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Global Environmental Change Regimes – Impact Assessment on the Basis of an extended GTAP-Model

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Global Environmental Change Regimes

Impact assessment on the basis of an extended GTAP-model

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Abstract

A consistent mapping of all complex ramifications (including direct and indirect effects) of various greenhouse policies in an open institutional economy requires the use of a general equilibrium framework. From the existing set of available equilibrium models we have selected the so-called GTAP-model. This paper presents the results of experiments with the extended GTAP-model, coined the GTAP-CDM. This experiment emphasises the costs of various Kyoto policy regimes, interpreted as packages of institutions and instruments serving to control for global environmental change. As specific instruments, we have chosen to analyze the impact of one of the Kyoto Protocol instruments, viz. Clean Development Mechanism (CDM). As far as institutions are concerned, we discuss various policy options, since the negotiations on these instruments will provide various possibilities for the final form of climate policy regimes to become effective.

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1. *Setting the Scene*

Global environmental change policy is increasingly looking for sustainability strategies that take into account the transboundary nature of environmental externalities. As a consequence, we observe an increasing popularity of international environmental agreements. The implementation of such agreements is however, fraught with many difficulties, as in an international context there are always (absolute or relative) winners and losers. This situation leads to complex negotiation procedures which have to find a balance between sound economic principles, environmental sustainability requirements and political acceptability conditions. Nevertheless, the awareness has grown that a coordinated environmental policy is of critical importance to ameliorate the impacts of environmental decay on the natural ecosystem as well as on the socio-economic system. The reasons for this growing recognition of the need for a strong transboundary policy stem from the following factors: (i) pollution sources are multiple and difficult to identify; (ii) transaction costs on coping with individual pollutants may be very high; (iii) in an international context, it is almost impossible to create a negotiation platform among all polluters and all victims; (iv) the space-time interactions are impossible to map; and (v) the individual costs of coping with a distinct pollution case in the light of global environmental effects are hard to assess.

Several economic instruments have been set up to offer decision support for international environmental agreements, such as game strategies (see e.g. Carraro, 1999) or institutional procedures. A bottleneck has always been the question how to deal with burden sharing of environmental policies. Such equity issues may also explain differences in the acceptance rate of involvement in global environmental policy agreements by individual countries. The history of long-range transboundary air pollution (LRTAP) policies offers many illuminating learning effects on the caveats in such international agreement processes. Already in 1979 a first protocol to LRTAP under the auspices of the UN-economic Commission for Europe, was signed with 33 signatory parties and ever since various additional protocols have come in place. Also the European Commission is playing an increasingly active role in environmental negotiation platforms, as can be seen in recent discussions center around the Kyoto protocol.

In this context, there is also a rising need for solid scientific information which may support intertemporal decision-making in the environmental field. Integrated assessment models, policy scenario studies and general equilibrium models are examples of scientific tools aimed at understanding the transboundary complexity of global environmental issues and related policies. Nevertheless, it is clear that still many hurdles have to be taken before a satisfactory policy support system can be developed.

This paper forms one of the steps by applying a general equilibrium model to the global environmental change regime, defined as institutes and institutions for controlling global environmental change; where institutes refer to formal relationships such as organizations and legislation concerning climate change policies and where institutions indicate informal relationships such as principles, norms and values in regard to the behavior of actors in case of climate change issues (Haas 1975, Krasner 1983).

More specifically, this paper focusses on possible future regimes under the Kyoto Protocol. In 1992, some countries - now always widely labeled as Annex 1 countries - voluntarily agreed to restrict their GHG emissions to a certain threshold amount under the United Nations Framework Convention on Climate Change (UNFCCC). This agreement was an important step in setting up of a global environmental change policy regime.

A provisional contour of this international policy regime is visible after the achievement of the Kyoto Protocol in which Annex 1 countries agreed on legally binding emission restrictions in the period 2008-2012. In this protocol, three policy mechanisms, viz. Emission Trading (ET), Joint Implementation (JI) and Clean Development Mechanism (CDM), are introduced in order to have a 'cost-effective' way of implementing the GHG-emission restriction. Currently, after the failure of the world community to achieve an agreement during the sixth Conference of Parties in the year 2000 and the likely scenario of United States' non-participation, it becomes clear that the global environmental regime is still fragile. For analyzing policy impacts of global climate policies, this fragility of the climate regime leads us to consider policy impacts of various possibilities of a future climate policy regime.

In order to illustrate the impacts of various regimes, this paper tries to answer the following research questions: '*what are the likely impacts of some Kyoto regimes (in particular CDM) for the world as a whole as well as for the individual participating world regions or countries*?'.

For reasons of simplicity, this paper compares the impacts of four possible future regimes to the non-action regime, i.e. the Business-as-Usual (BaU). The BaU refers to the situation where no change occurs and is interchangebly used to refer to the base-regime where no policy instruments are introduced. The four possible future regimes are set-up in two dimensions. In these four policy regimes, the agreed Kyoto emission restrictions are imposed for the participating countries. The difference between the four regimes is that along the one dimension, we have a division between two regimes, one in which the USA participates as an Annex 1 country and another regimes in which the USA does not participate; along the second dimension, we have to distinguish the use or non-use of the cost-effective instrument of CDM.

The first dimension is introduced, as the possible non-participation of USA will definitely make a difference for the macroeconomic variables as well as for the global level of CO2 emissions. This influence is not only importance because of the USA's large share in global economic activity and related global carbon emission, but also because of the political influence and the domino-effect it might have on the global climate change negotiation. The danger is, of course, that the USA non-participation regime may become a precursor to another future regimes. The uncertainties and difficulties which prevailed previous to the Berlin negotiations, which is a follow-up of the COP-6 negotiation in The Hague, may underwrite this political implication. However, the USA non-participation regime may deep illustrate the economic and political consequences of a decision of a single country to withdraw from an international agreement.

The second dimension introduced here, viz. the quantification of the specific impact of CDM, is widely discussed, since domestic emission restriction is a costly regime. It is often argued that the Kyoto Protocol instruments may be more cost-effective. This paper will provide a tentative quantitative assessment of this instrument, as (i) there are still many arguments pro and contra the cost-effectiveness of CDM (see e.g. Begg et al. 2001), and (ii) international emission trading (IET) is already widely discussed in the literature (for modeling experiments see e.g. Parry and Williams 1999; and for policy impact analysis see e.g. Jensen and Rasmussen 1999, Bollen et al. 2000, Zhang 2001a, b).

We like to emphasise the tentative character of our quantitative assessment, as the results largely depend on specific assumptions to be discussed in Section 2 and further specified in the introductory part of Sections 3 and 4. Three important simplifying assumptions influencing the cost-effectiveness of the CDM-instrument are: i) the rate of carbon emission reduction of 20%; ii) the amount of CDM-investments from the Annex 1 countries; and iii) the determination of the baseline. We will illustrate this restriction briefly by presenting two different institutional settings for the baseline of CDM.

Against the background of the previous introductory remarks, the organization of the paper is now as follows. Section 2 deals with methodological issues on the analysis carried out in this paper. Section 3 presents an analysis for the regimes without CDM, while Section 4 presents the results for the regimes with CDM. Section 5 offers some concluding remarks.

