Impacts of EU options for post-Kyoto in the medium term - results from the GINFORS model

by

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Abstract

The EU has affirmed the strategic objective of limiting global temperature rise to not more than 2°C above pre-industrial levels at the Brussels summit in March 2007 under German presidency. The EU further committed to reducing GHG emissions by 20% compared to 1990 irrespective of the results of negotiations on a post-2012 agreement. If other industrialised countries commit themselves to similar reduction targets and economically more advanced developing countries agree upon adequate contributions to climate protection, the EU is willing to reduce emissions by 30% until 2020.

Using the extensive and disaggregated global GINFORS model, consequences of different possible post-Kyoto regimes on the German and European economy and other major economies in the medium run until 2020 are depicted. The approach is very extensive and detailed in comparison to already existing analyses: this holds for the number of explicitly modelled countries (50 and 2 regions) and 41 economic sectors, input-output tables, the bilateral trade flows, the detailed coverage of behavioural parameters, the coverage of energy balances and CO_2 emissions as well as the number and precise economic-political design of simulation runs. To confirm that the model results are technological feasible, results are matched with information on possible future technology pathways which are based on recent projections for Germany and Switzerland.

Costs of additional mitigation measures are expressed in deviation from the GDP in the reference scenario. In doing so, all macroeconomic and inter-industry interdependencies, nationally and internationally, are embodied in the results. Global emissions will double until 2030 compared to 1990 levels without the existence of a far-reaching climate regime after 2012. A unilateral commitment of the EU would only be a "drop in the bucket", which solely strengthens the credibility of the EU in international negotiations. A stabilisation of global emissions in 2020 compared to 2010 can only be achieved, if all developed and at least the large developing countries (G5) participate and if all existing market-ready reduction technologies are used.

Keywords: Global modelling, economy-energy-environment modelling, climate change, international policy

1. Introduction

In their „International Policy Architecture for the Post-Kyoto Era" Olmstead and Stavins (2006) stress three elements as the basic features for a post-Kyoto climate regime. They are convinced that "this overall approach can be made scientifically sound, economically rational and politically pragmatic" (Olmstead and Stavins 2006, p. 37).

There should be a broad participation of all major industrialized nations and key developing countries. The exclusion of the key developing countries would favour carbon leakage: Carbon intensive productions would be concentrated in these countries, which would hinder reaching the global targets. Further, the costs for these countries of joining the system would rise over time. At the same time, the relatively low-cost potential of carbon reduction in these countries today could not be used. The relevance of CO_2 emissions of developing countries is underlined by a forecast of Nakicenovic and Swart (2000), who expect that more than the half of global CO_2 will be emitted in developing countries in 2020. According to the current IEA (2007) world energy outlook, this will already be the case in 2010.

They further conclude that targets of the system should start at current emission levels and not with the Kyoto targets. This is especially essential for the participation of the U.S. – but also for some other industrialized countries – because the actual emissions of the U.S. are about 25% higher than its Kyoto target. Furthermore, the country specific targets should first allow for the growth path of emissions to peak, but staying below the business as usual path, and fall later. Such a path would avoid that the existing capital stock becomes completely obsolete in the short run. The decarbonisation of the technology will later create a new capital stock which allows for higher rates of emission reductions. The authors underline the consistency of this argumentation with estimates of least cost time paths made by Manne and Richels (1997) and Wigley et al. (1996).

In general, market based instruments should be installed because most economists agree that regulatory approaches are not efficient. Tradable permits on a global level are the cost-efficient instrument under a future global regime. For the time being, McKibbin and Wilcoxen (2002) argue that for some countries carbon taxes or hybrid systems may be more attractive since uncertainties about carbon prices can be avoided. Citing Edmonds et al. (1997) Olmstead and Stavins recommend an international tradable permit system for the industrialized countries because this would reduce costs by 50 percent.

The paper at hand tries to calculate the global economic and environmental effects of different concrete carbon regimes that are in line with both the regime just discussed and the current climate policy of the European Union. We are interested in a medium term analysis up to 2020 or at latest 2030. This demands a solid estimation of both the reference path and the alternative paths in relative and absolute terms. For such an exercise an empirically validated model is needed (as the instrument of the analysis). The global multi-country and multi-sector economic environmental model GINFORS with its econometrically estimated parameters fulfils this requirement.

The EU has affirmed the strategic objective of limiting global temperature rise to not more than 2°C above pre-industrial levels at the Brussels summit in March 2007 under German presidency. The EU further committed to reducing GHG emissions by 20% compared to 1990 irrespective of the results of negotiations on a post-2012 agreement. If other industrialised countries commit to similar reduction targets and economically more advanced developing countries agree upon adequate contributions to climate protection, the EU is willing to reduce emissions by 30% until 2020. Further more, EU targets were set for a substantial expansion of the use of renewable energies as well as for an increase in energy productivity. These targets not only contribute to climate change mitigation but also to energy security in the EU due to a reduced dependency on energy imports. The EU explicitly emphasises three objectives of energy and climate change policy: security, competitiveness of EU industries and sustainability.

Based on these European policy targets the paper discusses different scenarios concerning the participation of industrialized and key developing countries and follows the framework of Olmstead and Stavins (2006): For industrialized countries a hybrid approach is assumed: Tradable permits are introduced for basic industries including electricity, following the example of the EU ETS, whereas for the other industries and households a carbon tax enforces decarbonisation. The firms under the permit trading systems can achieve a certain percentage of their emission reductions with flexible mechanisms (CDM) in developing countries. International trading of the permits is allowed between industrialized countries. For developing countries a carbon tax is assumed with a carbon price which reaches a certain percentage of the permit price in the industrialized countries. Emission targets have to be reached linearly so that permit prices and carbon taxes rise continuously.

