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Abstract:
Because of large economic and environmental asymmetries among world regions and the incentive to free ride, an international climate regime with broad participation is hard to reach. Most of the so far proposed regimes base on an allocation of emission rights that is to be perceived as fair. Yet, there are also some arguments to focus more on the actual welfare implications of different regimes and to aim for a "fair" distribution of resulting costs. Using the Computable General Equilibrium model DART, we analyze the driving forces of welfare implications in different scenarios where a global emission target derived from the 2 degree target is reached. These include two regimes that are often presumed to be "fair", namely a harmonized international carbon tax and a cap and trade system based on the convergence of per capita emission rights, and additionally an "equal loss" scenario where welfare losses relative to a business as usual scenario are equal for all major world regions.

We show that "equal losses" would mean in particular to compensate for the effects of climate policy on energy markets and e.g. to compensate for the loss of oil revenues as the Organization of Petroleum Exporting Countries (OPEC) argues for.

Keywords: international climate regime, emission targets, emission trading, taxes, distribution.

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

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1. Introduction

Even though not very likely in the moment, the aim still exists to reach at some point an international climate regime with binding emission constraints. Indeed, to effectively control global warming a broad participation and a significant reduction of global greenhouse gas (GHG) emissions is absolutely necessary. Yet, this is hard to achieve because of large economic and environmental asymmetries among world regions and the incentive to free ride in environmental negotiations. While the industrialized countries are responsible for almost 80% of past anthropogenic GHG emissions and have much higher per capita emissions than many of the developing countries, China's emissions of GHGs have already for some years surpassed the emissions of the previously biggest emitter USA in absolute terms and much of the expected future increase in GHG emissions is expected to occur in developing countries. The EIA (2013) expects that non-OECD carbon emissions exceed those of OECD countries by 127 percent in 2040. At the same time developing countries will suffer most from the adverse effects of global warming. Without a system that delivers in some sense a fair or just distribution of abatement activities and associated real or monetary transfers no international agreement is thus likely to be signed.

Fairness is 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 and Lucas 2005, Rose et al. 1998). Four key ethical principles to define a fair or just distribution of emission reductions or resulting economic costs from existing regime proposals can be derived from these discussions:

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.

For an overview of different Post-Kyoto regime proposals see e.g. Bodansky et al. (2004) or Höhne et al. (2005) that both summarize 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.

In terms of policy instruments 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 Kyoto-Protocol included different forms of emission trading and since emission trading is the predominant climate policy instrument in a growing number of countries and regions (see e.g. World Bank 2014) many proposals tend to favor a continuation and deepening of cap and trade systems but there are also alternative voices arguing for an internationally harmonized carbon tax (Nordhaus 2006). 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 and is also perceived as fair in the sense that everybody pays the same per ton of carbon and that each country gets the revenue generated in its own country which is in line with the sovereignty criterion. Most proposals though focus on emission trading and a fair distribution of emission rights that are derived from or in line with a mix of the fairness and equity criteria and principles described above[1]. The often discussed "contraction & convergence" proposal (Meyer 2000) for example is a combination of the egalitarian and sovereignty principles. It implies that per capita emission rights 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. Mostly this save level is assumed to be 450 or 550 ppmv CO_2e. Along the same lines, but accounting also for the capability/ability to pay criterion the "common but differentiated convergence (CDC)" regime (Höhne et al. 2005; Höhne et al. 2006) implies also that all countries' per capita emissions converge, but differentiated, as countries only start to converge when their per capita emissions are at a certain percentage above the global average. Scenarios in the spirit of equal per capita emissions also received support from major politicians and scientists.

For the welfare effects of climate policy in the context of outcome based criteria not only allowance allocation and abatement costs are important but indirect effects such as changes in trade-flows, production patterns and the terms of trade. Overall indirect effects are driven in particular by the effects of climate policy on energy prices. Gross of carbon prices, energy prices increase and causes shifts in competitiveness of different sectors, depending on their absolute and relative (to other sectors and countries) energy intensity and their ability to substitute energy for other inputs (abatement costs). Even more importantly demand for fossil fuel is reduced driving down fossil fuel prices net of carbon prices. This is positive for energy importing regions and negative for energy

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

exporting regions. Or as the IPPC (2007, p. 9) puts it: “Fossil fuel exporting nations […] may expect […] lower demand and prices and lower GDP growth due to mitigation policies“. Existing modeling results show that in different contexts regional economic adjustment costs of climate mitigation policy are by a large extent driven by international energy market effects (see e.g. Böhringer and Rutherford 2002, Böhringer et al. 2014, Klepper and Peterson 2006; 2007). Already in the context of the Kyoto Protocol, the Organization of Petroleum Exporting Countries (OPEC) and especially Saudi Arabia believed that this will reduce revenues from oil exports and argued that it should be compensated for these losses (see e.g. Depledge 2008). It can thus be expected that such effects generally play an important role for the acceptance of a climate regime.

Outcome based criteria have received much less attention than allocation based criteria even though findings from experimental economics indicate that contributing to mitigating emissions in such a way that welfare losses are equalized among “rich” and “poor” participants leads to a higher chance of coming to a successful agreement. In these studies, a public good (which can be interpreted as avoiding catastrophic climate change) is only provided if the joint contributions of a group of players reach a certain threshold. In successful groups, “rich” players contribute more than “poor” players, when players start with different endowments (Milinski et al. 2011; Tavoni et al. 2011; Waichman et al. 2014). Usually they contribute proportional to their initial endowment (Milinski et al. 2011; Waichman et al. 2014) which can be interpreted as giving up an equal proportional share of a future GDP stream or as equal (welfare) losses. Waichman et al. (2014) also demonstrate that different initial endowments have a much stronger influence on the burden sharing of successful groups than asymmetric risk.

Only very few studies analyzed related scenarios numerically with the help of climate-economy models. Van Ruijven et al. (2010) who undertake a comprehensive survey on modelling studies assessing post-Kyoto climate regimes only find two studies (Rose et al. 1998 and Vaillancourt et al. 2008) that analyze scenarios where allowances are distributed according to outcome based criteria e.g. in such a way that net loss in GDP or per capita GDP are equalized. Yet, the models in these papers do not account for any terms-of-trade effects and thus also not for the energy market effects. This is why e.g. in Rose et al. (1998) Eastern Europe and the Former Soviet Union (FSU) receive much more allowances based on equal per capita allocation than in a scenario where GDP losses are equalized. This is very contrary to the finding of many Computable General Equilibrium (CGE) studies (including e.g. Klepper and Peterson 2007) that find that especially the FSU suffers most from any international climate regime because of the energy market effects. That large compensation is needed for energy exporting regions is also the finding of two existing CGE studies analyzing outcome based criteria. Waisman et al. (2013) assess the magnitude of monetary transfers oil producers in the Middle-East may claim to compensate for their losses due to climate policy and find these to be substantial. Jacoby et al. (2008) analyze two scenarios where Non-Annex I countries receive emission allowances such that they are equally well off as without climate policy while the burden sharing across industrialized countries differs. Additionally there is one scenario where they are only compensated for direct mitigation costs (and not e.g. the energy market effects of climate policy) and one where their welfare reductions are capped at -3% in each year. In this study though, the FSU as part of Annex I is not compensated and experiences the largest welfare losses through global climate policy. Nevertheless the paper shows again that especially the energy exporting regions need to be compensated. The Middle-East alone receives more than a quarter of the net financial transfers through emission trading. Finally, Tian et al. (2012) use a "global equilibrium emissions and trade model" that is rather aggregated (and does e.g. not capture energy market effects) but covers climate damages to model different burden sharing scenarios. These also include scenarios derived from outcome based fairness criteria that are difficult to compare to the other scenarios though. They find that large financial transfers to different developing and emerging countries (in the model especially China and to a lesser degree India and Russia) are needed to compensate them for losses incurred when undertaking emission reductions.

None of the studies includes energy market effects and looks at a scenario where all countries face the same reduction in welfare.

In this paper we thus focus on a scenario where (cumulated) welfare costs of mitigating emissions from today until 2050 are equal across all our model regions. The implications of such a scenario are compared to two other stylized climate regimes. As a case-of-reference the first regime is a harmonized international carbon tax. The second regime is a cap and trade system based on a CDC allowance allocation which stands for a regime that is based on a distribution of emission rights that is often presumed as fair.

Overall, the objective of this paper is to (a) determine and discuss the driving forces for the level of compensation that some regions need to receive from others if we aim for equal losses and (b) compare other common scenarios that are based on other fairness criteria to the equal loss scenario.

