Do border measures affect carbon leakage?

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This paper is based on a study which was carried out at the request of the Directorate General for Trade of the European Commission.

Abstract

In this paper we quantify the effects of the pledged commitments that have been made after the Copenhagen Climate Change Conference in December 2009 making use of the CGE-model WorldScan. We analyze the impacts of climate policy variants up to the year 2020, in particular on economic welfare and carbon leakage. We consider two main policy cases: ambitious and modest pledges.

In the first case Annex I countries ambitiously adopt relatively low caps on GHG-emissions and allow free permit trade amongst each other. In this scenario China and India impose relative targets for CO_2 emission-intensities of 45% and 25% below 2005 intensities. In the second case Annex I countries impose modest emission ceilings without permit trade and without the use of CDM. In this scenario China and India impose more modest relative targets too. Only in the EU permit trade occurs, separately within the Emissions Trading Scheme (ETS) and within the sectors outside ETS.

In addition, we consider various variants for the case of modest pledges. The most important of these are: allowing Annex I countries to use CDM up to one third of the reduction effort and allowing industrialized countries to apply border measures (BM) for the ETS-sectors. In the BM case we assume that Annex I countries simultaneously adopt carbon import levies and carbon export refunds on all trade with non-Annex I. The level of these border measures is based upon the average prevailing direct and indirect carbon costs in domestic production of the ETS-sectors.

In all policy cases carbon leakage is considerable. Production leakage in absolute terms is rather modest though. Our simulations suggest that border measures are rather ineffective in reducing leakage. With additional simulations we show that the fossil fuel price channel is the most important cause of carbon leakage. Because border measures do not address this channel, they hardly affect carbon leakage.

Contents

1 Introduction

Climate change and trade interact in various different ways. At present, the main interaction is between climate change policy and trade, the effect of climate change itself on trade to date is limited. A major concern is the adverse impact which climate policies might have on the competitiveness of countries which implement more ambitious climate policies compared to other countries. Differences in climate change policies will not only have an impact on trade; it can also increase emissions in regions with no or less ambitious climate change policies, the so-called carbon leakage.

In this paper, we assess the competitive effects and leakage for different policy scenarios including border measures and CDM with WorldScan, a multi-sector, multi-region, global general equilibrium model. We build upon earlier work (Wobst et al., 2007; Manders and Veenendaal, 2008; Hayden, Veenendaal and Zarnić, 2010; Boeters and Koornneef, 2010). The version of WorldScan used for this study, which is being developed together with the Netherlands Environmental Assessment Agency PBL, includes other greenhouse gases next to CO_2 and renewable energy in more detail than previous versions. Furthermore, the most recent GTAP-data (Badri et al. 2008) have been used to calibrate the model. We find that the growth of energy intensive production and trade in non-Annex I have significantly raised the assessments by modelling teams of the rates of production and carbon leakage that go with unilateral climate change policies in Annex I. Yet, our assessments for various policy cases indicate that EU production leakage in 2020 for the energy intensive sector will remain relatively modest in absolute terms. We find that border measures are rather ineffective in reducing leakage rates. The fossil fuel price channel appears to be the dominant channel that causes leakage and border measures do not address this channel.

In section 2 we briefly discuss the various forms that border measures can take and the impact assessments available from the literature. We present simulations with the WorldScan model of policy scenarios including border measures and CDM in section 3. Section 4 concludes.

2 Border measures

2.1 Design of border measures (BM)

The impacts on competitiveness and leakage due to unilateral climate policy may be reduced by introducing border measures which reduce trade distortions caused by carbon pricing. There are several types of border measures.

One distinction is between border measures for imports and for exports. Border measures on imports protect industries on their domestic market through an increase in the costs of importers. These cost increases can be realised by means of border taxes, mandatory allowance purchase by importers or embedded carbon standards (Wooders 2009). Taxes and mandatory allowance purchase both raise costs directly by charging importers to pay for the carbon embodied in their imports. Carbon standards raise costs indirectly by requiring that products meet specific standards, otherwise they will not be allowed on the market. On export markets, domestic industry can be supported through rebates, which recompense them for the carbon costs incurred on their exports.

Full border adjustments, combining charges and border rebates, protect domestic firms on both import and export markets and, when applied to all embodied carbon content of imports and exports, eliminate loss of competitiveness and both operational and investment carbon leakage which arise as a result of carbon price differentials. However, carbon leakage caused by reduced fossil fuel prices will not be completely eliminated. One the one hand, fossil fuel prices will fall less because export rebates will increase demand for fossil energy for export production, on the other hand import tariffs will reduce demand from producers from countries without climate change policies.

Full border adjustment on all embodied carbon of both final and intermediate products will not be feasible in practice. It would necessitate the calculation of all carbon emitted in the production chain up till the point where a product is imported, for all products imported. Moreover, the specific production processes in the country of origin would have to be known as well, because there can be considerable differences in emissions depending on the process used. For example, steel made with sustainable produced charcoal has no net emissions, while steel from recycled scrap metal uses considerably less energy than primary steel production with BOF furnaces.

Therefore a balance has to be struck between comprehensiveness of border measures and administrative costs. There are several options to limit the detail and coverage of border measures and at the same time reduce the competitiveness impact for the major sectors affected by climate change policies. A first option is to limit BM to those sectors for whom carbon leakage and trade impacts are expected to be a severe problem. The main markets to which border measures might be applied are steel, cement, aluminium and fertilizer (see also Monjon and Quirion 2010).

The way the emissions are calculated for imported or exported products on which the import tax or export rebate are based can also be simplified. Instead of using actual emissions, Godard (2007) and Ismer and Neuhoff (2004) have suggested to use the Best Available Technology (BAT), the technology which emits least to produce a specific product such as, for example, aluminium ingots. In some cases, the BAT might emit zero emissions, such as the production of aluminium with hydro power. The BAT would therefore have to be adjusted, for example through the requirement that the technology has a certain minimum market share, otherwise a BM based on the BAT would not be effective. The product-specific benchmarks which are currently being developed by the EC for the allocation of free allowances to those sectors that are deemed to be at a significant risk of carbon leakage might be used as the BAT on which the BM could be based.