The paper is organized as follows: Chapter 2 gives a short presentation of the model GINFORS. Chapter 3 discusses the scenarios, the simulation results are presented in chapter 4. Some conclusions in chapter 5 close the paper.

2. The GINFORS model

The simulation instrument – the global model GINFORS (**G**lobal **IN**terindustry **FOR**ecasting **S**ystem) – describes the economic development, energy demand, CO_2 emissions and resource inputs for 50 countries, 2 regions, 41 product groups, 12 energy carriers and 6 resources. The regions are "OPEC" and "Rest of the World". The explicitly modelled region "OPEC" and the 50 countries cover about 95% of world GDP and 95% of global CO_2 emissions. The aggregated region "Rest of the World" is needed for the closure of the system. The model is documented in Meyer et al. (2007) and Meyer et al. (2008). An application of the model can be found in Giljum et al. (2008).

The countries and regions are linked on the sector level for 25 commodities and one service good with trade flows and prices using a bilateral trade model. For every country and the "OPEC" region there exists a macro model, an energy model and a resource model. Input-output models are available for 24 economically important countries that represent about 80% of world GDP. The macro models explain the balance of payments, the different components of final demand, aggregated labour supply and demand, the wage rate and the GDP deflator. The input-output models calculate sectoral production, sectoral employment, prices and wages. The energy models estimate final energy demand in deep sectoral disaggregation, the energy carrier structure and energy conversion. CO_2 emissions are linked to energy demand. Domestic prices for fossil carriers are driven by exogenous world market prices and domestic taxes, prices for electricity are given by the input-output model. For each country all different models are linked interdependently.

Assuming exchange rates in the long run flexible the overall balances of the countries are zero, so that the balance of the capital account equals the balance of the current account with negative sign, which is given by the trade flows and additional transfers. With some exceptions, the exchange rates are explained by the purchasing power parity hypothesis which gives good empirical validation for the long run. The model solution always implies that global savings equal global investment.

The main difference to neoclassical CGE models is the determination of prices. Prices are determined due to the mark-up hypothesis by unit costs and not specified as long run competitive prices. But this does not mean that the model is demand side driven, as the use of input-output models might suggest. It is correct, that demand determines production, but all demand variables depend on relative prices, and prices are given by unit costs of the firms using the mark-up hypothesis, which is typical for oligopolistic markets. The difference between CGE models and GINFORS can be found in the underlying market structure and not in the accentuation of either market side. Firms are setting the prices depending on their costs and on the prices of competing imports. Demand is reacting on price signals and thus determining production. Hence, the modeling of GINFORS includes both demand and supply elements.

Besides the usual interdependencies of the circular flow of income GINFORS depicts the interdependencies of prices and volumes as well as of prices and wages. The model is non-linear, because there are many multiplicative connections of variables in definitions, and many behavioral equations are estimated in double-logarithms. It is a dynamic model, due to the lags in behavioral equations. The nonlinearity combined with the interdependency of the system requires an iterative solution procedure, which is given by the Gauss-Seidel algorithm. The dynamic structure allows a year by year solution for a longer time path. The model is running in historic time, and time is not reversible.

All parameters of the model are estimated econometrically, and different specifications of the functions are tested against each other, which gives the model an empirical validation. Yet another confirmation of the model structure as a whole is given by the convergence property of the solution which has to be fulfilled year by year. The time series data for the econometric estimations was taken for the period 1980-2004. For a number of variables the data was only available for a shorter time period. International datasets from the OECD, the IEA, and the IMF have been used.

Technical progress is endogenized by the cost push hypothesis. But for energy, technological developments under a post-Kyoto framework cannot solely be econometrically estimated based on past developments due to lacking experience. Based on bottom-up-information from recent energy projections for the German Ministry of Economics and Technology, the Energy Report IV (EWI, Prognos 2005) and the corresponding oil price version (EWI, Prognos 2006) and international technology projections of the IEA (2006b), two possible evolution paths for technologies that form the basis for future development were estimated: (1) "restrained" technological development for the reference scenario without tightened climate protection strategies, the basic assumption being moderate autonomous technological change, and (2) "accelerated" technological development, in which existing efficiency technologies faster diffuse into the market during the investment cycles assuming higher mitigation efforts. In particular evolution paths regarding average specific energy consumptions per unit of production or reference (e.g. heating surface, vehicle km) were determined. The specific targets for 2020 compared to 2005 in important sectors in the “accelerated” technological development scenario have the following lower bounds (or upper bounds in the case of bio fuels) (1) specific energy consumption of industry (integrated) per unit of production: -14%, (2) specific energy consumption of heating: -30%, (3) specific energy consumption of gasoline-driven passenger cars: -25% and (4) share of bio fuels in total fuel consumption: 25%.

These findings are taken into account in the simulation runs with GINFORS. Thus, technologically meaningless developments from the point of view of the bottom-up analysis can be avoided. The approach therefore is superior to many purely economic models, which assume, for sufficient price changes, large substitution possibilities of production factors between sets of technologies, even though the possibilities of substitution may remain restricted until 2020 or 2030 given the existing capital stocks.

Due to the medium-term time horizon, the project focuses on already existing technologies („best practice“), as for example highly efficient heat insulation, moderated electric motors as cross-sectional technologies, usage of waste heat, etc. Technologies currently under development or speculative technologies are not included here. For conventional power plants it is differentiated between fast or slow conversion of high efficiencies. It is assumed that CCS (Carbon Capture and Storage) technologies are not standard by 2020, but gradually reach market readiness. Key technologies like bio- and nanotechnologies are assumed to have especially high potential to generate more energy and material efficient products and methods of production after 2020.

