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Distribution Matters - Taxes vs. Emissions Trading in Post Kyoto Climate Regimes

by

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Abstract:
The policy instruments for emissions reductions will be an integral part of a Post Kyoto Climate Regime. In this paper we compare a harmonized international carbon tax to a cap and trade system with different allocation rules for the emission caps. The caps are based either on the requirement for equal percentage reductions in all countries or the "contraction and convergence" proposal that leads to converging per capita emission rights. The quantitative analysis is based on simulations with the CGE model DART. The harmonized carbon tax tends to favor industrialized countries but is less favorable to developing countries. The welfare effects of a cap and trade system depend crucially on the allocation rule for emission rights. The "contraction and convergence" approach leads to welfare gains for countries like China, India and Subsaharan Africa whereas it imposes welfare losses upon industrialized countries which are larger than those under other cap and trade schemes or a tax scenario. Independent from the allocation rule that is used regions exporting fossil fuels experience strong welfare losses from the reduction in the demand for fossil fuels and the fall in prices that results from the imposition of the international climate policies.

Keywords: Post Kyoto, emission targets, emission trading, taxes, distribution

JEL classification: H22, H23, H87, D58, Q48, Q52

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Introduction

In spring 2005, the Kyoto Protocol finally entered into force and established the first binding international targets for greenhouse gas (GHG) emissions. According to this agreement, GHG emissions in the major industrial countries are to be reduced by on average 5% relative to the 1990 level in the first so-called Kyoto commitment period from 2008 to 2012. Yet, besides that it is very unclear whether these targets will be met, the major GHG emitting industrial country, the USA, has withdrawn from the Protocol and the fast growing Asian countries, including India and China, that are responsible for a growing share of global GHG emissions so far face no emission reduction requirements. Already for some time now there is a discussion on a potential Post-Kyoto agreement. In this context innumerable proposals in more or less detail have been put forward. The 2004 overview by Bodansky et al. (2004) alone covers 44 different proposals which differ with respect to the emission path to be reached, the type of targets, the measures taken to reach the targets and the differentiation between different countries.

There is a general agreement that the implementation of any regime should be based on instruments that lead to an efficient allocation of abatement activities. Since the current Kyoto-Protocol focuses on marked-based approaches many proposals tend to favor a continuation and deepening of cap and trade systems. Recently though, several arguments - e.g. Nordhaus (2006) - in favor of an internationally harmonized carbon tax are brought forward. Such a tax is argued to bring about several advantages with respect to e.g. simplicity, dynamic flexibility, associated uncertainties and administrational and political feasibility.

Given the fact that China's emissions of GHGs are currently in the process of surpassing those of the biggest emitter USA and that by 2030 the developing countries are estimated to contribute more than 50% to global GHG emissions, there is also agreement that in any Post-Kyoto regime developing countries need to play a substantial role. This also means that emissions control in these countries must be combined with incentives to participate. Also, it is clear that not only efficiency but also distribution matters. The distribution of real or perceived costs and benefits of different Post-Kyoto policy regimes will therefore play an important role in the upcoming negotiations. Without a system that delivers in some sense a fair or just distribution of abatement activities and associated real or monetary transfers no Post-Kyoto agreement is likely to be signed. Whereas a uniform carbon tax may require additional transfers in order to induce countries to participate in a global tax system, a system with tradable emission rights can be designed in such a way that the allocation of emission rights is made in such a way that incentives for participation automatically arise.

When talking about emission targets, fairness is mostly discussed either with respect to a fair distribution of emissions targets (a*llocation based criteria)* or a fair differentiation of commitments in terms of the economic effects (o*utcome based criteria.)* (den Elzen & Lucas 2005). Furthermore, den Elzen & Lucas (2005) derive four key ethical principles to define a fair or just distribution of emission reductions or resulting economic costs from the large number of regime proposals

Egalitarian – all human beings have equal rights in the use of the atmosphere. Hence, equal emission rights should be allocated to every person or to countries on a per capita basis.

Sovereignty & acquired rights – all countries have the same right to use the atmosphere as a recipient of emissions. Hence, the current emission levels mark the status quo and all reductions should start from this baseline.

Responsibility/polluter pays – the countries responsible for most of the accumulated emissions so far (thus the industrial countries) should bare a larger burden. Hence, accumulated historical emissions should provide the basis for determining reduction obligations.

Capability/ability to pay – richer countries should bare a larger burden compared to poorer countries. Again, this implies stricter targets for industrial countries, but also leads to a differentiation between different developing and transition countries.

Most proposals use a mix of criteria and principles. The often discussed “contraction & convergence” proposal by the Global Common Institute for example is a combination of the egalitarian and sovereignty principles. It implies that per capita emissions of each country converge to a common level until a certain date (e.g. 2050 or 2100) such that overall global emissions are reduced to assure a “safe” level of atmospheric greenhouse gas concentration.[1] Mostly this save level is assumed to be 450 or 550 ppmv CO_2e. Another proposal that is often put forward is to require equal percentage reductions of emissions for all countries. This is also denoted grandfathering and is solely based on the sovereignty principle.

There are already some papers and studies that try to evaluate and compare different regime proposal with regard to different criteria. While some are rather qualitative (e.g. Aldy et al. 2003, Bodansky et al. 2004), there are also a few quantitative studies based on different modeling approaches (e.g. Böhringer & Welsch 2004, Buchner & Carraro 2005, Bollen et al. 2004, Criqui et al. 2003, den Elzen et al. 2005, den Elzen & Lucas 2005, Nacicenovic & Riahi

[1] See den Elzen & Lucas (2005) for a more detailed discussion on how different proposals build on a mix of different principles.

2003). None of these studies though looks at the rather new proposal of a harmonized international carbon tax. The aim of this paper is to compare such a harmonized international carbon tax with two emissions trading scenarios that mark two extreme distributions of emission targets. The focus in this comparison is on the international distribution of emissions and economic costs and their implications especially for the developing countries.

The paper proceeds as follows. In the next section a simple partial equilibrium model based on marginal abatement costs is used to derive some general implications of the harmonized tax proposal compared to different emissions trading regimes. In order to derive some quantitative results for a set of stylized emissions trading scenarios and a tax scenario, the computable general equilibrium model DART is used. In section 3 the model and the scenarios are described. Section 4 presents and discusses the simulation results. Section 5 concludes.

1. Harmonized taxes vs. emissions trading – a first analysis

As mentioned above, the focus of this paper is on the distributional implications of different Post-Kyoto regime proposals. A very simple instrument that can be used to get a first idea of how an international harmonized carbon tax compares to different regimes of emissions trading are marginal abatement cost curves.

The marginal abatement cost (MAC) for emissions (e.g. CO_2 emissions) in a specific sector or region represents the cost of the last ton of emission reduction undertaken in order to fulfill a certain reduction target. The MACs for different targets taken together form the marginal abatement cost curve (MACC) that shows the MAC for varying amounts of emission reductions. Once such curves are available for different world regions it is very easy to determine permit prices, total abatement cost and regional emissions for different scenarios of international emission trading but also for a tax scenario. A detailed description of the use of MACCs to study emissions trading regimes is provided by Ellerman & Decaux (1998) and Criqui et al. (1999). Figure 1 shows typical MACCs for two countries A and B.

The y-axis shows the carbon price, while the x-axis marks the amount of carbon reduction – either in terms of absolute or in terms of relative CO_2-emissions reductions. The MACCs thus show the marginal costs for a certain amount of (absolute or relative) emissions reductions.[2] As drawn in figure 1, the costs for reducing the same absolute or relative amount of emissions are higher for country A. Two results that are relevant in our context can be derived.

[2] Note that of course the two cases of absolute and relative MACCs do lead to different pictures. For two countries it is even possible that the ranking of absolute and relative MACCs is different.

