cost increase is larger the larger the deviation. The firm, consequently, chooses the smallest deviation possible. At home, the firm chooses the lowest possible amount guaranteeing compliance, given the choice of an amount equal to the quota abroad.

Regarding the non-compliance choices the same logic applies as in the case without the quota. Every domestic abatement choice except for the compliant firm's optimal choice leads the government to monitor with certainty. That is, at home the firm chooses the compliant firm's level of abatement. However, abroad, where abatement is not observable for the government, the firm chooses no abatement at all.

Any quota smaller than the efficient abroad abatement in the absence of the quota is a binding quota. Therefore, for illustration purposes I hereafter denote the quota as $x_F^{max} = (x^{min}/2) - \Delta$ which implies the compliance allocation is $(x_H^*, x_F^*) = ((x^{min}/2) + \Delta, (x^{min}/2) - \Delta)$ and the non-compliance

allocation is $(x_H, x_F) = ((x^{min}/2) + \Delta, 0)$. That is, compared to the optimal allocation without a quota, some of the abroad abatement is shifted homeward with a quota.

2.2.2.2. The Government's Decision

The government can only affect the firm's choice through the monitoring policy it implements in the first stage. I assume that the government can perfectly observe the domestic abatement of the firm, but abroad abatement is initially unobserved and only disclosed upon request. Making this request causes monitoring cost m for the government. That is, the government balances the benefits of abatement, $b(\sum x_i)$ with $i = \{H, F\}$, against the monitoring cost. If the monitoring cost was very large compared to the benefits of abatement, the government would never monitor to induce compliance (the monitoring probability would be $\mu = 0$) and the firm would never comply. In this case there would be no monitoring problem. Thus, I assume that the benefits of abatement are sufficiently high compared to the monitoring cost, such that the government wants to monitor with a positive probability and wants to induce compliance.

Proposition 2.1.
Under incomplete information, the government can implement the first best abatement allocation $x_H^{FB} = x_F^{FB} = x^{min}/2$ *by choosing the monitoring probability*

$$\mu^* = \frac{c\left(\frac{x^{min}}{2}\right)}{S + c\left(\frac{x^{min}}{2}\right)}.$$

Proof.
The firm chooses to comply whenever it is indifferent between compliance and non-compliance: $C(x^{min}/2, x^{min}/2) = E[C(x^{min}/2, 0)]$. This is the case if $2c(x^{min}/2) = \mu(S + c(x^{min}/2)) + c(x^{min}/2)$, which reduces to $\mu^* = c\left(x^{min}/2\right)/\left(S + c\left(x^{min}/2\right)\right)$. □

The government can implement compliance with the monitoring probability that makes the firm indifferent between compliance and non-compliance.

When compliance is induced and the monitoring probability is set optimally, the expected welfare is

$$W^* = b\left(\sum x_i^*\right) - \sum c\left(x_i^*\right) - \mu^* m,$$

with $i = \{H, F\}$.

Proposition 2.2.
Under incomplete information, the welfare maximizing choice differs from the first best choice of abatement $x_H^{FB} = x_F^{FB} = {}^{x^{min}}/_2$. *Instead, the government prefers to set a strictly positive quota, such that* $x_F^* < {}^{x^{min}}/_2$.

Proof.
Using Lemma 2.3 and a quota, $x_F^{max} = ({}^{x^{min}}/_2) - \Delta$, the compliant firm chooses $x_H^* = ({}^{x^{min}}/_2) + \Delta$, $x_F^* = ({}^{x^{min}}/_2) - \Delta$

and the non-compliant firm chooses $x_H = ({}^{x^{min}}/_2) + \Delta$ and $x_F = 0$.

That is, the monitoring probability implementing compliance becomes

$$\mu^*(\Delta) = \frac{c\left(\frac{x^{min}}{2} - \Delta\right)}{S + c\left(\frac{x^{min}}{2} - \Delta\right)}.$$

Then the corresponding optimal welfare is

$$\begin{aligned} W^*(\Delta) &= b\left(x^{min}\right) - c\left(\frac{x^{min}}{2} + \Delta\right) - c\left(\frac{x^{min}}{2} - \Delta\right) \\ &\quad - \frac{c\left(\frac{x^{min}}{2} - \Delta\right)}{S + c\left(\frac{x^{min}}{2} - \Delta\right)} m. \end{aligned}$$

Deriving the welfare with respect to Δ yields

$$\begin{aligned}\frac{\partial W^*(\Delta)}{\partial \Delta} &= -c'\left(\frac{x^{min}}{2}+\Delta\right)+c'\left(\frac{x^{min}}{2}-\Delta\right)\\ &\quad+\frac{\left(S+c\left(\frac{x^{min}}{2}-\Delta\right)\right)c'\left(\frac{x^{min}}{2}-\Delta\right)}{\left(S+c\left(\frac{x^{min}}{2}-\Delta\right)\right)^2}m \qquad (2.4)\\ &\quad-\frac{c\left(\frac{x^{min}}{2}-\Delta\right)c'\left(\frac{x^{min}}{2}-\Delta\right)}{\left(S+c\left(\frac{x^{min}}{2}-\Delta\right)\right)^2}m. \qquad (2.5)\end{aligned}$$

That is

$$\frac{\partial W^*}{\partial \Delta}\mid_{\Delta=0}=\frac{Sc'\left(\frac{x^{min}}{2}\right)}{\left(S+c\left(\frac{x^{min}}{2}\right)\right)^2}m>0,$$

as S, m and $c'(\cdot)>0$. □

Once information is incomplete and the government has to exert costly monitoring to verify abroad abatement, the government faces a trade-off. It is a trade-off between distorting the allocation of domestic and abroad abatement and increasing the firm's incentive to comply by reducing the amount of abatement to be implemented abroad and thereby reducing the monitoring probability necessary to induce compliance. Shifting abroad abatement to home, starting from the first best allocation $x_H^{FB}=x_F^{FB}={}^{x^{min}}/_2$ where the distortion is zero, results in a negative welfare effect from the distortion that is smaller than the positive welfare effect from the increased compliance incentive of the firm. This is due to the assumption of increasing, but equal abatement cost functions at home and abroad.[29]

The introduction of a marginal shift increases welfare, but what remains to be identified is the optimal shift from abroad to domestic abatement.

[29] If the abatement costs at home were larger than abroad, $c_H(\cdot)\geq c_F(\cdot)\,\forall x_H, x_F$, the condition under which welfare increases with a shift from abroad to domestic abatement would no longer be always fulfilled. Rather, the difference between the domestic and abroad abatement cost functions, $c_H(\cdot)$ and $c_F(\cdot)$, and their relation to the monitoring cost m will then play a role.

Claim 2.1.
If

$$c'(0)\left[1+\frac{m}{S}\right]-c'\left(x^{min}\right)<0 \tag{2.6}$$

then the optimal quota is such that $\Delta^{opt}\in(0,{}^{x^{min}}/_{2})$ and the amount of abroad abatement is positive.

Proof.
Taking equation (2.4) at $\Delta={}^{x^{min}}/_{2}$ yields

$$\frac{\partial W^{*}(\Delta)}{\partial\Delta}\mid_{\Delta=\frac{x^{min}}{2}}=c'(0)\left[1+\frac{m}{S}\right]-c'\left(x^{min}\right).$$

That is, ${}^{\partial W(\Delta)}/_{\partial\Delta}\mid_{\Delta=\left({}^{x^{min}}/_{2}\right)}<0$ if condition (2.6) is fulfilled.

Since $\Delta\in[0,{}^{x^{min}}/_{2}]$ by definition, ${}^{\partial W(\Delta)}/_{\partial\Delta}\mid_{\Delta=\left({}^{x^{min}}/_{2}\right)}<0$ is sufficient for $\Delta^{opt}<{}^{x^{min}}/_{2}$ and from Proposition 2.2 is known that $\Delta^{opt}>0$. □

Welfare decreases in Δ at the upper bound $\Delta={}^{x^{min}}/_{2}$, if condition (2.6) holds. Thus, reducing Δ to $\Delta<{}^{x^{min}}/_{2}$ generates a welfare increase, implying that $\Delta^{opt}<{}^{x^{min}}/_{2}$ and abroad abatement is positive. Condition (2.6) is more likely to be fulfilled the smaller marginal cost $c'(0)$ and monitoring costs m and the larger fine S, abatement obligation x^{min}, and marginal cost $c'(x^{min})$. The intuition behind this is the following. A smaller monitoring cost, makes the government more willing to allow for abroad abatement that brings along the need for monitoring. A larger fine S makes the likelihood for non-compliance smaller such that the government is more willing to allow for the less observable abatement abroad.

A larger abatement obligation x^{min} increases the efficiency benefits from dividing abatement between home and abroad, due to the convex cost functions. Likewise, the more convex the costs functions, the larger are efficiency benefits from dividing abatement between home and abroad. If $c'(0)$ is small, the first unit of abroad abatement is cheap and if $c'(x^{min})$ is

large, the last unit of domestic abatement is expensive, thus, the government would want to allow for abroad abatement and shift some domestic abatement abroad.[30]

If condition (2.6) is violated the solution for Δ^{opt} may be such that no abroad abatement is allowed, provided that the assumptions over the cost functions ensure that welfare is strictly concave in Δ.[31] However, there is empirical evidence for abroad abatement, suggesting that the solution for Δ^{opt} should be an interior one, such that abroad abatement occurs.

2.3. Conclusion

This chapter considers a classical monitoring framework with a representative firm that minimizes abatement costs subject to an emission standard. Further, the regulator monitoring the firm faces heterogeneous observability of abatement carried out at home versus carried out abroad. I find that it is feasible for a regulator to choose its policy such that the first best abatement allocation is implemented even under incomplete information regarding abroad abatement. I show, however, that this first best allocation is not socially optimal under incomplete information. In fact, a government concerned with welfare maximization should apply a quota to restrict the use of abroad abatement certificates. Such a quota, inducing a shift from abroad to domestic abatement, reduces the firm's incentive for non-compliance. As non-compliance becomes less likely, the government can induce compliance via a smaller monitoring probability than without a quota, which implies that expected monitoring costs are smaller. The quota, of course, simultaneously distorts the abatement allocation of the firm away from the efficient allocation, which affects welfare negatively. However, at the margin, this negative distortion effect is smaller than the positive effect reducing the monitoring expenditure. That is, at least a small quota on abroad abatement should always be welfare enhancing in

[30] For quadratic cost functions $c'(0)=0$, which implies that condition (2.6) would then always be fulfilled.

[31] Convexity of the cost function $c(\cdot)$ does not guarantee concavity of the welfare function, due to the last term of the welfare function $-c(x^{min}/2-\Delta)m/(S+c(x^{min}/2-\Delta))$, containing the monitoring probability of the government.

this framework. The results might not apply if the policy measure of choice was not a quota, but a discount on/an allowability reduction for abroad abatement.

Furthermore, my results suggest that while a small quota on abroad abatement should be welfare enhancing, the government might not want to fully prohibit abroad abatement altogether, but might want to allow for some. The government is more likely to allow for abroad abatement, the smaller the monitoring cost and the cost for the first unit of abroad abatement and the larger the fine for non-compliance, the abatement obligation and the cost of the last unit of domestic abatement.

Chapter 3.

Reduced Allowability and the Allocation of Emission Abatement

3.1. Introduction

To fight climate change, industrialized countries have agreed to emission reduction obligations under the Kyoto Protocol. These emission reduction obligations implicitly determine emission caps for many firms within the covered countries. Effectively, firms receive emission allowances up to a predefined cap. The firms emit Green House Gas (GHG) as a byproduct of their production process, and they may freely do so as long as they have emission allowances to counteract them. All emissions that exceed the cap have to be offset. Firms can offset these excess emissions either by abating at home, by buying emission allowances from other firms that have an excess capacity, or by using the Clean Development Mechanism (CDM).[32] The CDM is a GHG offset mechanism introduced in paragraph 12 of the Kyoto Protocol, which allows firms from industrialized countries to abate in developing countries exploiting the latters' lower abatement costs. For each metric tonne of CO_2 abatement under the CDM, industrialized country firms receive one emission allowance, a so called Certified

[32] Home abatement could involve domestic abatement action such as changing the production technology, e.g., by introducing carbon filters or it could imply that firms reduce their goods production to reduce emissions.

Emission Reduction (CER), in return. CERs can then be used to offset excess emissions.[33]

Scholars and politicians have raised several concerns over the CDM.[34] The most prominent and much-cited ones are the additionality problem and the low-hanging fruits issue.