3. The scenarios

In the reference scenario the development of the central exogenous variables is based on international projections of institutions like the UN and the IEA. The world market prices for fossil fuels are taken from the reference scenario of the World Energy Outlook 2006 (IEA 2006). The UN (2005) population projection is used as exogenous information. In the medium variant this corresponds to a world population of about 8 billion in 2030. For the EU, it is assumed that the European Trading System (ETS) of permit trading for primary industries will still be in force till 2030 with a permit price of 7.5 €/tCO_2, which together with the other already installed policy instruments guarantees among others that the Kyoto targets will be met until 2012.

The alternative climate policy scenarios are differentiated according to assumed policy instruments and participating countries. Concerning the participation we distinguish between different scenarios: scenario EU with Europe (EU-27) as the only region with an active climate policy. In scenario IL all industrialized countries without the U.S. join a carbon regime. The scenario U.S. assumes that the carbon regime is extended to all industrialized countries including the U.S. In scenario G5 the most important developing countries China, India, Brazil, South Africa and Mexico (G5) join additionally.

In scenario EU-1 EU27 alone realizes a hybrid carbon regime with the unilateral target of a reduction of THG emissions of 20% below the emissions of 1990. The rule for burden sharing is the following: All EU15 countries face the same percentage reduction from their 2008-2012 Kyoto target levels. The 12 new member states (NMS12) start from their reference level in 2008 to 2012. We assume that the EU ETS will be in force until 2030. Due to actual debates there will be a change from grandfathering to auctioning and benchmarking and the air-transport sector will additionally be part of the system. In the electricity sector the permits are auctioned, while for the other primary industries and the air-transport sector a benchmarking approach is assumed. These industries will only have to pay for permits, if their energy productivity is above industry average. Those with better technologies win and those with bad technologies lose. There is an incentive to improve the technology, but the industry as a whole has no additional costs. The use of flexible Kyoto instruments as the Clean Development Mechanism (CDM) is not allowed.

All other industries and the households face a carbon tax. The government uses the auctioning and the carbon tax revenues to reduce income taxes. The tax rate starts from zero in 2012 and rises linearly to reach 100 €/t CO_2 in EU15 countries and 50 €/t CO_2 in the 12 new member states (NMS) in the year 2020. The permit trade is an EU wide market. The supply of permits is given year by year as the difference between the target for Europe and the emissions of the non-ETS sectors. Hence, there is a unique emission cap for Europe, which clears the permit market, and guarantees that for Europe as a whole the targets will be reached in every year. This does not mean though that the targets will be reached in all countries. Compensation payments between the countries will clear the market. It is assumed that payers finance the amount by reducing their governmental expenditures, and the receiving countries accordingly expanding their governmental expenditures.

Out of ten studied variations of this scenario, scenario EU-11 shows compared with scenario EU-1 the effects of a tightened target and of CDM: In this scenario it is assumed that the GHG emission target is a unilateral 30%

reduction compared to 1990, but it is allowed for the firms in the permit market to achieve up to 50% of their reductions in developing countries.

Scenario IL comprises all industrialized countries excluding the U.S. The assumptions of the hybrid carbon regime are the same as in scenario EU-11. We further assume that the ETS is the leading market, and the other industrialized countries are price takers. This seems to be a realistic assumption since governments in other countries may fear higher avoidance costs compared to the EU, e.g. in the U.S. ceilings for permit prices are discussed (EIA 2008). Thus, it may be cheaper to accept a common carbon price, but not a common reduction target. The carbon tax rates for all industrialized countries in the non-ETS sectors are 100 €/t C O_2 just as in the EU15 countries. All other assumptions in scenario IL are identical with scenario EU-11.

In scenario USA all industrialized countries participate in the hybrid carbon regime including the U.S. All other assumptions are the same as in scenario IL.

Scenarios G5 include all industrialized countries and the 5 most important developing countries China, India, Brazil, South Africa and Mexico. In scenario G5-1 it is assumed that these countries introduce a carbon tax for all sectors that linearly rises from zero in 2012 to converted 23 €/t CO_2 in 2020. So the carbon price in the primary industries is the same in all countries, but it is much lower in G5 in all other industries and for the households compared to industrialized countries. For scenario G5-2 the tax rate rises linearly from zero in 2012 to 25% in 2020 of the permit price of the industrialized countries and 50% in 2030. Hence, scenario G5-2 assumes only a very low carbon tax with a maximum of about 6 €/t CO_2 in 2020. In both scenarios we assume a "soft" participation of the developing countries in two dimensions: They do not participate in the permit market for the primary industries and they introduce much lower carbon tax rates than the industrialized countries.

4. Simulation Results

4.1 The Reference Scenario

Table 1 gives an overview for the most important economic and environmental variables for selected regions and countries. There will be a slight reduction in the average growth rates of world GDP after 2010 which takes place more or less in all regions. Nevertheless the difference between growth in G5 and the new member states of the EU (NMS12) on the one side and in the industrialized countries on the other side will continue. In 2030, the share of G5 in world GDP will reach 39.6 % against 44.9 % of the industrialized countries.

Since there is growth in energy productivity, global energy-related CO_2 emissions will increase less than GDP. The growth rate is 50% until 2030 compared to historic 2004 emissions without additional mitigation measures. Compared to the base year of the Kyoto Protocol, 1990, they almost double. The EU27 will still produce about 10% of global emissions (15% in 2004). The main increase of global emissions can be ascribed to developing countries – particularly to China, which probably already today is the world's biggest CO_2 emitter.

Forecasts of exogenous variables like the oil price have been taken from the IEA (2006a). It should be mentioned that the price given in Table 1 is expressed in US dollars of the year 2000. So in nominal terms the US inflation has to be added. The population projection stems from medium variant of UN (2005).