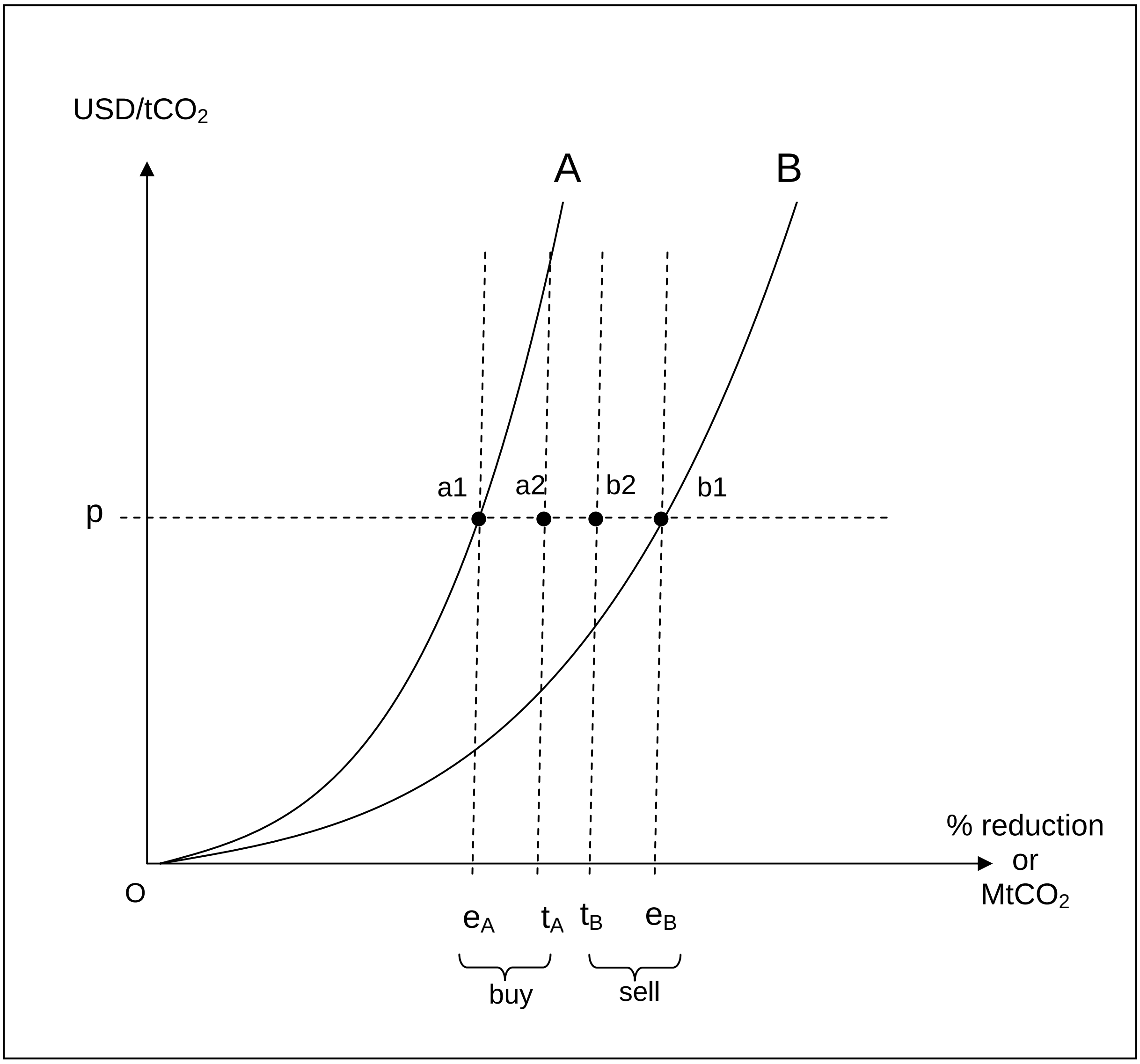

Figure 1: Marginal abatement cost curves of two countries A and B

Assume that both countries face a harmonized carbon tax of p USD/tCO_2. The first result that follows directly from figure 1 is that a harmonized carbon tax implies higher absolute resp. relative emission reductions for the country with lower abatement costs. If the MACCs are drawn for absolute emission reduction, total abatement costs can be derived. For country A the costs are the area Oe_Aa_1 and for country B the area Oe_Bb_1. Thus, the total abatement costs are always higher for countries with lower abatement costs. In terms of percentage costs of emission reductions the low cost country will always reduce a higher percentage of its emissions than a high cost country, i.e. one with a steep MACC.

Sets of MACCs for several world regions and/or countries have been derived with different models such as the bottom-up models POLES and TIMER the top-down models EPPA, WORLDSCAN and also DART. Even though the MACCs differ across models and a MACC for one country depends on the assumptions about emission reductions in other countries (see Klepper & Peterson 2006) and on the year for which the MACC is constructed, the relative order of the level of MACCs of different countries and world regions is relatively constant across models and across scenarios for both absolute and relative MACCs[3]. Table 1 shows the ranking of MACCs of different world regions.

Table 1: Comparison of different MACCs

Rank	Country regions	Model
Absolute MACCs		
1	Japan	DART, EPPA, POLES
2	Africa	DART
3,4	Other Annex B, Eastern Europe	DART, EPPA, POLES
5	Latin America	DART
6,7,8	Western Europe, Former Soviet Union, India	DART, EPPA, POLES
9, 10	Middle East, Pacific Asia	DART
10,11	USA	DART, EPPA, POLES
10	China	DART, EPPA, POLES
Relative MACCs		
1,2,3	Japan*, Western Europe, USA	EPPA, WORLDSCAN, POLES, TIMER2010
4	Brazil	EPPA
5	Eastern Europe	EPPA, WORLDSCAN, POLES, TIMER2010/2030
6	Former Soviet Union**	EPPA, WORLDSCAN, POLES, TIMER2010
7	Pacific Asia	EPPA
8	India	EPPA
9	China	EPPA, WORLDSCAN , POLES, TIMER2010/2030

* One of the lowest MACCs in TIMER2030, ** One of the highest MACCs in TIMER 2030

Source: den Elzen & Both (2002), Criqui et al. (1999), Ellerman & Decaux (1998), own simulations.

The steepest absolute MACCs are found in Japan, followed by sub-Saharan Africa. China and the USA possess the lowest ones, mainly because of the sheer size of the two economies and their emission levels. Comparing absolute marginal abatement costs is therefore not very meaningful. The ranking of MACCs according to the percentage emission reductions gives a better indication of the burden of a uniform global tax. Table 1 shows that

[3] One drawback of the MACCs in literature is that they are mostly for the year 2010. As the MACCs derived from the TIMER model in den Elzen & Both (2002) show, the order of MACCs can change over time.

a harmonized tax mostly implies higher percentage reductions for the developing countries compared to industrialized countries. China and India, the two developing countries which are most important for an agreement on an effective Post-Kyoto regime, face the highest relative emission reductions. It is therefore very unlikely that a proposal for a global tax without redistribution of at least part of the revenues will be a politically feasible option. The numerical welfare effects of such a global tax are illustrated in section 3.

The second result which is a little more difficult to derive is the comparison of a harmonized tax scenario to an emissions trading scenario. The countries that sell emission rights in the emission trading scenario are always better off then in the tax scenario, while buying countries are worse off. This implication of figure 1 needs to be explained.

Note first, that in the absence of any uncertainty or transaction costs, a harmonized tax is equivalent to an emission trading system where every region receives an endowment of emission rights which is identical to the level of the emissions resulting from the harmonized tax. Note also, that if a harmonized tax or any emissions trading scheme should achieve the same overall emission reduction level, the carbon price (either set directly as a tax, or emerging from any distribution of emission rights in an emission trading scheme) is the same. Assume now that we have an emissions trading regime that leads to the same amount of overall emission reduction as the harmonized tax p (thus to a reduction of $e_A + e_B$). If the emissions trading scheme does not allocate the reduction targets e_A and e_B but at t_A and t_B such that $t_A + t_B = e_A + e_B$, then the two countries will start trading emission rights. In figure 1, country A has an allocation of emission rights resulting in a reduction target of t_A and country B of t_B. In this case, country A has a larger reduction target then under a harmonized tax. Under emissions trading, it buys e_At_A emission permits from B. This leads to a shifting of the reduction burden and the distribution of abatement costs. In the scenario shown in figure 1, country A needs to reduce more than under the tax scenario. It buys emission allowances of which the costs are represented by area $e_At_Aa_2a_1$. So while A needs to transfer this amount to B in order to buy the emission rights, country B receives an additional income equivalent to the area $t_Be_Bb_2b_1$. Although both countries are gaining from the opportunity to trade, the country which is scarce of emission rights will be worse of than the better endowed country. It is, however, not the absolute endowment that matters as to who will be buying emission rights – therefore being less well-off – but the endowment relative to the shape of the MACC. Consider, for example, the case in which the countries are of identical size and receive the same reduction target, i.e. $t_A = t_B$, then country A will still be worse off since it has higher abatement costs than country B.