2. Methodological issues

2.1 Introduction

The findings in this paper are based on insights and analysis from recent simulations with the so-called GTAP-CDM model, a static global applied general equilibrium model that is extended with characteristics of CDM, such as technological progress and investments from the Annex 1 countries in the Non-Annex 1 countries in order to achieve the Kyoto reduction target on emissions.

The simulations in this paper are based on aggregated data related to the year 1995 from the GTAP-4E database, collected by the Global Trade Analysis Project team as well as the energy volume data from the International Energy Agency (IEA) transformed for the GTAP-E model by Truong (1999). We have chosen not to project the data to the year 2010, since such a projection requires several assumptions about future developments, which are still uncertain. In other words, in the trade-off between i) a less 'intuitive' approach based on historical data, and ii) a more 'intuitive' approach for the year 2010 data with many uncertainties about the 'validity' and 'reliability' of the projected data, we have chosen for the first approach. The aggregated data refer to 5 world regions, i.e. USA, EU, Economies in Transition (EIT), Rest of Annex 1 regions (RAX), and Rest of World (ROW). Furthermore, the model employs 12 types of commodities, i.e., 5 primary input factors, 5 energy products (coal, petroleum, gas, oil and electricity), 1 capital good and 1 other output.

Our choice for the use of GTAP is partly driven by the fact that the GTAP-team also provides a fully documented, publicly available global data base as well as software for simulation purposes. Furthermore, GTAP is a proper model for analyzing the impacts of climate change regimes related to the Kyoto agreements and mechanisms, as those are related to the medium term, i.e. the period 2008-2012 (see also Kremers et al. 2001 for other reasons). Of course, the choice for a static versus a dynamic model is a trade-off between taking the real world complexities into account versus neglecting long run behavior and effects. In the dynamic context, complexities relating to technological change, e.g. the timing-issue (Grubb 1997, de Groot 2001) and the related uncertainties (Carraro and Hourcade 1998) play an important role. However, the use of a dynamic model, like WorldScan for example, would lead to a problematic interpretation of the short run impact (see e.g. Bollen et al. 2000). The static model reduces these complexities, but could add information on regional differences and trade effects in the analysis. In this context, the emission reduction target should be interpreted as if it is (i) voluntarily agreed, and (ii) the optimal solution from a dynamic optimization process which takes the complex interaction between the economic and the ecological systems into account.

2.2 The model

GTAP-CDM is based on GTAP-E, which is a specific application of the base GTAP model to energy substitution, as developed by Truong (1999). GTAP-CDM is innovative, because it provides a way to endogenize technological change in a general equilibrium model (see e.g. Carraro and Hourcade 1998). The base GTAP-model is a static multi-region, multi-sector applied general equilibrium model developed by the Global Trade Analysis Project team. In the GTAP-model, the world-economy is divided into a number of regions. In each of the regions, consumers are described by an aggregated regional household sector. Its income is allocated to consumption, public expenditure and savings. The share of consumption and public expenditure makes it possible to perform a demand for goods which are produced by the production sector (either domestic or foreign). The savings are used for investments in capital goods.

On the consumers' side, GTAP-E has reformulated the demand function by adding a carbon tax for consumers' expenditure as well as public expenditure on final goods which will emit carbon gasses when used, e.g. petroleum and gasoline. On the producers' side, the reformulation by GTAP is more complicated. We will briefly describe the production structure of the model, because this is relevant for the formulation of CDM. For an overview of the GTAP-base model, we refer to Hertel and Tsigas (1998); for an overview of relevant changes and the complete GTAP-E model, we refer to Truong (1999).

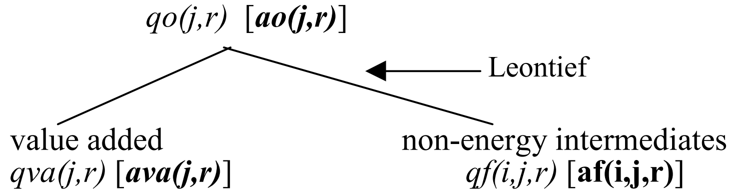

Figure 2.1 First level of production structure for output of industry *j* in region *r* in GTAP-E source: Truong 1999

On the production side, GTAP-E uses the GTAP-formulation for the output of an industry *j* in region *r* (denoted as *qo(j,r)*) which is modeled in a nested structure. The first level nest in the production function has a Leontief form and is produced by two input factors, viz. a composite intermediates nest (*qf(i,j,r)*) and a value-added nest (*qva(i,j,r)*); a graphical representation is given in Figure 2.1. In contrast to the base-GTAP model, the composite intermediate nest in GTAP-E consists of non-energy commodities. The energy commodities are transferred to the capital-energy composite in the value-added nest.

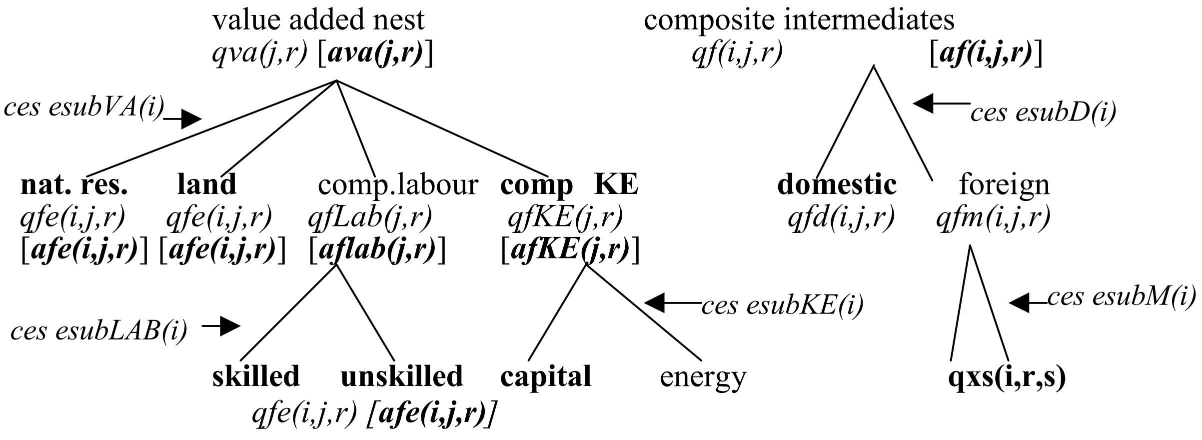

Figure 2.2 The value added nest and composite intermediates nest in GTAP-E

The use of a Leontief form for the first level is, as Hertel and Tsigas (1998) stated, based on the assumption of separability in production. This assumption implies that the elasticity of substitution between any individual primary factor, on the one hand, and intermediate inputs, on the other hand, is equal to zero. Hertel and Tsigas (1998) stated that, because of the Leontief form in the first nest and the assumption of constant return to scale, the mix of intermediate inputs is independent of the prices of primary factors.