The additionality problem arises when CERs are paid out for emission reductions that would have also occurred in the absence of the CDM. Emission reductions occurring in the absence of the CDM could result either from foreign direct investment projects or from domestic projects of the developing country itself. When CERs are paid out for such non-additional emission reductions they effectively increase emissions above the Kyoto target instead of reducing them to meet the target. This happens due to the fact that the CDM is a pure offset mechanism which implies that abating one unit abroad means emitting one unit more at home. (see e.g. Greiner and Michaelowa 2003).

The low-hanging fruits issue arises when industrialized counties make use of the cheapest abatement options in the developing world, thereby crowding out cheap future abatement options of developing countries. The idea is that developing counties will face abatement obligations on their own in the future and that the crowding out of cheap future abatement options will leave them with high cost abatement only. High cost abatement, however, might prevent the developing countries from abating at all.[35]

Mainly driven by the additionality concern mentioned above, governments have introduced restrictions on CERs. Some introduced quotas and others thought about discounts for non-domestic abatement units. This happened despite the fact that restricting the use of abroad abatement stands in contrast to the economic argument behind the CDM. The mechanism was intended to be a market mechanism allocating abatement efficiently between abatement options all over the globe. That means that, from an efficiency

[33] A detailed explanation of the CDM process can be found in Section 1.2 of this thesis.

[34] A general overview of the concerns regarding the CDM is provided in Paulsson (2009) or Bakker et al. (2011).

[35] On the low-hanging fruits issue, see e.g. Rose et al. (1999) and Narain and van't Veld (2008). Chapter 1 of this thesis provides a static analysis of crowding out in this context. A further paper dealing with crowding out of future abatement in the context of climate policy is Elsayyad and Morath (forthcoming).

viewpoint one should expect no discounting, but rather full allowability.

Quotas are used in the EU and were planned in Australia, and a discount was discussed in California. The Californian government wanted to allow CERs to be imported at a rate of 1.25 to 1 domestic abatement unit, which is equivalent to a discount of 20% on CERs (Pew Center 2009). While domestic emission allowances offset 1 tonne of CO_2 equivalent, then, CERs would only offset 20% of this tonne. In that case, CERs are, so to say, less allowable to the abatement obligations than domestic emission allowances are.[36]

The hope was that such a discount or allowability reduction generates real emission reductions, breaking the pure offset character of the mechanism and thereby reducing the severity of the additionality problem.[37] In this chapter I abstract from other restrictions on CERs and focuses on a price instrument as it was discussed for California. That is, I analyze how an allowability or discount rate for CERs affects the equilibrium allocation of domestic and abroad abatement. I will examine whether or not reduced allowability necessarily leads to a decrease of abatement in developing countries and if not, under which condition abroad abatement might actually increase as a reaction to reduced allowability.

To answer these questions, I employ a cost minimization framework with a representative firm facing an abatement obligation. Comparative statics with respect to the allowability rate show that the effect of reduced allowability, both on domestic abatement in the industrialized country as well as on abroad abatement under the CDM, can be decomposed in a substitution and a quantity effect. The substitution effect is similar to a substitution effect caused by a change in the relative "prices" of domestic and abroad abatement. More precisely, the substitution effect corresponds to the change in abatement stemming from a compensated relative decrease in the allowability of CERs. The quantity effect measures the change resulting from the increased need for abatement when previously used CERs

[36] Furthermore, the EU ETS completely excludes the import of some CERs from specific non-supported projects (nuclear power, forestry). Also, from 2012 onwards the import of CERs generated in advanced developing countries is prohibited. However, these restrictions will not be subject to my analysis.

[37] Schneider (2009) makes this argument and Alexeew et al. (2010), Bakker et al. (2011) and Francois and Hamaide (2011) followed in the same spirit.

are less allowable.

I find that domestic abatement increases as a result of an allowability reduction for CERs. Both partial effects, the substitution and the quantity effect induce this increase. However, the effect of an allowability reduction on abroad abatement is ambiguous. While the quantity effect again works towards an abatement increase, the substitution effect points in the opposite direction and works towards a decrease. Which of the two dominates the other and therefore the direction of the overall effect depends on the policy advantage at home weighted with domestic relative to abroad equilibrium abatement and the abatement elasticity of marginal domestic abatement costs. I show that, under plausible assumptions, abroad abatement can increase as a result of a relative allowability reduction for CERs. The results are robust to the introduction of a secondary market for emission certificates as long as the price is endogenous, i.e. reacts to changes in the allowability of CERs.

The decomposition of the change in abatement induced by a changed allowability rate in substitution and quantity effect might remind the reader of the textbook Slutsky decomposition. However, decomposing the effect a relative price change has on a household's consumption decision is not the analog to the problem I analyze in the chapter at hand, but the dual problem is. One could think of two goods being consumed by a household and utility weights for each of these goods. Then, a change in the utility weight of one good imposes a quantity and substitution effect on a consumer's choice of how much to expend on one or the other good. This utility weight is analogous to my allowability rate on abroad abatement certificates.

Regarding the stated goal of weakening the additionality problem, my results are in line with the policy maker's intention. Effective emission reductions increase with an allowability reduction, and the CDM moves from pure offsetting to actual GHG abatement. However, the issue of crowding out might become more severe with an allowability reduction. As mentioned above, I find that abroad abatement does not necessarily decrease as a reaction to an allowability reduction, but might also increase. When crowding out is an issue, this issue worsens as abroad abatement increases.

Thematically, this chapter joins the literature on permit trade with offset, in which allowances from offset efforts are restricted. In this context Braun et al. (forthcoming) try to explain the price spread between European Emission Allowances (EUAs) and certificates from the CDM. They find that CER import restrictions have explanatory power for this spread and that the introduction of such restrictions reduces the demand for CERs. However, they do not consider the choice between producing EUAs or CERs and their import restriction is a quantity restriction that specifies how many domestic emissions are allowed to be offset by CERs instead of EUAs. I, in turn, define the import restriction as the fraction of CERs generated abroad which is allowed to be imported to the ETS. Braun et al. (forthcoming) are silent on the amount of CERs generated, i.e. the amount of abatement occurring abroad, whereas I am focusing on the change in this amount. Klemick (2012) defines the import restriction in a similar way as I do, namely as the trading ratio between offset credits and GHG allowances. That is: the fraction of an EUA that a firm gets for one CER generated abroad. However, she looks for the optimal discount parameter in a world with three GHG emitting sectors where only one of them faces an emission cap and emission leakage occurs between the sectors.[38] She finds that a discount or allowability rate smaller than one is optimal when sectors are only partially covered and leakage occurs between covered and uncovered sectors. She further states that a discount rate smaller than one can be optimal even in the absence of leakage, if the emission baseline is not stringent enough or when the emission cap is too lose. The effect of an allowability reduction on the abatement decision is not a part of her analysis. I, however, focus precisely on this effect and its decomposition into quantity and substitution effects. Bréchet et al. (2012) model the CDM as

[38]The term "leakage" refers to an increase of emissions in the uncovered sector resulting from a decrease of emissions in the covered sector. Leakage can occur for various reasons. One reason could be: Being covered by the environmental policy increases the production cost of the covered sector relative to the uncovered one, at constant demand, resulting in a production shift towards the uncovered sector. This production shift is accompanied by an emission increase in the covered sector. Another reason could be: In sectors that place a restriction on the use of polluting goods the demand for these goods decreases, which leads to a decrease of the prices for these goods. Consequently, sectors that are not subject to any restrictions buy more of the polluting goods and end up emitting more.

part of a global market for emission reductions but do not consider changes in the (discount/allowability) rate of CERs.

The following section introduces the theoretical framework for the case where a firm can simply generate domestic and abroad abatement. It displays the equilibrium analysis, comparative statics and the results. Section 3 extends the model introducing a third abatement option, namely buying emission credits on a secondary market. The analysis first focuses on the case with an exogenous price for bought credits before it examines the one with an endogenous price. Section 4 concludes.

3.2. Theoretical Framework

3.2.1. Model

There is one representative firm that has to fulfill an abatement obligation $x^{min} > 0$.[39] To fulfill its abatement obligation the firm can either abate at home, x_H, or abroad, x_F.[40] However, while one unit of domestic abatement, x_H, fully counts towards the abatement obligation, one unit of abroad abatement, x_F, counts only as α units towards the abatement obligation. That means that $x^{min} = x_H + \alpha x_F$, where $\alpha \in (0, 1]$, is the allowability parameter for emission reductions carried out abroad.[41]

Abatement, x_H and x_F, generates abatement costs. The cost functions mapping these costs differ between home and abroad. That is, abatement

[39] $x^{min} > 0$ is exogenously given and results from the firm's output production decision and the emission allowances the firm received, prior to this analysis. The firm's output production generates emissions as by-product. Emission allowances offset these emissions, but those emissions that exceed the allowances constitute the abatement obligation, x^{min}.

[40] Home abatement could be a production reduction or refitting factories, while abroad abatement can also include the use of new factories that generate less emissions than a counterfactual baseline.

[41] The firm does not interact with other firms. That is, firms neither compete on the output market, nor do they compete with others with respect to abatement costs, in the sense that abatement becomes more expensive the more abatement projects are already carried out by others. I deliberately abstract from strategic interaction between firms to focus on the effects that occur when a firm's isolated decision between domestic and abroad abatement is distorted by an allowability reduction for abroad abatement certificates.

x_H causes abatement cost $c_H = h(x_H)$, while x_F causes cost $c_F = f(x_F)$. The cost functions $h(\cdot)$ and $f(\cdot)$ are assumed to be increasing, strictly convex, continuous and differentiable with $h'(x_H) > 0$, $h''(x_H) > 0$, $f'(x_F) > 0$, $f''(x_F) > 0$ and $h(0) = f(0) = 0$.

The firm's objective is to meet its abatement need x^{min} at the lowest possible costs. That is, the firm chooses its domestic and foreign abatement x_H, $x_F \in [0, \infty)$ to minimize the abatement cost, $C = c_H + c_F$, subject to its minimum abatement constraint, $x_H + \alpha x_F \geq x^{min}$.

$$\min_{x_H, x_F} h(x_H) + f(x_F)$$

$$s.t.\ x^{min} \leq x_H + \alpha x_F.$$

The firm's optimal choice of domestic and abroad abatement equalizes the marginal cost for emission reduction at home and abroad,

$$h'(x_H^*) = \frac{1}{\alpha} f'(x_F^*). \tag{3.1}$$

Meanwhile, the minimum abatement constraint must be binding,

$$x^{min} = x_H + \alpha x_F. \tag{3.2}$$

That is, the equilibrium amount of domestic abatement, x_H^*, is implicitly characterized by:

$$h'(x_H^*) - \frac{1}{\alpha} f'\left(\frac{1}{\alpha}\left(x^{min} - x_H^*\right)\right) = 0, \tag{3.3}$$

while the equilibrium amount of abroad abatement, x_F^*, solves equation

$$h'\left(x^{min} - \alpha x_F^*\right) - \frac{1}{\alpha} f'(x_F^*) = 0. \tag{3.4}$$

Equations (3.3) and (3.4) show that optimal abatement, x_H^* and x_F^*, depends on the marginal cost of domestic and abroad abatement, on the abatement obligation, x^{min}, and on the allowability rate for emission reductions carried out abroad, α.