4.2 The results for unilateral EU scenarios

The price of ETS allowances will rise to 30 Euro2005/t CO_2 to meet the reduction target. This is approximately equal to 10 Cent per litre fuel oil. To achieve about the same percentage reduction in the non-ETS sectors, an increase of the CO_2 price to 100 Euro2005 per ton (or 32 Cent per litre of diesel fuel) is needed in the EU15. In the remaining EU27 countries, an increase of 50 Euro2005 per ton is sufficient due to high energy efficiency potentials there.

Compared to the reference scenario the increased CO_2 abatement costs have a negative economic impact on EU27. Gross domestic product (GDP) of the EU27 will be 0.55%, or 73 billion Euros, lower in 2020 compared to the reference scenario according to Table 2. The major reason for that is a decrease in international competitiveness resulting in declining exports and rising total imports, even though energy imports decrease. Additionally, the higher prices have a negative impact on domestic demand. Growth dynamics, i.e. the average annual GDP growth rate, can however almost be maintained.

Tab. 1: Main values of the reference scenario

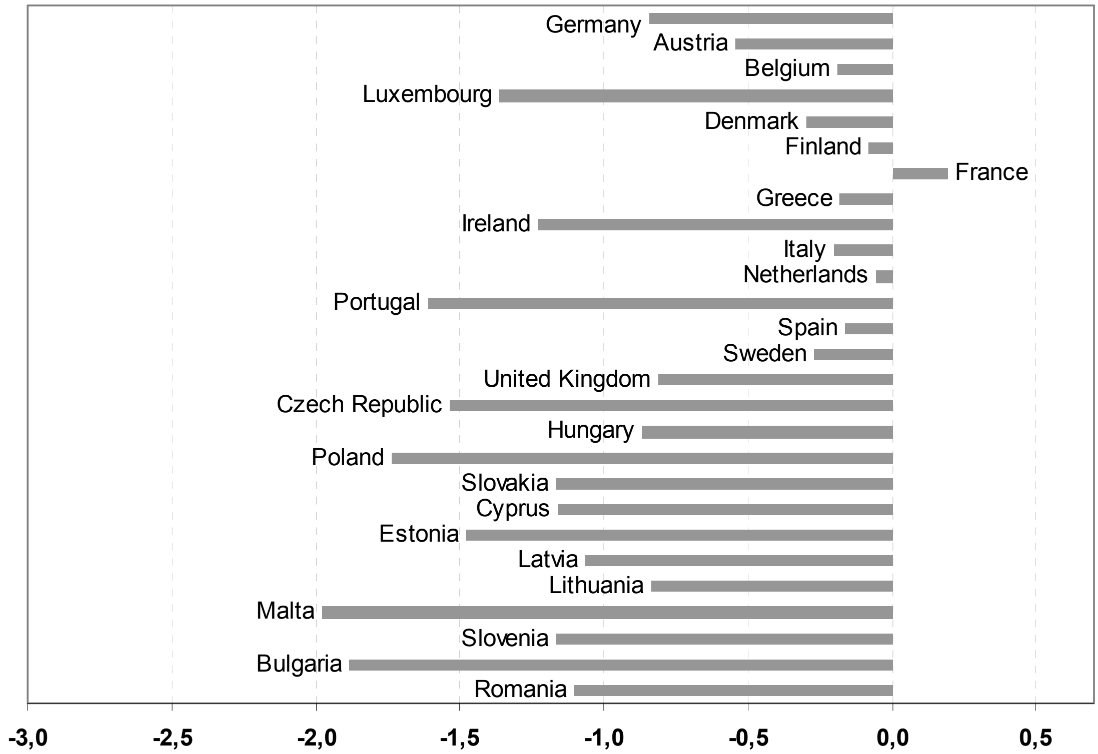
GDP: average annual growth rates		1990-2000	2000-2010	2010-2020	2020-2030
	in %				
Germany		2.1	1.4	1.5	1.3
EU-15		2.3	1.9	2.0	1.7
NMS-12		2.3	4.0	4.0	3.2
EU-27		2.3	2.1	2.2	1.9
other developed countries		3.5	2.6	2.3	2.0
thereof USA		3.3	2.7	2.6	1.9
G5		6.7	6.8	5.1	3.6
World		**3.6**	**3.9**	**3.4**	**2.7**
share in world-GDP	**1990**	**2000**	**2010**	**2020**	**2030**
	in %				
Germany	5.7	4.9	3.9	3.2	2.8
EU-15	25.3	22.1	18.2	15.8	14.4
NMS-12	2.2	2.3	2.4	2.6	2.7
EU-27	27.5	24.4	20.7	18.4	17.1
other developed countries	37.9	37.4	33.2	29.7	27.8
thereof USA	23.6	22.9	20.4	18.8	17.4
G5	17.4	23.4	30.8	36.4	39.6
World	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
CO_2 emissions from fossil fuel combustion	**1990**	**2005**	**2010**	**2020**	**2030**
	Mt CO_2				
Germany	966	829	806	797	757
EU-15	3,118	3,281	3,229	3,169	3,130
NMS-12	954	725	739	779	733
EU-27	4,072	4,007	3,968	3,949	3,863
other developed countries	8,716	9,542	10,160	11,374	12,001
thereof USA	4,842	5,729	6,108	7,085	7,405
G5	3,585	7,009	8,495	11,789	14,215
World	**20,683**	**26,703**	**29,613**	**35,975**	**40,326**
CO_2 emissions: deviations compared to 1990	**1990**	**2005**	**2010**	**2020**	**2030**
	in %				
Germany		-14.3	-16.6	-17.6	-21.7
EU-15		5.3	3.6	1.7	0.4
NMS-12		-24.0	-22.5	-18.3	-23.2
EU-27		-1.6	-2.5	-3.0	-5.1
other developed countries		9.5	16.6	30.5	37.7
thereof USA		18.3	26.2	46.3	52.9
G5		95.5	137.0	228.9	296.6
World		**29.1**	**43.2**	**73.9**	**95.0**
other figures	**1990**	**2000**	**2010**	**2020**	**2030**
world population in Mill.	5,264	6,086	6,843	7,578	8,199
population DE in Mill.	79.3	82.2	82.6	82.2	81.4
population EU-27 in Mill.	439.7	483.7	492.8	494.0	490.7
CO_2 allowance price in Euro2005/t			7.0	7.5	7.5
oil price in US$2000/bbl.	17.9	28.0	50.0	47.0	60.0