The EU benchmarks do not necessarily reflect the actual emissions of imported products. These emission might either be higher or lower than the calculated benchmark. In the first case, imported goods will have a cost advantage compared to the benchmark level of EU firms. In practice, this cost advantage will probably be limited. Demailly and Quirion (2008) show for the cement industry that the difference in carbon leakage between BM based on BAT and BM based on their actual emissions is minimal.

In the latter case, foreign firms with lower emissions than the benchmark suffer a cost disadvantage because the import BM is based on a higher emission rate. An option is to allow firms to provide evidence that their emissions are below the benchmark and subsequently to use these actual emissions as a basis for applying the BM. This will moreover provide an incentive for foreign firms to reduce their emissions. However, it might be quite cumbersome from an administrative point of view and be subject to fraud because it will be difficult to verify the emission data provided by foreign firms.

In the case of a rebate on exports, either the EU benchmark might be used or the actual emissions, based on emission data which have to be supplied for the ETS. This does raise the problem of assigning emissions to specific products, which might be infeasible in the case of complex production processes in which different goods are produced at the same time. This option is therefore only available when emission can straightforwardly be allocated to specific products. In that case, it is preferable to use the actual emissions if these are lower than the benchmark. Otherwise, these firms would receive more allowances than needed and export would be subsidised.

While it appears to be feasible to set the direct emissions for a number of products on which BM can be based, this poses considerably more problems for embodied emissions in downstream products. The question is whether it is necessary to apply border measures also to embodied emissions or not in order to limit the negative impact of climate change policy on competitiveness and to limit carbon leakage. This will depend on the effect on the costs of finished products of embodied emissions. Monjon and Quirion (2010) report that steel and aluminium related emissions in a 1 ton car is about 1.6 ton of CO_2. For a CO_2 price of €30, this would amount to a production cost increase of a car of €48, which is negligible on the total costs of car production. However, this might be different for intermediate products such as steel or aluminium semi manufactured goods such as, for example, car bodies.

The administrative costs of BA depend directly on the number of goods to which BM are applied and whether both imports and exports are included. Furthermore, using emission data from the exporting countries considerably increases the administrative burden compared with the use of domestic emissions.

If BM are applied to countries which do not take on climate change policies, they should be applied by all countries which take part in a climate change agreement. Otherwise, BM can lead to strategic behaviour which reduces their effectiveness. Trade in energy-intensive goods to which BM are applied could be shifted to countries with climate policies but without BM. For example, assume that both Japan and the EU take part in a climate change agreement, with the EU introducing BM but Japan not. Steel exports from China will than be redirected from the EU to Japan (Cosbey 2008 and Houser 2008). The EU would import more steel from Japan, because BM would not apply. Consequently, BM will be less effective and emissions will be reduced less. An alternative is to apply BM to all other countries, including those who have introduced climate policies as well. However, this would impose carbon costs on imports from participating countries while they also have to pay carbon costs in their own country (unless they receive a rebate on their exports).

BM will raise costs for firms exporting from countries without climate policies. These countries can choose between accepting the BM or introducing climate policies of their own such that importing countries do not apply BM any more for their exports. Which option is more attractive will depend on the relative costs of BM versus the policies required to have the BM removed. We will come back to this in section 3 were the effects of BM are discussed with the CGE model WorldScan.

Concluding, BM appear to be feasible at acceptable costs if they are applied to a limited number of products and if use is made of either observed domestic emissions or the EU benchmarks which are being developed for the allowance allocation in the third phase of the ETS. In order to be effective, they have to be applied by all countries which take on climate policies; otherwise exporting countries can redirect their exports to those countries without BM.

2.2 Economic and trade effects of BM

The welfare effects of BM depend on the various effects outlined above. Using a partial equilibrium approach, Gros (2009) shows that a carbon tariff on imports will improve global welfare because it introduces carbon pricing in countries without climate policies. Due to the import tariff on carbon, worldwide emissions will be lower, which increases global welfare. This increase is larger than the decrease caused by consumer and producer loss as a result of the tariff, which reduces consumption of energy intensive goods.

In recent studies on the economic and trade effects of BM which use CGE-models, the focus is on the welfare effects for on the one hand countries with climate change policies which introduce BM and on the other hand countries without climate policies. The welfare effect of lower worldwide emissions is not included in these studies.

Burniaux et al. (2010) have studied the effects of BM with the use of the ENV-Linkages model for two scenarios. In the first scenario, the EU alone cuts its emissions with 20% in 2020 and 50% in 2050, compared to 2005 emissions. In the second scenario, all Annex-I countries reduce their emissions with the same amounts. As is to be expected, carbon leakage is larger in the EU scenario, 6.5 percent of EU emission reductions in 2020, than in the Annex-I scenario, 4.5 percent of the emission reduction in Annex-I countries.

Burniaux et al. (2010) model various variants for border measures. BM apply either to imports or to both imports and exports. They are based on the carbon content of the imported products (the actual emissions realised by the production) or on domestic product carbon content, which is closer to the benchmark approach for determining the carbon content on which the BM is based. BM are based on only the direct carbon content of products, leaving out the carbon content of the inputs used to produce these goods. Alternatively, the carbon in the electricity inputs used to produce the imported goods is counted as well.

The main result for all types of BM is that they can be effective in addressing carbon leakage in the EU scenario but are less effective in the Annex-I scenario. In the EU scenario, leakage occurs more through competitiveness loss, while in the Annex-I scenario the fossil fuel price channel is more important. As has been discussed above, BM do not address this last leakage channel, therefore the effect on leakage in the Annex-I scenario is limited.