3.2.2. Effect of an Allowability Reduction

Equations (3.3) and (3.4) suggest that changes in the allowability rate α do affect equilibrium abatement. It remains to be seen how equilibrium abatement is affected. What are the effects $^{dx_H^*}/_{d\alpha}$ and $^{dx_F^*}/_{d\alpha}$ of reducing α? Total differentiation of equations (3.1) and (3.2) yields,[42]

$$\frac{dx_H^*}{d\alpha} = -\frac{\frac{1}{\alpha} f'(x_F^*)}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)} - \frac{\frac{1}{\alpha} f''(x_F^*)\, x_F^*}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)} \tag{3.5}$$

and

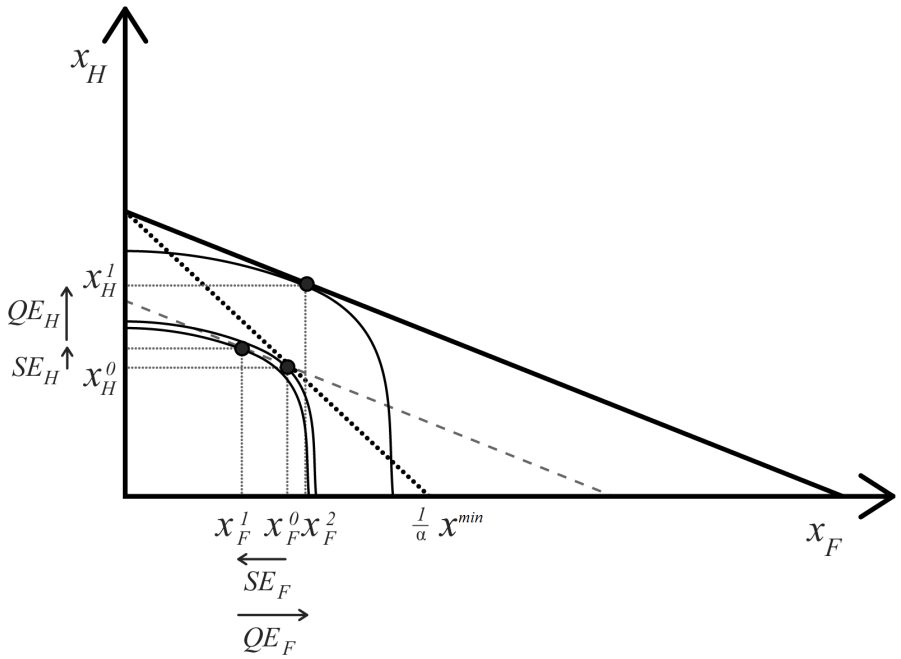
$$\frac{dx_F^*}{d\alpha} = \frac{\frac{1}{\alpha^2} f'(x_F^*)}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)} - \frac{h''(x_H^*)\, x_F^*}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}. \tag{3.6}$$

The overall effect of an increase in the allowability rate α on the level of optimal domestic and abroad abatement consists of a substitution effect (SE) and a quantity effect (QE). For equations (3.5) and (3.6), the first term on the right hand side is the SE and the second term is the QE. The SE is the change in abatement solely induced by the change in relative allowability, while the QE is the change in abatement induced by the need for additional abatement resulting from the allowability reduction for abroad abatement.

Figure 3.1 graphically displays the decomposition in substitution and quantity effect. The old equilibrium lies where the black dotted, downward-sloping minimum abatement line is tangent to a solid black iso-cost-curve - the firm abates x_H^0 at home and x_F^0 abroad. In doing so, the firm fulfills its abatement obligation x^{min}, as the combination lies on the black dotted line that represents all combinations of domestic and abroad abatement, which fulfill the abatement obligation. Decreasing α changes the relative valuation of domestic and abroad abatement. Domestic abatement becomes relatively more valuable and abatement abroad relatively

[42] See Appendix C for intermediate steps.

Figure 3.1.: The Effect of an Allowability Reduction for Abroad Abatement Certificates



less valuable. The black dotted line spins outward around its y-intercept and becomes the solid black, downward-sloping line. The new equilibrium lies where the solid black, new minimum abatement line, is tangent to a solid black iso-cost-curve. Abatement at home and abroad amounts to x_H^2 and x_F^2. The difference $x_H^2 - x_H^0$ gives the overall effect of a decrease in α on domestic abatement, the difference $x_F^2 - x_F^0$ gives the overall effect of a decrease in α on abatement abroad. However, the overall effect can be decomposed into two partial effects: a substitution effect (SE) and a quantity effect (QE). To isolate the SE, I look at the effect that occurred if the firm was exactly compensated for a decrease in α with a smaller abatement obligation x^{min} such that it could still uphold the old equilibrium abatement. The compensated minimum abatement line is the dashed gray, downward-sloping line. With this compensated minimum abatement line, the equilibrium abatement was x_H^1 and x_F^1. Now the difference $x_H^1 - x_H^0$ and $x_F^1 - x_F^0$ provides the isolated SE and the difference $x_H^2 - x_H^1$ and $x_F^2 - x_F^1$ the isolated QE of a decrease in α on the abatement at home and abroad. While both SE and QE go in the opposite direction of a change

in α for domestic abatement, this is only true for the QE in case of abroad abatement. The SE of abroad abatement goes in the same direction as the change in α. As indicated in the introduction, the resemblance with the textbook Slutsky decomposition, depicting the substitution and income effect of a relative price change for a consumer choosing between two goods, is not coincidental.[43] However, to be precise, it is not exactly the textbook case that is analogous to my problem at hand, but its dual problem.[44]

Likewise, in the abatement decision at hand, the firm minimizes its abatement cost, subject to a minimum abatement constraint, by optimally choosing its domestic and foreign abatement. As the allowability of abroad abatement decreases, the equilibrium abatement decision changes. This effect on equilibrium abatement is then decomposed into a substitution effect resulting from the change in relative allowability and a quantity effect resulting from the fact that, as foreign abatement counts less, the original equilibrium abatement falls short of the minimum abatement requirement. That is, domestic and possibly also abroad abatement has to increase to fill the shortfall.

Proposition 3.1.
Both partial effects of a reduction in allowability α, the substitution and quantity effects, on optimal domestic abatement, x_H^*, are negative. Therefore, the optimal amount of investment in domestic abatement, x_H^*, increases, as allowability α decreases.

Proof.
The denominator of equation (3.5) is positive, as $\alpha \in (0, 1]$ and $h''(\cdot)$, $f''(\cdot) > 0$ due to the strict convexity of cost functions $h(\cdot)$, $f(\cdot)$.

[43] E.g. Mas-Colell et al. (1995) cover the Slutsky decomposition.

[44] In the dual problem, an individual minimizes its consumption expenditure while keeping its utility constant. The individual does so by optimally choosing the consumption amounts of two different goods. Suppose now that the two different goods have different utility weights for the deciding individual and that the utility weight for one of the goods decreases. The decreased utility weight affects the distribution of consumption between the two goods. This consumption effect can be decomposed into a substitution effect resulting from the change in relative utility weights and a quantity effect resulting from the fact that consumption now falls short of fulfilling the original utility level. Either the consumption of one or the other good, or of both goods has to increase to fill this shortfall. This, in turn, leads to an increase in expenditure.

Therefore, $SE_H < 0$, as $-(1/\alpha) f'(x_F^*)$ is negative. This is due to $\alpha \in (0,1]$ and the assumption of continuously increasing abroad abatement costs.

Furthermore, $QE_H \leq 0$, as $-(1/\alpha) x_F^* f''(x_F^*)$ is non-positive. This is due to the fact that $\alpha \in (0,1]$, that $x_F \in [0,\infty)$ and that $f(\cdot)$ is strictly convex. □

The allowability reduction makes domestic abatement more valuable relative to foreign abatement. Hence, the optimal domestic abatement increases. This explains the negative SE_H in equation (3.5). Regarding the negative QE_H in equation (3.5), the argument is the following: as allowability α decreases, the original abatement allocation of domestic and abroad abatement is no longer sufficient to comply with the minimum abatement obligation x^{min}.[45] This is due to the fact that, after the decrease in the allowability rate, only a fraction of the formerly allowed abroad abatement can be used as offset. The amount of allowable abatement $x_H^0 + \alpha x_F^0$, where the superscript denotes the old equilibrium, falls short of the obligation x^{min}. This shortfall has to be compensated with an abatement increase. The increase can result from increasing domestic and abroad abatement. Therefore, the QE_H is negative. As both partial effects, of an allowability reduction on domestic abatement are negative, so is the cumulative effect of the two. That is, domestic abatement reacts with an increase to the allowability reduction.For the effect of an allowability reduction on abroad abatement, $dx_F^*/d\alpha$, the results are less straightforward.

Proposition 3.2.
While the substitution effect of a reduction in allowability α on optimal abroad abatement x_F^* is positive, the quantity effect is negative. Therefore, abroad abatement increases as a result of a decrease in allowability α if and only if the value of domestic relative to abroad equilibrium abatement is smaller than the abatement elasticity of marginal domestic abatement costs.

That is, if $x_H^*/\alpha x_F^* < \epsilon_{h'(x_H^*),x_H^*}$, *where* $\epsilon_{h'(x_H^*),x_H^*} = h''(x_H^*)\left(x_H^*/h'(x_H^*)\right)$.

[45] The prerequisite for this is that abroad abatement, occurs in the original equilibrium. If x_F^* was zero, the QE_H would be as well.

Proof.
The denominator of equation (3.6) is positive, as $\alpha \in (0,1]$ and $h''(\cdot)$, $f''(\cdot) > 0$ due to the strict convexity of cost functions $h(\cdot)$, $f(\cdot)$.

Therefore, $SE_F > 0$, as $(1/\alpha^2) f'(x_F^*)$ is positive. This is due to $\alpha \in (0,1]$ and the assumption of continuously increasing abroad abatement costs.

However, $QE_F \leq 0$, as $-h''(x_H^*)x_F^*$ is non-positive. This is due to the assumptions that $x_F \in (0,\infty]$and that $h(\cdot)$ is strictly convex.

From $SE_F > 0$ and $QE_F \leq 0$ follows directly that

$dx_F^*/d\alpha < 0$ if $SE_F < -QE_F$, while $dx_F^*/d\alpha \geq 0$ if $SE_F \geq -QE_F$.

That is, $dx_F^*/d\alpha < 0$ for $(1/\alpha) f'(x_F^*) < \alpha h''(x_H^*) x_F^*$

and $dx_F^*/d\alpha \geq 0$ for $(1/\alpha) f'(x_F^*) \geq \alpha h''(x_H^*) x_F^*$.

As in equilibrium $(1/\alpha) f'(x_F^*) = h'(x_H^*)$, this is equivalent to

$$\frac{dx_F^*}{d\alpha} < 0 \text{ iff } \frac{1}{\alpha x_F^*} < \frac{h''(x_H^*)}{h'(x_H^*)} \text{ and } \frac{dx_F^*}{d\alpha} \geq 0 \text{ iff } \frac{1}{\alpha x_F^*} \geq \frac{h''(x_H^*)}{h'(x_H^*)},$$

which is again equivalent to

$$\frac{dx_F^*}{d\alpha} < 0 \text{ iff } \frac{x_H^*}{\alpha x_F^*} < \epsilon_{h'(x_H^*),x_H^*} \text{ and } \frac{dx_F^*}{d\alpha} \geq 0 \text{ iff } \frac{x_H^*}{\alpha x_F^*} \geq \epsilon_{h'(x_H^*),x_H^*}.$$

□

Decreasing the allowability of abroad abatement makes domestic abatement more valuable relative to abroad abatement. This works towards a decrease of optimal abroad abatement and explains the positive SE_F in equation (3.6). Regarding the negative QE_F in equations (3.6), the same argument holds as for Proposition 1: as allowability α decreases, the original abatement allocation of domestic and abroad abatement no longer suffices to comply with the minimum abatement obligation x^{min}. This shortage has to be compensated with an abatement increase. The increase can result from increasing domestic and abroad abatement, therefore the QE_F is negative.

As substitution and quantity effects point into different directions and neither clearly outweighs the other, an allowability reduction can a priori increase abroad abatement, leave it unchanged or decrease it.

The case where abroad abatement decreases as a result of an allowability reduction is unsurprising. This is the case in which the positive SE_F outweighs the negative QE_F. That means that the overall effect of a decrease in allowability α on abroad abatement goes in the same direction as the corresponding substitution effect does.