Table 2: Main numerical results in 2020, different scenarios

	scenario	design		changes compared to reference scenario [%]		vs.1990 [%]
				BIP	CO_2	CO_2
participation: EU-27 unilateral	EU-1	participation: EU-27 unilateral	DE:	-0.84	-15.8	-30.6
		CO_2 price of ETS: 30 Euro/t	EU-15:	-0.41	-13.2	-11.7
		equivalent CO_2 price, non-ETS:	NMS-12:	-1.41	-22.0	-36.3
		100 Euro/t in EU-15, 50 Euro/t in NMS-12	EU-27:	-0.55	-14.9	-17.5
		usage of flexible mechanisms: no	USA:	0.13	0.1	46.5
		EU-burden-sharing based on Kyoto targets	G5:	0.41	0.2	229.6
		allocation: auctioning energy sector	world:	0.13	-1.4	71.5
	EU-11		DE:	-0.95	-10.7	-26.4
		as scenario EU-1 except for	EU-15:	-0.58	-8.8	-7.2
			NMS-12:	-1.26	-15.2	-30.7
		EU unilateral, 30% reduction	EU-27:	-0.68	-10.0	-12.7
		usage of flexible mechanisms: 50%	USA:	0.09	0.1	46.5
		CO_2 price of ETS: 23 Euro/t	G5:	0.72	-4.3	214.9
			world:	0.20	-2.4	69.8
participation: multilateral	IL	as scenario EU-11 except for	DE:	-0.87	-10.7	-26.3
		participation: all dev. countries excl. USA	EU-15:	-0.55	-8.7	-7.2
		CO_2 price of ETS: 23 Euro/t	NMS-12:	-1.26	-15.2	-30.7
		uniform CO_2 price in developed countries	EU-27:	-0.65	-10.0	-12.7
		commitments of other developed	USA:	0.15	0.2	46.6
		countries as model outcome	G5:	0.82	-5.2	211.6
		usage of flexible mechanisms: 50%	world:	0.11	-4.9	65.4
	USA		DE:	-0.51	-10.4	-26.2
			EU-15:	-0.45	-8.6	-7.1
		as scenario IL except for	NMS-12:	-1.24	-15.0	-30.6
		participation: all developed countries	EU-27:	-0.56	-9.9	-12.6
			USA:	-1.03	-22.6	13.3
			G5:	0.47	-7.9	203.0
			world:	-0.62	-10.7	55.3
	G5-1	as scenario USA except for	DE:	-0.71	-10.6	-26.3
		participation: all developed countries and G5	EU-15:	-0.61	-8.8	-7.2
		CO_2 price of ETS: 23 Euro/t	NMS-12:	-1.61	-15.1	-30.7
		CO_2 tax in G5 (all sectors): 23 Euro/t	EU-27:	-0.75	-10.0	-12.7
		usage of flexible mechanisms: 50%	USA:	-1.02	-22.6	13.3
		application of flexible mechanisms in G5	G5:	-1.92	-20.3	162.2
		is not allowed	world:	-1.69	-16.4	45.4
	G5-2		DE:	-0.59	-10.5	-26.2
		as scenario G5 except for	EU-15:	-0.51	-8.7	-7.2
			NMS-12:	-1.36	-15.1	-30.6
		CO_2 tax in G5 (all sectors): 5,75 Euro/t	EU-27:	-0.63	-9.9	-12.7
			USA:	-1.04	-22.6	13.3
			G5:	-0.54	-8.9	199.6
			world:	-1.05	-12.6	52.1

The effects within the EU27 differ between countries due to differences in carbon intensity, especially in electricity generation (see Figure 1). Effects on economies having an export surplus are above-average. Impacts on the new member states (NMS12) are especially unfavourable due to their high carbon intensity and low energy prices. Emission reductions in these countries are above-average as well. France slightly benefits from a unilateral action of the EU due to low CO_2 emissions in electricity generation, which is mainly based on nuclear power, and its rather low dependence on exports. Economic performance of most non-EU countries improves due to a rise in international competitiveness against the EU compared to the reference scenario. Only those countries as Russia that are major energy suppliers for the EU are negatively affected.

Figure 1: **GDP in 1995 prices in selected countries: percentage deviations of scenario EU-1 against reference scenario in 2020**



Despite of the favourable design of the ETS for energy-intensive industries, those that are especially exposed to international competition might still relocate some of their production. Indirect effects of higher electricity prices, e.g. in aluminium production, are hard to avoid.