The subsequent nests are, independently from each other, in turn characterized by Constant Elasticity of Substitution (CES) production functions; see Figure 2.2. The CES function has the property that the substitution elasticities (*ESUB(i)*) between all the input factors within the function are constant (see Hertel and Tsigas 1998).

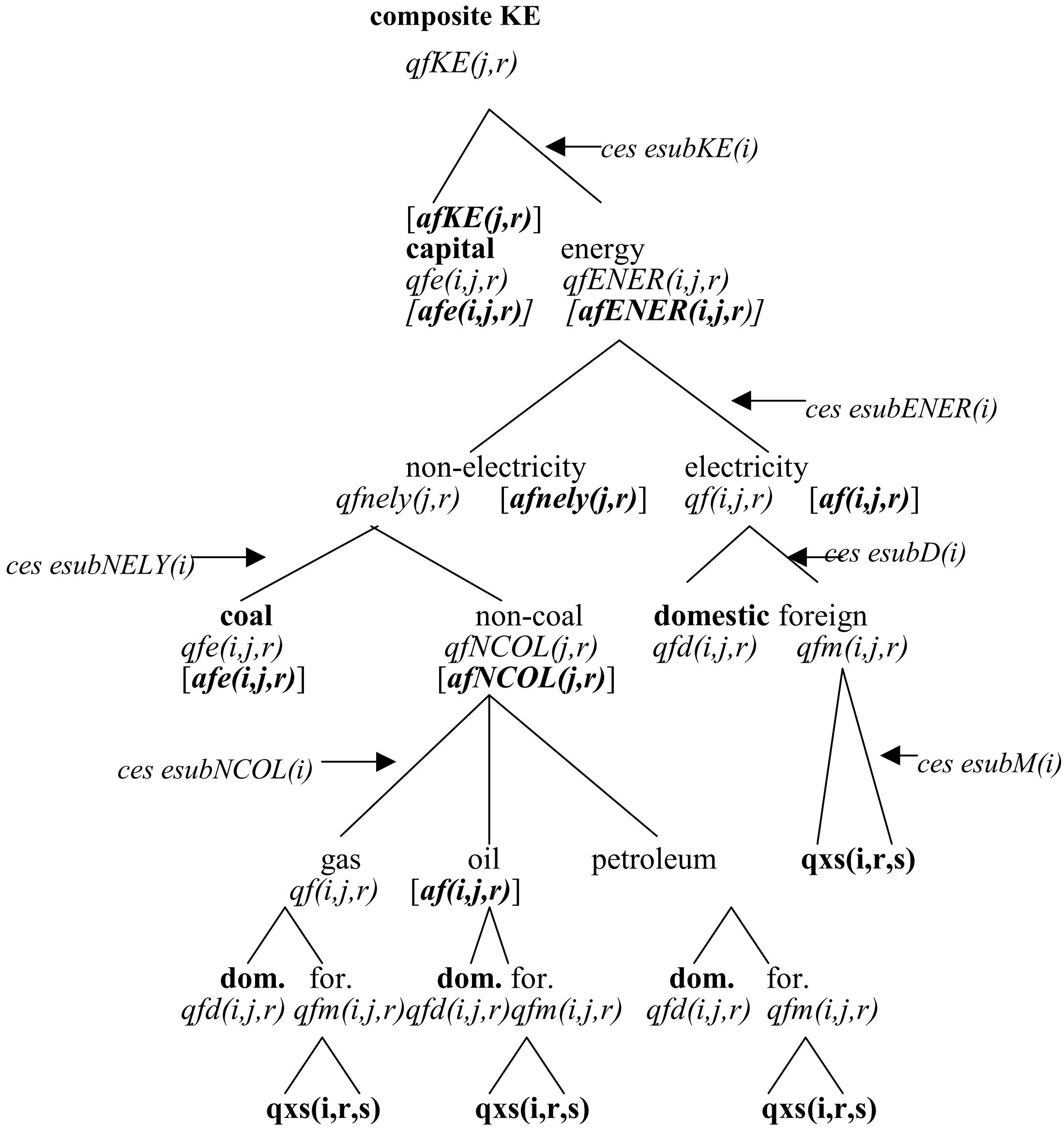

Figure 2.3 The production of energy in GTAP-E
source: Truong 1999.

Furthermore, GTAP-E follows the base-GTAP model in the use of the Armington assumption in the composite intermediates nest in order to allow for intra-industrial trade. This means that the commodities are assumed to be different according to the location where they are produced. In other words, the CES function has as intermediate production factors: (i) domestic inputs (*qfd*) and (ii) foreign inputs (*qfm*), where the foreign inputs are in turn assumed to be composed of foreign inputs from the individual foreign regions (*qxs*). Two relevant substitution parameters are related herewith, i.e. *esubD(i)* and *esubM(i)*. The first is the elasticity of substitution between domestic versus import of all agents in all regions and the second is the elasticity of substitution defined for imports from different regions.

The value added nest is in GTAP produced by a CES production function from the endowments: land, composite labour (*comp. labour*, which is a CES-function of the skilled and unskilled labour) and capital. In GTAP-E, natural resources (*nat. res.*) form a new endowment in the production of the value-added nest. Furthermore, Truong (1999) merged the energy composite with the capital endowment as part of input factors for the value added. The capital energy composite (*comp KE*) has a CES form with capital and energy as inputs; see Figure 2.3 for a graphical representation. The energy nest is further produced by a multilevel structure of electric and non-electric energy. The non-electric nest is composed of coal and non-coal inputs. the non-coal nest is composed of the inputs: gas, oil and petroleum products. Interesting to note is that the inputs in the energy nest are also meeting the Armington assumption.

From a conceptual point of view, this means that Truong assumes that energy inputs are part of the endowment commodities which are owned by producers. The advantage of this formulation is, as Truong (1999) stated, that this formulation allows for: i) substitution between the fuels; ii) substitution between energy and capital in the energy-capital composite nest; and iii) substitution between the energy-capital composite nest and other factors (see Troung 1999: 33). In this way, GTAP-E allows capital and energy to be depending on the model parameters, substitutes or complements.

GTAP-CDM tries to offer a framework for endogenizing technological progress for the Non-Annex 1 countries; this in contrary to GTAP and GTAP-E, where technological progress, which in Figure 2.3 is shown in brackets, is exogenously given for each nest. The main problem associated with endogenizing technological progress in a general equilibrium framework is the lack of data. As collecting data needs time, GTAP-CDM used a proxy for the function of technological progress in order to offer some ex ante prognoses of the cost-effectiveness of CDM. This proxy of the function of technological progress uses the main idea of endogenous growth theory on technological progress. More precisely, the idea that the R&D sector uses the input factors that would otherwise be used in the production sectors to produce its own product, viz. technological progress. Then, at a given moment where the economy is in equilibrium, the level of technology in that economy may be approximated by the existing level of input factors in the production sector. Moreover, the marginal productivity of the input factors in the R&D sector may also be determined by the marginal productivity of the input factors in the production sector.