Using domestic emissions instead of the emissions from exporting firms to determine BM leads leaves leakage at a higher rate for the EU scenario, about 25% higher relative to the case with BM on the basis of foreign emissions. The reason for this is the lower carbon content of European goods and therefore lower border tax levels for imports.

Another difference is between using only direct emissions or including indirect emissions from electricity inputs used to produce the final goods as well. The latter case is more effective, halving leakage in the Annex-I scenario compared to BTA based on direct emissions only.

The welfare effect of introducing BM (measured as the equivalent variation in income) are small (in the range of 0.1 percent higher welfare relative to the baseline compared with

scenarios without BM) but positive for the implementing countries, which are offset by comparable welfare losses in the rest of the world. The net effect on global welfare is therefore limited, however this does not include the welfare increase due to the lower emissions.
There is hardly any effect of BM on the output of energy intensive sectors, the effect is even negative in the longer run (2030) in both scenarios. One reason for this is that import measures increase the costs of energy-intensive inputs which are imported, such as steel or aluminium ingots. This has a negative effect on the production costs and therefore on demand, which offsets the gain in market share because of reduced competition from foreign firms. Moreover, the effect of the increase in carbon price on demand for energy-intensive products is more important than the loss of competitiveness with respect to foreign firms who do not have to bear carbon costs.
Winchester et al. (2010) use the EPPA-model to study BM in a scenario where Annex-I countries (except FSU) reduce their emissions in 2025 with cap-and-trade emission trading with 18 to 35 percent relative to 2000. The BM in their study is a tariff on imported goods, based on the embodied emissions. This tariff either applies to all sectors or to manufacturing (which includes both energy-intensive and other industry sectors) and is introduced in the US alone or in all Annex-I countries minus FSU (termed the coalition). In terms of comparability with other studies, the variant with import tariffs in all coalition countries is the most relevant. BM have a small positive effect on welfare for the coalition countries, which falls 0.1 percent less relative to the baseline compared with the scenario without BM. Welfare loss in non-coalition countries is larger, 0.5 percent relative to the baseline compared with the case without BM. Global welfare decreases with the introduction of BM. Leakage is reduced by the import tariff on industrial imports with about 60% compared to scenario without BM. This is also reflected in the change in industry output with the introduction of the import tariff, which increases with about 1 percent relative to the cap-and-trade scenario in the energy-intensive sectors and with more than 0.5 percent for the other industrial sectors. In order to estimate the relative importance of carbon leakage through loss of competitiveness versus the fossil fuel price channel, Winchester et al. (2010) estimate leakage with a variant in which crude oil prices are set at the level in the baseline scenario through a global oil tax. This reduces leakage as much as the import tariff, with about 60% compared to the cap-and-trade scenario. Consequently, in their study oil price controls are as effective in tackling leakage as import tariffs.
Manders and Veenendaal (2008) consider BM in the CGE-model WorldScan against the background of a scenario in which the EU is the only region with a strong climate change policy while other Annex-I parties only have limited policies (around 2 percent reduction compared to the baseline) and non-Annex I no policies. EU emissions are reduced with 14 percent compared to 2005 levels. Economic welfare in the EU reduced by 7 percent in 2020 compared to the baseline. Output in the ETS sectors in the EU declines with 4.5 percent relative to the baseline and carbon leakage is 3.3 percent. Two forms of BM are modeled, a levy on imports and a refund on exports, both for the ETS sectors. The levy is based on the embodied

carbon content of domestic production, the refund on exports gives a full refund of the carbon price. The import levy has a small positive effect on welfare, which improves by 0.03 percent relative to the case without BM. The refund reduces welfare slightly (with 0.05 percent), caused by the revenue which is spent on the refund. The import levy reduces leakage with 1.4 percent relative to the baseline, the refund with 1.3 percent. Together, these BM limit leakage to 0.5 percent. Manders and Veenendaal (2008 also consider a policy scenario in which CDM is available to the ETS sectors, up to a limit of one third of the yearly reduction effort needed to meet the target. CDM considerably reduces the permit price, from 52 €/ton CO_2 in the scenario without CDM to 27 €/ton CO_2 if CDM is allowed. The effect on welfare is small, from -0.72 without CDM to -0.70 with CDM. Carbon leakage is reduced with 3 percent relative to the baseline, from 3.3 to 0.3 percent when CDM is allowed. CDM also reduces competitiveness loss considerably; compared with the scenario without CDM, employment in the ETS-sectors falls with 2 percent (relative to the baseline) from -3.2 till -1.2 percent. CDM considerably reduces the impact of stand-alone climate change policy within the EU, which reduces the need for BM to combat competitiveness loss and carbon leakage.

The study by Fischer and Fox (2009) is the only study which compares the effects on competitiveness and leakage of BM with different allocation methods. They use a partial equilibrium model which is parameterized with the outcomes of a simulation with the CGE GTAP-EG model in which only the US introduces a $50/ton emission price on CO_2. Leakage rates range from 11 percent for the paper, pulp and printing sector to 64 percent for the refined petroleum products. With the exception of oil products, leakage in the energy-intensive sectors is more due to oil price changes worldwide (the oil price channel of carbon leakage) than because of changes in product prices, which result in leakage rates ranging from 2 till 14 percent for different energy-intensive sectors, or about 20-40 percent of total leakage per sector. Fischer and Fox (2009) compare import taxes, export rebates and output-based allocation. The latter is the most effective in reducing production losses, which are reduced with 40-60 percent for energy-intensive sectors with the exception of oil products compared with the scenario without compensating measures. Both import taxes and export rebates reduce production losses for these sectors roughly with 10-20 percent. The effectiveness of all measures in reducing carbon leakage for these sectors is limited; they achieve a net additional emission reduction of at most 5 percent compared to the scenario without any measures.

The modelling studies discussed yield several insights on competitiveness, leakage and measures to mitigate adverse effects of partial climate change policies. Obviously, the degree of loss of competitiveness and leakage depends on the stringency of policies and the size of the coalition. For the range of policies assumed in the CGE-modelling studies, carbon leakage is between 3 and 11 percent. Leakage declines when the size of the coalition which introduces climate change policies increases.