The following numerical analysis is based on simulations with the computable general equilibrium model DART that is briefly presented together with the analyzed scenarios in section 2. The results section 3 discusses the international distribution of emission allocation under the different scenarios which is to a smaller degree dependent on the model assumptions as well as the more relevant but more disputable cost effects which depend on the structure and specific assumptions of the DART model. In this context we assess the relevance of different driving forces including in particular the energy market effects in more detail. Section 5 summarizes and concludes.

2. The DART model and choice of the analyzed core climate regimes

In this section we briefly present the DART model and discuss our climate policy scenarios.

2.1 The DART-Model in a nutshell

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 international emission reduction scenarios, it is calibrated to an aggregation of 13 regions and 16 sectors, which are shown in table 1.

Table 1: DART Regions and Sectors

Countries and regions			
Annex B		**Non-Annex B**	
WEU	Western Europe	CPA	China, Hong-Kong
EEU	Eastern Europe	IND	India
FSU	Former Soviet Union	LAM	Latin America
USA	United States of America	PAS	Pacific Asia
CAN	Canada	MEA	Middle East, North Africa
JPN	Japan	AFR	Sub-Saharan Africa
ANZ	Australia, New Zealand		
Production sectors/commodities			
Energy Sectors		**Non-Energy Sectors**	
COL	Coal Extraction	AGR	Agricultural Products
GAS	Natural Gas Production & Distribution	CRP	Chemical Products
CRU	Crude Oil	ETS	Other Energy Intensive Production
OIL	Refined Oil Products	OLI	Other Light Industries
ELY	Non-Renewable Electricity	OHI	Other Heavy Industries
COLCCS	Advanced COL with CCS	MOB	Mobility
GASCCS	Advanced GAS with CCS	SVCS	Services
WIN	Wind Power		
SOL	Solar Power		
HYD	Hydro Power		
SBIO	Electricity from (Solid) Biomass		

Compared to former model versions, electricity generation was split into conventional generation and new generation technologies from renewable sources and generation with carbon capture and storage (CCS). Six electricity generation technologies (COLCCS, GASCCS, WIN, SOL, HYD, SBIO) based on bottom-up data from the TIMER model (de Vries et al. 2001) were included into the model.

Electricity from different generation technologies is assumed to be perfectly substitutable. Each technology has a convex cost function which induces use of several technologies. There is learning behavior which reduces the cost disadvantage of renewables compared to conventional generation over time. The cost functions are calibrated to reach similar deployment levels as in the TIMER model (for more details see Weitzel 2010). CCS is modeled as a slack activity (i.e. a latent technology which is specified but not used in the base year because it is too expensive) with a cost function similar to Paltsev et al. (2010).

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.

The model is calibrated to the GTAP7 database (Narayanan and Walmsley 2008) that represents production and trade data for 2004. For the calibration towards a given GDP path, which is in line with the OECD Environmental Outlook (OECD 2012), labor factor productivity is adjusted accordingly. To also match emissions from the Environmental Outlook, the supply elasticities of fossil fuels are adjusted in DART. There are autonomous energy improvements of 1% per year, for the electricity sector 0.1%. For a more technical description of the DART model see the appendix of Weitzel et al. (2012).

In the resulting business as usual (BAU) scenario global CO_2 emissions more than double from about 25 $GtCO_2$ in 2004 to about 54 $GtCO_2$ in 2050 and figure 1 shows the regional emission pathways. While emissions in the industrialized regions are rather stable or grow only slightly, emissions in the emerging and developing countries are two to three times larger in 2050 compared to 2004. In India, emissions are even more than five times as high. Due to their size, almost two thirds of additional emissions stem from China (around one third) and India (around a quarter). Annex B regions together without the Former Soviet Union only contribute less than five percent.

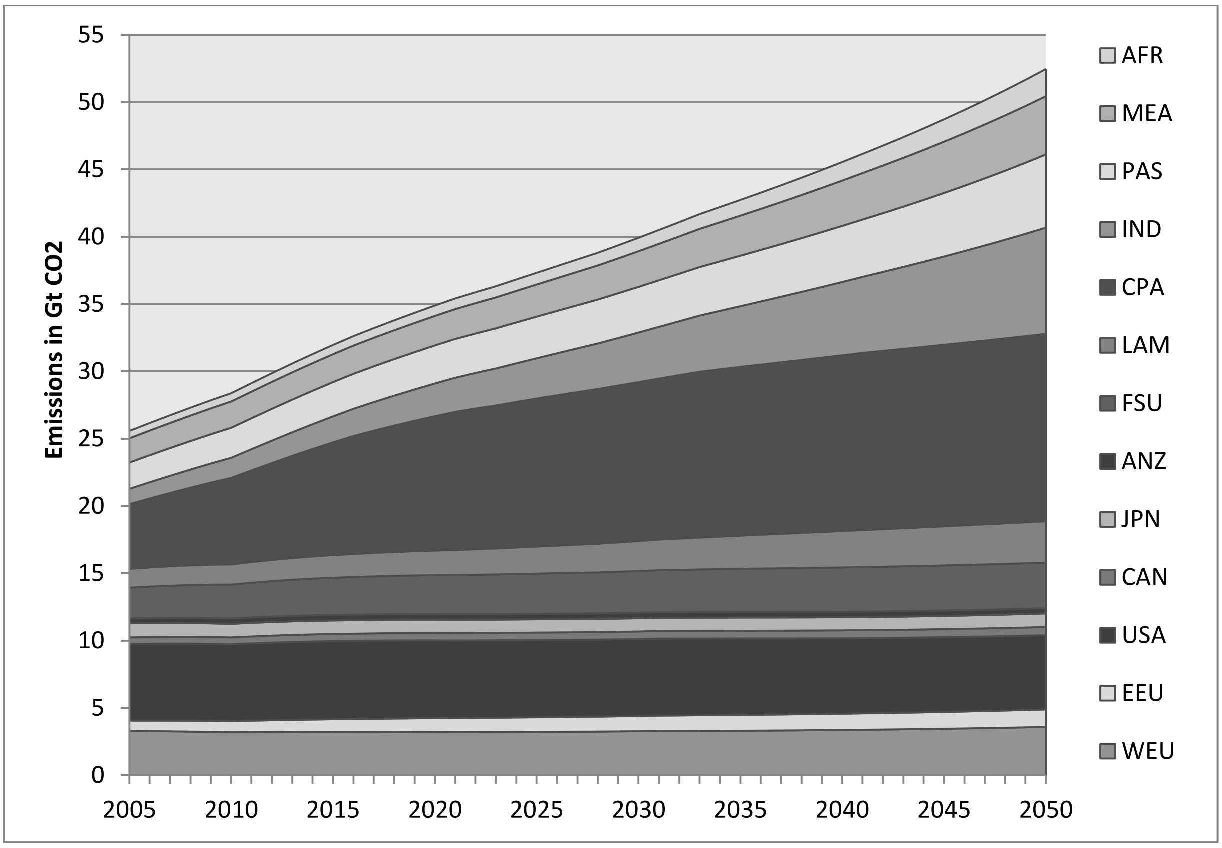

Figure 1: Regional emission pathways in [BAU] 2005 – 2050

2.2. Definition of core climate policy scenarios

We define three climate policy scenarios with the same global emission path taken from Johansson et al. (forth.) that is in line with not exceeding two degrees of global warming compared to pre-industrialized times with a probability of more than 50%. Global energy related CO_2 emissions reach 18.1 $GtCO_2$ in 2050, 28% below 2004 emissions and 65% below 2050 baseline emissions. The scenarios comprise an internationally harmonized carbon tax and two different emissions trading regimes.

The first reference climate policy scenario **[tax]** is a harmonized international carbon tax. This scenario represents an efficient bottom-up strategy where each country domestically reduces own emissions, bearing the costs of doing so and where there is no mechanism for addressing international burden sharing. It is economically equivalent to a scenario with only national climate policies, no burden sharing, but (by coincidence) internationally efficient abatement levels in all countries. The level of the tax is endogenously generated to reach the global emission targets specified for each year. It grows from less than 1 USD/tCO_2 before 2014 to around 16 USD/tCO_2 in 2020, 105 USD/tCO_2 in 2035 to around 334 USD/tCO_2 in 2050 (see Johansson et al. forth. for a discussion). The additional tax income is redistributed lump sum to national consumers.