More interesting is the case of Proposition 3.2, in which abroad abatement increases due to the allowability reduction. An increase of abroad abatement occurs when the negative QE_F outweighs the positive SE_F. This is the case when a relatively large part of the additional abatement need resulting from a decreased α is covered by expanding abroad abatement - of the total quantity effect QE_H+QE_F, i.e. of the increase in the firm's overall abatement, a relatively large part is allotted to abroad abatement. Generally, either domestic abatement or abroad abatement, or both, can increase to fill the additional abatement need, but the increase of abroad abatement will be strong enough to overcompensate the abatement reduction due to the relative change in allowability only if the negative QE_F on abroad abatement outweighs the positive SE_F on abroad abatement. That is, abroad abatement increases if the following is true:

$$\frac{x_H^*}{\alpha x_F^*} < \epsilon_{h'\left(x_H^*\right),x_H^*}. \tag{3.7}$$

The left hand side of condition (3.7) is domestic over abroad equilibrium abatement where abroad abatement is discounted by the allowability rate α such that the entire expression is displayed in domestic abatement units. If this relative value of domestic to abroad abatement is smaller than the elasticity of marginal domestic abatement costs, abroad abatement increases with a reduction in allowability α. Condition (3.7) is more likely to be fulfilled if (i) the policy advantage at home is small (alpha is large) and (ii) the marginal abatement cost at home at the optimum reacts strongly to increases in domestic abatement. The condition implies that abroad abatement increases as a reaction to an allowability reduction when the policy advantage at home weighted with relative domestic equilibrium abatement

is smaller than the reaction of the marginal domestic abatement costs to a 1% increase of domestic abatement. Further, for $h''(x_H^*) \to 0$ the condition would never be fulfilled, but as $h''(x_H^*)$ gets larger so does the probability that condition (3.7) is fulfilled. That is, the more convex domestic abatement costs are in equilibrium, the more likely is it that abroad abatement increases with a decrease in α.The intuition behind this is that a decrease in α makes abroad abatement more expensive relative to domestic abatement but, as long as positive amounts of abroad abatement are carried out, also increases the amount of effective abatement needed to meet the abatement obligation. As abroad abatement becomes more expensive, the firm reduces abroad abatement and increases domestic abatement. In addition to that, however, the firm must increase its overall abatement to ensure that the abatement obligation is met. This increase will be covered solely by a domestic abatement increase when marginal domestic abatement costs are close to constant. In this case, all additional units of domestic abatement cost are nearly the same as the last unit in the pre-change equilibrium. However, as soon as domestic abatement costs are sufficiently convex in equilibrium, that is, as soon as the costs for additional units of domestic abatement increase sufficiently quickly, the increase will be covered by both an increase in domestic and in abroad abatement.

3.3. Alternative Abatement Option: Buying Certificates on a Secondary Market

So far, I have assumed that a firm can only decide between actively abating at home or abroad. However, the firm might have an additional option: buying emission allowances on a secondary market. One of these allowances is equivalent to the abatement of one tonne of CO_2 equivalent and fully allowable to the firm's abatement obligation.[46]The firm I have in mind is subject to an emission trading scheme (ETS) and affected by the change

[46]I do not make a distinction between allowances generated at home or abroad. Allowances x_A can be generated both ways, but are measured in units of domestic allowances.

in the allowability rate. It also uses the Clean Development Mechanism. This firm can buy allowances x_A at price p.

3.3.1. Exogenous Price

Suppose a firm faces an exogenous price p on the secondary market for emission certificates. That is, the firm's abatement decision has no effect on the price and, therefore, neither has a change in α.[47] The firm can either be efficient or inefficient. If efficient, the firm has low marginal abatement costs and sells abatement units on the market. If inefficient, the firm has high marginal abatement costs and buys abatement units on the market.[48] Independent of being a seller or buyer of emission certificates, the firm minimizes:

$$\min_{x_H, x_F, x_A} h(x_H) + f(x_F) + p x_A$$

$$s.t.\ x^{min} \leq x_H + \alpha x_F + x_A,$$

where $x_A < 0$ if the firm is efficient and $x_A > 0$ if the firm is inefficient. This yields the first order conditions:

$$p = h'(\widetilde{x}_H) = \frac{1}{\alpha} f'(\widetilde{x}_F) \tag{3.8}$$

and

$$x^{min} = \widetilde{x}_H + \alpha \widetilde{x}_F + \widetilde{x}_A. \tag{3.9}$$

Again, $\widetilde{x}_A < 0$ if the firm is efficient and $\widetilde{x}_A > 0$ if the firm is inefficient.[49]

Condition (3.8) ensures that marginal abatement costs are equalized between the three abatement options. The marginal cost of buying (marginal benefit of selling) abatement is simply the price. Condition (3.9) secures

[47] Only one firm or a small fraction of firms that is subject to the ETS and uses the CDM is affected by the allowability change.

[48] Low marginal abatement costs imply that $h'(x_H^*) = (1/\alpha) f'(x_F^*) < p$. High marginal abatement costs imply that $h'(x_H^*) = (1/\alpha) f'(x_F^*) > p$, where x_H^* and x_F^* correspond to the optimal choices in the case without a secondary market in the previous section.

[49] $\widetilde{x}_H$, $\widetilde{x}_F$ and $\widetilde{x}_A$ denote equilibrium choices.

that the minimum abatement obligation is fulfilled in equilibrium. Let $\widetilde{x}_{AS}$ denotes the equilibrium supply of allowances sold if the firm is a seller and $\widetilde{x}_{AD}$ the equilibrium demand for allowances bought if the firm is a buyer.

Proposition 3.3.
When buying emission certificates constitutes an additional abatement option and prices are exogenous, a decrease in allowability α has no effect on domestic abatement. However, abroad abatement and the number of sold allowances each decrease if the firm is a seller, while bought allowances increase if the firm is a buyer.

Proof.
Total differentiation of equations (3.8) and (3.9) results in the following effects of a change in allowability α on domestic and abroad abatement:

$$\frac{d\widetilde{x}_H}{d\alpha} = \frac{1}{h''(\widetilde{x}_H)}\frac{dp}{d\alpha} \text{ and } \frac{d\widetilde{x}_F}{d\alpha} = \frac{1}{\alpha}\frac{f'(\widetilde{x}_F)}{f''(\widetilde{x}_F)}.$$

These effects are independent of the firm being a seller or buyer of emission certificates. But the effect on the choice of how much to sell/buy, of course, depends on being a seller or buyer. If the firm is a seller, it is

$$\frac{d\widetilde{x}_{AS}}{d\alpha} = \frac{f'(\widetilde{x}_F)}{f''(\widetilde{x}_F)} + \widetilde{x}_F,$$

if the firm is a buyer, it is

$$\frac{d\widetilde{x}_{AD}}{d\alpha} = -\frac{f'(\widetilde{x}_F)}{f''(\widetilde{x}_F)} - \widetilde{x}_F.$$

As p is by assumption exogenous, that is, ${}^{dp}/_{d\alpha} = 0$, the effect on domestic abatement is

$$\frac{d\widetilde{x}_H}{d\alpha} = \frac{1}{h''(\widetilde{x}_H)}\frac{dp}{d\alpha} = 0.$$

The effect on abroad abatement is

$$\frac{d\widetilde{x}_F}{d\alpha} = \frac{1}{\alpha}\frac{f'(\widetilde{x}_F)}{f''(\widetilde{x}_F)} > 0,$$

this results directly from the assumption of continuously increasing and convex abroad abatement costs and from $\alpha \in (0, 1]$. The effect on sold

abatement is

$$\frac{dx'_{AS}}{d\alpha} = \frac{f'(\widetilde{x}_F)}{f''(\widetilde{x}_F)} + \widetilde{x}_F > 0,$$

the first term is positive due to the assumption of continuously increasing and convex abroad abatement costs, and the second term is non-negative, as $x_F \in [0, \infty)$. Likewise, the effect on bought abatement is

$$\frac{d\widetilde{x}_{AD}}{d\alpha} = -\frac{f'(\widetilde{x}_F)}{f''(\widetilde{x}_F)} - \widetilde{x}_F < 0.$$

□

In the case where the market price of domestic emission allowances is exogenous, i.e. unaffected by the abatement choice of the firm under consideration, the firm's domestic abatement remains unaffected by changes in the allowability parameter α, while its abroad abatement and the amount of allowances sold decreases (the amount of allowances bought increases). Intuitively, these effects can be explained by the following reasoning. Suppose in equilibrium the firm uses a mix of all three abatement options. An increase in the allowability parameter, α, then triggers similar effects as in Section 3.2. First, compared to the old equilibrium, abroad abatement becomes more expensive compared to the other options, and, second, a larger amount of abatement is needed to fulfill the obligation x^{min}.

If the firm is a selling firm, starting in an equilibrium in which it used both domestic and abroad abatement and sold over-produced abatement on the secondary market, a decrease in α reduces abroad abatement. As a direct consequence, the quantity sold, x_{AS}, is reduced. The firm reduces the quantity sold to provide the additional units needed to fulfill x^{min} as the marginal sales benefits foregone are smaller than the abatement costs for one additional unit of domestic or abroad abatement would be. This is the case, as the cost functions $h(\cdot)$ and $f(\cdot)$ are strictly convex while the market price p is fixed.

Also, if the firm is a buying firm starting in an equilibrium in which it used all three abatement options (domestic and abroad abatement and buying on the secondary market), a decrease in α reduces abroad abatement. The

firm uses the cheapest option to compensate for the abatement loss. The cheapest option is to increase the amount of abatement bought, as the market price p is fixed, while abatement costs at home and abroad follow a convex increase.

Domestic abatement is unaffected by the allowability reduction both if the firm is an efficient, selling firm and if the firm is an inefficient buying firm. Hence, domestic abatement remains unchanged, abroad abatement decreases and an efficient firm decrease its supply while an inefficient firm increases its demand.

These results are contrary to those in Section 3.2. In Section 3.2, the analysis without a fixed price option of selling/buying allowances, I find that domestic abatement always increases and abroad abatement might either increase or decrease. This was due to the fact that a decrease in α generated the need for more abatement and this need had to be fulfilled using the two options at hand, domestic and abroad abatement. However, as soon as a third option exists, this third option is chosen whenever it is cheaper than the other two. Reducing fixed price supply or increasing fixed price demand is always cheaper than abating at increasing marginal abatement costs. However, once the price for bought allowances is endogenous, the analysis and the resulting effects change substantially, as will be shown in the next subsection.

3.3.2. Endogenous Price

Now suppose there are two firms i and j that have asymmetric abatement obligations $x_i^{min} \geq x_j^{min}$ but face the same abatement cost functions $h(\cdot)$ and $f(\cdot)$ at home and abroad.[50] Furthermore, the firms engage in bilateral trade of emission certificates and the price for traded certificates is a result of this bilateral interaction.

Proposition 3.4.
Consider two firms i and j with abatement obligations $x_i^{min} \geq x_j^{min}$. With

[50] One can think of two firms that face similar abatement opportunities and receive the same amount of initial allowances prior to my analysis, but differ in the emission intensity of their final good production process. That is, they differ in the amount of emissions they need to offset and therefore face different abatement obligations.

an endogenous price for traded certificates, firms i and j abate $\widetilde{x}_i = \widetilde{x}_j = (x_i^{min}+x_j^{min})/2$ $\forall \alpha \in (0,1]$. Furthermore, i buys $\left((x_i^{min}+x_j^{min})/2\right) - x_j^{min}$ certificates from j.[51]

Proof.
Let p be the equilibrium price from equation (3.8). For p and $\forall \alpha \in (0,1]$, $p = h'(\widetilde{x}_{H_i}) = (1/\alpha) f'(\widetilde{x}_{F_i})$ and $p = h'\left(\widetilde{x}_{H_j}\right) = (1/\alpha) f'\left(\widetilde{x}_{F_j}\right)$ have to hold in equilibrium.

That is, $h'(\widetilde{x}_{H_i}) = (1/\alpha) f'(\widetilde{x}_{F_i}) = h'\left(\widetilde{x}_{H_j}\right) = (1/\alpha) f'\left(\widetilde{x}_{F_j}\right)$.

Therefore, $\widetilde{x}_{H_i} = \widetilde{x}_{H_j}$ and $\widetilde{x}_{F_i} = \widetilde{x}_{F_j}$ must hold as well.[52]

By definition, overall abatement must be $x_i^{min} + x_j^{min}$. As $\widetilde{x}_i = \widetilde{x}_j$, i and j share the overall abatement,

$$\widetilde{x}_i = \widetilde{x}_j = \frac{x_i^{min} + x_j^{min}}{2}.$$

Therefore, as $x_i^{min} \geq x_j^{min}$, j sells

$$\widetilde{x}_{AS_j} = \frac{x_i^{min} + x_j^{min}}{2} - x_j^{min} = \widetilde{x}_{AD_i}$$

units of abatement to i. □

For two firms i and j that differ only in their abatement obligation, $x_i^{min} \geq x_j^{min}$, but are completely symmetric with respect to their abatement cost functions $h(\cdot)$ at home and $f(\cdot)$ abroad, optimal outputs must be the same if trade is possible between the two. Intuitively, if i abated more than j, the marginal abatement costs would not be equalized between the two. Rather, i would have larger marginal abatement costs than j. Reducing its abatement by one unit would generate more cost savings for i than increasing its abatement by one unit would generate in additional costs for j. Hence, they equalize their marginal costs by equalizing their abatement and j sells its overproduction to i, who needs it to comply with its abatement obligation.