The studies that analyze different emission trading scenarios such as per capita convergence of emissions or different multi-stage scenarios, in which countries adapt emission targets once they reach a certain level of GDP (Böhringer & Welsch 2004, Criqui et al. 2003) show that in these scenarios the USA and Western Europe and to a smaller degree the remaining Annex B countries as well in some cases the Eastern European countries become buyers of emission allowances, while the largest sellers are Africa, China and India. Whether Latin America is a seller or a buyer differs between the studies and scenarios. If a late convergence year is assumed (e.g. 2100) in the scenarios with convergence of per capita emissions, the USA are in some simulations selling allowances in later years, while some developing countries have to buy. Overall, in a partial equilibrium context, a harmonized international carbon tax – compared to two popular proposals of Post Kyoto regimes that rely on emissions trading – tends to result in larger abatement costs for major developing countries and lower abatement cost for industrial countries.

Since there are not yet any quantitative comparisons of the tax proposal with other emissions trading scenarios we will provide such a comparison based on simulations with the DART model. When analyzing the simulation results, we will also discuss some further effects that are evidently important for the distribution of burdens and incentives for developing countries.

2. Quantitative Simulations

In this section we will introduce the DART model which will be used to simulate a set of stylized emissions trading scenarios. These scenarios will then be compared with a harmonized international carbon tax. In order to make the tax solution comparable to the cap-and-trade approaches all scenarios are designed to achieve the same world wide reduction target of 40% relative to 1990 levels. The scenario design is also presented in this section. The simulation results will then be discussed in section 4.

2.1. The DART-Model

The DART (Dynamic Applied Regional Trade) Model is a multi-region, multi-sector recursive dynamic CGE-model of the world economy. For the simulation of Post-Kyoto emission reduction scenarios, it is calibrated to an aggregation of 12 regions and 11 sectors, which are shown in Table 2.

The economy in each region is modeled as a competitive economy with flexible prices and market clearing. There exist three types of agents: a representative consumer, a representative producer in each sector, and regional governments. All regions are connected through bilateral trade flows. The DART-model has a recursive-dynamic structure solving for a sequence of static one-period equilibria. The major exogenous drivers are the rate of productivity growth, the savings rate, the rate of change of the population, and the change in human capital. The model horizon goes until the year 2050.

Table 2: DART Regions and Sectors

Countries and regions			
Annex B		**Non-Annex B**	
EUW	Western Europe	CPA	China, Hong-Kong
EEU	Eastern Europe	IND	India
USA	United States of America	LAM	Latin America
JPN	Japan	PAS	Pacific Asia
FSU	Former Soviet Union	MEA	Middle East, North Africa
OAB	Other Annex B (Canada, Australia, New Zealand)	AFR	Sub-Saharan Africa
Production sectors/commodities			
Energy Sectors		**Non-Energy Sectors**	
COL	Coal Extraction	IMS	Iron, Metal, Steel
GAS	Natural Gas Production & Distribution	PPP	Pulp & Paper Products
CRU	Crude Oil	CEP	Chemical Products
OIL	Refined Oil Products	AGR	Agricultural Products
EGW	Electricity	MOB	Transportation Services
		OTH	Other Manufactures & Services

The model is calibrated to the GTAP6 database that represents production and trade data for 2001. The elasticities of substitution for the energy goods coal, gas, and crude oil are calibrated in such a way as to reproduce the emission projections of the EIA (EIA 2002). For a more detailed description of the DART model, see Springer (2002) or Klepper et al. (2003).

2.2. Scenario Design

Since the aim of this paper is not to analyze concrete regime proposals but rather to show how internationally harmonized carbon taxes compare to different emissions trading regimes where the targets are derived from applying different equity criteria and principles we create three extreme scenarios of distributing emission rights.

Since the focus is not on absolute levels but on the distribution of reductions and costs, in all scenarios the same path of global emissions reductions is assumed. In particular we assume a global reduction of CO_2 emissions by 40% relative to 1990 levels until 2050 which is in the range of emission reductions deemed necessary to reach a 550 ppmv target of atmospheric greenhouse gas concentration (see e.g. WBGU 2003). We furthermore assume that global emissions start to be reduced linearly from 2010 on[4] until the 40% reduction target is reached in 2050. We then look at three different regimes that use allocation based criteria.

[C&C] In this scenario, emissions converge to equal per capita emissions in all countries until 2050. This scenario is following the so-called contraction and convergence proposal which is based on the egalitarian principle but also to some degree on the sovereignty principle, since current emission levels are the starting point. As in Böhringer & Welsch (1998) we assume that from 2010 on per capita emissions start to converge to a common level that is reached in 2050. In particular, if $pce_i(t)$ is the level or per capita emissions of country i in year t and pct is the uniform level of per capita emissions in 2050 then $pce_i(t)$ is defined as

$$pce_i(t) = \frac{40-(t-2010)}{40} pce_i(2010) + \frac{t-2010}{40} pct$$

The total carbon limit $carblim_i(t)$ for a country in a certain year is obtained by multiplying the per capita emission right by the country's population in that year $pcarb\lim_i(t) = pce_i(t) * pop_i(t)$

[grand90] In this scenario it is assumed that all countries face the same relative reduction target. Thus all countries have to reduce their emissions by 40% relative to 1990 by 2050. Thus, the base year is the same as for the current Kyoto Protocol. This proposal is based on the sovereignty and acquired rights principle only and corresponds to a grandfathering of the emission rights of the status quo in 1990.

[grand2010] In this scenario all countries face the same relative emission reduction target, but the base year is now 2010. Compared to the base year 1990 this favors the countries with large growth rates which are in particular China and India, so that they are likely to have more incentives to participate.

Figure 2 illustrates the resulting global emission reductions relative to the business as usual (BAU) scenario without any climate policy. Emissions under the BAU scenario as computed by DART rise from around 30 $GtCO_2$ in 2001 to around 41.2 $GtCO_2$ in 2050. In 2030 they have reached a level of 37.1 $GtCO_2$. The slow growth of emissions between 2030 and 2050 is mostly due to the increasing prices for fossil fuels that act like an implicit carbon tax. In the two grandfathering scenarios global emissions decrease linearly until they reach the emission target of around 13 $GtCO_2$ in 2050. The emission path for the [C&C] scenario partially lies above the grandfathering scenarios since the formula we use to calculate the

[4] We do not assume that the Kyoto targets are reached for the first commitment period from 2008 – 2012. This is for simplicity, but there is also some justification for this, since neither the EU, nor Canada or Japan are on track to meet their targets in the remaining time.

emission endowments in [C&C] leads to less then linear reductions during the phase of high population growth. In 2050, the emissions reach the same level of 13 $GtCO_2$ as the other scenarios.

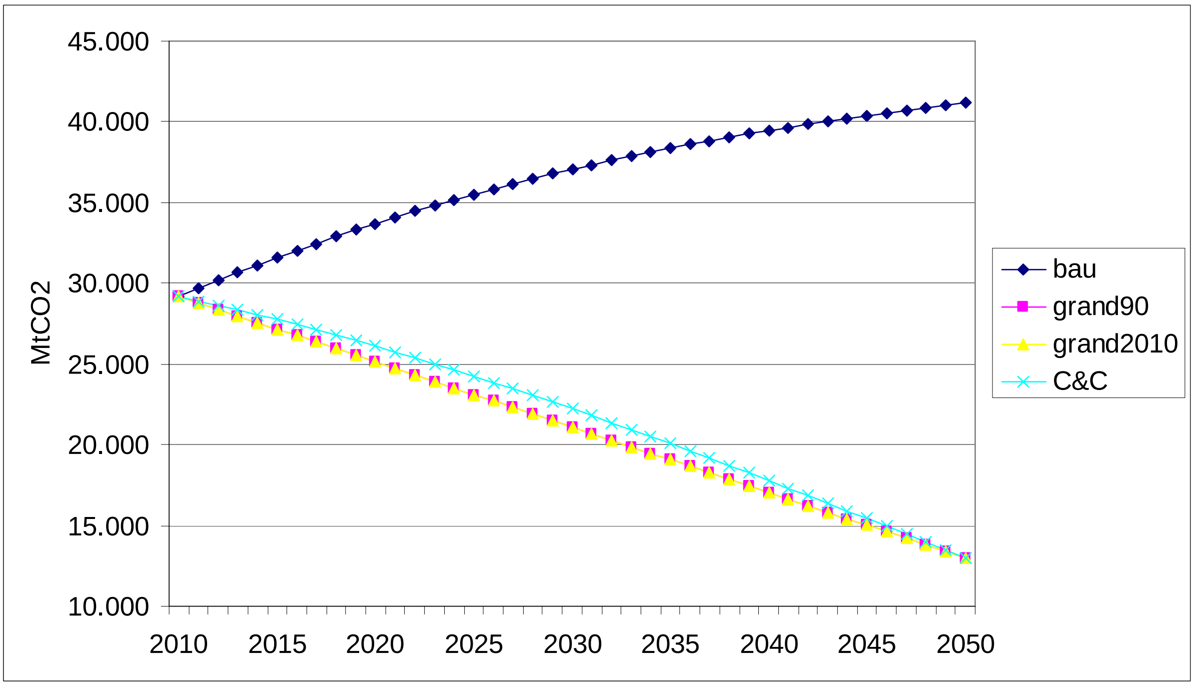

Figure 2: Global emissions in the different scenarios and in the business as usual run

Although the global emission paths are almost identical the three scenarios represent very different allocations of emission rights. Whereas the two “grandfathering” scenarios represent the logic of imposing reduction targets according to current or historical emissions, the C&C scenario is derived from the endpoint with equal per capita emission rights.