Thus, the incorporation of CDM in GTAP-CDM has the following characteristics: (i) Annex 1 countries levy energy taxes to raise funds for CDM investments; (ii) non-Annex 1 countries receive these investments and will hence face increasing technological progress in their production processes; and (iii) as a result of technological progress in the non-Annex 1 countries, Annex 1 countries will acquire a certain amount of emission credits.

2.3 The regimes

The base regime is the Business as Usual (BaU) situation, whereby no policy change, viz. carbon emission restriction, would be introduced. In this regime, the CO2 emission would be unrestricted, although not unlimited, as the level of economic activity is determined by the available endowments. In this regime, there is no shadow price for carbon emission, and countries would, from an economic point of view, not exploit CDM-activities, as there is no reward for it. The base regime forms our benchmark on which the impact of other regimes will be applied and presented.

For our analysis, we work with two policy dimensions to construct dinstinct regime possibilities. The first dimension relates to the participation of USA and the second dimension relates to the implementation of CDM. Regime possibilities in which the USA participate are denoted as USA_P and USA_P+CDM. Along the second dimension, regimes USA_P+CDM and USA_NP+CDM includes CDM. Table 2.1 summarizes the regimes which will be analyzed in this paper.

	no emission constraint	emission constraint	emission constraint and CDM
US participation	base regime (=Business as Usual)	USA_P	USA_P+CDM
US non participation		USA_NP	USA_NP+CDM

Table 2.1 The regime possibilities under analysis

In regimes USA_P and USA_P+CDM, the participating Annex 1 regions are USA, EU and RAX; the non-participating region is EIT, and the Non-Annex 1 countries are formed by ROW. In these regimes, the participating Annex 1 regions are reducing 20% of their 1995-CO2 emissions, while the Non-Annex 1 countries and the non-participating Annex 1 countries would act under a BaU-strategy. The percentage of 20% has been chosen for the reason of comparability with the Truong (1999) results for the GTAP-E model.

In these regimes, the reduction targets are achieved by each individual participating Annex 1 region through a tax on energy products (oil, coal, petroleum, gas and electricity). The reason for not including EIT as participating Annex 1 countries in our analysis is that (i) this region would not exceed their emission targets, and (ii) this region would not undertake

CDM activities, because (a) these countries are themselves in transition and (b) there are no incentives to undertake CDM activities, because the shadow price for emission reduction in these countries are negligible. In regimes USA_NP and USA_NP+CDM, Non-Annex 1 countries are still the rest of the world; the non-participating countries are EIT and the USA.

3. *Effects without CDM*

3.1 Introduction

In regimes USA_P and USA_NP, the carbon tax is differentiated according to the CO2 emissions of the energy products. Given the CO2 emission coefficient in GTAP-E, which is given in Table 3.1, the differentiated carbon tax means that the tax on coal is higher than that on gas.

energy products	coal	Petroleum	crude oil	gas	electricity
CO2 coefficient	3.8107	2.7638	0	1.8844	0

(in tonnes of CO2 per tonne of oil equivalent (toe))

Table 3.1. CO2 emission content in GTAP-E model

Source: Truong 1999 (p. 47)

These coefficients are purely technical relationships in terms of CO2 emission of the underlying energy products. The reason for crude oil to have a zero-CO2 emission coefficient is that crude oil is mainly used as a material input into petroleum refining; thus it is a ‘feedstock’ rather than an energy input. For electricity, the zero coefficient is used in order to avoid double-counting, as electricity is produced from other primary fuels which have non-zero CO2 emission coefficients.

The carbon tax would in the first instance lead to a higher price for the energy products, so that demand decreases. A secondary effect of the differentiated carbon tax is that there will be some switching in the demand for energy products, because energy products with a higher carbon content (coal, for example) become relatively more expensive as compared to energy products with a lower carbon content (e.g. gas). Furthermore, in a multi-sector, multi-region economy where the economic activities are interrelated with each other, there are also other kinds of secondary effects. The price differences between the energy products would also result in switching in import demand for products produced with these energy products. Together with changes in the world markets of energy products, this would lead to carbon leakage. An implication of carbon leakage is that the final world level of emission reduction is less than the aggregate target set by the Annex 1 countries.

All these direct and second-order effects also play a role in the USA_NP regime, where the United States do not join the Annex 1 group. The USA’s decision would affect the final allocation of the economic resources as well as the extent of the world level of emission reduction.

3.2 Impact on emission reduction and carbon tax

Table 3.2 shows the emission changes in comparison to the BaU scenario for USA_P and USA_NP. The carbon tax of USA_P correspond to Truong's (1999) calculation, where a tax of US$21.1 per ton of carbon emission is found for the EU in an eight country simulation. Carbon tax from GTAP-E/CDM is low compared to other models because of the incorporation of energy substitution in this model (for a discussion, see Truong 1999).

relative to the BAU in 1995

	regime USA_P: Annex 1 incl. USA			**Regime USA_NP: Annex 1 excl. USA**		
	Target CO2 emission %	Actual CO2 emission %	Carbon tax US$/tCO2	Target CO2 emission %	Actual CO2 emission %	Carbon tax US$/tCO2
USA	-20	-20	14.57	none	1.54	0
EU	-20	-20	22.13	-20	-20	20.79
EIT	none	3.39	0	none	2.58	0
RAX	-20	-20	22.88	-20	-20	21.46
ROW	none	3.18	0	none	2.28	0
World		-8.08	7.85		-3.31	4.27

Table 3.2: Carbon emission target and carbon tax for USA_P and USA_NP

Source: own GTAP-E/CDM calculations

Table 3.2 also shows that the United States has the lowest carbon tax among the Annex 1 countries. This result corresponds to the above mentioned study of Truong (1999) and Bollen et al. (2000). The results for the Rest of Annex 1 countries differ slightly. This may be due to a different aggregation between the three studies. In Table 3.2, we see that the Rest of Annex 1 countries has the highest carbon tax. This corresponds to the results of Truong (1999) for Japan, although in Bollen et al. (2000) Japan has almost the lowest carbon tax among the Annex 1 countries except for the Economies in Transition (=Eastern Europe and Former Soviet Union).

Interesting in Table 3.2 is the fact that the carbon tax for USA_NP differs only slightly from USA_P for the European Union and the Rest of Annex 1 countries. The reason for this small difference is that in our calculations each region still has to meet the target within the region. The lower carbon tax however, is probably related to a lower economic activity rather than more efficiency within both regions. In USA_NP, we see that, in spite of high reduction targets in EU and RAX, the total world emission is only reduced by 3.3%. Thus, there is some carbon leakage. This indicates that a part of CO2 emission reduction is cancelled out by extra CO2 emission by firms in the USA and other non-participating countries.