[51] Equilibrium choices are marked with tildes.

[52] Recall that i and j have identical cost functions $h(\cdot)$ for domestic and $f(\cdot)$ for abroad abatement and that the asymmetry is introduced via $x_i^{min} \geq x_j^{min}$.

Corollary 3.1.
With an endogenous price for traded certificates, the effects of a reduction in α are exactly as in Propositions 3.1 and 3.2.

Proof.
From Proposition 3.4 follows that the amount sold

$$\widetilde{x}_{AS_j} = \frac{x_i^{min} + x_j^{min}}{2} - x_j^{min}$$

is independent of α ($d\widetilde{x}_{AS_j}/d\alpha = 0$). That is, the effect of a reduction in α can only be allotted to firm $i's$ individual decision to invest in x_{H_i} and x_{F_i}. As the decrease in α as well as the abatement obligation x_i^{min} is the same as without trade, the effects on $\widetilde{x}_{H_i}$ and $\widetilde{x}_{F_i}$ are analogous to the ones without trade, as well. The same holds true for firm j. From here on, see the proof of Propositions 3.1 and 3.2. □

If two firms bilaterally trade certificates on a secondary market, the amount of emission certificates that is traded is unaffected by changes in α. This is due to the fact that the amount traded is half the difference between the high and low abatement obligation and this difference is independent of changes in allowability α due to the exogeneity of the abatement obligations. Consequently, the increased need for abatement resulting from the fact that abroad equilibrium abatement now counts less to the abatement obligation than before has to be fully dealt with by the individual firm. That is, as in the analysis without trade, the firm only has two options to meet the increased need for abatement: domestic and abroad abatement. An allowability reduction increases domestic abatement. At the same time, foreign abatement can increase (decrease) as a result of a decrease in allowability α if the value of domestic equilibrium abatement relative to abroad equilibrium abatement is smaller than (larger than) the abatement elasticity of marginal domestic abatement costs.

As the firm's problem is analogous to the one without trade, condition (3.7) applies again. That is, abatement abroad increases, reacting to an allowability reduction, when in equilibrium the policy advantage at home

weighted with domestic relative to abroad abatement is smaller than the abatement elasticity of marginal domestic abatement costs.

While the amount of traded emission certificates remains unchanged, the price for the intramarginal certificate increases with an allowability reduction. As marginal abatement costs over all abatement options have to be equalized in equilibrium and marginal abatement costs at home and abroad increase with a decrease in α, the same has to hold for p.

The fact that traded emissions remain unchanged despite the price increase is due to the symmetry of firms i and j with respect to the abatement cost functions. This symmetry implies that the supply and demand curves for traded certificates have the same elasticities. As, in addition to that, the change in α affects both firms in the same way, the supply curve shifts upwards in the same way that the demand curve shifts upwards. That is, the price increases, but the amount of traded emission credits remains the same.

This would change if firms i and j were asymmetric with respect to their abatement cost functions and supply and demand curves had different elasticities. With a decrease in α, the amount traded would then increase if supply was more elastic than demand and would decrease if supply was less elastic than demand. The intuition is that the amount traded would increase if the seller's reaction were more elastic to the price effect, but would decrease if the buyer's reaction were more elastic to the price effect.

In contrast to the case with an exogenous price, however, $d\widetilde{x}_H/d\alpha$ will never be zero, but will always be negative. Furthermore, while the condition for $d\widetilde{x}_F/d\alpha < 0$ would be stricter if the firms had asymmetric elasticities of supply and demand, an increase of foreign abatement following from the allowability reduction can never be ruled out entirely. The reason for this is that the supply of emission certificates can never be perfectly elastic in the two firm case as abatement cost functions are convex by assumption.[53]

[53] To offer perfectly elastic supply, selling firm j would need constant marginal abatement costs (where marginal abatement costs are larger than average abatement costs) for the domestic and abroad abatement that makes up its supply. However, firm j has, by assumption, convex abatement costs for domestic and abroad abatement. Therefore, its supply of emission certificates will never be perfectly elastic.

3.4. Conclusion

This chapter considers a firm's decision to abate at home and abroad in a classical economic framework, i.e., cost minimization under a minimum output constraint. In this framework, decreasing the allowability of abroad emission certificates induces an increase of domestic abatement, but the effect on abroad abatement is ambiguous. I show that abroad abatement can also increase, when the policy advantage at home weighted with domestic relative to abroad abatement is smaller than the abatement elasticity of marginal domestic abatement costs. These findings are robust to the introduction of a secondary market for certificates as long as the price for certificates reacts to the change in allowability.

With respect to the policy goal associated with an allowability reduction, the objective of providing a counter measure against non-additionality - by breaking the pure offset character of the CDM and generating real emission reductions - seems to be met. The results in this chapter imply that emissions of affected firms (weakly) decrease due to the allowability reduction for CERs. Emissions decrease if firms used abroad abatement before the policy change and continue to use it afterward, and emissions would remain unchanged in the extreme case in which abroad abatement was fully substituted for by domestic abatement.

My results, however, do not only suggest that overall abatement increases, but also that a part of this increase can happen abroad. If abroad abatement increases, an implication of this increase could be the reinforcement of the crowding out of low-hanging fruits in the developing world.

Likewise, reducing the allowability of abroad abatement might fail to reduce the monitoring problem regarding abroad abatement considered in Chapter 2 if abroad abatement does not react with a decrease, but with an increase.

Consequently, a quota on abroad abatement, as considered in Chapter 2, may be (weakly) superior to an allowability or discount rate whenever policy-makers care about the crowding-out of (future) abatement efforts of the developing countries or care to reduce the monitoring problem regarding abroad abatement. The reason for this is that with a quota the quantity effect is omitted. Admittedly for every allowability reduction, there should

exist a corresponding reduction in the total abatement obligation such that the combined policy (allowability reduction plus reduction in abatement obligation) leads to an equivalent outcome as a given quota. However, politicians never considered decreasing the abatement obligation along with the allowability of abroad abatement. That is, opposing effects on the abatement allocation resulting from discount or allowability rate and quota can not be ruled out.

While I show that the possibility for the increase of abroad abatement exists, it is up to further research to provide deeper insights into the condition under which we see an increase of abroad abatement. A means to generate these insights could be the empirical estimation of the domestic policy advantage and the elasticity of marginal domestic abatement costs, which determine the condition for an increase of CDM abatement.

Appendix A.

Appendix to Chapter 1

Legal Framework on the Clean Development Mechanism

Articles 3 and 12 of the Kyoto Protocol[54]

Article 3

1. The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.

2. Each Party included in Annex I shall, by 2005, have made demonstrable progress in achieving its commitments under this Protocol.

3. The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I. The greenhouse gas emissions by sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8.

[54] UNFCCC (1997)

4. Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide, for consideration by the Subsidiary Body for Scientific and Technological Advice, data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to, or subtracted from, the assigned amounts for Parties included in Annex I, taking into account uncertainties, transparency in reporting, verifiability, the methodological work of the Intergovernmental Panel on Climate Change, the advice provided by the Subsidiary Body for Scientific and Technological Advice in accordance with Article 5 and the decisions of the Conference of the Parties. Such a decision shall apply in the second and subsequent commitment periods. A Party may choose to apply such a decision on these additional human-induced activities for its first commitment period, provided that these activities have taken place since 1990.

5. The Parties included in Annex I undergoing the process of transition to a market economy whose base year or period was established pursuant to decision 9/CP.2 of the Conference of the Parties at its second session shall use that base year or period for the implementation of their commitments under this Article. Any other Party included in Annex I undergoing the process of transition to a market economy which has not yet submitted its first national communication under Article 12 of the Convention may also notify the Conference of the Parties serving as the meeting of the Parties to this Protocol that it intends to use an historical base year or period other than 1990 for the implementation of its commitments under this Article. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall decide on the acceptance of such notification.

6. Taking into account Article 4, paragraph 6, of the Convention, in the implementation of their commitments under this Protocol other than those under this Article, a certain degree of flexibility shall be allowed by the Conference of the Parties serving as the meeting of the Parties to this Protocol to the Parties included in Annex I undergoing the process of transition to a market economy.

7. In the first quantified emission limitation and reduction commitment period, from 2008 to 2012, the assigned amount for each Party included in Annex I shall be equal to the percentage inscribed for it in Annex B of its aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A in 1990, or the base year or period determined in accordance with paragraph 5 above, multiplied by five. Those Parties included in Annex I for whom land-use change and forestry constituted a net source of greenhouse gas emissions in 1990 shall include in their 1990 emissions base year or period the aggregate anthropogenic carbon dioxide equivalent emissions by sources minus removals by sinks in 1990 from land-use change for the purposes of calculating their assigned amount.

8. Any Party included in Annex I may use 1995 as its base year for hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride, for the purposes of the calculation referred to in paragraph 7 above.

9. Commitments for subsequent periods for Parties included in Annex I shall be established in amendments to Annex B to this Protocol, which shall be adopted in accordance with the provisions of Article 21, paragraph 7. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall initiate the consideration of such commitments at least seven years before the end of the first commitment period referred to in paragraph 1 above.

10. Any emission reduction units, or any part of an assigned amount, which a Party acquires from another Party in accordance with the provisions of Article 6 or of Article 17 shall be added to the assigned amount for the acquiring Party.

11. Any emission reduction units, or any part of an assigned amount, which a Party transfers to another Party in accordance with the provisions of Article 6 or of Article 17 shall be subtracted from the assigned amount for the transferring Party.

12. Any certified emission reductions which a Party acquires from another Party in accordance with the provisions of Article 12 shall be added to the assigned amount for the acquiring Party.

13. If the emissions of a Party included in Annex I in a commitment period are less than its assigned amount under this Article, this difference shall, on request of that Party, be added to the assigned amount for that Party for subsequent commitment periods.

14. Each Party included in Annex I shall strive to implement the commitments mentioned in paragraph 1 above in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention. In line with relevant decisions of the Conference of the Parties on the implementation of those paragraphs, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, consider what actions are necessary to minimize the adverse effects of climate change and/or the impacts of response measures on Parties referred to in those paragraphs. Among the issues to be considered shall be the establishment of funding, insurance and transfer of technology.

Article 12

1. A clean development mechanism is hereby defined.

2. The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.

3. Under the clean development mechanism:

(a) Parties not included in Annex I will benefit from project activities resulting in certified emission reductions; and

(b) Parties included in Annex I may use the certified emission reductions accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, as determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

4. The clean development mechanism shall be subject to the authority and guidance of the Conference of the Parties serving as the meeting of the Parties to this Protocol and be supervised by an executive board of the clean development mechanism.

5. Emission reductions resulting from each project activity shall be certified by operational entities to be designated by the Conference of the Parties serving as the meeting of the Parties to this Protocol, on the basis of:

(a) Voluntary participation approved by each Party involved;

(b) Real, measurable, and long-term benefits related to the mitigation of climate change; and

(c) Reductions in emissions that are additional to any that would occur in the absence of the certified project activity.

6. The clean development mechanism shall assist in arranging funding of certified project activities as necessary.

7. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, elaborate modalities and procedures with the objective of ensuring transparency, efficiency and accountability through independent auditing and verification of project activities.

8. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall ensure that a share of the proceeds from certified project activities is used to cover administrative expenses as well as to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation.

9. Participation under the clean development mechanism, including in activities mentioned in paragraph 3 (a) above and in the acquisition of certified emission reductions, may involve private and/or public entities, and is to be subject to whatever guidance may be provided by the executive board of the clean development mechanism.

10. Certified emission reductions obtained during the period from the year 2000 up to the beginning of the first commitment period can be used to assist in achieving compliance in the first commitment period.

Modalities and Procedures for a Clean Development Mechansim[55]

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ANNEX

Modalities and procedures for a clean development mechanism

A. Definitions

1. For the purposes of the present annex the definitions contained in Article 1[1] and the provisions of Article 14 shall apply. Furthermore:

(a) An "emission reduction unit" or "ERU" is a unit issued pursuant to the relevant provisions in the annex to decision 13/CMP.1 and is equal to one metric tonne of carbon dioxide equivalent, calculated using global warming potentials defined by decision 2/CP.3 or as subsequently revised in accordance with Article 5;

(b) A "certified emission reduction" or "CER" is a unit issued pursuant to Article 12 and requirements thereunder, as well as the relevant provisions in these modalities and procedures, and is equal to one metric tonne of carbon dioxide equivalent, calculated using global warming potentials defined by decision 2/CP.3 or as subsequently revised in accordance with Article 5;

(c) An "assigned amount unit" or "AAU" is a unit issued pursuant to the relevant provisions in the annex to decision 13/CMP.1 and is equal to one metric tonne of carbon dioxide equivalent, calculated using global warming potentials defined by decision 2/CP.3 or as subsequently revised in accordance with Article 5;

(d) A "removal unit" or "RMU" is a unit issued pursuant to the relevant provisions in the annex to decision 13/CMP.1 and is equal to one metric tonne of carbon dioxide equivalent, calculated using global warming potentials defined by decision 2/CP.3 or as subsequently revised in accordance with Article 5;

(e) "Stakeholders" means the public, including individuals, groups or communities affected, or likely to be affected, by the proposed clean development mechanism project activity.