The other two scenarios assume international emission trading from 2012 on but differ in their allocation of emission rights. They represent in some sense also scenarios where international burden sharing is addressed by other mechanism than gains/losses from emission trading, such as e.g. financial “climate funds”, technology transfer or development aid. Compared to a tax regime countries that are able to sell emission allowances are better off, while countries that need to buy emission allowances are worse off. The resulting carbon price is comparable to the one in the tax scenario, since it is also economically efficient. Small changes (not more than 5%) result from wealth effects that impact the production structure and growth of the model regions.

The “common but differentiated convergence” **[CDC]** regime (Höhne et al. 2005; 2006) implies that all countries’ per capita emissions converge until 2065, but countries only start to converge when their per capita emissions are at a certain percentage above the global average. In our specification we define different country groupings according to their current income levels, i.e. developed countries, Advanced Developing Countries (ADCs) and Other Developing Countries (ODCs) that take on different reduction objectives in terms of start year for convergence, convergence level and convergence year. The parameters are chosen such that the global pathway (Johansson et al. forth.; Lucas et al. 2013) is met. This leads to more stringent targets than the Copenhagen pledges for 2020. After 2020, the developed countries and ADCs start getting fewer emissions rights instantly following the per capita emission convergence trajectories; developed countries converging in 2040 and the ADC in 2050. China and India start in 2025 and 2030, respectively. The other ODCs start in 2035. Between 2020 and the start of convergence countries follow their baseline trend. Therefore, countries that made a 2020 pledge (including China and India) have similar reductions compared to their baseline emissions as in 2020 until they start converging. China, India and the other ODCs take 30 years to converge. All countries converge to a level of 1.75 tCO_2/capita by 2065. This implies severe reductions in all world regions except Sub-Saharan Africa – if not already compared to 2004 emissions (where also India and almost Pacific Asia meet this target) then compared to BAU emissions in 2050. Compared to today, reductions are particularly severe for Northern America and Australia/New Zealand where emissions are 15 – 20 tCO_2 per capita. Since poorer regions generally start from lower per capita emissions than industrialized countries which also have to start reducing earlier, this regime already implies significant compensation for reductions. Globally, per capita emissions have to be reduced from around 4 tCO_2/capita today or even 5.8 tCO_2/capita in 2050 in the BAU scenario.

In the **[equal loss]** scenario emission rights are allocated such that the welfare changes relative to the BAU are equal for all countries (in every year). Keeping global emissions equal to the other scenarios emission rights are endogenously adjusted such that the gains and losses from trading lead to the same overall welfare changes.

3. Driving forces of welfare effects and necessary compensations in an equal welfare loss scenario

In this section we discuss the model results. Since this paper is about burden sharing and focusses on the implications of a scenario where welfare impacts resulting from climate policy are the same for all model regions, we start by presenting the welfare impacts for all three scenarios and then discuss their driving forces.

3.1 Welfare effects

To compare the welfare impacts across scenarios we use for each model region the discounted sum of equivalent variation over the entire model horizon with a discount rate of 2%. This measure is compared to the same measure in the [BAU] scenario. Figure 2 reports relative changes for the three climate scenarios.

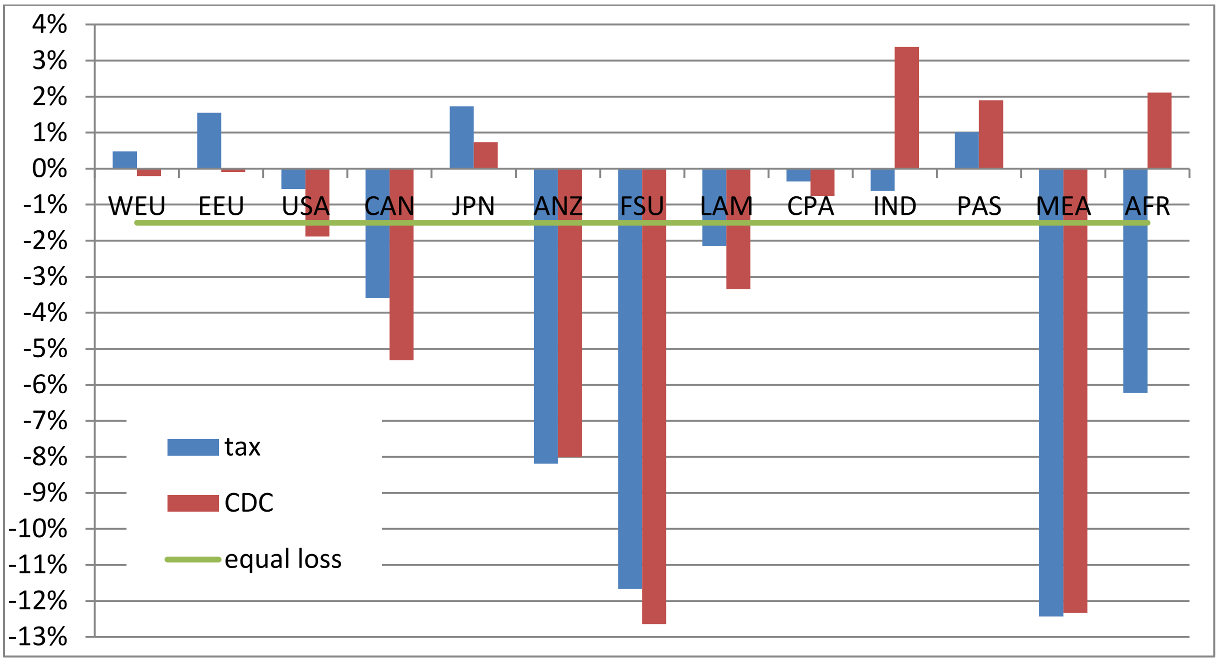

Figure 2: Welfare effects (cumulated and discounted) for the [tax] and the [CDC] scenario. The horizontal line represents welfare losses in the [equal loss] scenario.

In our reference scenario [tax] with an international harmonized carbon tax, the welfare impacts differ significantly across regions. Welfare in Western and Eastern Europe, Japan and Pacific Asia even slightly increases (by up to 1.7%) while welfare slightly decreases (by 0.4 to 2.1%) in the USA, China, India and Latin America. The remaining regions experience more dramatic welfare reductions especially the Middle East/ North Africa, the Former Soviet Union and Australia/New Zealand where welfare losses reach 8.2 - 12.4%.

In the [CDC] scenario burden sharing changes significantly compared to the [tax] scenario but is not necessarily more equitable in terms of welfare impacts. While some regions get closer to the global average welfare loss of around 1.5% (Europe, USA, Japan, China, Sub-Saharan Africa), others move away from it (Canada, Former Soviet Union, Latin America, India, Pacific Asia). India, Pacific Asia and Sub-Saharan Africa receive so many emission rights that they now experience welfare gains.

By setting, all regions experience the same welfare reduction of around 1.5% in the [equal loss] scenario. This is depicted by the horizontal line in figure 2.

Welfare results from a CGE model are driven by two components (see Morris et al. 2012): (1) the direct welfare costs of abatement that can be measured as the integral under the marginal abatement cost (MAC) curve and (2) indirect welfare effects that involve terms of trade effects, interactions with other distortions, and saving and growth effects from policies in earlier years. The latter include in particular energy market effects that were already mentioned in the introduction. If there is emission trading, a third component exists that is (3) gains / losses from emission trading.

In the following three sections we look at the different components in more detail. For the first two components we focus on the [tax] scenario that does not include the third component. We then turn to the transfers inherent in the [CDC] and especially the [equal loss] scenario.

3.2 Abatement Costs

Independently of how large abatement costs are, the higher the abatement level – in absolute but also in relative terms – the larger the burden. Figure 3 shows how much cumulated emissions from 2012 (where abatement starts) to 2050 have changed in the [tax] compared to the [BAU] scenario in the different regions. Related to absolute abatement levels, table 2 shows the share of regional abatement in global abatement.

As expected, the reduction burden is unequally distributed. Globally, cumulated emissions from 2012 to 2050 are reduced by around 35% (indicated by the horizontal line in figure 3). Absolute abatement is driven very much also by size. Relative abatement gives more information about where abatement is relatively cheap and where it is relatively expensive. In particular in the industrialized regions (Western Europe, Canada, Japan) but also in Latin America and Pacific Asia abatement is comparatively expensive and thus below the average. These regions are all relatively carbon efficient, i.e. CO_2 emissions per unit of GDP are low. Regions where abatement is comparatively cheap and that thus abate over-average are in particular Sub-Saharan Africa and India.