Import BM will reduce leakage with 30-60 percent. The effect is larger if indirect embodied emissions are included and when the actual carbon content is used instead of a calculated content based on domestic embodied emissions. However, in practice this will be difficult to implement. The effect of import BM on the competitiveness of energy-intensive industry is less clear, with some studies showing a small or no effect at all. This is also reflected in the effect of import tariffs on welfare in the implementing countries, which is also limited. Introducing export rebates can further reduce leakage, the effect on energy-intensive output and welfare is also small.

In the CGE-modelling study (Fischer and Fox 2004), output-based allocation is both successful in reducing leakage and competitiveness loss, moreover welfare is also increased compared with grandfathering allowances. However, in the partial equilibrium study of Fischer and Fox (2009), output-based allocation is considerably more effective in minimising the loss of competitiveness of energy-intensive sectors, while it is not effective in reducing leakage.

Another option is to allow firms to use CDM credits to meet their obligation. This can significantly reduce the impact of stand-alone climate policies on leakage and competitiveness and thereby reduce the need for complementary BM. Some form of domestic climate policy in CDM host countries which requires firms or sectors to reduce emissions to some extent before the can sell CDM credits can further improve the effect of CDM on leakage and competitiveness.

In the next section we present assessments made with WorldScan of the macroeconomic consequences and impact of climate policies, BM and CDM on trade and leakage.

3 WorldScan scenarios

WorldScan

The macroeconomic consequences of specific climate policy scenarios are assessed using the global applied general equilibrium model WorldScan (see Bollen, Manders and Mulder, 2004; Lejour *et al*., 2006; Wobst *et al*., 2007; Manders and Veenendaal, 2008; Hayden, Veenendaal and Zarnić, 2010; Boeters and Koornneef, 2010). WorldScan data for the base year 2004 are to a large extent taken from the GTAP-7 database (Narayana and Walmsley, 2008) that provides integrated data on bilateral trade flows and input-output accounts for 57 sectors and 113 countries and regions. The WorldScan version used in this study includes the detailed electricity technology specification developed by Boeters and Koornneef (2010) and the conventional

Table 3.1 Overview of regions, sectors and technologies and production inputs in WorldScan

Regions[a)]	*Sectors*[b)]	*Inputs*
Germany	Cereals (Wheat and Cereal Grains NEC)	*Factors*
France	Oilseeds	Low-skilled labour
United Kingdom	Sugar Crops (Sugar Cane, Sugar Beet)	High-skilled labour
Italy	Other Agriculture	Capital
Spain	Minerals NEC	Land
Netherlands	Oil	Natural resources
Other EU15	Coal	
Poland	Petroleum Coal Products	*Non-electricity energy carriers*
Rest of EU-27	Natural Gas (incl. gas distribution)	Coal
Norway	**Electricity**	Petroleum, coal products
Switzerland	**Energy Intensive Manufacturing**	Natural gas
Russia	Vegetable Oils and Fats	Modern biomass
Ukraine	Consumer Food Products	Biodiesel
USA	Other Consumer Goods	Ethanol
Canada	Capital Goods and Durables	
Japan	Road and Rail Transport	*Other intermediates*
Australia	Other Transport (water and air)	Cereals (Wheat & Cereal Grains)
New Zealand	Other Services	Oilseeds
Brazil		Sugar Crops (Sugar Cane&Beet)
Middle East and North Africa	*Electricity Technologies*	Other Agriculture
China (incl. Hong Kong)	Conventional fossil (without CCS)	Minerals NEC
India	Fossil with CCS	Oil
Rest of the World	Nuclear	Electricity
	Wind	Energy Intensive Manufacturing
	Biomass	Vegetable Oils and Fats
	Hydropower	Consumer Food Products
		Other Consumer Goods
	Conventional biofuel technologies	Capital Goods and Durables
	Ethanol	Road and Rail Transport
	from sugar beet	Other Transport (water and air)
	from sugar cane	Other Services
	from wheat	
	from corn	
	Biodiesel	

a) Non-Annex I regions are denoted in italics

b) ETS-sectors are denoted in bold

biofuel technologies developed by Wobst *et al.* (2007). The model distinguishes 18 sectors. The ETS consists of two sectors (electricity and energy intensive manufacturing) while the other sectors and household activities belong to non-ETS. Factor markets for high- and low-skilled labour, capital, land and natural resources are distinguished in each of the selected 23 countries and regions (Table 3.1). Six non-electricity energy carries are distinguished: coal, petroleum and coal products, natural gas, modern biomass, biodiesel and ethanol. Combustion of the first three of these contributes to the CO_2-emissions simulated by the model. The model also covers emissions of methane and nitrous oxide, from the combustion of energy, industrial processes and agricultural activities (such as rice cultivation, livestock production and fertilizer use). The model can also deploy end-of-pipe methods to reduce GHG-emissions.[1]

3.1 Policy cases

Using WorldScan we assess the impacts of five policy variants up to the year 2020, in particular on economic welfare and carbon leakage.

We first show the impacts of AMBITIOUS PLEDGES which is a scenario in which Annex I countries ambitiously adopt relatively low caps on GHG-emissions and allow free permit trade amongst each other. In this scenario China and India impose relative targets for CO_2 emission-intensities of 45% and 25% below 2005 intensities. The EU imposes a targeted 20% share of renewable energy in final energy use.

In a second case, PLEDGES, we implement the more modest pledges that were made by the countries up to the Copenhagen Climate Change Conference in December 2009. PLEDGES describes a climate policy in which Annex I countries impose modest emission ceilings without permit trade and without the use of CDM. In this scenario China and India impose relative targets for CO_2 emission-intensities of 40% and 20% below 2005 intensities. Only in the EU permit trade occurs, separately within the ETS and the non-ETS. Again, the EU imposes a targeted 20% share of renewable energy in final energy use.