3.3 Other economic impacts

Although the emphasis in the literature on the impact of emission restriction is on the carbon tax and the related marginal reduction costs (see e.g. special issue of Energy Journal 1999), it is expected that the economic impacts of the various regimes encompass also other macroeconomic variables. In this paper, we will present the estimates of the impact on terms of trade, trade balance in ratio to real GTAP, real GDP, GDP in value terms and real capital goods. These are indicators which are partly used to measure the 'international competitiveness' of the countries. The relative importance of each of the indicators however, depends on the decisionmakers. For example from a theoretic economic point of view, the real GDP is more important as it measures the amount of goods which are consumed, while from the consumers' point of view the value of GDP may be more important as it accounts also for the relative price changes. From a trade point of view on the other hand, the terms of trade or the trade balance are more attractive as indicators than GDP. Finally, the indicator of 'real capital goods' is used for long run economic development.

relative to the BAU in 1995

	regime USA_P: Annex 1 incl. USA					**Regime USA_NP: Annex 1 excl. USA**				
	terms of trade %	trade balance/ real GDP %	real GDP %	value GDP %	real capital goods %	terms of trade %	trade balance/ real GDP %	real GDP %	value GDP %	real capital goods %
USA	0.13	0.14	-0.17	0.53	-0.88	0.42	-0.32	0.01	0.62	1.87
EU	0.09	0.30	-0.21	0.32	-1.56	-0.10	0.51	-0.37	-0.16	-2.74
EIT	-0.07	-0.60	0.03	0.46	3.09	-0.04	-0.45	0.01	0.16	2.27
RAX	0.17	0.02	-0.22	0.53	-0.09	0.00	0.12	-0.23	0.22	-0.50
ROW	-0.26	-0.54	0.09	0.49	2.15	-0.04	-0.41	0.06	0.37	1.66

Table 3.3 Indicators for international competitiveness for USA_P and USA_NP

Source: own GTAP-CDM calculations

In Table 3.3, we find that the terms of trade for USA_P are positive for the participating Annex 1 regions. This result suggests a plea for participation, as these countries receive relatively more for the same amount of their exports. However, by looking at the terms of trade for USA_NP, we conclude that the USA is even better off by non-participation. In both regimes, the indicator for trade balance in relation to real GDP suggests that the participating countries would export more than they would import.

The indicator 'real percentage change in capital goods' may encourage the USA not to participate in Annex 1, as the participating regions are faced with a decrease in the amount of capital goods. This holds also for the indicator 'percentage change in terms of real GDP', as all participating countries are confronted with a decrease in the amount of GDP. Non-participation of USA would have some impact on the EU, as in USA_NP, the EU would be confronted with a real GDP loss of 0.37%, whereas in USA_P, this is only 0.21%. Even in terms of value of GDP, USA_NP gives a loss of 0.16% for the EU. The indicator 'value of GDP', however, emphasizes the USA's incentive for non-participation, as USA_NP gives a rise of 0.62% of GDP in value terms for the USA.

4 Implications of CDM

Clean Development Mechanism is one of the important instruments in the Kyoto Protocol that aims at contributing in a cost-effective way to achieve the amount of emission reduction, as it has voluntarily been agreed by Annex 1 countries under the Kyoto Protocol.

4.1 The formulation of CDM

A basic concept of CDM is that Annex 1 countries are allowed to invest in projects which achieve sustainable development in Non-Annex 1 countries, for which, in return, Annex 1 countries receive some amount of 'Certified Emission Reductions' (CERs) which can be subtracted from the voluntarily agreed amount of reduction to be achieved by the country under consideration.

In the analysis carried in this section, investments from Annex 1 countries for CDM-activities are provided by a 5% tax on all intermediate energy products for production of traded commodities in participating Annex 1 countries. The allocation of these investments to sectors in Non-Annex 1 countries are exogenously determined according to the CO2 emission share of the specific sector in the total CO2 emission of all sectors in all Non-Annex 1 countries. The amount of investment allocated in the specific sector in Non-Annex 1 countries determines in turn the rate of technological progress in this specific sector.

For the determination of the amount of CERs however, a standard method is not at hand yet. This is a result of uncertainties regarding the practical form of CDM that should be negotiated after the Kyoto Protocol. One of the issues in the negotiations is how to set the baseline and how to calculate (i) the part of emission due to more efficient technologies as a result of investments from Annex 1 and (ii) the part of emission which would be the case if there would be no investments from Annex 1 countries (see e.g. Begg et al 2001). Like the introduction of carbon tax, secondary effects would lead to a reallocation of economic resources in a general equilibrium setting.

For reasons of simplicity, CERs in the simulations performed in this paper are determined solely owing to emission reduction that is accreditable to technological progress in Non-Annex 1 countries within a single year. However, because GTAP-CDM is a static model, while the technological progress due to CDM-investments has also a sustainable character, we will also perform an analysis for the baseline calculation for CERs which is 10 and 20 times the emissions reduction in the Non-Annex 1 countries within a year. In regarding to these numbers, if we look at the economic lifetime of investments, a factor of 10 or 20 is conservative for capturing the sustainable character of CDM-investments in a static model, as it counts for a period of 8.5 years and 15 years repsectively at a annual interest rate of 4%. These numbers partly represent the still uncertain institutional setting, as a high baseline (Baseline C) will positively affect the cost-effectiveness of the CDM-instrument, while a low baseline (Baseline A) requires a relatively high investment from the Annex 1 countries to achieve a same amount of CER.

4.2 Results for emission reduction and carbon tax

The contribution of technological progress as a result of CDM-activities to CERs attributed to Annex 1 countries is presented in Table 4.1, which also shows other results of regime USA_P+CDM and USA_NP+CDM with regard to emission reduction and the corresponding carbon tax. In this table, emission targets from participating Annex 1 countries are achieved by a non-CDM part and a CDM part. The non-CDM part is the result of carbon tax. In Table 4.1, we see that this part is lower than the target; this leads to a lower carbon tax per tonne CO2 for participating countries. The non-CDM part of Non-Annex 1 countries is calculated from the demand for energy products by these countries, as if technological progress would not have taken place. The CDM-part is calculated from the remaining part that can be ascribed to technological progress as a result of CDM-activities by Annex 1 countries. Actual emissions in Non-Annex 1 countries are the eventually perceivable emissions from these countries, while the non-CDM part is calculated from the notion 'as if' no CDM and thus technological progress has occurred. The similarities and the differences between the regimes if CDM is taken into account will be analyzed below through decomposition of price and emission components.

relative to the BAU in 1995

	USA_P+CDM: CDM and Annex 1 incl. USA					**USA_NP+CDM: CDM and Annex 1 excl. USA**				
	Tar. red.	Non-CDM part	CDM part CER	Actual emis.	Carbon tax	Tar. red.	Non-CDM part	CDM part CER	Actual emis.	Carbon tax
	%	%	%	%	$/tCO2	%	%	%	%	$/tCO2
USA	-20	-19.76	-0.24	-19.76	14.25	no	2.02	0	2.02	0.00
EU	-20	-19.28	-0.62	-19.28	19.78	-20	-19.18	-0.82	-19.18	18.07
EIT	no	3.59	0	3.59	0.00	no	2.70	0	2.70	0.00
RAX	-20	-19.47	-0.53	-19.47	21.81	-20	-19.39	-0.61	-19.39	19.98
ROW	no	3.32	0.66	2.66	0.00	no	2.36	0.55	1.81	0.00
World		-7.78		-8.02	7.41		-2.97		-3.17	3.83

Table 4.1 Emission reduction and carbon tax for CDM-regimes

Source: own GTAP-E/CDM calculations

4.3 Decomposition of emission components in Non-Annex 1 countries

Figure 4.1 gives a comparison of carbon taxes for participating countries between the four regimes under analysis. It shows that CDM would result in lower carbon tax. This result is the strongest for EU, which means that the EU would benefit most from CDM activities.