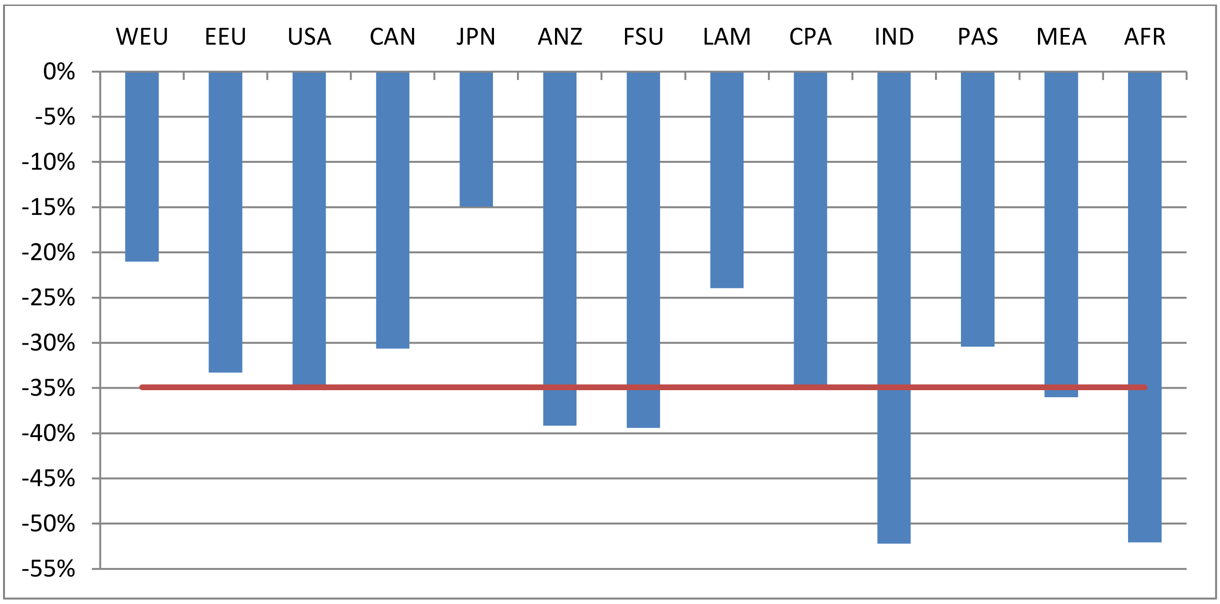

Figure 3: Reductions of cumulated emissions 2012 – 2050 in the [tax] relative to the [BAU] scenario. The horizontal line represents the average reductions.

Table 2: Share of regions in total cumulative abatement

WEU	EEU	USA	CAN	JPN	ANZ	FSU	LAM	CPA	IND	PAS	MEA	AFR
4.9%	2.6%	13.9%	1.2%	1.0%	1.1%	8.6%	3.9%	28.4%	15.3%	7.7%	7.3%	4.1%

Theoretically - as mentioned above - direct welfare costs can be measured as the integral under a marginal abatement costs (MAC) curve. It is disputable though how such a curve that depends amongst others on past national climate policies and climate policies abroad should be constructed and which are the right MAC curves to take in which situation (Klepper and Peterson, 2006; Morris et al., 2012). Typically MAC curves are assumed to be convex, but Morris et al. show that this does not need to be the case. If they would be linear, direct abatement costs could be calculated as 0.5 x carbon price x level of abatement. This can thus act as a rough approximation. The share of regional abatement costs in global abatement costs is proportional to the abatement shares (shown in table 2) in this approach. Thus in absolute terms, China has to bear almost one third of global abatement costs, followed by India and the USA both with a share of around 15%. For the welfare effects it is more informative to put the abatement costs in relation to GDP. This is done in figure 4 that shows approximated abatement costs in 2050 as a share of GDP in 2050 and also the average share in the period 2012 to 2050. To explain these shares figure 5 shows the carbon intensity of GDP.

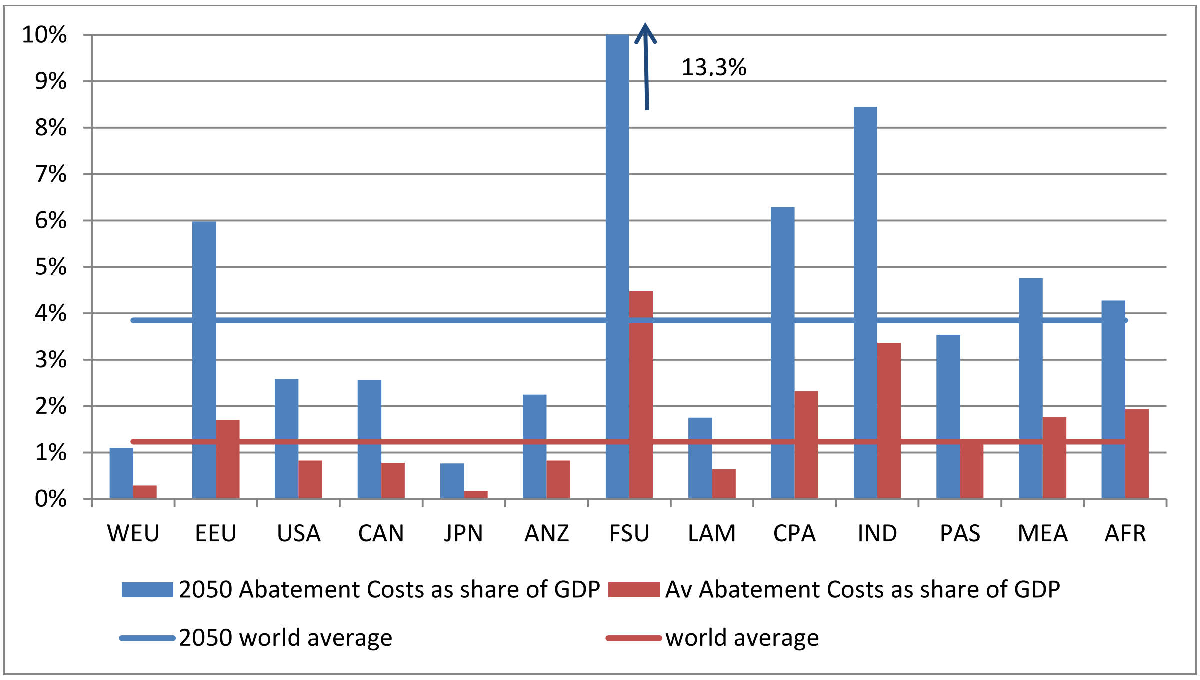

Figure 4: Approximated abatement costs (0.5*(BAU emissions – actual emissions)*carbon price) in the [tax] scenario as share of GDP in [BAU] for 2050 and the average abatement costs from 2012 to 2050.

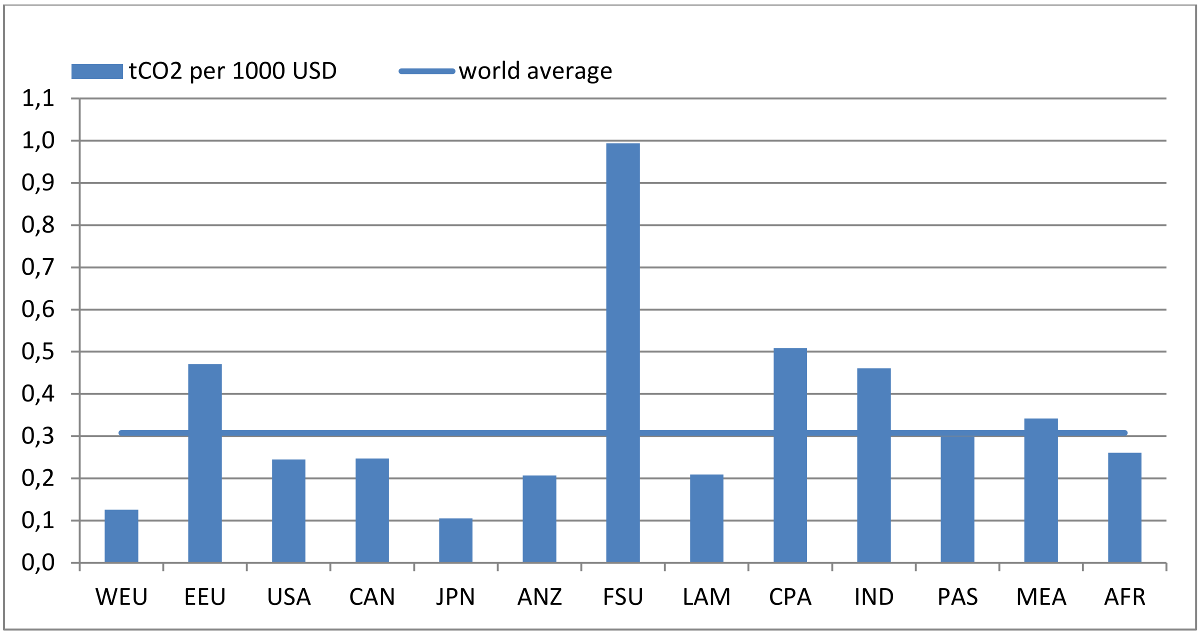

Figure 5: Carbon intensity of GDP in the [BAU] scenario in 2050 in tCO_2 per 1000 USD.