In the third variant, PLEDGES WITH CDM, the assumptions are the same as in PLEDGES, but in addition the Annex I countries are allowed to use CDM up to 1/3 of the reduction effort.[2] CDM supplies may originate from all production sectors of non-Annex I countries.

In the fourth scenario, PLEDGES WITH BM, the assumptions are the same as in PLEDGES, but now the industrialized countries apply border measures for the ETS-sectors. They

[1] Emission profiles consistent with the World Energy Outlook (2009) and the costs of end-of-pipe adjustments and abatement potentials are taken from the GAINS model (http://gains.iiasa.ac.at). With 'end-of-pipe' methods already formed contaminants are removed from a stream of air. They are called 'end-of-pipe' as they are normally implemented as a last stage of a process before the stream is disposed of or delivered. Examples are the adoption of farm technologies that prevent inefficient fertilizer use and a higher frequency of leakage controls in gas distribution networks.

[2] This assumption is derived from the '20 20 in 2020' proposal of the European Commission in which the use that can be made of carbon credits from CDM is limited. We have adopted these constraints for the EU and assumed that for ETS-sectors at most one third of the yearly reduction efforts (baseline minus target) may be covered by CDM-credits, while the yearly CDM-ceiling for non-ETS is 3% of 2005 emissions. For other Annex I countries the constraint for the ETS-sectors is applied (one third of the total reduction effort).

simultaneously adopt carbon levies on imports and carbon refunds on exports. The level of these border measures is based upon the average prevailing direct and indirect carbon costs in domestic production of the ETS-sectors.

In the fifth case, PLEDGES WITH FA, we follow the assumptions of PLEDGES, but in stead of assuming that all permits are auctioned, we take into account free permit allocation to energy-intensive manufacturing in the EU. The main subsidy effect of free allocation results from the free allocation to entrants. Hence, in this policy case we lower production costs by providing a subsidy to EU energy-intensive manufacturing that equals the value of the allowances that are available to new firms. The entrant reserve is 5% of total allowances available in the period 2013-2020.

3.2 Baseline

The effects of climate policy depend strongly on the underlying baseline. Our policy scenarios are based on the baseline of the 2009 World Energy Outlook (WEO, IEA, 2009). With our baseline we deviate from the WEO-baseline in one respect however. We remove the ETS-caps from the WEO in order to establish a level playing field for our assessments of the mitigation pledges in an international context.

According to our baseline, global population will continue to expand. Combined with worldwide economic growth of 2.7% per year global demand for energy will be almost 30% higher in 2020 than in 2004. This expansion predominantly takes place in non-Annex I, thus partially reducing the gap in energy consumption per capita with the industrialized countries. Table 3.1 gives some key characteristics of the baseline for the 2004-2020 period. The table indicates that in the baseline energy- and GHG-intensities are declining worldwide and especially in non-Annex I. In principle our baseline follows the fossil fuel price projections of the 2009 World Energy Outlook. Thus the oil price will reach 100 US$ per barrel in 2020. In Europe the gas price is expected to lag behind the oil price. Regional coal prices are expected to remain constant at their 2009 level.

Basically, the main difference between the WEO-baseline and our baseline is increased energy consumption in the EU (due to the lifting of ETS-caps) and reduced energy consumption elsewhere (due to somewhat higher fossil fuel prices) resulting in slightly increasing emissions in the EU over the period 2004-2020 and slightly decreasing emissions in Japan and the USA. Table A.1 in the Annex provides the differences in characteristics of both baselines.

Table 3.2 Characteristics of baseline scenario, average annual growth (%), 2004-2020

	Population	GDP volume	Energy consumption a)	GHG emissions	Energy intensity	GHG intensity b)
Annex I	0.3	1.8	0.0	0.1	-1.8	-0.0
EU-27	0.3	1.5	0.6	0.5	-1.0	-0.1
Germany	-0.1	1.1	0.0	0.2	-1.1	0.0
France	0.5	1.3	0.5	0.3	-0.8	-0.2
United Kingdom	0.5	1.6	0.0	0.1	-1.6	0.0
Italy	0.3	0.9	1.7	1.3	0.8	-0.3
Spain	1.1	2.4	1.1	0.9	-1.3	-0.1
Netherlands	0.2	1.3	-0.4	-0.3	-1.8	0.1
Other EU15	0.4	1.8	0.8	0.8	-0.9	-0.1
Poland	-0.1	3.2	0.7	0.7	-2.5	-0.3
Rest of EU-27	-0.3	3.3	0.7	0.6	-2.7	-0.2
Norway	0.5	1.3	-1.0	-0.7	-2.3	0.2
Switzerland	0.2	1.2	-0.8	-0.8	-2.1	0.1
Russia	-0.5	4.4	0.6	0.9	-3.7	0.2
Ukraine	-0.5	4.3	-0.6	-0.2	-4.9	0.3
USA	0.9	2.1	-0.5	-0.4	-2.6	0.0
Canada	0.9	2.0	0.4	0.2	-1.7	-0.2
Japan	-0.2	1.1	-1.2	-1.0	-2.3	0.1
Australia	1.0	2.1	1.1	0.8	-0.9	-0.4
New Zealand	1.1	2.0	0.6	0.2	-1.4	-0.5
Non-Annex I	1.3	5.4	3.2	3.0	-2.2	-2.9
Brazil	1.0	3.3	2.5	2.5	-0.8	0.0
Middle East and North Africa	1.8	3.7	1.1	1.3	-2.6	0.1
China (incl. Hong Kong)	0.7	8.2	4.4	3.3	-3.7	-1.1
India	1.3	7.1	4.6	3.2	-2.5	-1.4
Rest of the World	1.5	4.5	2.5	2.6	-1.9	0.1
World	1.1	2.7	1.6	-1.6	-1.1	-1.7