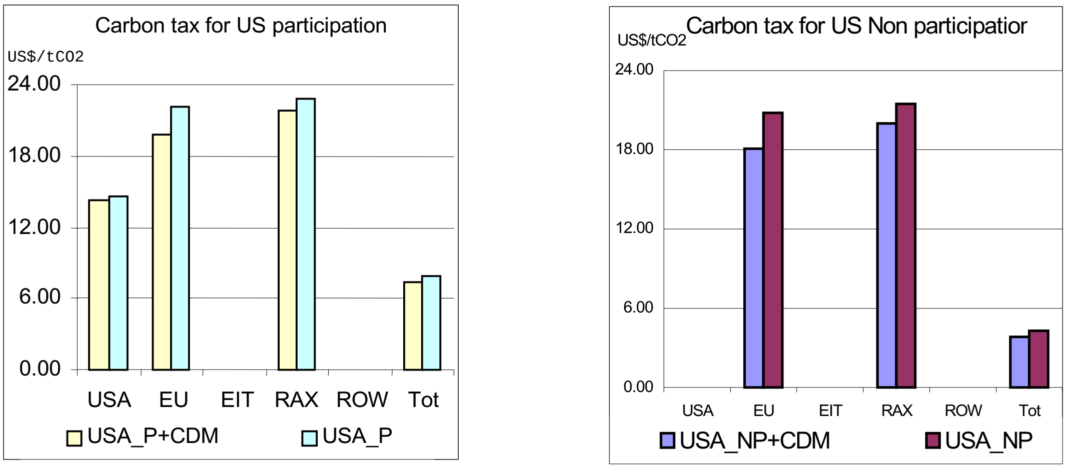

Figure 4.1 Impact for carbon tax as a result of CDM

A comparison between Table 3.2 and Table 4.1 gives also information on substitution effects which results in carbon leakage. Figure 4.2 decomposes the effect of CDM by comparing carbon leakage to ROW in regimes USA_P and USA_P+CDM. In USA_P, emission in ROW would grow by 3.18%, while in USA_P+CDM, this growth would be 2.66%.

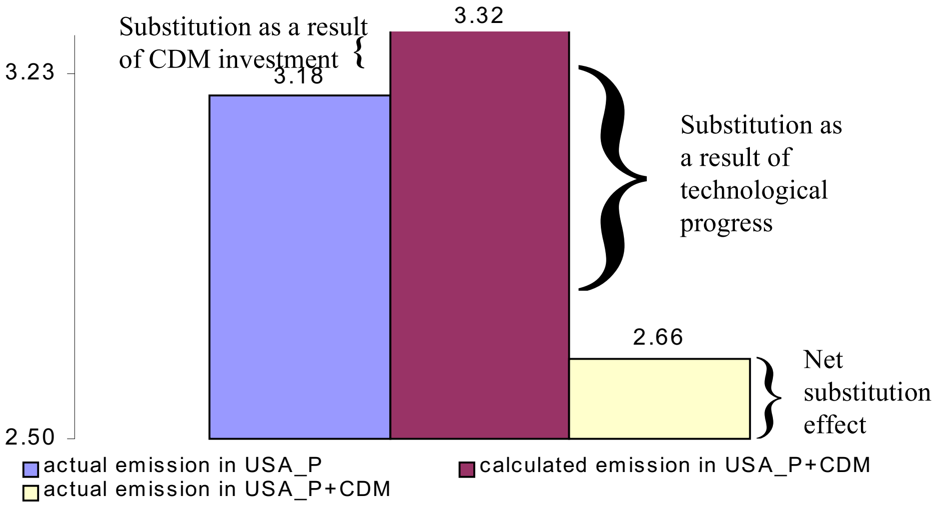

Figure 4.2 Decomposition of carbon leakage for ROW by regimes USA_P and USA_P+CDM

The reduced effect of carbon leakage could be attributed to (i) a substitution effect as a result of reallocation of economic resources by CDM activities from Annex 1 countries; this is (3.32%–3.18%=) 0.04% of the emission; (ii) an efficiency effect as a result of technological progress from CDM activities, this is (2.66%–3.32%=) –0.66% of the emissions. In this simulation, there still remains a net substitution effect as a consequence of a price effect caused by carbon tax on energy products, which is 2.66% of the ROW's emissions. In this figure, we see that carbon leakage may be reduced by CDM-investments.

Finally, a comparison between Table 3.2 and Table 4.1 shows that the final impact on the total reduction for the world as a whole depends on the relationships between the above mentioned substitution effects. In case the USA is part of participating Annex 1 countries, the world emission reduction as a result of CDM is slightly higher than in the non-CDM case: minus 8.02% (USA-P+CDM) versus minus 8.08% (USA-P). In case of USA non-participation however, the world emission reduction in CDM case is minus 3.17%, while in the non-CDM case it is minus 3.31%. Thus, at the world-level, we have the so-called rebound-effect (Howarth 1997) which indicates that more energy efficient production process would lead to an increased demand for energy products for which the demand effect is stronger than the technology effect. This results in an increase in emission in stead of an expected decrease in emission as a result of higher energy efficiency in the production of the output level.

4.4 A comparison of economic effects

The economic impacts of undertaking of CDM activities are shown in Table 4.2. In this table, the previous result that participating Annex 1 countries would be faced with a loss in real GDP still holds. This also applies to the result for the terms of trade and the trade balance: the USA is better off in case of a non-participation policy. A comparison between Table 3.3 and Table 4.2 shows that for the USA, an implementation of CDM will enlarge the impact for the macroeconomic variables under consideration in case of a non-participation strategy.

relative to the BAU in 1995

	regime USA_P+CDM: CDM and Annex 1 incl. USA					**regime USA_NP+CDM: CDM and Annex 1 excl. USA**				
	terms of trade %	trade balance %	real GDP %	value GDP %	real capital goods %	terms of trade %	trade balance %	real GDP %	value GDP %	real capital goods %
USA	0.42	0.02	-0.22	1.04	-0.22	0.89	-0.66	0.02	1.26	3.83
EU	-0.08	0.94	-0.76	-0.09	-5.02	-0.33	1.25	-0.97	-0.79	-6.72
EIT	0.09	-1.11	0.06	0.90	5.72	0.12	-0.89	0.04	0.44	4.60
RAX	0.38	-0.12	-0.28	1.02	0.45	0.14	0.04	-0.30	0.55	-0.20
ROW	-0.29	-1.07	0.34	1.19	4.54	-0.01	-0.87	0.26	0.96	3.77

Table 4.2: Macroeconomic indicators for CDM-regimes relative to BaU

Source: own GTAP-CDM calculations

For the convenience of comparison, we have subdivided the results from CDM regimes by those from the non-CDM regimes. The results from this division are given in Figure 4.3 and

Figure 4.4. In both figures, a value above 0 indicates that the impacts on the macroeconomic indicators are in the same direction for both the CDM case and the non-CDM case. A value above 1 indicates that CDM would magnify the impacts (either positive or negative). A value below zero indicate some adverse effects, i.e. there is a change in sign. Furthermore, the letter P in the bar indicates the positiveness of the value for the indicator in the CDM case. Clearly, the value for the terms of trade for the USA in Figure 4.3 is positive in the CDM case, and it is around three times as high as the non-CDM case.