B. Role of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol

2. The Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP) shall have authority over and provide guidance to the clean development mechanism (CDM).

3. The COP/MOP shall provide guidance to the Executive Board by taking decisions on:

(a) The recommendations made by the Executive Board on its rules of procedure;

(b) The recommendations made by the Executive Board, in accordance with provisions of decision 17/CP.7, the present annex and relevant decisions of the COP/MOP;

(c) The designation of operational entities accredited by the Executive Board in accordance with Article 12, paragraph 5, and accreditation standards contained in appendix A below.

4. The COP/MOP shall further:

(a) Review annual reports of the Executive Board;

[1] In the context of this annex, "Article" refers to an Article of the Kyoto Protocol, unless otherwise specified.

[55] UNFCCC (2005)

(b) Review the regional and subregional distribution of designated operational entities and take appropriate decisions to promote accreditation of such entities from developing country Parties;[2]

(c) Review the regional and subregional distribution of CDM project activities with a view to identifying systematic or systemic barriers to their equitable distribution and take appropriate decisions, based, inter alia, on a report by the Executive Board;

(d) Assist in arranging funding of CDM project activities, as necessary.

C. Executive Board

5. The Executive Board shall supervise the CDM, under the authority and guidance of the COP/MOP, and be fully accountable to the COP/MOP. In this context, the Executive Board shall:

(a) Make recommendations to the COP/MOP on further modalities and procedures for the CDM, as appropriate;

(b) Make recommendations to the COP/MOP on any amendments or additions to rules of procedure for the Executive Board contained in the present annex, as appropriate;

(c) Report on its activities to each session of the COP/MOP;

(d) Approve new methodologies relating to, inter alia, baselines, monitoring plans and project boundaries in accordance with the provisions of appendix C below;

(e) Review provisions with regard to simplified modalities, procedures and the definitions of small-scale project activities and make recommendations to the COP/MOP;

(f) Be responsible for the accreditation of operational entities, in accordance with accreditation standards contained in appendix A below, and make recommendations to the COP/MOP for the designation of operational entities, in accordance with Article 12, paragraph 5. This responsibility includes:

(i) Decisions on re-accreditation, suspension and withdrawal of accreditation;

(ii) Operationalization of accreditation procedures and standards;

(g) Review the accreditation standards in appendix A below and make recommendations to the COP/MOP for consideration, as appropriate;

(h) Report to the COP/MOP on the regional and subregional distribution of CDM project activities with a view to identifying systematic or systemic barriers to their equitable distribution;

(i) Make publicly available relevant information, submitted to it for this purpose, on proposed CDM project activities in need of funding and on investors seeking opportunities, in order to assist in arranging funding of CDM project activities, as necessary;

(j) Make any technical reports commissioned available to the public and provide a period of at least eight weeks for public comments on draft methodologies and guidance before documents are finalized and any recommendations are submitted to the COP/MOP for their consideration;

[2] In the context of this annex, "Party" refers to a Party to the Kyoto Protocol, unless otherwise specified.

(k) Develop, maintain and make publicly available a repository of approved rules, procedures, methodologies and standards;

(l) Develop and maintain the CDM registry as defined in appendix D below;

(m) Develop and maintain a publicly available database of CDM project activities containing information on registered project design documents, comments received, verification reports, its decisions as well as information on all CERs issued;

(n) Address issues relating to observance of modalities and procedures for the CDM by project participants and/or operational entities, and report on them to the COP/MOP;

(o) Elaborate and recommend to the COP/MOP for adoption at its next session procedures for conducting the reviews referred to in paragraphs 41 and 65 below including, inter alia, procedures to facilitate consideration of information from Parties, stakeholders and UNFCCC accredited observers. Until their adoption by the COP/MOP, the procedures shall be applied provisionally;

(p) Carry out any other functions ascribed to it in decision 17/CP.7, the present annex and relevant decisions of the COP/MOP.

6. Information obtained from CDM project participants marked as proprietary or confidential shall not be disclosed without the written consent of the provider of the information, except as required by national law. Information used to determine additionality as defined in paragraph 43 below, to describe the baseline methodology and its application, and to support an environmental impact assessment referred to in paragraph 37 (c) below, shall not be considered as proprietary or confidential.

7. The Executive Board shall comprise 10 members from Parties to the Kyoto Protocol, as follows: one member from each of the five United Nations regional groups, two other members from the Parties included in Annex I, two other members from the Parties not included in Annex I, and one representative of the small island developing States, taking into account the current practice in the Bureau of the Conference of the Parties.

8. Members, including alternate members, of the Executive Board shall:

(a) Be nominated by the relevant constituencies referred to in paragraph 7 above and be elected by the COP/MOP. Vacancies shall be filled in the same way;

(b) Be elected for a period of two years and be eligible to serve a maximum of two consecutive terms. Terms as alternate members do not count. Five members and five alternate members shall be elected initially for a term of three years and five members and five alternate members for a term of two years. Thereafter, the COP/MOP shall elect, every year, five new members, and five new alternate members, for a term of two years. Appointment pursuant to paragraph 11 below shall count as one term. The members, and alternate members, shall remain in office until their successors are elected;

(c) Possess appropriate technical and/or policy expertise and shall act in their personal capacity. The cost of participation of members, and of alternate members, from developing country Parties and other Parties eligible under UNFCCC practice shall be covered by the budget for the Executive Board;

(d) Be bound by the rules of procedure of the Executive Board;

(e) Take a written oath of service witnessed by the Executive Secretary of the UNFCCC or his/her authorized representative before assuming his or her duties;

(f) Have no pecuniary or financial interest in any aspect of a CDM project activity or any designated operational entity;

(g) Subject to their responsibilities to the Executive Board, not disclose any confidential or proprietary information coming to their knowledge by reason of their duties for the Executive Board. The duty of the member, including alternate member, not to disclose confidential information constitutes an obligation in respect of that member, and alternate member, and shall remain an obligation after the expiration or termination of that member's function for the Executive Board.

9. The COP/MOP shall elect an alternate for each member of the Executive Board based on the criteria in paragraphs 7 and 8 above. The nomination by a constituency of a candidate member shall be accompanied by a nomination for a candidate alternate member from the same constituency.

10. The Executive Board may suspend and recommend to the COP/MOP the termination of the membership of a particular member, including an alternate member, for cause including, inter alia, breach of the conflict of interest provisions, breach of the confidentiality provisions, or failure to attend two consecutive meetings of the Executive Board without proper justification.

11. If a member, or an alternate member, of the Executive Board resigns or is otherwise unable to complete the assigned term of office or to perform the functions of that office, the Executive Board may decide, bearing in mind the proximity of the next session of the COP/MOP, to appoint another member, or an alternate member, from the same constituency to replace the said member for the remainder of that member's mandate.

12. The Executive Board shall elect its own Chair and Vice-Chair, with one being a member from a Party included in Annex I and the other being from a Party not included in Annex I. The positions of Chair and Vice-Chair shall alternate annually between a member from a Party included in Annex I and a member from a Party not included in Annex I.

13. The Executive Board shall meet as necessary but no less than three times a year, bearing in mind the provisions of paragraph 41 below. All documentation for Executive Board meetings shall be made available to alternate members.

14. At least two thirds of the members of the Executive Board, representing a majority of members from Parties included in Annex I and a majority of members from Parties not included in Annex I, must be present to constitute a quorum.

15. Decisions by the Executive Board shall be taken by consensus, whenever possible. If all efforts at reaching a consensus have been exhausted and no agreement has been reached, decisions shall be taken by a three-fourths majority of the members present and voting at the meeting. Members abstaining from voting shall be considered as not voting.

16. Meetings of the Executive Board shall be open to attendance, as observers, by all Parties and by all UNFCCC accredited observers and stakeholders, except where otherwise decided by the Executive Board.

17. The full text of all decisions of the Executive Board shall be made publicly available. The working language of the Executive Board shall be English. Decisions shall be made available in all six official languages of the United Nations.

18. The Executive Board may establish committees, panels or working groups to assist it in the performance of its functions. The Executive Board shall draw on the expertise necessary to perform its functions, including from the UNFCCC roster of experts. In this context, it shall take fully into account the consideration of regional balance.

19. The secretariat shall service the Executive Board.

D. Accreditation and designation of operational entities

20. The Executive Board shall:

(a) Accredit operational entities which meet the accreditation standards contained in appendix A below;

(b) Recommend the designation of operational entities to the COP/MOP;

(c) Maintain a publicly available list of all designated operational entities;

(d) Review whether each designated operational entity continues to comply with the accreditation standards contained in appendix A below and on this basis confirm whether to reaccredit each operational entity every three years;

(e) Conduct spot-checking at any time and, on the basis of the results, decide to conduct the above-mentioned review, if warranted.

21. The Executive Board may recommend to the COP/MOP to suspend or withdraw the designation of a designated operational entity if it has carried out a review and found that the entity no longer meets the accreditation standards or applicable provisions in decisions of the COP/MOP. The Executive Board may recommend the suspension or withdrawal of designation only after the designated operational entity has had the possibility of a hearing. The suspension or withdrawal is with immediate effect, on a provisional basis, once the Executive Board has made a recommendation, and remains in effect pending a final decision by the COP/MOP. The affected entity shall be notified, immediately and in writing, once the Executive Board has recommended its suspension or withdrawal. The recommendation by the Executive Board and the decision by the COP/MOP on such a case shall be made public.

22. Registered project activities shall not be affected by the suspension or withdrawal of designation of a designated operational entity unless significant deficiencies are identified in the relevant validation, verification or certification report for which the entity was responsible. In this case, the Executive Board shall decide whether a different designated operational entity shall be appointed to review, and where appropriate correct, such deficiencies. If such a review reveals that excess CERs were issued, the designated operational entity whose accreditation has been withdrawn or suspended shall acquire and transfer, within 30 days of the end of review, an amount of reduced tonnes of carbon dioxide equivalent equal to the excess CERs issued, as determined by the Executive Board, to a cancellation account maintained in the CDM registry by the Executive Board.

23. Any suspension or withdrawal of a designated operational entity that adversely affects registered project activities shall be recommended by the Executive Board only after the affected project participants have had the possibility of a hearing.

24. Any costs relating to the review referred to in paragraph 22 above shall be borne by the designated operational entity whose designation has been withdrawn or suspended.

25. The Executive Board may seek assistance in performing the functions in paragraph 20 above, in accordance with the provisions of paragraph 18 above.

E. Designated operational entities

26. Designated operational entities shall be accountable to the COP/MOP through the Executive Board and shall comply with the modalities and procedures in decision 17/CP.7, the present annex and relevant decisions of the COP/MOP and the Executive Board.

27. A designated operational entity shall:

(a) Validate proposed CDM project activities;

(b) Verify and certify reductions in anthropogenic emissions by sources of greenhouse gases;

(c) Comply with applicable laws of the Parties hosting CDM project activities when carrying out its functions referred to in subparagraph (e) below;

(d) Demonstrate that it, and its subcontractors, have no real or potential conflict of interest with the participants in the CDM project activities for which it has been selected to carry out validation or verification and certification functions;

(e) Perform one of the following functions relating to a given CDM project activity: validation or verification and certification. Upon request, the Executive Board may, however, allow a single designated operational entity to perform all these functions within a single CDM project activity;

(f) Maintain a publicly available list of all CDM project activities for which it has carried out validation, verification and certification;

(g) Submit an annual activity report to the Executive Board;

(h) Make information obtained from CDM project participants publicly available, as required by the Executive Board. Information marked as proprietary or confidential shall not be disclosed without the written consent of the provider of the information, except as required by national law. Information used to determine additionality as defined in paragraph 43 below, to describe the baseline methodology and its application, and to support an environmental impact assessment referred to in paragraph 37 (c) below, shall not be considered as proprietary or confidential.