a) Total of coal, refinery products, natural gas, biofuels, commercial biomass and renewable energy

b) GHG-intensity represents the ratio of GHG-emissions and energy consumption

Source: WorldScan

3.3 Simulation outcomes

Against the background of our baseline the outcomes of the AMBITIOUS PLEDGES policy scenario indicate modest costs and modest benefits at the global level. At the expense of 0.2% of global economic welfare a decrease in global emissions of 4% is reached in 2020 against the baseline (Table 3.3). On average economic welfare decreases by 0.3% in Annex I and by 0.1% in non-Annex I. Permit trade within Annex I occurs against a permit price of 9 euro/tCO_2-eq. and due to permit trade emissions in individual countries of Annex I may differ from the emission targets in 2020. The table shows that permits are bought from Eastern Europe, Russia and Ukraine. The carbon leakage rate in this scenario amounts to 16%. This leakage rate is defined as the increase of GHG-emissions in non-Annex I countries as a percentage of the

Table 3.3 **AMBITIOUS PLEDGES, 2020**

	Percentage GHG reduction			Emission price	Economic welfare [a)]
	Target (*or 2020 emissions*) compared to 2005 emissions	Target compared to baseline emissions 2020	Emissions 2020 compared to baseline emissions 2020		
	(%)	(%)	(%)	€ / tCO_2	(%)
Annex I	-13	-14	-14	9	-0.3
EU-27	-19	-29	-15	9	-0.5
Germany	-28	-35	-12	9	-0.4
France	-26	-32	-10	9	-0.2
United Kingdom	-30	-34	-18	9	-0.5
Italy	-26	-44	-11	9	-0.3
Spain	-23	-39	-12	9	-0.3
Netherlands	-30	-30	-18	9	-0.9
Other EU-15	-24	-35	-25	9	-0.7
Poland	20	3	-14	9	-0.6
Rest of EU-27	13	-3	-18	9	-0.8
Norway	-44	-37	-4	9	-1.2
Switzerland	-31	-22	-3	9	-0.1
Russia	18	3	-16	9	-1.1
Ukraine	77	83	-11	9	3.9
USA	-17	-12	-12	9	-0.2
Canada	-17	-19	-15	9	-0.5
Japan	-30	-18	-13	9	-0.2
Australia	-29	-37	-17	9	-0.8
New Zealand	-36	-38	-11	9	-0.5
Non-Annex I	*59*	-	2	-	-0.1
Brazil	*50*	-	3	-	0.0
Middle East and North Africa	*24*	-	2	-	-0.6
China (incl. Hong Kong)	*70*	-	1	-	0.0
India	*64*	-	2	-	0.2
Rest of the World	*53*	-	3	-	-0.1
World	*22*	-	-5	-	-0.2

a) Equivalent variation as % of national income of the baseline

Source: WorldScan

Table 3.4 **PLEDGES, 2020**

	Percentage GHG reduction			Emission price[a)]	Economic welfare [b)]
	Target (*or 2020 emissions*) compared to 2005 emissions	Target compared to baseline emissions 2020	Emissions 2020 compared to baseline emissions 2020		
	(%)	(%)	(%)	€ / tCO_2	(%)
Annex I	-7	-7	-13	-	-0.3
EU-27	-9	-21	-21	31	-0.5
Germany	-15	-22	-16	11	-0.3
France	-15	-22	-19	11	-0.4
United Kingdom	-17	-21	-21	11	-0.4
Italy	-14	-34	-18	11	-0.4
Spain	-10	-29	-20	11	-0.4
Netherlands	-17	-17	-17	11	-0.7
Other EU-15	-14	-27	-29	11	-0.7
Poland	15	-1	-22	11	-0.6
Rest of EU-27	10	-5	-25	11	-0.6
Norway	-35	-27	-27	115	-1.4
Switzerland	-21	-10	-10	39	-0.2
Russia	33	17	4	-	-1.3
Ukraine	77	83	5	-	0.3
USA	-17	-12	-12	12	-0.1
Canada	-17	-19	-19	14	-0.5
Japan	-30	-18	-18	14	-0.2
Australia	-10	-20	-20	13	-0.7
New Zealand	-28	-30	-30	51	-0.5
Non-Annex I	*62*	-	3	-	0.0
Brazil	*53*	-	6	-	0.1
Middle East and North Africa	*26*	-	4	-	-0.5
China (incl. Hong Kong)	*72*	-	2	-	0.1
India	*66*	-	4	-	0.3
Rest of the World	*57*	-	6	-	0.0
World	*26*	-	-3	-	-0.2

a) For EU-27 ETS-price, for member states non-ETS-price, for other Annex-I countries national carbon tax

b) Equivalent variation as % of national income of the baseline

Source: WorldScan

emissions reduction in Annex I countries. This means that 16% of the emission reduction in Annex I is compensated by increasing GHG-emissions in non-Annex I. Overall, Annex I reduces emissions with 13% compared to the baseline at limited economic costs. The relative targets on CO_2-emission intensities in China and India (45% and 25% respectively below 2005 intensities) appear not to be binding in this scenario. [3]

The outcomes of the PLEDGES policy scenario indicate costs and benefits at the global level that are very similar to those of AMBITIOUS PLEDGES. At a cost of 0.2% of global economic welfare global emissions arrive at a level that is 3% below the baseline in 2020. On average economic welfare decreases by 0.3% in Annex I while in non-Annex I economic welfare remains almost unchanged with respect to the baseline. Due to permit trade in ETS and non-ETS 2020 emissions of individual EU member states may differ from their emission targets. The table shows that permits are mainly bought by the largest member states of EU-15 from the new member states and from the smaller countries of EU-15. The carbon leakage rate in PLEDGES amounts to 36% (see also Table 3.8).