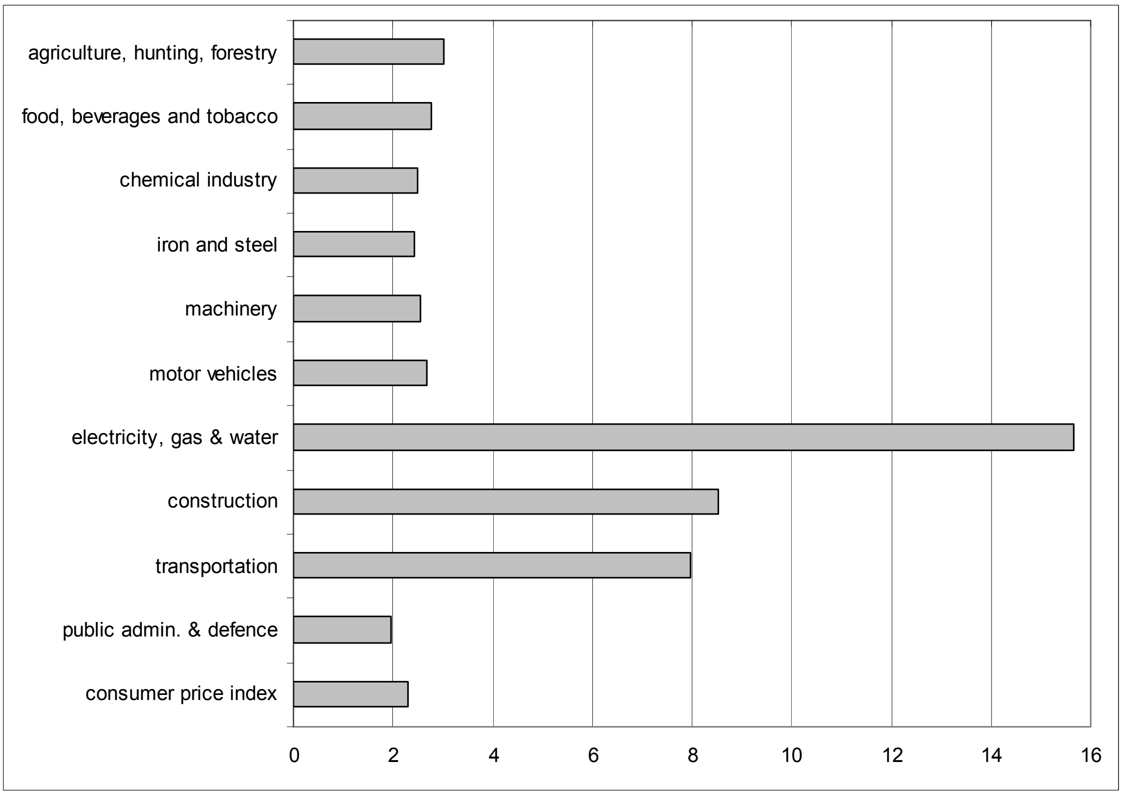
Global CO_2 emissions are reduced by 1.4% (504 Mt CO_2) only compared to the reference scenario. Emissions outside the EU27 rise by 14% (85 Mt CO_2) of the avoided emissions within the EU (589 Mt CO_2) due to relocation effects (carbon leakage) mainly to the U.S. and G5 countries. Given these facts, a unilateral action of the EU is appropriate from a macroeconomic point of view only, if it leads to a participation of additional countries in the international post-Kyoto regime.

The negative impact on GDP in Germany (-0.8% or -22 billion Euro) is slightly above EU average in 2020. Per-capita income reduces by about 275 Euro compared to the reference scenario in 2020. Reasons for this are a rather high export dependency and the above-average CO_2 intensity of electricity generation, which results from the virtually completed phasing out of nuclear energy in 2020. In the case of a unilateral commitment of the EU there is no rise in demand for mitigation technologies outside the EU, which could compensate the decline in exports. Figure 2 gives as an example the sector price effects for Germany: Price increases are highest for electricity, gas and water and in the construction and transport sectors.

Using flexible mechanisms (scenario EU-11) such as CDM, which allows for achieving part of the emission targets in developing countries, could reduce mitigation costs considerably. E.g. if the use of credits from CDM projects is limited to 50%, the EU27 could reduce emission by 30%, for the same costs that it would face for a 20%-reduction in the case of not using these flexible mechanisms. China, India, Brazil and the other developing countries will now reduce their emissions instead of expanding it via carbon leakage, and the positive effects on GDP are for theses countries stronger than in the scenario EU-1.

Further scenarios, not explicitly discussed here, point out that the costs of action for the EU27 can be twice or only half as high for a given reduction target, depending on the allocation method of allowances, recycling of auction revenues and the use of flexible mechanisms. Crucial decisions on these issues will have to be taken during the coming months and years, especially on the EU level. The combination of alternative approaches can reduce or increase mitigation costs to levels outside the range presented above.

Figure 2: **Price effects in Germany: percentage changes of scenario EU-1 against reference scenario in 2020**



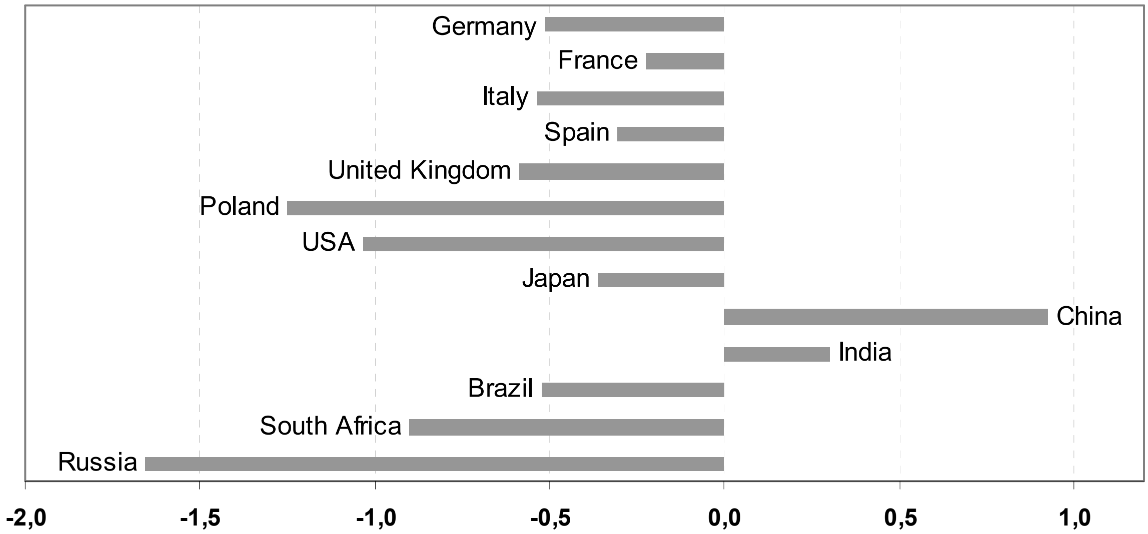
4.3 The economic impacts of international participation in 2020