In scenario [grand90] the 40% reduction by 2050 is imposed to each region according to the 1990 emissions. This will, of course penalize the fast growing regions - mainly China, India, the Asian Tigers and Latin America – since they will face much tighter targets relative to their business-as-usual emissions. In contrast, scenario [grand2010] accounts for the by 2010 already realized baseline emission growth. Therefore the regions with fast baseline growth will be faced with a lower percentage reduction than in scenario [grand90]. In scenario [C&C] regions with currently high per capita emissions face the largest burden since they need to converge towards those regions with low per capita emissions. Figure 3 shows the per capita emissions in 1990 and in the business as usual scenario in 2050 and illustrates that the industrial countries face the largest emission reductions, while the developing countries and especially Africa and India need to reduce fewer emissions. These effects are illustrated in section 4.1. which presents the simulation results.

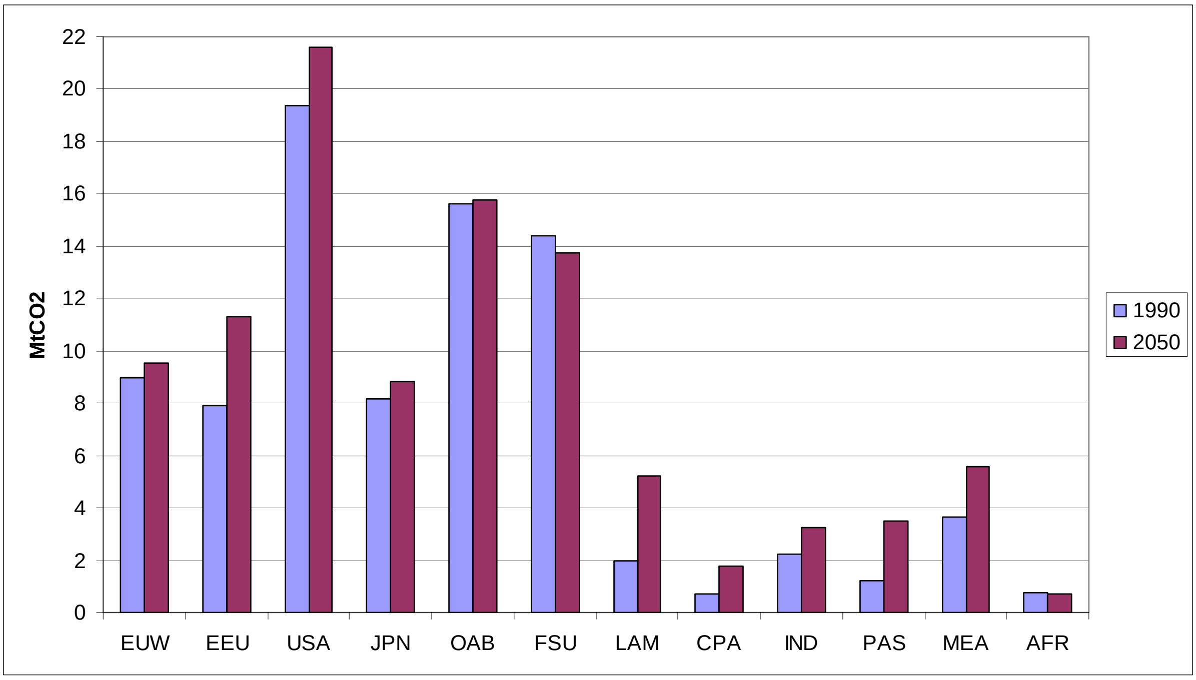

Figure 3: Per capita emissions in the DART regions in 1990 and in 2050 in the business as usual scenario.

In all three scenarios, we assume that the targets can be met with a system of unlimited international emissions trading. The global carbon prices for the emission rights are shown in Figure 4. At the beginning carbon prices rise rather slowly and only reach around 30 USD/tCO_2 in 2020. Then prices start to rise more quickly and reach around 115 – 120 USD/tCO_2 in 2030 thus representing the increasing marginal cost of global carbon abatement activities. The carbon prices under contraction and convergence (C&C) are slightly below those of the grandfathering scenario. In 2030 there is a difference of 15.5% between the carbon price in the [grand90] and the [C&C] scenario. Only in the last ten years between 2040 and 2050 this trend will be turned around and the prices under grandfathering are up to 20% below the C&C prices.

Two factors are driving this effect: One is the difference in the world wide emission constraint which allows in the C&C scenario slightly higher emissions than the grandfathering scenarios before they all converge to the overall reduction of 40% in 2050. As mentioned this is due to the fact that the C&C constraint is nonlinear whereas the grandfathering constraint is linear in time. The second effect results from the fact that the emission constraint is relaxed in the C&C scenario especially for developing countries, and these regions tend to grow faster than the industrialized countries. This enables the fast growing regions to accumulate more capital than the more constrained regions. Hence, in later periods when the emission restriction becomes tighter for these economies the world capital stock and the production capacity have grown larger than in the other scenarios. Consequently, the carbon prices will be higher in later periods.

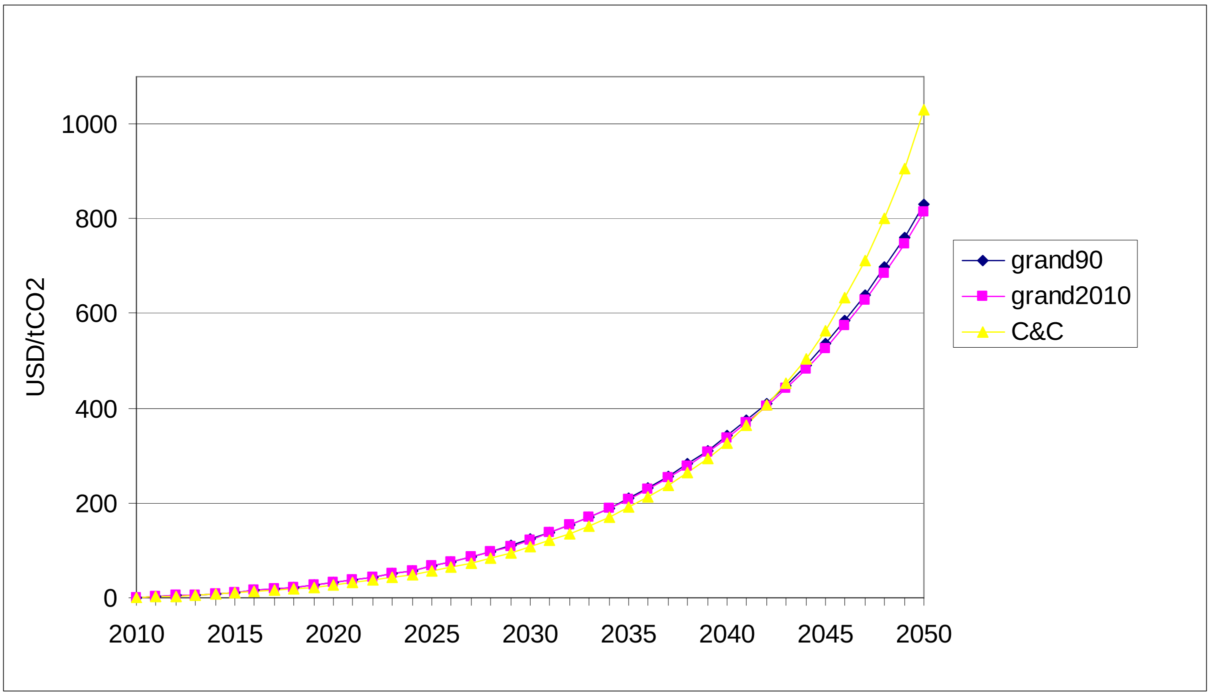

Figure 4: Carbon prices in the different scenarios

We now come to our tax scenario. In a model with complete information and zero transaction costs, a scheme with emissions caps and international emissions trading is equivalent to a uniform international carbon taxes. In other words, for every tax schedule there exists one distribution of emission rights that corresponds to a certain tax level which than results in the same allocation of resources. It is thus possible to design a tax scenario where the tax is exactly equal to the allowance prices derived from the emissions trading scenarios and which will reproduce the same global emissions path. However, since the different scenarios result in different emission growth paths in the intermediate periods one would need to create a different tax schedule for each scenario making comparisons and the presentation rather intransparent. We therefore choose to take the average price of the trading scenarios to construct the scenario with a harmonized international carbon tax