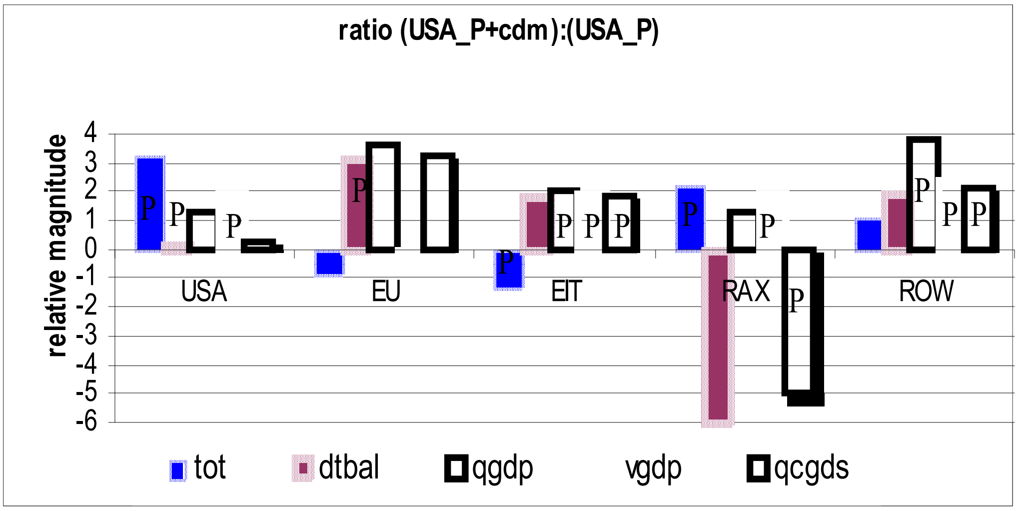

Figure 4.3 Relative magnitude of CDM effect in regard to USA participation regimes

Figure 4.3 shows the impact of CDM in proportion to the non-CDM case for the USA-participation case. In this figure, we see that most variables are above zero. This indicates that there are not so many adverse effects, if the CDM instrument is applied. This holds for both the USA and ROW. However, this indicates that the impacts of emission restriction would be enlarged by the CDM instrument, e.g. the real GDP and the real capital goods for EU become more negative, while the trade balance becomes more positive.

For the EU, there is a minor adverse effect for the terms of trade. By looking at the relevant numbers in Table 3.3 and Table 4.2, we see that for the EU, the terms of trade in the non-CDM case is positive (=0.09%), while in the CDM case, it is negative (-0.08%). For the EIT on the other hand, we observe clearly terms of trade gains from CDM. It will change from minus 0.07% in non-CDM case to plus 0.09% in the CDM case. For RAX, there are losses in trade balance (from plus 0.02% to minus 0.12%), but there are also gains in the terms of real amount of capital goods (from minus 0.09% to plus 0.45%).

Figure 4.4 shows the impact of CDM in proportion to the non-CDM case for a USA non-participation strategy. In this figure, we see that the adverse effect only applies to the terms of trade for the EIT. Instead of a loss of –0.04%, it gains 0.12%. Furthermore, CDM magnifies the effects, if the USA-decides to adopt a non-participation position. For the USA and the EU, the relative magnitude is above 1. This holds also for other indicators than the terms of trade for the EIT and the ROW. This indicates that for these regions, CDM would be more costly if compliance with the emission target is costly, as CDM would probably strengthen the impacts of policies aiming at emission reduction. Only for RAX, there seems to be some trade-off between the relative gain from the capital goods sector (instead of –0.50% loss, the CDM case gives –0.20% loss) against relative loss from trade balance (from 0.12% to 0.04%) and a loss of real GDP (from –0.23% to –0.30% in CDM case).

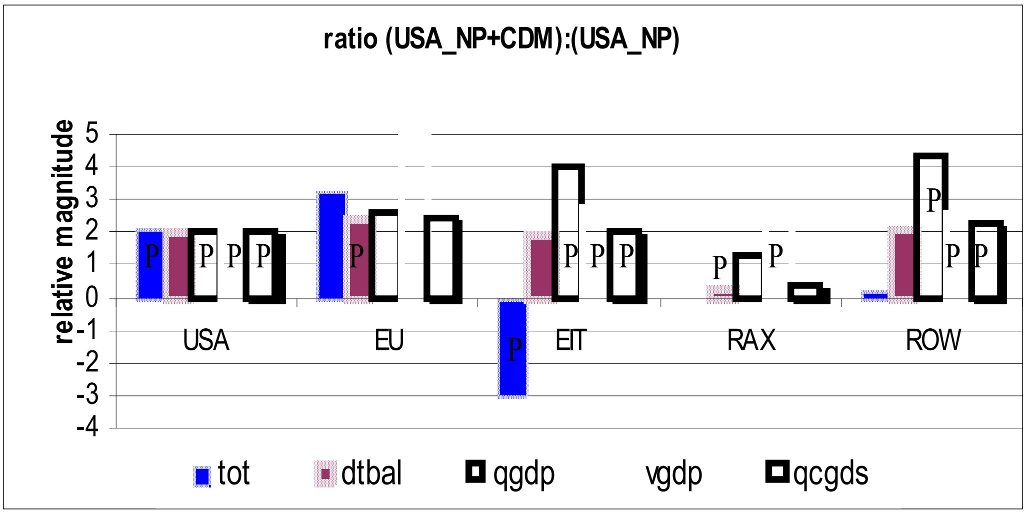

Figure 4.4 Relative magnitude of CDM effect in regard to USA non-participation case

In the next subsection, the robustness of this conclusion will be tested by showing how the impact of CDM would be altered if another design for CDM is chosen, i.e. another calculation methods for baseline is applied.

4.5 The issue of baselines

The calculation of baselines forms one of the problems for CDM investments. At the project level, this is shown in Chapter 7 in this book by van Ierland and de Leeuw (2001). In a static general equilibrium model where emissions reduction due to CDM-investment could easily be spotted, the problem is how to value the future emission reductions as a result of current CDM investments.

As is pointed out, a standard method is not at hand yet. Therefore, we will illustrate this by showing for the USA participation regimes how the indicators as discussed in the previous sections will be affected by a different calculation of the baseline, i.e. Baseline B for a case where CER is worth 10 times as much as in the single period case (Baseline A); and Baseline C where CER is worth 20 times as much as in the single period case. Table 4.3 shows the results for the USA participation case for Baseline B and Baseline C.