This leakage rate is considerably higher than the leakage rates that were found in previous analyses with applied general equilibrium models that were calibrated to the GTAP-6 database with base year 2001. As an example, Manders and Veenendaal (2008) report a carbon leakage rate of 3.3% for a similar scenario and a production leakage rate of 38% for ETS-sectors.[4] Reasons for the higher leakage rates may be that the 2004 GTAP-7 data show for non-Annex I both a higher share in global fossil energy use and a higher share in global trade in energy-intensive products. Thus, both the price channel for carbon leakage and the trade channel may have become more important. On the one hand fossil energy use in non-Annex I is calibrated at a higher base year level. Expansion of energy consumption in non-Annex I due to lower fossil fuel prices thus tends to become more important. On the other hand trade in energy-intensive manufacturing with non-Annex I is also calibrated at a higher base year level which fosters leakage via trade. If the model used in the analysis of Manders and Veenendaal (2008) would have been calibrated to the 2004 base year data, they would have reported a carbon leakage rate of 14% and a production leakage rate of 50%. The carbon leakage rate for PLEDGES is of the same order of magnitude as the rates reported in Böhringer *et al.* (2010) for similar simulations in 2020 with a static CGE-model calibrated to the 2004 GTAP database. Conversely, in a similar policy setting OECD (2009) reports a much lower carbon leakage rate of 0.7% in 2020 using a CGE-model calibrated to the 2001 GTAP dataset.

In PLEDGES we have assumed that the EU 20% renewables target has been met. If we would have dropped this assumption and let the model endogenously determine the optimal level of renewables in the EU the ETS emission prices would rise from 31 to 45 euro per ton CO_2-eq. while non-ETS-prices would be unaffected (Table A.2 in the Annex). The reason is that renewables are mainly replacing emissions from fossil power generation and thus the reduction effort within ETS has to increase if the share of renewables declines. Abandoning the 20% renewables target yields a gain of 0.05% in economic welfare at the EU-level. This 2020 gain is

[3] Table 4.10 below gives an overview for 2020 of the CO_2-intensities of China and India for selected policy cases.

[4] Their scenario IMPASSE assumes 20% emissions reduction in 2020 with respect to 1990 in the EU and imposes also (quite generous) emission caps on the other countries of Annex I. The production leakage rate is defined as the increase in ETS-production outside the EU as a percentage of the decrease of ETS-production in the EU.

relatively small because in the baseline the share of renewables is already quite high (15% in 2020).

Table 3.5 **PLEDGES WITH CDM, 2020**

	Percentage GHG reduction			Emission price[a),b)]	Economic welfare [c)]
	Target (*or 2020 emissions*) compared to 2005 emissions	Target compared to baseline emissions 2020	Emissions 2020 compared to baseline emissions 2020[d)]		
	(%)	(%)	(%)	€ / tCO_2	(%)
Annex I	-7	-7	-5	-	-0.2
EU-27	-9	-21	-13	9	-0.4
Germany	-15	-22	-10	6	-0.3
France	-15	-22	-9	6	-0.2
United Kingdom	-17	-21	-16	6	-0.4
Italy	-14	-34	-9	6	-0.2
Spain	-10	-29	-9	6	-0.2
Netherlands	-17	-17	-17	6	-0.8
Other EU-15	-14	-27	-23	6	-0.6
Poland	15	-1	-9	6	-0.4
Rest of EU-27	10	-5	-17	6	-0.8
Norway	-35	-27	-18	58	-0.8
Switzerland	-21	-10	-6	20	-0.1
Russia	33	17	3	-	-0.9
Ukraine	77	83	4	-	0.2
USA	-17	-12	-8	9	-0.1
Canada	-17	-19	-14	10	-0.3
Japan	-30	-18	-12	10	-0.1
Australia	-10	-20	-14	10	-0.7
New Zealand	-28	-30	-20	31	-0.3
Non-Annex I	*53*	-	-2	6	0.0
Brazil	*46*	-	0	6	0.1
Middle East and North Africa	*25*	-	3	6	-0.3
China (incl. Hong Kong)	*63*	-	-3	6	0.1
India	*54*	-	-4	6	0.2
Rest of the World	*48*	-	0	6	0.0
World	*22*	-	-5	-	-0.2

a) For EU-27 ETS-price, for member states non-ETS price, for other Annex-I countries national carbon tax, for non-Annex I countries CDM-price

b) If emission prices in Annex I exceed the CDM-price this is due to the limit imposed on the allowable use of CDM of one third of the reduction effort.

c) Equivalent variation as % of national income of the baseline

Source: WorldScan

d) The emissions reported here are actual emissions, therefore CDM emission reductions are taken into account in the non-Annex I countries where these emission reductions are realised.

If we allow CDM to be used in Annex I – up to one third of targeted emissions reductions – policy costs diminish and policy benefits increase to some extent at the global level compared to PLEDGES. In PLEDGES WITH CDM a decrease in global emissions of 4% is reached in 2020 at the expense of 0.2% of global economic welfare (Table 3.5). On average economic welfare

Table 3.6 PLEDGES WITH BM, 2020

	Percentage GHG reduction			Emission price [a)]	Economic welfare [b)]
	Target (*or 2020 emissions*) compared to 2005 emissions	Target compared to baseline emissions 2020	Emissions 2020 compared to baseline emissions 2020		
	(%)	(%)	(%)	€ / tCO_2	(%)
Annex I	-7	-7	-13	-	-0.3
EU-27	-9	-21	-21	32	-0.5
Germany	-15	-22	-16	11	-0.3
France	-15	-22	-19	11	-0.4
United Kingdom	-17	-21	-21	11	-0.4
Italy	-14	-34	-18	11	-0.4
Spain	-10	-29	-20	11	-0.4
Netherlands	-17	-17	-16	11	-0.6
Other EU-15	-14	-27	-29	11	-0.7
Poland	15	-1	-23	11	-0.6
Rest of EU-27	10	-5	-25	11	-0.6
Norway	-35	-27	-27	117	-1.4
Switzerland	-21	-10	-10	39	-0.2
Russia	33	17	4	-	-1.3
Ukraine	77	83	5	-	0.3
USA	-17	-12	-12	12	-0.1
Canada	-17	-19	-19	14	-0.5
Japan	-30	-18	-18	14	-0.2
Australia	-10	-20	-20	13	-0.7
New Zealand	-28	-30	-30	52	-0.5
Non-Annex I	*61*	-	3	-	0.0
Brazil	*53*	-	5	-	0.1
Middle East and North Africa	*26*	-	4	-	-0.5
China (incl. Hong Kong)	*72*	-	2	-	0.1
India	*66*	-	3	-	0.3
Rest of the World	*56*	-	6	-	0.0
World	*26*	-	-4	-	-0.2