[tax] In this scenario all regions implement the same uniform carbon tax. The level of the tax is taken as the average of the carbon prices of the emissions trading scenarios. The additional tax income will be redistributed in lump sum to consumers.

With this construction of scenarios it is now possible to compare the tax scenario with the different emissions trading scenarios in terms of the regional distribution of emission reductions and their economic costs at the regional as well as at the global level.

The model is run until the year 2050. Nevertheless, the following discussion focuses on the year 2030 only. One reason for this is that the uncertainty of model results grows over time since the model is calibrated to the data from the base year 2001. In addition, it is difficult to know how technological and structural change, especially in the energy sectors, will change the economy over time. There is also some justification for doing so since current negotiations for Post-Kyoto agreements are not likely to go beyond even 2025. Qualitatively the results remain similar for the year 2050. Where this is not the case, it will be mentioned.

3. Simulation results

The DART model is used to simulate the four Post-Kyoto scenarios introduced above. The discussion will focus on the impact of the three different allocations of emission rights and on the difference between an emissions trading scheme and a tax solution with the uniform tax applied in every region and tax receipts remaining in the region. The year 2030 is taken as the reference year for illustrating the impact of the scenarios. These results are compared to the situation in 2010 the time at which the decisions about the targets are expected to be finalized.

4.1 Emission reductions

In order to show the challenges for a Post-Kyoto regime we computed the emission targets for the scenarios [grand90], [grand2010] and [C&C]. For the tax scenario, the emissions were computed using the average prices of the trading scenarios as discussed above. Those emissions can be interpreted as the allocation of emission rights which are comparable to the targets of the three trading scenarios and for which the tax is equivalent to an emission trading scheme with this particular allocation of emission rights. These targets are displayed in Figure 5. In [grand2010] all countries face the same relative reduction target of 28% relative to 2010. In the scenario [grand90] with the base year 1990 those countries with the high growth rates in the period between 1990 and 2010 face higher and those with low growth rates lower relative reduction targets. Therefore, developing countries would be faced with reduction targets over 30% whereas the OECD countries would get endowments requiring reductions of only 25% to 29%.[5] It is clear that any uniform percentage reduction target for the Post-Kyoto period which is based on 1990 emissions will favor the industrialized countries and the countries of the former Soviet Union.

The picture for the contraction and convergence scenario is very different. Here, the industrial countries have to reduce their emission by 35 to 45% relative to 2010 while in the developing countries emission reductions are much smaller (22% in China, 7% in Latin America, 13% in Middle East, 1% in Pacific Asia). In some countries emissions are even allowed to grow (by 36% in India and 111% in Africa). As could be expected, for the developing countries, [C&C] is the most generous scenario, while it is most severe for Eastern Europe, the countries of the former Soviet Union, and Japan.

It is interesting to see how the implicit targets of the [tax] scenario compare to the emissions trading scenarios. In fact, the results are very diverse without a simple pattern as Figure 5 shows.

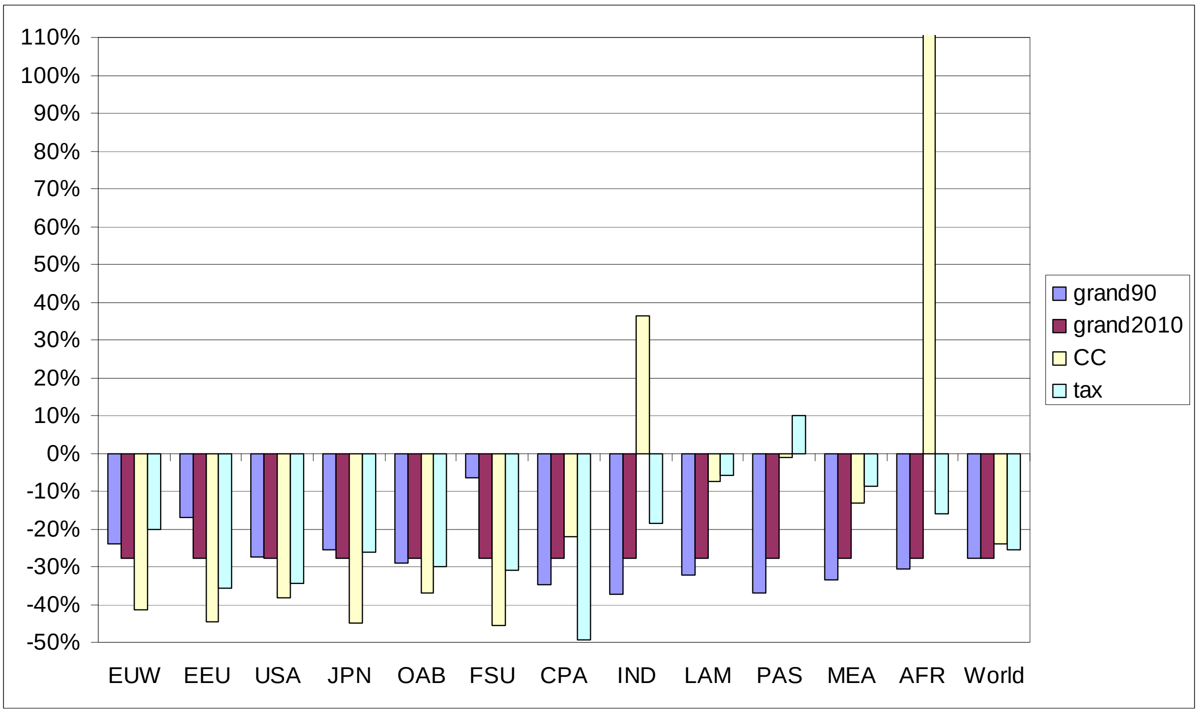

Figure 5: Emission target in 2030 relative to 2010 emissions

Whereas for Western Europe, Japan and the other Annex B countries put together in the DART region OAB the uniform tax is almost equivalent to the endowment with emission rights under the grandfathering scenarios, the USA will get a somewhat lower endowment resulting in stronger reduction targets. Compared to the grandfathering solution all developing countries except China will benefit from a uniform tax. One region gets even an endowment larger than its 2010 emissions and that is Pacific Asia. This is due to the fact that in the period 2010 to 2030 business as usual emissions in this region grow very fast compared to the rest of the world. Therefore, the initially low tax will not be sufficient to actually reduce emissions below the 2010 levels in this region whereas it achieves this in all the other regions. When compared to the contraction and convergence approach the tax

[5] A spezial case is region FSU, the former Soviet Union. Since 1990 is a year before the economic collaps with high emissions, the reduction in 2030 relative to 2010 is small because the economic contraction in the 1990s has

solution favors industrialized countries by giving them larger implicit emission rights than in the [C&C] scenario. In contrast, India, China and Africa become substantially worse off by the uniform tax.