F. Participation requirements

28. Participation in a CDM project activity is voluntary.

29. Parties participating in the CDM shall designate a national authority for the CDM.

30. A Party not included in Annex I may participate in a CDM project activity if it is a Party to the Kyoto Protocol.

31. Subject to the provisions of paragraph 32 below, a Party included in Annex I with a commitment inscribed in Annex B is eligible to use CERs, issued in accordance with the relevant provisions, to contribute to compliance with part of its commitment under Article 3, paragraph 1, if it is in compliance with the following eligibility requirements:

(a) It is a Party to the Kyoto Protocol;

(b) Its assigned amount pursuant to Article 3, paragraphs 7 and 8, has been calculated and

Appendix B.

Appendix to Chapter 2

Mathematical Appendix

Proof of Lemma 2.2.

Proof.

a) For a compliant firm, see proof of Lemma 2.1.

b) Suppose that the firm is non-compliant and chooses (x'_H, x'_F) such that $x'_H + x'_F < x^{min}$.

If $(x'_H, x'_F) = (x^{min}/2, 0)$ then the firm's expected costs are

$$E\left[C\left(\frac{x^{min}}{2}, 0\right)\right] = c\left(\frac{x^{min}}{2}\right) + \mu\left(S + c\left(\frac{x^{min}}{2}\right)\right). \tag{B.1}$$

In (B.1), the firm has a cost of domestic abatement equal to $c\,(x^{min}/2)$. Moreover, with probability μ it is monitored and has to pay fine S plus the cost of the required ex post abatement. Given $x'_H = x^{min}/2$ the cost-minimizing ex post abatement choice is $(x''_H, x''_F) = (0, x^{min}/2)$, which yields additional costs of $c\,(x^{min}/2)$.

Suppose first that $x'_F \geq x^{min}/2$. Since the firm is non-compliant, this implies that $x'_H < x^{min}/2$. Thus, the firm is monitored with probability one and its cost is

$$C\,(x'_H, x'_F) = c\,(x'_F) + S + c\left(x^{min} - x'_F\right)$$

where $(x''_H, x''_F) = (x^{min} - x'_F - x'_H, 0)$ is the ex post cost-minimizing abatement choice (Since x'_F is already larger than $x^{min}/2$, there will be no further abroad abatement.). With

$$c\left(x'_F\right)+S+c\left(x^{min}-x'_F\right) > c\left(\frac{x^{min}}{2}\right)+S+c\left(\frac{x^{min}}{2}\right) > E\left[C\left(\frac{x^{min}}{2},0\right)\right],$$

the firm is strictly better off when choosing $(x'_H, x'_F) = (x^{min}/2, 0)$ than when choosing $x'_F \geq x^{min}/2$ (and $x'_H < x^{min} - x'_F$).

Now suppose that $x'_F < x^{min}/2$.

If the firm chooses $x'_H > x^{min}/2$, it is monitored with probability one.

Since the ex post cost-minimizing abatement choice is

$(x''_H, x''_F) = (0, x^{min} - x'_H - x'_F)$, its cost is

$$\begin{aligned} C\left(x'_H, x'_F\right) &= c\left(x'_H\right) + c\left(x'_F\right) + S + \left(c\left(x^{min} - x'_H\right) - c\left(x'_F\right)\right) \\ &> c\left(\frac{x^{min}}{2}\right) + S + c\left(\frac{x^{min}}{2}\right) \\ &> E\left[C\left(\frac{x^{min}}{2},0\right)\right]. \end{aligned}$$

If the firm chooses instead $x'_H < x^{min}/2$, its cost-minimizing ex post abatement choice is $(x''_H, x''_F) = ((x^{min}/2) - x'_H, (x^{min}/2) - x'_F)$ which yields a total cost of

$$\begin{aligned} C\left(x'_H, x'_F\right) &= \left(x'_H\right) + c\left(x'_F\right) + S + \left(c\left(\frac{x^{min}}{2}\right) - c\left(x'_H\right)\right) \\ &\quad + \left(c\left(\frac{x^{min}}{2}\right) - c\left(x'_F\right)\right) \\ &= S + c\left(\frac{x^{min}}{2}\right) + c\left(\frac{x^{min}}{2}\right) \\ &> E\left[C\left(\frac{x^{min}}{2},0\right)\right]. \end{aligned}$$

Finally, if $x'_H = x^{min}/2$, the firm is monitored with probability μ only. The ex post cost-minimizing abatement equals $(x''_H, x''_F) = (0, x^{min}/2)$. This yields

an expected cost of

$$\begin{aligned} E\left[C\left(\frac{x^{min}}{2}, x'_F\right)\right] &= c\left(\frac{x^{min}}{2}\right) + c\left(x'_F\right) + \mu\left(S + c\left(\frac{x^{min}}{2}\right) - c\left(x'_F\right)\right) \\ &= c\left(\frac{x^{min}}{2}\right) + (1-\mu)\, c\left(x'_F\right) + \mu\left(S + c\left(\frac{x^{min}}{2}\right)\right), \end{aligned}$$

which is strictly higher than $E\left[C\left({}^{x^{min}}/_2, 0\right)\right]$ for all $x'_F > 0$, $\mu < 1$. Altogether, this shows part b). □

Legal Framework on linking the EU ETS and the CDM

Linking Directive[56]

L 338/18 EN Official Journal of the European Union 13.11.2004

DIRECTIVE 2004/101/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 27 October 2004

amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms

(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof,

Having regard to the proposal from the Commission,

Having regard to the opinion of the European Economic and Social Committee (1),

After consulting the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty (2),

Whereas:

(1) Directive 2003/87/EC (3) establishes a scheme for greenhouse gas emission allowance trading within the Community (the Community scheme) in order to promote reductions of greenhouse gas emissions in a cost-effective and economically efficient manner, recognising that, in the longer-term, global emissions of greenhouse gases will need to be reduced by approximately 70 % compared to 1990 levels. It aims at contributing towards fulfilling the commitments of the Community and its Member States to reduce anthropogenic greenhouse gas emissions under the Kyoto Protocol which was approved by Council Decision 2002/358/EC of 25 April 2002 concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder (4).

(2) Directive 2003/87/EC states that the recognition of credits from project-based mechanisms for fulfilling obligations as from 2005 will increase the cost-effectiveness of achieving reductions of global greenhouse gas emissions and shall be provided for by provisions for linking the Kyoto project-based mechanisms, including joint implementation (JI) and the clean development mechanism (CDM), with the Community scheme.

(3) Linking the Kyoto project-based mechanisms to the Community scheme, while safeguarding the latter's environmental integrity, gives the opportunity to use emission credits generated through project activities eligible pursuant to Articles 6 and 12 of the Kyoto Protocol in order to fulfil Member States' obligations in accordance with Article 12(3) of Directive 2003/87/EC. As a result, this will increase the diversity of low-cost compliance options within the Community scheme leading to a reduction of the overall costs of compliance with the Kyoto Protocol while improving the liquidity of the Community market in greenhouse gas emission allowances. By stimulating demand for JI credits, Community companies will invest in the development and transfer of advanced environmentally sound technologies and know-how. The demand for CDM credits will also be stimulated and thus developing countries hosting CDM projects will be assisted in achieving their sustainable development goals.

(4) In addition to the use of the Kyoto project-based mechanisms by the Community and its Member States, and by companies and individuals outside the Community scheme, those mechanisms should be linked to the Community scheme in such a way as to ensure consistency with the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol and subsequent decisions adopted thereunder as well as with the objectives and architecture of the Community scheme and provisions laid down by Directive 2003/87/EC.

(5) Member States may allow operators to use, in the Community scheme, certified emission reductions (CERs) from 2005 and emission reduction units (ERUs) from 2008. The use of CERs and ERUs by operators from 2008 may be allowed up to a percentage of the allocation to

(1) OJ C 80, 30.3.2004, p. 61.
(2) Opinion of the European Parliament of 20 April 2004 (not yet published in the Official Journal) and Council Decision of 13 September 2004 (not yet published in the Official Journal).
(3) OJ L 275, 25.10.2003, p. 32.
(4) OJ L 130, 15.5.2002, p. 1.

[56] EU (2004)

each installation, to be specified by each Member State in its national allocation plan. The use will take place through the issue and immediate surrender of one allowance in exchange for one CER or ERU. An allowance issued in exchange for a CER or ERU will correspond to that CER or ERU.

(6) The Commission Regulation for a standardised and secured system of registries, to be adopted pursuant to Article 19(3) of Directive 2003/87/EC and Article 6(1) of Decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol [1], will provide for the relevant processes and procedures in the registries system for the use of CERs during the period 2005 to 2007 and subsequent periods, and for the use of ERUs during the period 2008 to 2012 and subsequent periods.

(7) Each Member State will decide on the limit for the use of CERs and ERUs from project activities, having due regard to the relevant provisions of the Kyoto Protocol and the Marrakesh Accords, to meet the requirements therein that the use of the mechanisms should be supplemental to domestic action. Domestic action will thus constitute a significant element of the effort made.

(8) In accordance with the UNFCCC and the Kyoto Protocol and subsequent decisions adopted thereunder, Member States are to refrain from using CERs and ERUs generated from nuclear facilities to meet their commitments pursuant to Article 3(1) of the Kyoto Protocol and pursuant to Decision 2002/358/EC.

(9) Decisions 15/CP.7 and 19/CP.7 adopted pursuant to the UNFCCC and the Kyoto Protocol emphasise that environmental integrity is to be achieved, *inter alia*, through sound modalities, rules and guidelines for the mechanisms, and through sound and strong principles and rules governing land use, land-use change and forestry activities, and that the issues of non-permanence, additionality, leakage, uncertainties and socioeconomic and environmental impacts, including impacts on biodiversity and natural ecosystems, associated with afforestation and reforestation project activities are to be taken into account. The Commission should consider, in its review of Directive 2003/87/EC in 2006, technical provisions relating to the temporary nature of credits and the limit of 1 % for eligibility for land use, land-use change and forestry project activities as established in Decision 17/CP.7, and also provisions relating to the outcome of the evaluation of potential risks associated with the use of genetically modified organisms and potentially invasive alien species in afforestation and reforestation project activities, to allow operators to use CERs and ERUs resulting from land use, land use change and forestry project activities in the Community scheme from 2008, in accordance with the decisions adopted pursuant to the UNFCCC or the Kyoto Protocol.

(10) In order to avoid double counting, CERs and ERUs should not be issued as a result of project activities undertaken within the Community that also lead to a reduction in, or limitation of, emissions from installations covered by Directive 2003/87/EC, unless an equal number of allowances is cancelled from the registry of the Member State of the CERs' or ERUs' origin.

(11) In accordance with the relevant treaties of accession, the *acquis communautaire* should be taken into account in the establishment of baselines for project activities undertaken in countries acceding to the Union.

(12) Any Member State that authorises private or public entities to participate in project activities remains responsible for the fulfilment of its obligations under the UNFCCC and the Kyoto Protocol and should therefore ensure that such participation is consistent with the relevant guidelines, modalities and procedures adopted pursuant to the UNFCCC or the Kyoto Protocol.

(13) In accordance with the UNFCCC, the Kyoto Protocol and subsequent decisions adopted for their implementation, the Commission and the Member States should support capacity building activities in developing countries and countries with economies in transition in order to help them take full advantage of JI and the CDM in a manner that supports their sustainable development strategies. The Commission should review and report on efforts in this regard.

(14) Criteria and guidelines that are relevant to considering whether hydroelectric power production projects have negative environmental or social impacts have been identified by the World Commission on Dams in its November 2000 Report 'Dams and Development — A New Framework for Decision-Making', by the OECD and by the World Bank.

[1] OJ L 49, 19.2.2004, p. 1.

(15) Since participation in JI and CDM project activities is voluntary, corporate environmental and social responsibility and accountability should be enhanced in accordance with paragraph 17 of the Plan of implementation of the world summit on sustainable development. In this connection, companies should be encouraged to improve the social and environmental performance of JI and CDM activities in which they participate.

(16) Information on project activities in which a Member State participates or authorises private or public entities to participate should be made available to the public in accordance with Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information [1].

(17) The Commission may mention impacts on the electricity market in its reports on emission allowance trading and the use of credits from project activities.