Over time, abatement costs relative to GDP rise. Globally they reach 3.8% of GDP in 2050. The average from 2012 to 2050 is 1.2%. Qualitatively, the picture does not change much between the 2050 costs and the average cost, though there is a slight shift in ordering at some points. Regions where abatement costs are above average are in particular the Former Soviet Union, India, the Middle East/ North Africa, China and Eastern Europe. These are as figure 5 shows also the countries with the highest carbon intensity and as table 2 shows – with the exception of Eastern Europe among the regions that abate the largest shares. Regions where abatement costs are clearly below average (Western Europe, USA, Canada, Japan, Australia/ New Zealand, Latin America) are those that have the lowest carbon intensities.

If we now compare the approximated direct abatement costs to overall welfare cost in figure 2, we see that direct abatement costs can obviously only explain one part of the overall differences in welfare costs. The regions that are among those with the highest welfare cost, the Former Soviet Union, Middle East/ North Africa, Australia/ New Zealand and Sub-Saharan Africa also have above average abatement costs relative to GDP and above average emission reductions, even though the relations do not match those of overall welfare costs. What abatement costs cannot explain is e.g. why India and Eastern Europe that have above average abatement costs have very low or even positive welfare effects. Or why Canada and Latin America that have below average abatement costs have relatively high welfare costs. We thus turn to the indirect welfare effects.

3.3 Energy Market Effects and other indirect welfare effects

As discussed in the introduction there is evidence that energy market effects are among the most relevant drivers of welfare effects of climate policy: international climate policy increases fossil fuel prices gross of carbon prices and decreases fossil fuel prices net of carbon prices through reduced demand for fossil fuels. Thus fossil fuel exporting regions suffer both from lower sales and lower prices independently of whether they themselves reduce emissions or not. Vice versa energy importing countries gain from this effect.

To get a first picture how the different regions are effected by the energy market effects of climate policy, figure 6 puts net energy exports in the [BAU] scenario in 2050 (in Mtoe) in relation to changes in net energy prices in the [tax] scenario.

Major oil exporters are in particular the Middle East/ North Africa, the Former Soviet Union, Sub-Saharan Africa and Latin America that are together responsible for more than 98% of oil exports. Middle East/ North Africa, the Former Soviet Union and Canada are responsible for 88% of natural gas exports. Coal exports are much more diverse. The largest exporters are Australia/ New Zealand and Pacific Asia, responsible together for more than 50% of coal exports. On the import side, China, Pacific Asia and India import almost 80% of oil, China and India import more than 70% of coal. Gas imports are more diverse. China, Eastern Europe, Pacific Asia and Latin America as the largest three importers import about 80%. Altogether this indicates that China, Pacific Asia and India are profiting most from low energy prices, while Middle East/ North Africa, the Former Soviet Union and Sub-Saharan Africa suffer most.

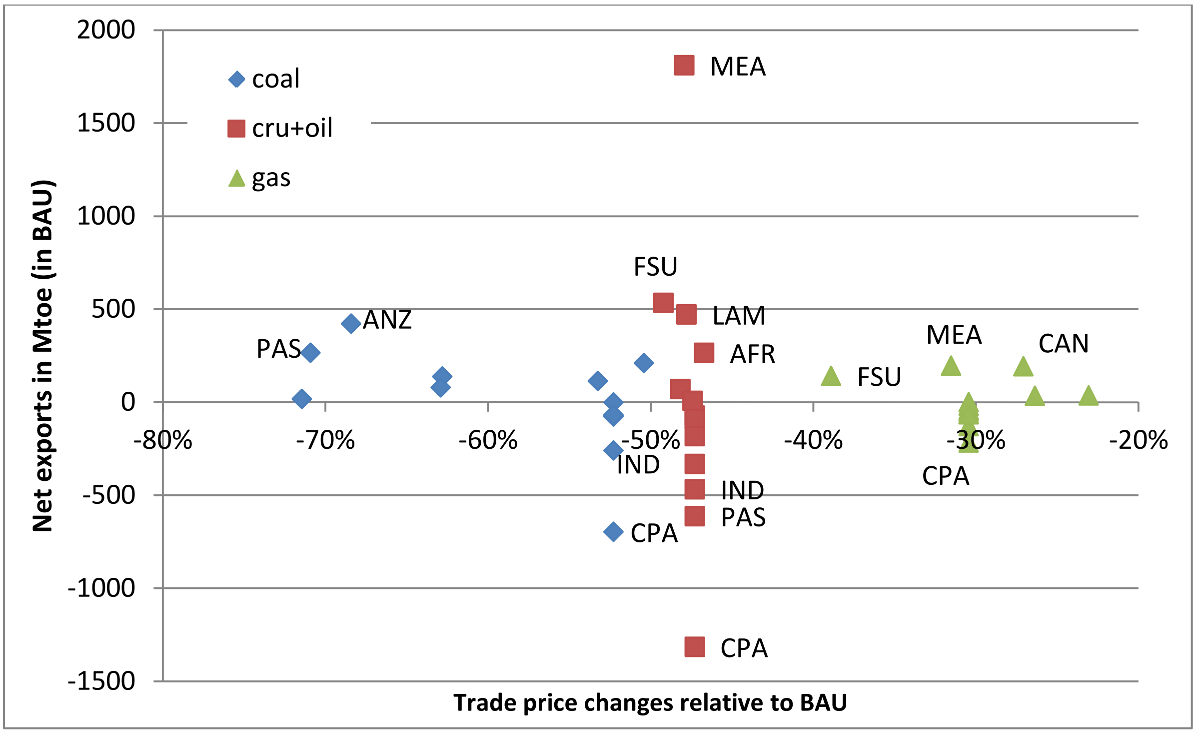

Figure 6: Net exports in the [BAU] scenario in Mtoe (vertical axis) and change in energy prices in the [tax] scenario (horizontal axis) in 2050.

Figure 6 also shows that there is – as expected – little spread in price changes for oil with basically a single world market price. The oil price decreases by around 50% in the [tax] relative to the [BAU] scenario. For coal and gas there is no single world market price. Both often involve a certain infrastructure that varies across countries and for coal there are also different qualities that are only imperfect substitutes. Generally, import/export prices for coal with its large carbon content react strongest to climate policy – they decrease by 50 to 70% in the [tax] scenario compared to the [BAU] scenario. Price changes are lowest for gas with its comparatively low carbon content – they decrease by 20 to 40%. Unfortunately, it is difficult to compare these reactions to price changes in other models, since these are often not reported or for different years and scenarios. Two studies that do at least report some price changes are the World Energy Outlook (IEA 2013) and Paltsev (2012). In IEA (2013) oil prices in the 450 ppm scenario (comparable to our 2 degree scenario) fall by around 30% in 2035 compared to the current policy scenario. In Paltsev (2012) they fall by 60% in the 450 ppm scenario compared to a no policy scenario. Natural gas prices differ across regions also in IEA (2013). In 2035 prices in the 450 ppm scenario are around 15% lower in the US and around 30% lower in the EU and Japan than in the current policy scenario. The 2050 gas producer price in the 450 ppm scenario in Paltsev (2012) is around 30% lower than in the no policy scenario. For both oil and gas, the price changes in DART are thus more or less in line with these studies. The OECD coal price is in IEA (2013) around 40% lower in the 450 ppm scenario compared to the current policy scenario.

Interestingly, in Paltsev (2012) the 2050 producer price for coal is only 9% lower in the 450 ppm scenario than in the no policy reference. Assumptions on CCS costs and availability obviously play an important role here.