Figure 6 shows the same targets but measured relative to business as usual emissions in 2030. The basic structure of the targets remains very similar but the reduction requirements in the different scenarios in many cases diverge less than in the comparison with 2010 emissions. It is remarkable that the grandfathering scenarios put a heavy burden on the fast growing developing countries as it is evident in India [IND], Pacific Asia [PAS], and especially Africa [AFR]. Whereas [C&C] allows them some leeway for growth – in Africa even 50% higher emissions then under their baseline – the grandfathering imposes reductions against their baseline of 50% and up to 60%. If the choice between a grandfathering system and the contraction and convergence approach is available, it is also interesting to note that among the rich countries the USA are less worse off by the [C&C] approach in terms of reduction against their business as usual path than are Western Europe and Japan which would have to reduce twice as much under [C&C] than under [grand90]. Finally, a tax solution would be strongly opposed by China but these simulations also show that even the USA should favor grandfathering and emission trading over taxes.

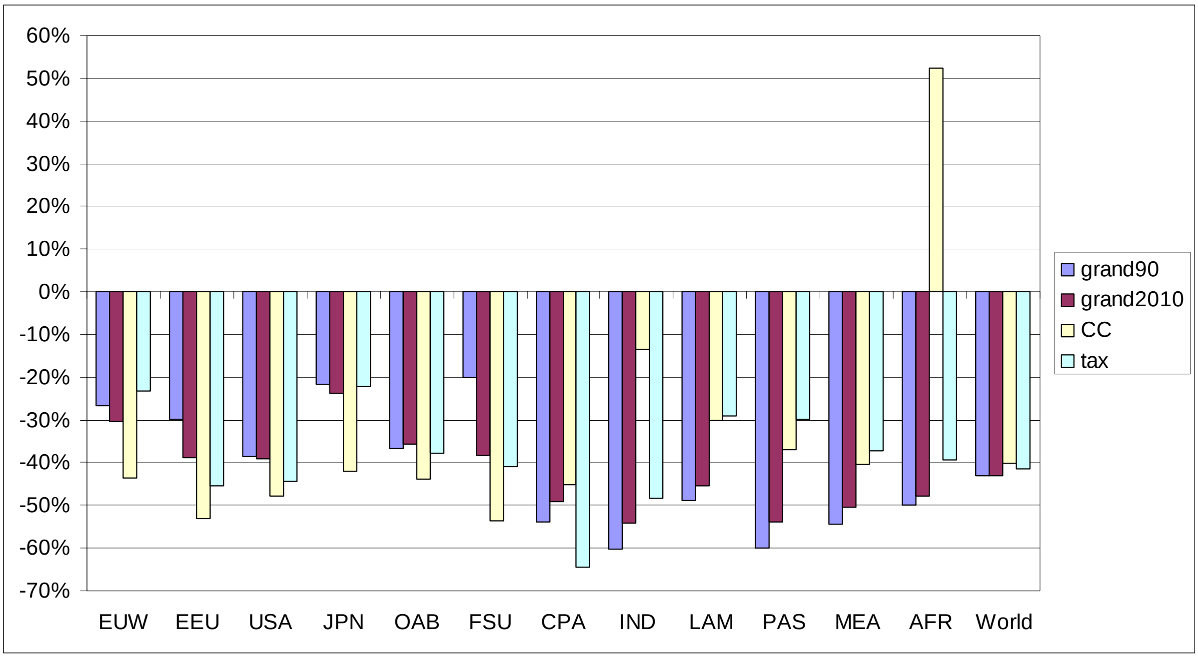

Figure 6: Emission target in 2030 relative to business as usual emissions in 2030

already brought about a drastic emission reduction.

3.2. Emission trading

The major feature of a cap-and-trade scheme is the ability of countries to meet their reduction targets by buying emission reduction credits abroad or to abate more than the required amount and sell it on the international market for emission rights. First of all, this leads to an efficient allocation of abatement activities but it also creates income effects as imports and exports of emission rights are accompanied by real income transfers. The direction and size of these transfers depend mostly on the relative marginal abatement costs and the degree of reduction required by the international cap-and-trade regime. These transfers and their welfare effects need to be taken into account when the international tax solution is to be compared to the different emission trading scenarios.

Figure 7 shows the net trade in emission allowances in the year 2030 with some unexpected results. The tightness of the emission cap has been shown in Figure 6 where reduction targets relative to BAU emissions are computed. The industrialized countries are in general less constrained in the grandfathering scenarios and therefore tend to be sellers of emission allowances. The opposite is true for the contraction and convergence approach where it is mainly India which is hardly constrained and Sub-Saharan Africa which is not constrained at all. However, abatement costs also determine whether a country is more likely to become a seller. Abatement costs are on average lower in developing countries than in the industrialized countries.

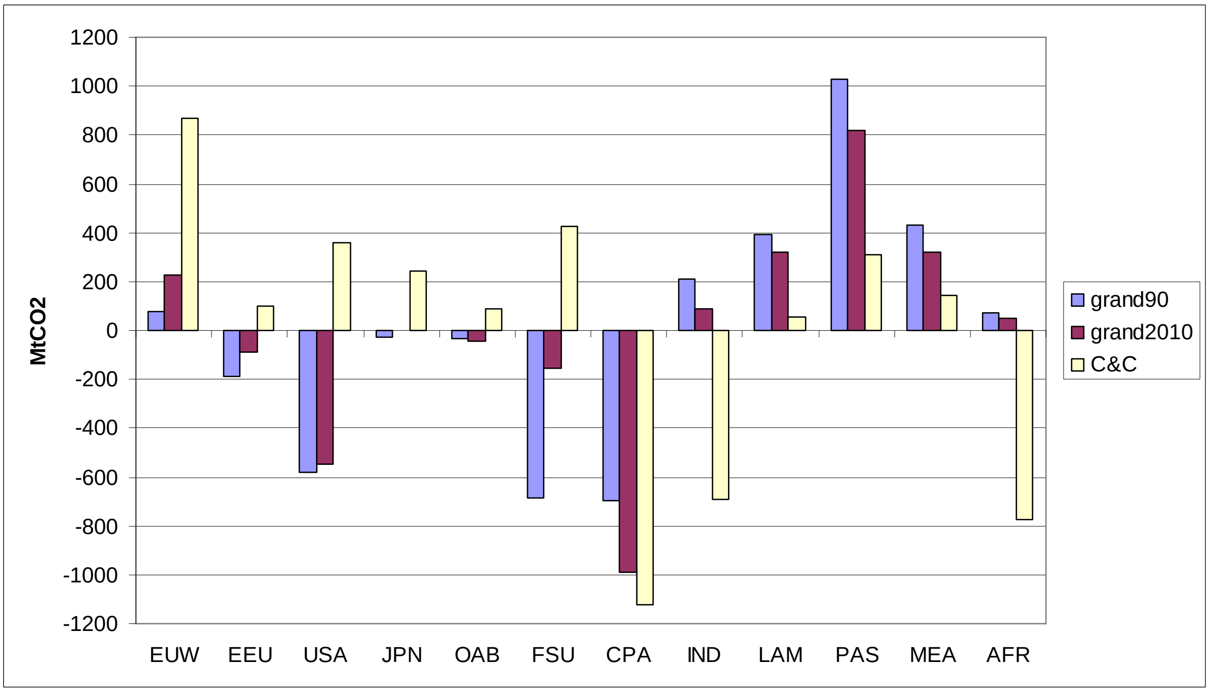

Figure 7: Emissions trading in 2030

The net effect of the emission constraint and the relative marginal abatement costs in the grandfathering scenarios is as follows: The largest importers will be Pacific Asia (PAS) followed by Latin America (LAM) and the Middle East and North Africa (MEA). The dominating exporters will be China (CPA) and – surprisingly – the United States (USA). A special case is the former Soviet Union (FSU) which is selling around 700 $MtCO_2$ if the base year for reductions is 1990 [grand90] but only about 150 $MtCO_2$ if the base year is 2010 [grand2010]. In the United States and China the abatement cost effect seems to dominate the reduction target. In Western Europe (EUW) a low reduction target but high marginal abatement costs lead to an import of emission allowances. It is also remarkable that even Sub-Saharan Africa (AFR) will be a net importer of allowances besides many other countries in Asia and Latin America. This is mainly due to the fact that the required emission reductions in these scenarios relative to BAU emission growth are very high (see Figure 6).

The contraction and convergence [C&C] scenario results in a more diverse trade pattern. Now, all industrial countries as well as the Former Soviet Union become buyers, while China, India and Africa are the only sellers. Latin America, Pacific Asia and Middle East remain buyers.[6] Although Western Europe (EUW) needs to reduce emissions by a bit more than 40% against their baseline they will buy the largest amount of emission allowances, namely almost 900 $MtCO_2$ whereas the United States (USA) with a reduction target of almost 50% will buy less than 400 $MtCO_2$. China (CPA) and India (IND) together will be supplying with 1.800 $MtCO_2$ the bulk of allowances with Africa (AFR) contributing the almost 800 $MtCO_2$.