(18) Following entry into force of the Kyoto Protocol, the Commission should examine whether it could be possible to conclude agreements with countries listed in Annex B to the Kyoto Protocol which have yet to ratify the Protocol, to provide for the recognition of allowances between the Community scheme and mandatory greenhouse gas emissions trading schemes capping absolute emissions established within those countries.

(19) Since the objective of the proposed action, namely the establishment of a link between the Kyoto project-based mechanisms and the Community scheme, cannot be sufficiently achieved by the Member States acting individually, and can therefore by reason of the scale and effects of this action be better achieved at Community level, the Community may adopt measures, in accordance with the principle of subsidiarity as set out in Article 5 of the Treaty. In accordance with the principle of proportionality, as set out in that Article, this Directive does not go beyond what is necessary in order to achieve that objective.

(20) Directive 2003/87/EC should therefore be amended accordingly,

HAVE ADOPTED THIS DIRECTIVE:

[1] OJ L 41, 14.2.2003, p. 26.

Article 1

Amendments to Directive 2003/87/EC

Directive 2003/87/EC is hereby amended as follows:

1. In Article 3, the following points are added:

'(k) "Annex I Party" means a Party listed in Annex I to the United Nations Framework Convention on Climate Change (UNFCCC) that has ratified the Kyoto Protocol as specified in Article 1(7) of the Kyoto Protocol;

(l) "project activity" means a project activity approved by one or more Annex I Parties in accordance with Article 6 or Article 12 of the Kyoto Protocol and the decisions adopted pursuant to the UNFCCC or the Kyoto Protocol;

(m) "emission reduction unit" or "ERU" means a unit issued pursuant to Article 6 of the Kyoto Protocol and the decisions adopted pursuant to the UNFCCC or the Kyoto Protocol;

(n) "certified emission reduction" or "CER" means a unit issued pursuant to Article 12 of the Kyoto Protocol and the decisions adopted pursuant to the UNFCCC or the Kyoto Protocol.'

2. The following Articles are inserted after Article 11:

'*Article 11a*

Use of CERs and ERUs from project activities in the Community scheme

1. Subject to paragraph 3, during each period referred to in Article 11(2), Member States may allow operators to use CERs and ERUs from project activities in the Community scheme up to a percentage of the allocation of allowances to each installation, to be specified by each Member State in its national allocation plan for that period. This shall take place through the issue and immediate surrender of one allowance by the Member State in exchange for one CER or ERU held by the operator in the national registry of its Member State.

2. Subject to paragraph 3, during the period referred to in Article 11(1), Member States may allow operators to use CERs from project activities in the Community scheme. This shall take place through the issue and immediate surrender of one allowance by the Member State in exchange for one CER. Member States shall cancel CERs that have been used by operators during the period referred to in Article 11(1).

3. All CERs and ERUs that are issued and may be used in accordance with the UNFCCC and the Kyoto Protocol and subsequent decisions adopted thereunder may be used in the Community scheme:

(a) except that, in recognition of the fact that, in accordance with the UNFCCC and the Kyoto Protocol and subsequent decisions adopted thereunder, Member States are to refrain from using CERs and ERUs generated from nuclear facilities to meet their commitments pursuant to Article 3(1) of the Kyoto Protocol and in accordance with Decision 2002/358/EC, operators are to refrain from using CERs and ERUs generated from such facilities in the Community scheme during the period referred to in Article 11(1) and the first five-year period referred to in Article 11(2);

and

(b) except for CERs and ERUs from land use, land use change and forestry activities.

Article 11b

Project activities

1. Member States shall take all necessary measures to ensure that baselines for project activities, as defined by subsequent decisions adopted under the UNFCCC or the Kyoto Protocol, undertaken in countries having signed a Treaty of Accession with the Union fully comply with the *acquis communautaire*, including the temporary derogations set out in that Treaty of Accession.

2. Except as provided for in paragraphs 3 and 4, Member States hosting project activities shall ensure that no ERUs or CERs are issued for reductions or limitations of greenhouse gas emissions from installations falling within the scope of this Directive.

3. Until 31 December 2012, for JI and CDM project activities which reduce or limit directly the emissions of an installation falling within the scope of this Directive, ERUs and CERs may be issued only if an equal number of allowances is cancelled by the operator of that installation.

4. Until 31 December 2012, for JI and CDM project activities which reduce or limit indirectly the emission level of installations falling within the scope of this Directive, ERUs and CERs may be issued only if an equal number of allowances is cancelled from the national registry of the Member State of the ERUs' or CERs' origin.

5. A Member State that authorises private or public entities to participate in project activities shall remain responsible for the fulfilment of its obligations under the UNFCCC and the Kyoto Protocol and shall ensure that such participation is consistent with the relevant guidelines, modalities and procedures adopted pursuant to the UNFCCC or the Kyoto Protocol.

6. In the case of hydroelectric power production project activities with a generating capacity exceeding 20 MW, Member States shall, when approving such project activities, ensure that relevant international criteria and guidelines, including those contained in the World Commission on Dams November 2000 Report "Dams and Development — A New Framework for Decision-Making", will be respected during the development of such project activities.

7. Provisions for the implementation of paragraphs 3 and 4, particularly in respect of the avoidance of double counting, and any provisions necessary for the implementation of paragraph 5 where the host party meets all eligibility requirements for JI project activities shall be adopted in accordance with Article 23(2).'

3. Article 17 is replaced by the following:

'*Article 17*

Access to information

Decisions relating to the allocation of allowances, information on project activities in which a Member State participates or authorises private or public entities to participate, and the reports of emissions required under the greenhouse gas emissions permit and held by the competent authority, shall be made available to the public in accordance with Directive 2003/4/EC.'

4. In Article 18 the following subparagraph is added:

'Member States shall in particular ensure coordination between their designated focal point for approving project activities pursuant to Article 6 (1)(a) of the Kyoto Protocol and their designated national authority for the implementation of Article 12 of the Kyoto Protocol respectively designated in accordance with subsequent decisions adopted under the UNFCCC or the Kyoto Protocol.'

5. In Article 19(3) the following sentence is added:

'That Regulation shall also include provisions concerning the use and identification of CERs and ERUs in the Community scheme and the monitoring of the level of such use.'

6. Article 21 is amended as follows:

(a) in paragraph 1 the second sentence is replaced by the following:

'This report shall pay particular attention to the arrangements for the allocation of allowances, the use of ERUs and CERs in the Community scheme, the operation of registries, the application of the monitoring and reporting guidelines, verification and issues relating to compliance with the Directive and the fiscal treatment of allowances, if any.'

(b) paragraph 3 is replaced by the following:

'3. The Commission shall organise an exchange of information between the competent authorities of the Member States concerning developments relating to issues of allocation, the use of ERUs and CERs in the Community scheme, the operation of registries, monitoring, reporting, verification and compliance with this Directive.'

7. The following Article is inserted after Article 21:

'Article 21a

Support of capacity-building activities

In accordance with the UNFCCC, the Kyoto Protocol and any subsequent decision adopted for their implementation, the Commission and the Member States shall endeavour to support capacity-building activities in developing countries and countries with economies in transition in order to help them take full advantage of JI and the CDM in a manner that supports their sustainable development strategies and to facilitate the engagement of entities in JI and CDM project development and implementation.'

8. Article 30 is amended as follows:

(a) in paragraph 2, point (d) is replaced by the following:

'(d) the use of credits from project activities, including the need for harmonisation of the allowed use of ERUs and CERs in the Community scheme;'

(b) in paragraph 2 the following points are added:

'(l) the impact of project mechanisms on host countries, particularly on their development objectives, whether JI and CDM hydroelectric power production project activities with a generating capacity exceeding 500 MW and having negative environmental or social impacts have been approved, and the future use of CERs or ERUs resulting from any such hydroelectric power production project activities in the Community scheme;

(m) the support for capacity-building efforts in developing countries and countries with economies in transition;

(n) the modalities and procedures for Member States' approval of domestic project activities and for the issuing of allowances in respect of emission reductions or limitations resulting from such activities from 2008;

(o) technical provisions relating to the temporary nature of credits and the limit of 1 % for eligibility for land use, land-use change and forestry project activities as established in Decision 17/CP.7, and provisions relating to the outcome of the evaluation of potential risks associated with the use of genetically modified organisms and potentially invasive alien species by afforestation and reforestation project activities, to allow operators to use CERs and ERUs resulting from land use, land-use change and forestry project activities in the Community scheme from 2008, in accordance with the decisions adopted pursuant to the UNFCCC or the Kyoto Protocol.'

Appendix C.

Appendix to Chapter 3

Deriving substitution and quantity effects

Total differentiation of equations (3.1) yields

$$h''(x_H^*)dx_H^* = \frac{1}{\alpha}f''(x_F^*)\,dx_F^* - \frac{1}{\alpha^2}f'(x_F^*)\,d\alpha.$$

This is equivalent to

$$dx_H^* = \frac{1}{\alpha}\frac{f''(x_F^*)}{h''(x_H^*)}dx_F^* - \frac{1}{\alpha^2}\frac{f'(x_F^*)}{h''(x_H^*)}d\alpha. \tag{C.1}$$

Total differentiation of equation (3.2) yields

$$dx^{min} = dx_H^* + x_F^* d\alpha + \alpha dx_F^*. \tag{C.2}$$

Plugging (C.1) into (C.2) gives:

$$dx^{min} = \left[\frac{1}{\alpha}\frac{f''(x_F^*)}{h''(x_H^*)} + \alpha\right]dx_F^* + \left[x_F^* - \frac{1}{\alpha^2}\frac{f'(x_F^*)}{h''(x_H^*)}\right]d\alpha.$$

Solving for a change in abroad abatement yields

$$dx_F^* = \left[\frac{h''(x_H^*)}{\frac{1}{\alpha}f''(x_F^*) + \alpha h''(x_H^*)}\right]dx^{min} + \left[\frac{\frac{1}{\alpha^2}f'(x_F^*) - h''(x_H^*)\,x_F^*}{\frac{1}{\alpha}f''(x_F^*) + \alpha h''(x_H^*)}\right]d\alpha.$$

That is, as $dx^{min} = 0$, the overall effect of a change in allowability α on abroad abatement is

$$\frac{dx_F^*}{d\alpha} = \frac{\frac{1}{\alpha^2} f'(x_F^*) - h''(x_H^*)\, x_F^*}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}.$$

Compensating for the change in α, that is, taking $dx^{min} = x_F^* d\alpha$, yields the isolated substitution effect:

$$dx_F^* = \left[\frac{h''(x_H) x_F^*}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}\right] d\alpha + \left[\frac{\frac{1}{\alpha^2} f'(x_F^*) - h''(x_H^*)\, x_F^*}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}\right] d\alpha.$$

The substitution effect abroad is therefore

$$SE_F = \frac{\frac{1}{\alpha^2} f'(x_F^*)}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}.$$

Consequently, the quantity effect $QE_F = {}^{dx_F^*}/_{d\alpha} - SE_F$ is

$$QE_F = -\frac{h''(x_H^*)\, x_F^*}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}.$$

Likewise, for changes in domestic abatement:

$$dx_H^* = \frac{\frac{1}{\alpha} f''(x_F^*)}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)} dx^{min} - \left[\frac{\frac{1}{\alpha} x_F^* f''(x_F^*) + \frac{1}{\alpha} f'(x_F^*)}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}\right] d\alpha. \quad \text{(C.3)}$$

That is, the overall effect of a change in allowability α on domestic abatement is

$$\frac{dx_H^*}{d\alpha} = -\frac{\frac{1}{\alpha} x_F^* f''(x_F^*) + \frac{1}{\alpha} f'(x_F^*)}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)},$$

while the substitution and quantity effects are

$$SE_H = -\frac{\frac{1}{\alpha} f'(x_F^*)}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}$$

and

$$QE_H = -\frac{\frac{1}{\alpha} f''(x_F^*)\, x_F^*}{\frac{1}{\alpha} f''(x_F^*) + \alpha h''(x_H^*)}.$$

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Eidesstattliche Versicherung

Ich versichere hiermit eidesstattlich, dass ich die vorliegende Arbeit selbständig und ohne fremde Hilfe verfasst habe. Die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sowie mir gegebene Anregungen sind als solche kenntlich gemacht.

Die Arbeit wurde bisher keiner anderen Prüfungsbehörde vorgelegt und auch noch nicht veröffentlicht. Sofern ein Teil der Arbeit aus bereits veröffentlichten Papers besteht, habe ich dies ausdrücklich angegeben.

Datum: 24.06.2015

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Sabine Aresin