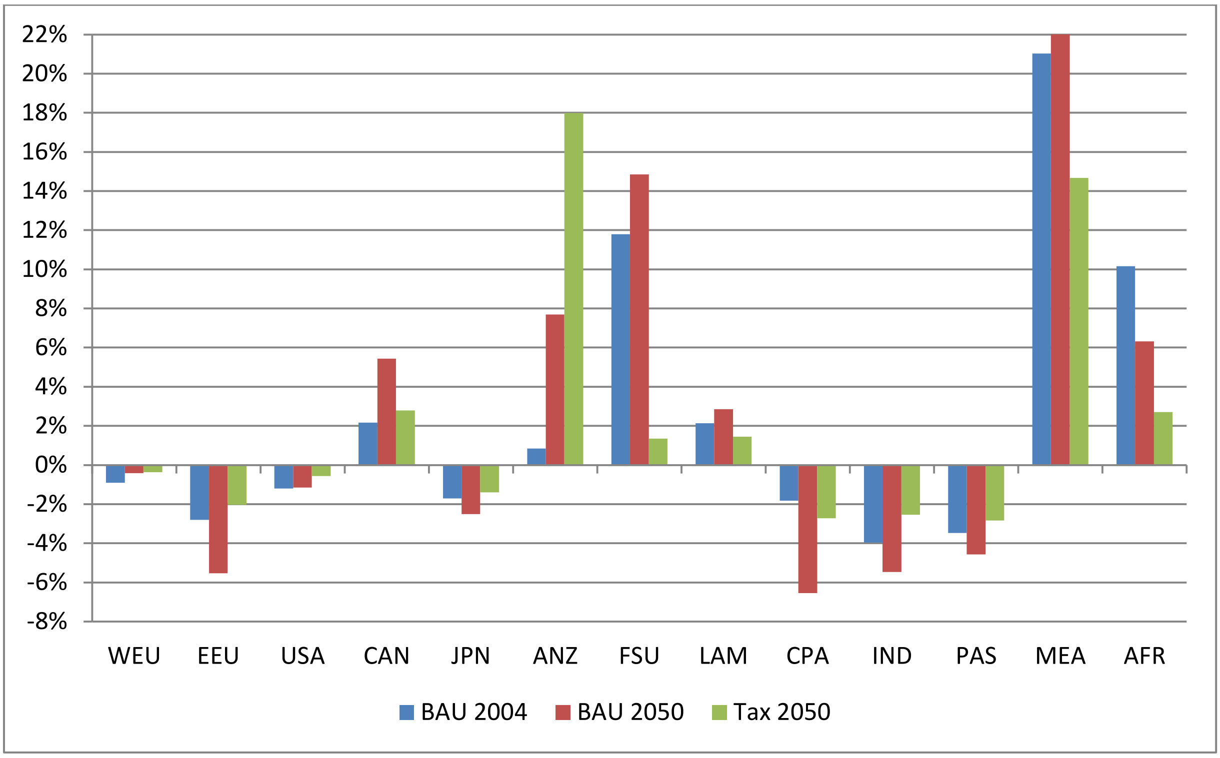

Figure 7: Value of net energy trade (imports are negative, exports are positive) relative to GDP.

Figure 7 takes into consideration the relative importance of the energy export activity for the various regions and shows the value of net exports of energy relative to GDP for the base year of the DART model, which is 2004 and then in [BAU] and [tax] scenarios in 2050. In all regions except Australia/ New Zealand, which is a large coal exporter, the share of net exports in GDP is dominated by trade in crude oil and refined oil products. In relative terms, energy exports are only significant in Middle East/ North Africa, Sub-Saharan Africa and the Former Soviet Union and to a smaller degree also in Canada and Australia/ New Zealand. Relative to GDP the role of imports is much less dominant but at least significant in China, India, Pacific Asia and Eastern Europe. Comparing the value of energy trade in 2050 in the [BAU] and in the [tax] scenario shows that the Middle East/ North Africa loses revenue from energy exports equivalent to 10% of BAU GDP in 2050. Australia/ New Zealand loses revenue equivalent to around 6% - more than the Former Soviet Union (around 5%) - because coal has an earlier and more pronounced drop in prices. On the other hand, China, Eastern Europe and India gain most because they are energy importers and also relatively energy intensive.

Figures 6 and 7 taken together show that especially the Middle East/ North Africa, the Former Soviet Union, Australia/ New Zealand and Sub-Saharan Africa suffer from the energy market effects of climate policy. Oil (and gas) exports are an important part of their economy and prices are significantly lower than in BAU. Though the share of energy exports in Australia/ New Zealand is lower, the price changes for coal are stronger. On the other side especially China, India and Pacific Asia and to a lesser degree Eastern Europe can gain most from lower energy prices.

Other indirect effects that e.g. affect the competiveness of different sectors or the overall economy are more difficult to measure. Overall terms of trade, for example do not change very much in most countries. Many of the effects are also related to the carbon intensity of production shown above in figure 5 – regions where production is carbon intensive loose competitiveness while the regions that are least carbon intensive gain competitiveness.

3.4. Compensating for welfare changes through emission trading

One way to change the burden sharing is through an adequate allocation of allowances in an emission trading scheme. More allowances mean a larger wealth for the region in question and also allowance importers provide transfers to allowance exporters relative to a tax scenario.

Figure 8 shows the share of the 2012 – 2050 cumulated emission allocation to different countries in the global cumulated emission target over the same time period. In the [tax] scenario these are the actual emissions. In the two emissions trading scenarios it is the allocation of allowances.

We can see that the [CDC] scenario implies on the one side less emission allowances than in the [tax] scenario especially for Western and Eastern Europe, the USA, Canada and Japan, though the changes are not drastic due to the convergence path in this scenario which starts of at current emissions. If we instead would look at 2050 only, the changes would be much more pronounced and the emission allowances are only about 50% of the emission in the [tax] scenario. Reductions in the emission allowances in the Former Soviet Union, Latin America, and China are much smaller. On the other side, India, and Sub-Saharan Africa and to a smaller degree Pacific Asia receive more allowances, and again this is even more pronounced when looking at 2050 only. For Australia/ New Zealand and the Middle East/ North Africa allowance do not change much. When looking at figure 2 again, we see that this emission allocation affects welfare accordingly. The regions that receive more rights (India, Sub-Saharan Africa, Pacific Asia) are now even overcompensated and welfare increases compared to the [BAU] scenario. Welfare in Australia/ New Zealand and the Middle East/ North Africa is not much affected. Welfare losses slightly increase in the Former Soviet Union, Latin America and China. In the USA and Canada the effects are more drastic and Western and Eastern Europe now also experience overall losses.

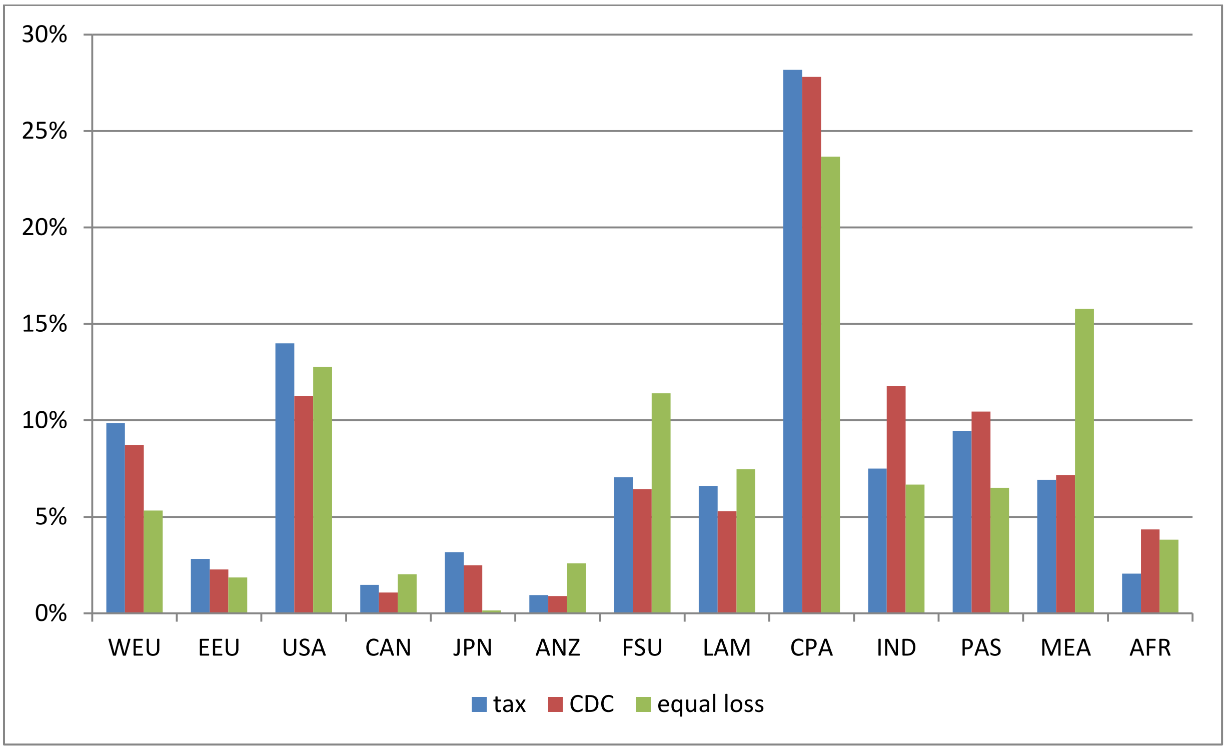

Figure 8: Shares of the 2012 – 2050 cumulated emission allocation to different countries in cumulated global emission; for tax actual emissions are shown.