When looking at the shares of the targeted emissions that are imported or exported, which are shown in Figure 8, the picture is qualitatively the same, but some of the results are smoothed. In absolute terms, China is clearly the largest seller in all trading scenarios. In relative terms, since it also has the largest absolute emissions, the FSU countries in the [grand90] scenario and India in the contraction and convergence scenario sell almost the same share of their targeted emissions. In the contraction and convergence scenario Africa is in relative terms by far the largest seller. Also, the maybe surprising result that in absolute terms the USA are one of the largest sellers is put into perspective. Figure 8 shows that the USA are only trading around 10% of their total emissions.

The volume of transfers in the three trading scenarios is substantial. At current prices the total value of emission rights traded would be in 2030 a little over 270 Billion USD in the scenario with equal reduction targets relative to 1990 [grand90] and in the contraction and convergence scenario [C&C]. If the reductions are based on 2010 emissions [grand2010] the volume of trade is smaller resulting in a transfer of around 272 Billion USD. China alone would under a contraction and convergence receive a return on its sales of emission rights of

120 Billion USD. It does so by increasing its emission reduction from a target of about 1.000 $MtCO_2$ (equivalent to about 20% reduction relative to 2010) to 2100 $MtCO_2$. On the other hand, Western Europe (EUW) with a target reduction of 1.600 $MtCO_2$ (minus 40%) will reduce 750 $MtCO_2$ inside the region and imports another 850 $MtCO_2$. Under the tax solution [tax] China would realize a tax income of 255 Billion USD to be redistributed within the country. In Western Europe and the United States these numbers would be significantly larger, i.e. 353 Billion USD and 492 Billion USD. Of course, if the energy efficiency of the world economy improves faster than expected, the prices for emission allowances and the tax rate would be lower thus reducing the financial flows within and between the regions.

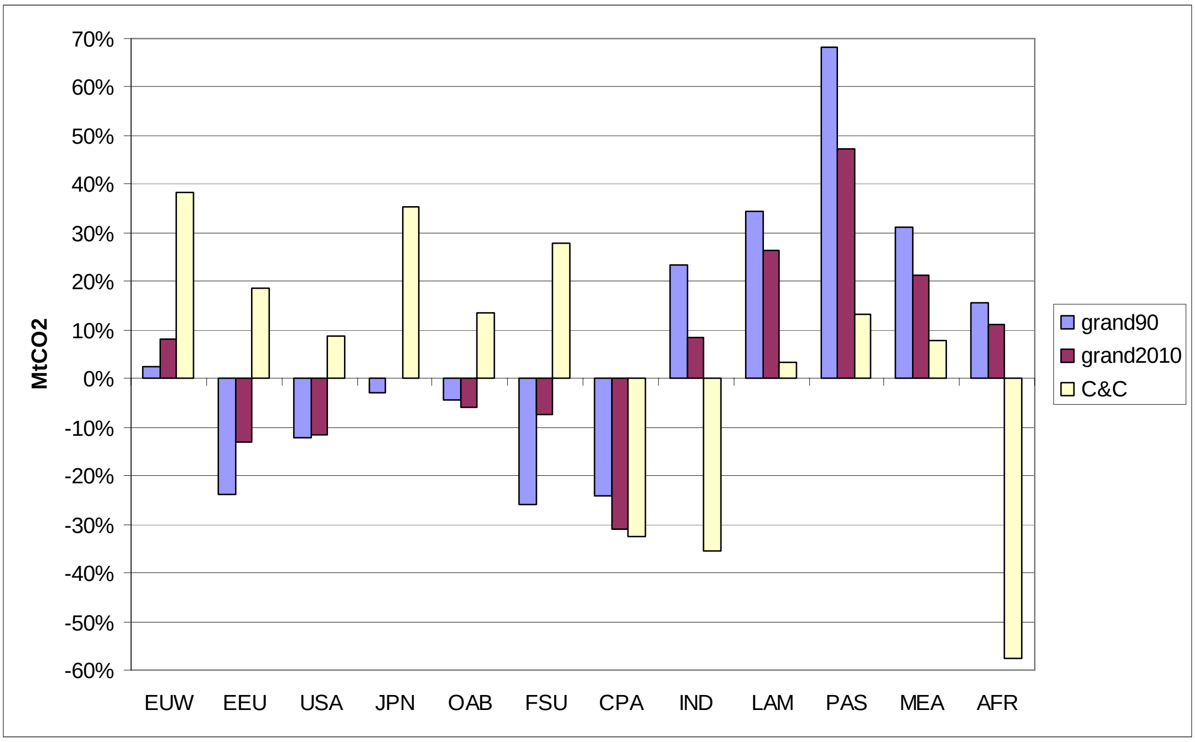

Figure 8: Emission exports and imports relative to the target emissions

3.3. Overall welfare effects

Trade volumes of emission allowances only indicate the amount of transfers taking place but they are not an indicator for the welfare effects of different Post-Kyoto scenarios. The internal economic structure and the degree to which an economy relies on energy inputs and on the sale of energy and energy intensive products are important determinants for the overall welfare effect. In particular, the interaction of energy prices with the prices of emission allowances or the emission tax is a major factor for the welfare effects. As the tax or price for

[6] In the long run, i.e. by 2050, Latin America and Pacific Asia become exporters of emission allowances as well.

CO_2 rises, gross prices for fossil energy increase – more so for coal and less for gas – thus reducing energy demand and lowering the energy prices net of their CO_2 component. Therefore, the combined effect of different marginal abatement costs, of different reduction targets, of the energy intensity of the economy, the amount of fossil energy produced and exported, and the demand elasticities for fossil energy simultaneously determine the welfare effects in the different regions. Figure 9 shows the distribution of the welfare losses relative to the business as usual scenario for the year 2030 under the different scenarios as well as the welfare effect for the world economy.

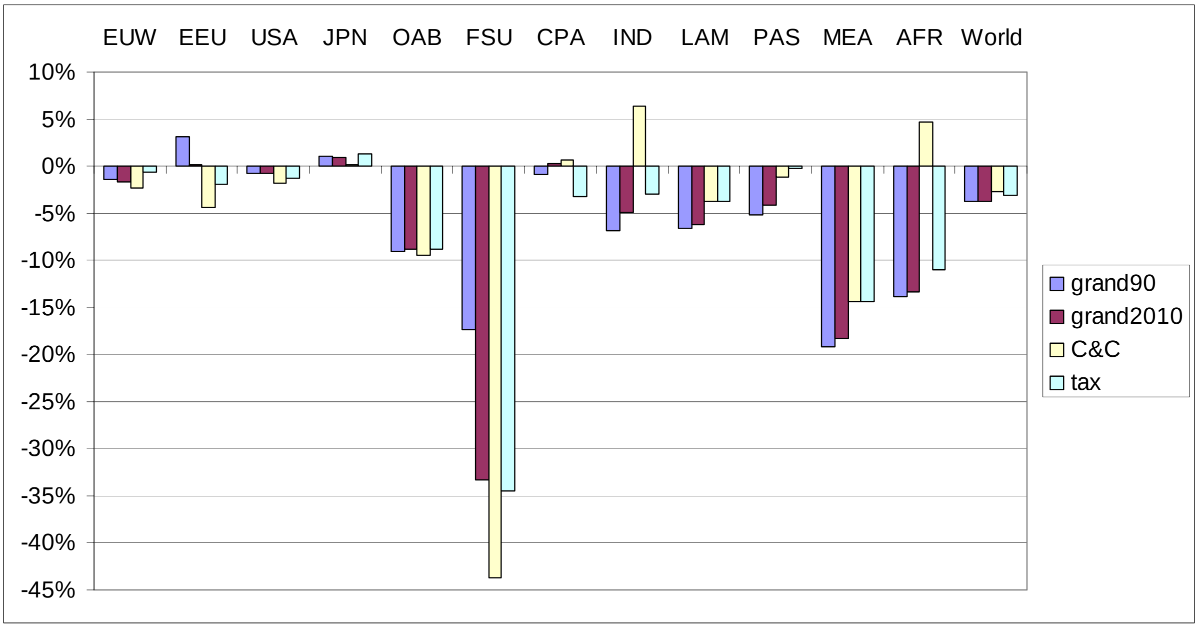

Figure 9: Welfare effects in 2030 – relative to business as usual

First of all, a 40% reduction of CO_2 emissions relative to 1990 by 2050 which translates into a reduction of world emissions between 25% and 28% in 2030[7] relative to 2010 will result in global welfare losses between 2.7% and 3.8%. The lowest welfare loss is connected with the contraction and convergence scenario, the highest with the reduction targets determined on the basis of 1990 emissions which favor industrialized countries and the former Soviet Union. However, the distribution of welfare effects across regions varies strongly.