Let us briefly remember the assumptions: A participation of industrialized countries without the U.S. in scenario IL assumes that there are two international permit markets for the primary industries plus air transport for EU27 and the industrialized countries without the U.S. For all other industries and households a carbon tax of 50 €/t CO_2 in the NMS and of 100 €/t in all other participating countries is assumed. CDM is allowed up to 50 % of the reduction obligations. The participating non-EU countries set a cap on their permit supply, which creates a permit price equal to the EU ETS permit price.

For the scenario IL we expect that the economic and environmental results for EU27 will be very close to that of scenario EU-11, because the only difference now is that industrialized countries outside the EU and without the U.S. join the climate policy of the EU. As Table 2 shows, the results for the EU compared with scenario EU-11 indeed change only marginally. Compared to scenario EU-11, the U.S. (+0.15%) and G5 countries (+0.82 %) profit from this broader basis of the carbon regime.

In scenario USA this country joins the carbon regime under the same conditions as before in IL the other industrialized countries, i.e. as a carbon price taker. Figure 3 shows the effects on GDP in the year 2020: The U.S. looses 1 % of its GDP in 2020, which is more than the European average. The reason is that the same absolute level of the carbon price causes a stronger relative rise in user prices of energy in the U.S. than in Europe, where energy tax rates are higher. For the EU27, the costs of the carbon regime are then reduced to 0.56 % in 2020, since an important competitor has joined the carbon regime and faces the same conditions. It is interesting that the GDP effects for the G5 countries are ambiguous: Rising prices in the U.S. will improve the exports of G5 countries and reduce their imports. On the other side the reduction of GDP in the U.S. will reduce imports and thus diminish exports from G5 countries. Both effects have different strengths for China, India and Brazil. For China the balance is positive, so that we now observe a plus of 1.0 % in 2020 of its GDP. For India and Brazil the negative effect is stronger so that India has now only a plus of 0.4 % of GDP in 2020 and Brazil is even negatively hit (-0.5 %) by the participation of the U.S..

Figure 3: **GDP in 1995 prices in selected countries: percentage deviations of scenario U.S. against reference scenario in 2020**



The complete (scenario G5-1) or the restricted (scenario G5-2) participation of the G5 countries China, India, Brazil, Mexico and South Africa in a post-2012 framework allocates parts of the mitigation costs to these countries. This is reflected in GDP losses compared to the reference scenario and scenario USA. In both scenarios the percentage decrease of GDP in these countries is higher than the one in the industrialized countries. This might serve as a reason for these countries to not fully participate in the post-Kyoto framework right from the start. Energy exporting countries like Russia (-4.9% respective -3.7 %) suffer from that regime. EU27 and especially Germany now face stronger losses in GDP in 2020 than in the scenario USA without the G5 countries. This is once more the outcome of two conflicting effects. Higher prices in the G5 countries reduce Germany's imports and raise its exports and so will improve its GDP. But the losses in GDP of the G5 countries reduce their imports and thus Europe's and Germany's exports.

Germany can reduce its mitigation costs if other developed countries (especially the U.S.) participate. The country has competitive advantages in low emission technologies (Lehr et al. 2008), but thereof resulting effects are limited by the reduction in global trade volumes. CDM activities in developing countries generally lower mitigation costs.

The impacts on global GDP in the simulation runs are in accordance with recent analyses of the IPCC (2008). Depending on the point of view one can bring forward the argument that the (level of) GDP in the participating countries is substantially lower for a given year than in the reference scenario, or that the annual economic growth (growth rate) is affected only marginally. The GDP-losses increase with the level of CO_2 prices and the level of emission reductions.