Compared to the [equal loss] scenario, allowance allocation in the [CDC] scenario is about right for the USA, while there are still too many rights for Western and Eastern Europe, Japan and China, though the [CDC] scenario is closer to the [equal loss] scenario than the [tax] scenario. India and Sub-Saharan Africa now receive too many instead of too few allowances. The reduced allowances for Pacific Asia, Canada, and the Former Soviet Union go into the wrong direction.

We can also see that in the [equal loss] scenario especially the Middle East/ North Africa and the Former Soviet Union receive a large (and over-time rising) share of allowances to compensate for the energy market effects. Allocation is lower than in the [tax] and [CDC] scenario especially in the regions where the energy market effects are positive (Western Europe, India, Pacific Asia). China's allowances peak in the early 2020s and are in 2050 almost 30% lower than in the [tax] scenario. Japan that is also a large importer of energy receives negative emission rights in later years.

One has to note that a different allowance allocation does not only mean a transfer, but also to some degree changes abatement costs (and levels) and the indirect effects of climate policy (components 1 and 2 of overall welfare effects). These effects would be constant e.g. in a static, single country setting but not in a general equilibrium setting, where there are also wealth effects. Mostly the changes from the [tax] to the [CDC] or [equal loss] scenario are minor, but in cases where the difference in the allocation becomes very large the effects are no longer negligible and the resulting increase/decrease in wealth affects the production and consumption structure of the economy and thus also marginal abatement costs, relative prices etc.

Because in the [equal loss] scenario the large oil importers have to compensate oil exporters, which reduces the importers' wealth and thus their overall demand for oil more than the compensation increases oil demand in the exporting regions, the oil price in 2050 for example is around 3% lower than in the [tax] scenario. This induces even higher compensation for the energy market effects. Effects on approximated abatement costs in 2050 are rather small and mostly not more than 1 to 2%. They work into the right direction (higher cost for countries that receive less rights, and lower costs for regions that receive more rights) so that less compensation through the allocation of emission allowances is necessary. Most important for the difference in welfare effects between the [tax] and the emission trading scenarios are of course the transfers in emission rights.

In the [CDC] scenario exporters of allowances are (in the entire trading period) India (53.5%), Sub-Saharan Africa (30%), Pacific Asia (13.7%) and Middle East/ North Africa (2.8%). The largest importers are the USA (34%), Latin America (16%) and Western Europe (15%). The remaining regions import smaller shares. In the [equal loss] scenario overall 2.3 times more emissions are traded than in the [CDC] scenario. The main exporters are Middle East/ North Africa (49%), Former Soviet Union (24%), Sub-Saharan Africa (10%), Australia/ New Zealand (9.1%), Latin America (4.8%) and Canada (3.1%). The largest importers are Western Europe (25.1%), China (25.1%), Pacific Asia (16.1%) and Japan (16.1%). The USA, Eastern Europe and India import 4-6% each. Relative to GDP the picture is slightly different also because the volume of emission trade has changed. Figure 9 shows the average share of the value of the income of allowance exports (positive numbers) respectively the costs of allowance imports (negative numbers) in GDP in both emission trading scenarios.

In the [equal loss] scenario the countries that gain from the lower energy prices and also from their positive competitiveness effects in their energy intensive industries pay up to 1.5 % of GDP to buy emission allowances. The large energy exporting regions receive revenue in the order of 2 to 6% of GDP for selling allowances. In absolute as well as in relative terms exporters of emissions are necessarily those that need most compensation for the negative indirect effects of climate policy: Middle East/ North Africa, the Former Soviet Union, Australia/ New Zealand and Sub-Saharan Africa. The largest importers are those that profit most from lower energy prices: China, Eastern and Western Europe, Japan and Pacific Asia. Of course, this allowance allocation implies very different per capita allowances (table 3). Australia/ New Zealand have even higher emission allowances than the Former Soviet Union and Middle East/ North Africa, as the negative relative impact is large for the coal exporter. This is also true for Canada that also exports coal and experiences the strongest negative effect on coal prices across all regions.

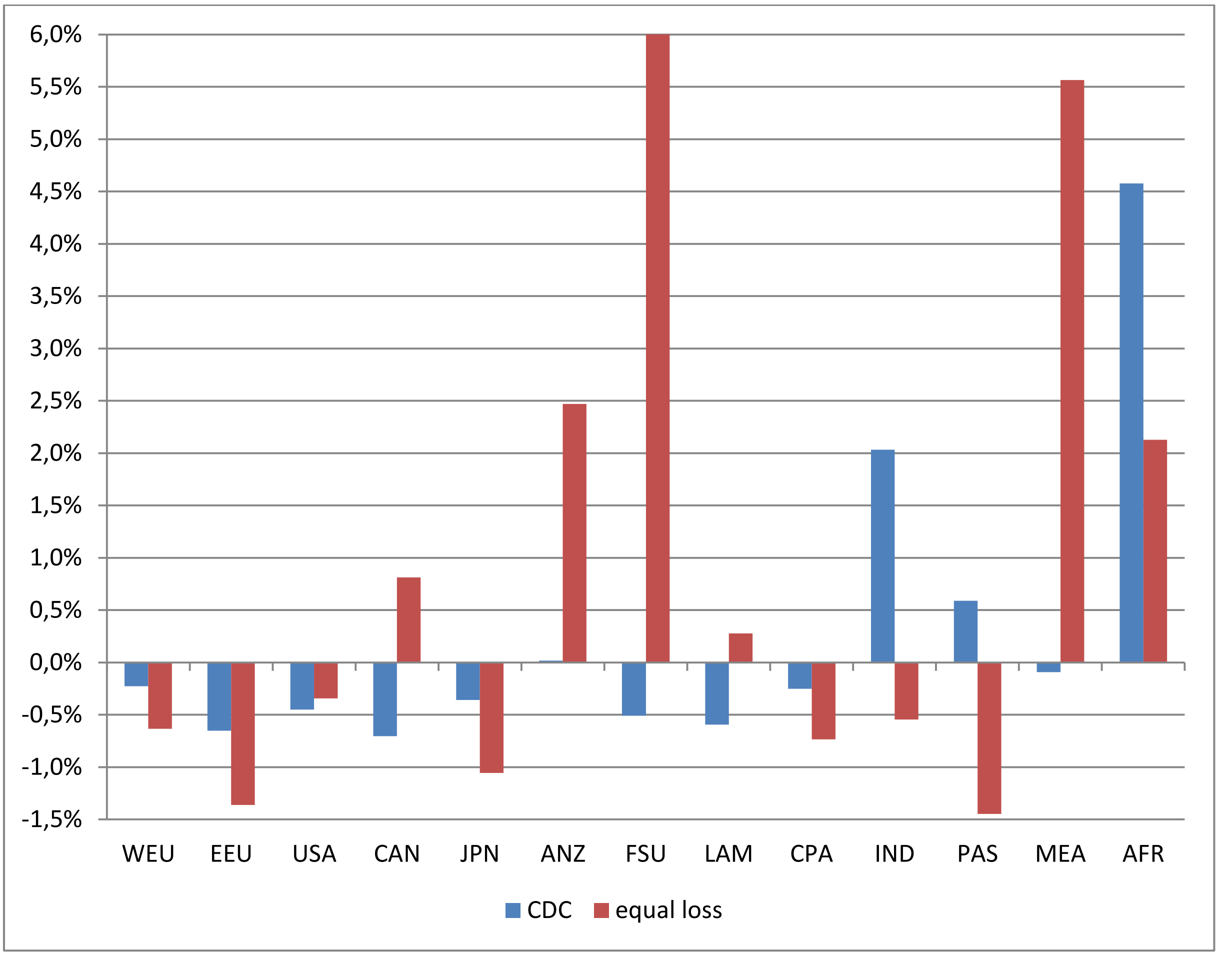

Figure 9: Average share of the value of the income of allowance exports (positive numbers) respectively the costs of allowance imports (negative numbers) in GDP.