It is apparent that the welfare effects seem to be dominated by the energy price effect in the energy exporting countries. The former Soviet Union (FSU) and Middle East and North Africa (MEA) whose economies depend to a large degree on energy exports experience the largest welfare losses in all scenarios. For this reason, Sub Saharan Africa (AFR), and the other Annex B countries (OAB) also face higher welfare losses than the world average since they too belong to the energy exporting regions. Compared to the reduction targets as shown in

[7] The differences occur because the scenarios result in different growth paths of the world economy.

Figures 5 and 6 which a much more evenly distributed across regions the strong bias of welfare effects is remarkable. Energy importing regions like Western Europe (EUW), the USA, Japan JPN), China (CPA), India (IND) or Pacific Asia (PAS) only face welfare losses of up to around 5 % or can even gain from climate policy (Japan).

The difference of welfare effects between the four scenarios is quite small in many regions. The CO_2 tax would be best for Western Europe with a welfare loss of only 0.6% compared to a loss of 2.3 % under contraction and convergence. For the United States the tax solution (welfare loss 1.3%) is not as good as the 40% reduction target with trading (0.8% welfare loss). It is quite substantial in the former Soviet Union where the trading scenario with reductions based on 1990 emissions is by far the best of all the negative scenarios with a welfare loss of only 17% compared to a 44% loss under contraction and conversion. In 1990 and the first commitment period of the Kyoto-Protocol there was still a substantial amount of hot air in the region FSU paired with a very energy intensive economy. Therefore, the reduction of 40% by 2050 is easier to achieve – requiring only a 20% reduction relative to business as usual in 2030 – than in the case where the reduction targets are based on 2010 emissions. On a smaller scale the same happens in the Eastern European countries (EEU) which also had some hot air in 1990. These two regions should therefore be strongly in favor of a 1990 base year for the determination of reduction targets whereas the other countries would be relatively indifferent as to which reference year would be chosen.

The contraction and convergence scenario is a special case. It is strongly beneficial to India (IND) and Sub-Saharan Africa (AFR) in absolute terms but also relative to all other Post-Kyoto options that were simulated. Both regions are allowed to increase their emissions - India by 520 $MtCO_2$ between 2010 and 2030, Sub-Saharan Africa by 710 $MtCO_2$. But they actually reduce emissions by 170 $MtCO_2$ (India) and 70 $MtCO_2$ (Sub-Saharan Africa) thus supplying almost 2.000 $MtCO_2$ on the international allowance market. This brings about a welfare increase compared to the business as usual scenario; hence they are winners of climate policy even without counting the benefits of reducing climate change.

China is also a special case in terms of the tax scenario. Whereas it gains welfare under the 40% reduction target with base year 2010 and under contraction and convergence it looses 3.3% welfare in the tax scenario. The reason becomes clearer if one takes a look at the emission targets in Figure 5. The uniform tax corresponds to an implicit endowment with emission rights that is much smaller than for other countries leading to a reduction target of almost 50% relative to emissions in 2010. Such a large reduction is a sign for low abatement costs in China relative to other regions. Yet, these low abatement costs can not be used to receive transfers from the rest of the world. In the trading scenarios China is always the largest supplier but compared to the size of the economy this income from exporting emission allowances results only in relatively small welfare gains. The situation in Africa is very similar but magnified by the fact that the export of allowances makes up a more important part of GDP. Chinas income from selling allowances under the contraction and conversion scenario is about 2% of GDP in 2030, Sub-Saharan Africa's income would be with 7% more than three times as much. In contrast, Western Europe as the largest buyer of allowances would only spend 0.6% of its GDP for this purpose.

5 Summary and Conclusions

The G8 summit in June 2007 has announced to "seriously consider" to cut in half the Greenhouse gas emissions by 2050. Yet, so far the negotiations have not centered around a specific Post-Kyoto framework. Instead, a continuation of the cap-and-trade framework of the Kyoto-Protocol together with its flexible mechanisms is one option that is being looked at. A relatively new proposal advocates a harmonized international carbon tax instead where countries impose the same tax rate and can keep the tax income and use it domestically. Both instruments are efficient in the sense that they – at least in theory and under full information – achieve a given emission target at minimal cost. Such a tax schedule as well as a cap-and-trade scheme – however it is designed – will need to be accepted at least by the big emitters. More important for reaching an agreement is thus the distribution of costs across countries. The decisive issue is clearly the treatment of the developing countries. While especially the US are only willing to reduce their emissions when e.g. China and India agree on binding targets as well, the developing countries argue that not only the industrial countries are those responsible for most of the past emissions but also that their per capita emissions are still much higher than in the developing countries. Besides the problem of agreeing on efficient climate policy, the equity issue is thus of major importance.

In this paper we compare a harmonized international carbon tax and a cap and trade system with respect to their distributional impacts focusing in particular on the developing countries. One can show theoretically that the buyers of emission allowances in a cap-and-trade scenario are better off and the sellers of allowances are worse off than in a tax scenario that leads to the same global emission reductions. Also, countries with relatively low marginal abatement costs face higher absolute costs under a tax scenario. In the light of existing studies on marginal abatement costs and on the effects of Post-Kyoto regime proposals with emissions trading, these results suggest that a harmonized tax is not likely to lead to an acceptable distribution of costs for major developing countries including China and India. We use the computable general equilibrium model DART to simulate a harmonized international emission tax and three cap-and-trade systems that are based on currently discussed proposals for distributing emission rights across countries. In particular, we compare the tax scenario to a cap-and-trade scenario where per capita emission converge until 2050 (commonly known as contraction & convergence) and to a system with equal percentage reductions – either in relation to 1990 emission or in relation to 2010 emissions (also denoted grandfathering of emission rights).

A look at the resulting emission reductions already reveals that a harmonized international carbon tax requires more reductions in the developing countries than the contraction and convergence scenario but – with the exception of China - less reductions than a grandfathering scenario. In the industrialized countries the picture is practically the opposite: the tax scenario requires fewer reductions than the contraction and convergence scenario but requires more reductions compared to the grandfathering scenarios.

For the overall welfare effects of the different Post-Kyoto regimes, other effects besides the volume of emission reductions are relevant as well. In particular, it turns out that the most important determinant of regional welfare costs is whether countries are energy exporters or importers. The reason is that large world wide emission reductions can only be achieved if energy demand is reduced as well. The reduced demand for energy in turn leads to falling energy prices. This reduces the comparative advantage of energy exporting countries such that those regions lose welfare compared to a no climate policy scenario and importers of energy gain. For this reason Middle East, Africa and Latin America as energy exporting regions suffer more from climate policy then China and India as energy importing regions. Since most industrialized countries are energy importers, this also means that they face relatively low welfare costs. Still, the stringency of the targets and the choice of emissions trading versus taxes are also relevant.

Altogether, because of the combinations these different effects there is no clear cut result between developing and industrialized countries or energy importers versus exporters. However, a few general tendencies can be identified. For the developing countries the tax scenario leads to higher welfare than the contraction and convergence scenario and to lower welfare than the grandfathering scenarios. China as a one of the most important emitters of greenhouse gases is a special case. Under the trading scenarios it has almost negligible welfare changes – basically because they benefit from selling large amounts of emission rights - the tax scenario implies a welfare loss of 4% relative to a business a usual scenario. Even though a harmonized tax may have advantages with respect to simplicity, dynamic flexibility, associated uncertainties as well as administrational and political feasibility when compared to emissions trading the implicit distribution of the welfare effects does not make this regime proposal likely to be agreeable to major developing countries. The most important determinant for the distribution of welfare effects is not connected to the design of the climate policy instrument; it is the reaction of the global fossil fuel markets. The regions exporting fossil fuels experience strong welfare losses from the reduction in demand for fossil fuels and the resulting fall in prices. This issue is has been largely ignored in the debate. We believe that a Post-Kyoto climate regime with global participation needs to address the potential income losses of energy rich countries.

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