As a result of a higher CER for the same CDM investments, we see that the non-CDM part of the emission reduction is accordingly lower. This results in a lower carbon tax, which is quite standard. More interesting is that for the EU, if CER is worth 20 times as much as in the single period case, the CDM part is nearly 75% of the target. This indicates that for the EU, CDM is a cheaper instrument than for USA. The carbon tax for the EU could be lowered to 3.81US$/tCO2 in comparison to 22.13 US$/tCO2 in the non-CDM case. While for the USA, the difference is only (14.57–9.79=) 4.78 US$/tCO2. RAX forms an intermediate between the EU and USA.

relative to the BAU in 1995

	USA_P+CDM									
	Tar. red.	Non-CDM part	CDM part CER	Actual emis.	Carbon tax	terms of trade	trade balance	real GDP	value GDP	real capital goods
	%	%	%	%	$/tCO2	%	%	%	%	%
Baseline B										
USA	-20	-17.53	-2.47	-17.53	12.08	0.30	0.09	-0.18	0.82	-0.59
EU	-20	-12.75	-7.25	-12.75	10.54	-0.02	0.70	-0.58	0.00	-3.77
EIT	no	2.89	0	2.89	0.00	0.06	-0.91	0.05	0.77	4.71
RAX	-20	-14.66	-5.34	-14.66	14.78	0.30	-0.09	-0.21	0.84	0.33
ROW	no	2.86	0.57	2.19	0.00	-0.28	-0.89	0.32	1.01	3.80
World		-6.08		-6.32	5.31					
Baseline C										
USA	-20	-15.02	-4.98	-15.02	9.79	0.22	0.12	-0.15	0.65	-0.77
EU	-20	-5.37	-15.63	-5.37	3.81	0.00	0.54	-0.47	0.01	-2.94
EIT	no	2.08	0	2.08	0.00	0.06	-0.75	0.05	0.67	3.85
RAX	-20	-9.23	-10.77	-9.23	8.43	0.26	-0.08	-0.14	0.70	0.34
ROW	no	2.20	0.68	1.52	0.00	-0.25	-0.73	0.30	0.86	3.18
World		-4.21		-4.45	3.42					

Table 4.3 Emission reduction, carbon tax and macroeconomic indicators for different assumptions on baseline calculations under USA_P+CDM.

From the macroeconomic indicators, we see that, except for a minor change in the trade balance and real capital goods for the USA, and the value of GDP for the EU and real capital goods for RAX, all other values for Baseline B and C tends to be lower than Baseline A. This indicates that the magnifying effects as observed in subsection 4.4 will be diminished if the baseline is set in more favour for the Annex 1 countries. An intuitive explanation for this result is that, considering the lower carbon tax, the economic distortion as a result of emission restriction is cancelled out by CDM activities. The impact of this process is bigger as the baseline for CDM is set higher.

5. Conclusion

In this paper, we have analyzed the impacts of possible future global environmental change regimes. For this purpose, we constructed four regimes based on the dimensions of (i) the implementation of emission restriction with or without Kyoto instrument 'CDM'; and (ii) decision of USA to be either non-participation or not. Of course, the future regime is still fragile and the categorization of possible future regimes may be done along many dimensions.

One of these possible future regimes that is not yet analysed in this paper is −as we have already mentioned− the pessimistic, but real, possibility of the domino-effect of a USA's non-participation. An optimistic future regime that we have not analyzed in this paper is that it is also possible that the process which has been set in motion, e.g. to prepare Activities Implemented Jointly (a precursor for the CDM projects) and CDM, the negotiations with the Umbrella group and so on, will have its own momentum. The industries and businesses in the USA that have already invested considerable time and manpower may wish to continue with 'implementation without ratification', such that process of technological progress in the Non-Annex 1 countries will be faster. In this sense, we may have a situation that the total CDM investments in the USA non-participation regime may be higher. The conclusion on the impact of CDM however would, as would be expected, not change very much. Clearly, this analysis needs much future work. In addition, one of the important issues related to technological change is the intertemporal trade-off (leading to the so-called First-comers, Late-comers dilemma) (see also Nijkamp and Castells, 2001).

From the regimes which are analysed in this paper, we sum up the following main conclusions. Firstly, in a multiregion, multisector general equilibrium model, we find that price and other substitution effects may result in possibilities to carbon leakage. Since carbon taxes in the Annex 1 countries raises the relative prices of their products. This leads to more demand for the products from the countries that do not introduce carbon taxes. Secondly, the USA participation case shows that technological progress as a result of CDM would reduce this leakage. However, a rebound effect may show up at a worldlevel. Thirdly, the simulation results shows that carbon tax is the lowest for the USA in the US participation case for 20% of emissions reduction through all participating countries. This means that, mariginally speaking, the USA is less afflicted by reduction than the other participating countries. In the USA non-participation case, the carbon tax for other countries does not change drastically. Fourthly, the simulation results show that CDM enlarges the impact for a large part of the macroeconomic variables under consideration. Some adverse effects appear to occur for EU, EIT and RAX. However, as is shown in subsection 4.5, this impact depends on the method for baseline calculation. As a consequence, this implies that the institutional arrangement on the design of CDM affects the macroeconomic results. Fifthly, as long as the institutional arrangements are not effectively implemented, an important element for the climate change negotiations is the result which may be deduced from the US non-participation regimes. From a single country's perspective, it may be possible that, in case only the environmental costs are taken into account (e.g. because the environmental benefits are transboundary), countries would have an incentive not to participate in Annex 1 countries. This result needs to be confirmed by future research for non-participation of other countries and under different assumptions concerning the reduction percentages, baselines and the calculation of environmental benefits. Finally, as is to be expected, the simulations show that the actual emission reduction at the world level is less in case the USA would decide not to participate.

The result that the world emission is higher in case that a country decides to non-participation combined with the result that countries has an incentive not to participate when only the costs are taken into account likely confirms the ultimate problem of environmental externalities: the prisoner's dillemma. It is well-known from earlier theoretical and empirical works on environmental economics that internalizing environmental externalities is welfare improving for the world as a whole. The voluntarily agreed commitment on greenhouse gas (GHG) emission of the Annex-1 countries in the United Nations Framework Convention on Climate Change may be regarded as an attempt to internalize environmental externalities caused by carbon emission.

In case of an externality, the equilibrium where an optimal amount of 'emission constraint' is effectively imposed, is also the optimal one. In a static model, every deviation from this 'optimal' emission constraint should be regarded as non-optimal, unless a trade-off between an extra amount of emission and economic variables related to long-term variables (e.g., savings, technology) is explicitly specified. This implies that, if an emission constraint is optimal, the business as usual will be non-optimal. Therefore, the impacts associated with emission constraints and CDM activities are actually welfare-improving instead of costly.

The prisoner's dillemma shows also that the welfare-improving implication of effective emission constraints does, however, not rule out that there exists some incentives for a single country not to participate. The USA non-participation case might be interpreted in this way. Therefore, future analysis should point out whether, after taken the environmental benefits into account, it is still beneficial for the USA not to participate or that the advantage will also show up for other countries if they decide not to participate. In that case, rationality may be able to guide the negotiationparties to realize that free riding, i.e. not take the transboundary environmental benefits into account, would results in a non-optimal, i.e. destructive, outcome.

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