In terms of allocation relative to BAU emissions, the second part of table 3 shows that half the regions (Western and Eastern Europe, USA, China, India, Pacific Asia) receive rights for only around 40 to 60% of their emissions. Another four regions (Canada, Former Soviet Union, Latin America and Africa) that all lose through energy market effects receive around 90% of their BAU emissions. Japan as a very energy efficient country and energy importer that profits from energy market effects receives basically no allowances at all. On the other extreme Middle East and Australia/ New Zealand receive 50 to 70% more allowances than BAU emissions. The main reason, while actual transfers through emission trading and allocated emissions are not the same is that transfers also depend on the level of abatement costs. The cheap abatement costs in the Former Soviet Union are the reason why this region receives large transfers in the [equal loss] scenario, even though the emission allocation is not more generous relative to BAU emissions than in e.g. Canada, Latin America or Africa.

Table 3: Allowance allocation in [equal loss]

WEU	EEU	USA	CAN	JPN	ANZ	FSU	LAM	CPA	IND	PAS	MEA	AFR
Per capita allocation in 2050												
1.8	1.6	3.6	8.4	0.1	9.9	8.9	2.5	2.3	0.9	0.7	6.4	0.6
Overall allocation relative to BAU emissions												
0.4	0.4	0.6	0.9	0.0	1.7	0.9	0.9	0.5	0.4	0.5	1.5	0.9

3.5. An alternative scenario excluding FSU/MEA from compensation

While there is experimental evidence that an [equal loss] scenario is perceived as fair and can increase the probability to contribute sufficiently to the global good of mitigating global warming the necessary large (absolute) compensation payments to exporters Former Soviet Union and Middle East/ North Africa might be politically infeasible in reality. We thus look at one alternative scenario where no surplus allowances are granted to these two regions in order to reduce the overall transfers. However, the high welfare losses under a [tax] or [CDC] scenario are not likely to induce participation of these regions. We therefore assume that there is no climate policy in these countries. To keep global emission constant to the other climate policy scenarios, the remaining countries therefore have to abate more. As a result, welfare losses in the Former Soviet Union and Middle East/ North Africa now decrease to 7.6% and 11.3%, respectively. They are thus better off than in the [tax] and [CDC] scenario. The remaining high welfare loss can mostly be explained by changes in energy trade. Due to carbon leakage the unconstrained emissions in these regions are even higher than in the [BAU] scenario and the other regions have to increase their abatement accordingly. Their cumulated emissions from 2012 to 2050 decrease by 14% compared to the other climate policy scenarios. Since abatement is especially cheap in the Former Soviet Union and Middle East / North Africa, their emissions are 80 – 90% higher than in the climate policy scenarios that include action in these regions. Thus, even when equal loss within the climate policy coalition is achieved, the average loss of 2.1% is higher than in the scenario where the Former Soviet Union and Middle East/ North Africa are compensated for adverse effects on the energy market (1.5%). This is due to the highly inefficient distribution of abatement, which leads to a zero carbon price in the Former Soviet Union and Middle East/ North Africa but a carbon price above US$ 1200/tCO_2 in 2050 in the other regions – compared to only around US$ 350/tCO_2 in the other climate policy scenarios.[2]

[2] When the Former Soviet Union and Middle East/North Africa are not compensated but have the same carbon price as the rest of the world, equalized welfare losses for the other regions amount to only 0.4%. In that case the Former Soviet Union and Middle East/North Africa have to bear losses of similar magnitude as in the tax scenario (12.4% and 11.6%, respectively).

4. Summary and Conclusions

A fair burden sharing of the costs of climate policies has always been at the heart of international climate negotiations. Most approaches so far focused on transfers through emissions trading and a fair distribution of emission allowances such as equal per capita emissions. Our simulations with the computable general equilibrium model DART have shown that in such a scenario, more precisely, a so-called "common but differentiated convergence" scenario where all countries' per capita emissions eventually converge, but countries only start to converge when their per capita emissions are at a certain percentage above the global average, the burden sharing in terms of welfare costs is still very unequal. We have thus in a first step tried to understand the driving forces behind these differences. For this we started with the [tax] scenario that does not include transfer of wealth through emission trading since the reduction target (in line with the 2 degree target) is reached efficiently with a uniform international carbon tax. We were able to show that there are two important factors that determine overall welfare effects: (1) direct abatement costs - the more countries have to abate, the higher the welfare costs and (2) indirect effects which are dominated by energy market effects – climate policy reduces the demand for fossil fuels and also their prices net of carbon costs which is beneficial for energy importers and detrimental for energy exporters. The first three columns of table 4 summarize and stress these findings. They show that the overall welfare effects in the [tax] scenario are explained by a combination of abatement costs and energy market effects.

Since there is experimental evidence that a burden sharing scheme implying equal welfare effects is most acceptable and since such a scenario has received very limited attention in existing simulations we have analyzed a scenario where emission allowance are allocated in such a way that the cumulated welfare losses are equal across model regions. The third column in table 4 shows the sign and the strength of the necessary transfers to achieve equal welfare losses across the regions mirroring the welfare effects in the tax scenario. The last column shows how generous emission allocation needs to be to achieve this transfer.

In this [equal loss] scenario the four regions that are most severely affected by the negative effects of reduced demand and prices for fossil fuel, namely the Middle East/ North Africa, the Former Soviet Union, Australia/ New Zealand and Canada receive very high per capita allowances (though not necessarily very much surplus emission relative to BAU) and thus transfers. This is most likely not politically acceptable and also raises the questions which effects of climate policies compensation should address. A few existing studies have e.g. analyzed scenarios where only the abatement costs are compensated because the energy market effects are not driven by whether a country is abating or not. Yet, this is certainly not an incentive to join a regime if other effects dominate. Since the energy exporting regions are not responsible for major shares of global emissions an alternative might be to not compensate them but abate more in the remaining coalition. We have analyzed one such scenario where the Middle East/ North Africa and the Former Soviet Union are not part of the climate coalition. This reduces transfer payments, but still comes at a high cost for these energy exporting regions. Furthermore, this scenario is more expensive also for the remaining countries because the global distribution of abatement is inefficient.

Table 4 – Summary of the main results

	Strength of welfare gains (+) / losses (-) in [tax][a]	Drivers of welfare effects in [tax]		Transfers in [equal loss]	
		Abatement costs[b]	Energy market effect[c]	gains/losses from emission trading [d]	Allowance allocation rel. to BAU [e]
WEU	+/-	-	+	-	-
EEU	+	--	+++	--	-
USA	-/+	-	+	-	-
CAN	-	-	-	+	+/-
JPN	+	-	++	--	--
ANZ	--	--	--	++	+
FSU	---	---	---	+++	+/-
LAM	-	-	-	+	+/-
CPA	-/+	--	+++	-	-
IND	-/+	---	+++	-	-
PAS	+	--	++	--	-
MEA	---	--	---	+++	++
AFR	--	--	--	++	+/-

[a] Based on changes of cumulated welfare in the [tax] relative to the [BAU] scenario (figure 2): --- < -10%; -- (-10%, -5%]; -(-5%, -1]; +/- (-1%, 1%]; +(1%, 5%].

[b] Based on approximated average abatement costs as share of GDP (figure 4): --- >3%; -- [1%, 3%); - [0%,1%)

[c] Based on value of net energy trade (imports are negative, exports are positive) relative to GDP BAU 2050 (figure 7): --- >10%; -- [5%, 10%); - [0%,5%), + [-2%,0%); ++ [-5%,-2%); +++ >5%

[d] Based on average share of the value of the income of allowance exports /costs of allowance imports in GDP (figure 9): -- <-1%; - [-1%,0%); + [0%,1%), ++[1%, 5%); +++ > 5%

[e] Based on overall allocation relative to [BAU] (table 3): -- > 0.1; - [0.1,0.6]; +/-[0.6,1); +[1,1.5); ++> 1.5

A more in depth (game theoretic) analysis of different coalition is a question for further research. What this paper has shown is that the actual burden of a stringent climate policy is not only driven by abatement cots, but more so by energy market effects. A completely equal burden sharing in terms of welfare losses is of course also a very academic scenario because these effects are – other than e.g. a certain allocation of allowances per capita – difficult to assess. Each model will give different results. Yet, ignoring these effects is not a solution either.

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