4.4 Climate change impacts of the scenarios

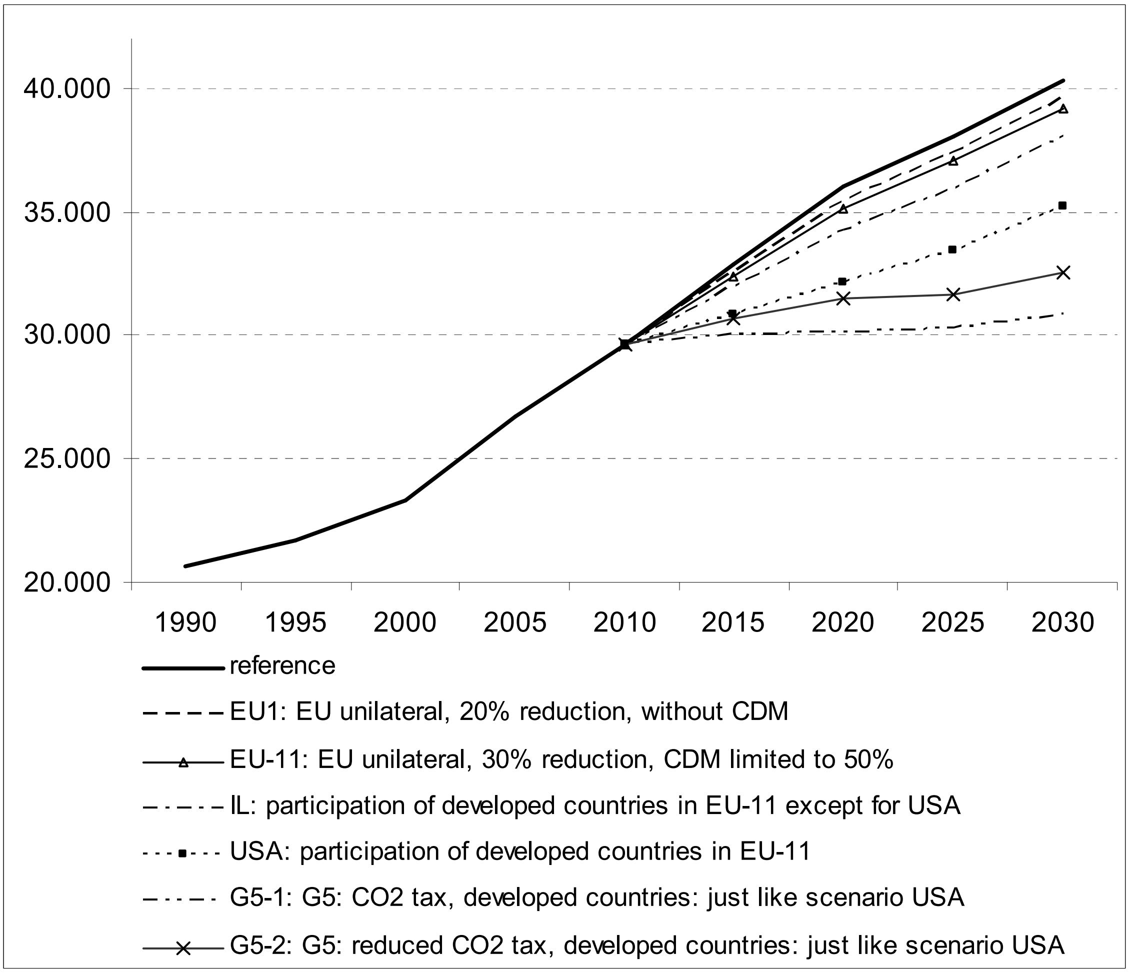
Global emissions will double until 2030 compared to 1990 levels without the existence of a far-reaching post-2012 climate regime (see Figure 4). A unilateral commitment of the EU would only be a "drop in the bucket", which solely strengthens the credibility of the EU in international negotiations to convince other countries of concerted action. A stabilisation of global emissions in 2020 compared to 2010 can only be achieved, if all developed and at least the large emerging (G5) countries participate and if all possible existing market-ready reduction technologies are used. Global emissions will still be 45% higher compared to 1990. Participation would still yield increased CO_2 emissions in the U.S. as well as in the G5 countries compared to 1990.

Additionally assuming a participation of countries not considered in the above analysis and the utilisation of sinks and further low-cost options of reducing non-CO_2 emissions could add up to a peak and reversal of the current trend of global emissions before 2020 without harming global economic growth to a large extend.

The energy-related CO_2 emissions in Germany are about 26% lower (30% for total GHG emissions) than in 1990 in the scenarios with international participation. Additional GHG reductions are financed through emission trading and CDM measures abroad (creditable and actually domestic reductions can differ substantially).

In the period beyond 2020 when new abatement technologies are available, which might also be used in developing countries, the 2°C target, which may require a bisection of global emissions by 2050, might become feasible. Aside from the establishment of a global carbon market, extensive technological developments until 2020 are therefore necessary. Actions to promote the deployment and diffusion of (new) technologies should be co-ordinated internationally.

Figure 4: Global energy-related CO_2 emissions in alternative scenarios, in Mt CO_2



5. Conclusions

Following Olmsted and Stavins (2006) we proposed a post-Kyoto carbon regime which is “scientifically sound, economically rational and politically pragmatic”: All industrialized countries and the major developing countries participate in our scenarios G5-1 and G5-2. Economic rationality is given since the scenarios establish a common CO_2 trading system for the primary industries and a common tax rate for the other industries and households in all industrialized countries. The scenarios are politically pragmatic for three reasons: First, there is a broad participation. Secondly, there is no reduction target for the industrialized countries outside the EU, and thirdly because the CO_2 tax rate for developing countries is only a small fraction of the tax rate in industrialized countries.

The G5 scenarios will in a medium term perspective allow decoupling economic growth and CO_2 emissions and reach a stabilization of CO_2 emissions on today’s levels until 2020. This would be in line with an emission path, which, in the long run, could meet the 2°C target. The scenarios are also consistent to ongoing discussions in the U.S about ceilings for carbon prices (EIA 2008). After 2020 a new regime with more ambitious targets could be introduced or already foreseen in a post-2012 agreement. The introduction of a still moderate, but almost global carbon price after 2013 will induce technical progress until 2020: The prerequisite for drastic emission cuts without harming economic growth.

The simulation results for scenario G5-2 show that the losses in GDP in 2020 are relatively low and quite equally distributed among different countries and regions. The highest costs will occur for the exporters of fossil fuels like Russia and the OPEC countries. They may react with rising fuel prices, which would induce a further reduction of emissions but also raise costs for the importing countries (Person et al. 2007). The developing countries may not be willing to accept any costs stemming from a climate regime due to low current and especially historic per capita emissions. On the other hand, they may accept the relative low costs to take part in the development and distribution of low carbon technologies.

Acknowledgment

The paper is based on a study for the German Ministry of Economy and Technology. We gratefully acknowledge financial support.

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