a) For EU-27 ETS-price, for member states non-ETS-price, for other Annex-I countries national carbon tax

b) Equivalent variation as % of national income of the baseline

Source: WorldScan

decreases by 0.2% in Annex I while in non-Annex I countries economic welfare remains at the baseline level. The carbon leakage rate falls from 36% to 13% when CDM is used (see also Table 3.8).[5]

Table 3.7 PLEDGES WITH FA, 2020

	Percentage GHG reduction			Emission price[a)]	Economic welfare [b)]
	Target (*or 2020 emissions*) compared to 2005 emissions	Target compared to baseline emissions 2020	Emissions 2020 compared to baseline emissions 2020		
	(%)	(%)	(%)	€ / tCO_2	(%)
Annex I	-7	-7	-13	-	-0.3
EU-27	-9	-21	-21	31	-0.5
Germany	-15	-22	-16	11	-0.3
France	-15	-22	-19	11	-0.4
United Kingdom	-17	-21	-21	11	-0.4
Italy	-14	-34	-18	11	-0.4
Spain	-10	-29	-20	11	-0.4
Netherlands	-17	-17	-16	11	-0.6
Other EU-15	-14	-27	-30	11	-0.7
Poland	15	-1	-22	11	-0.6
Rest of EU-27	10	-5	-25	11	-0.6
Norway	-35	-27	-27	115	-1.4
Switzerland	-21	-10	-10	39	-0.2
Russia	33	17	4	-	-1.3
Ukraine	77	83	5	-	0.3
USA	-17	-12	-12	12	-0.1
Canada	-17	-19	-19	14	-0.5
Japan	-30	-18	-18	14	-0.2
Australia	-10	-20	-20	13	-0.7
New Zealand	-28	-30	-30	51	-0.5
Non-Annex I	*62*	-	3	-	0.0
Brazil	*53*	-	6	-	0.1
Middle East and North Africa	*26*	-	4	-	-0.5
China (incl. Hong Kong)	*72*	-	2	-	0.1
India	*66*	-	4	-	0.3
Rest of the World	*57*	-	6	-	0.0
World	*26*	-	-3	-	-0.2

a) For EU-27 ETS-price, for member states non-ETS-price, for other Annex-I countries national carbon tax

b) Equivalent variation as % of national income of the baseline

Source: WorldScan

[5] Note that we modify the leakage rate in the case of CDM according to equation (4.2).

Would Annex I countries benefit from border measures? Our simulation outcomes show relatively small impacts of the adoption of import levies and export refunds for the energy intensive sector in the countries of Annex I (Table 3.6). Compared to PLEDGES the impacts on economic welfare are negligible for both Annex I and non-Annex I. Hence, chances are low that the adoption of BM will induce countries in non-Annex I to embark on GHG-mitigation programmes. Moreover, carbon leakage is hardly reduced. The leakage rate drops from 36% to 35%.

Finally, in our last scenario we indicate the impacts of free allowances for EU energy-intensive manufacturing. It turns out that the simulation outcomes do not noticeably differ from PLEDGES (Table 3.7). In PLEDGES WITH FA we lower production costs by providing a subsidy to EU energy-intensive manufacturing that equals the value of the allowances that are available to new firms (5% of the ETS-ceiling). Though there is some increase in the ETS-price the change is so small that it does not show up as a difference in the table. Apparently, in our assessment the impacts of free rather than auctioned allowances to energy-intensive manufacturing are negligible.

An overview of the outcomes for the five scenarios is given in Table 3.8. One may recall that we defined the leakage rate as the increase of GHG-emissions in non-Annex I countries as a percentage of the emissions reduction in Annex I countries. If we define the set of countries belonging to Annex I as I_A (and $I_{\#A}$ as its complement, indexing the countries of non-Annex I) the leakage rate can be expressed as

$$lr = \frac{\sum_{j \in I_{\#A}} e_j - b_j}{\sum_{i \in I_A} b_i - e_i} * 100 \qquad (3.1)$$

where e_i denotes emissions in the policy scenario and b_i emissions in the baseline for country *i*. With CDM, calculating the leakage rate is less straightforward because the emission reduction realised through CDM projects can either be attributed to the countries which produce these emission reductions or to those countries that buy the emission reductions. Using the latter approach has the advantage that the resulting leakage rate reflects the net effect of policies in Annex I countries on emissions in non-Annex I countries. Hence we modify the leakage rate for the case of CDM by adding CDM-demands to the denominator (keeping the targeted reduction unchanged Annex I) and adding CDM-supplies to the nominator (or subtracting them from the baseline as a reflection of the expectation that emissions will be reduced in CDM host countries with the CDM-credits that they supply).

$$lr_{cdm} = \frac{\sum_{j \in I_{\# A}} e_j - b_j + cdm_j^s}{\sum_{i \in I_A} b_i - e_i + cdm_i^d} * 100 \qquad (3.2)$$

Economic welfare is least affected in PLEDGES WITH CDM and most in AMBITIOUS PLEDGES (Table 3.8). Global emissions are most reduced in AMBITIOUS PLEDGES and PLEDGES WITH CDM while the reduction is smallest in PLEDGES and PLEDGES WITH FA. The leakage rates are relatively high in PLEDGES and PLEDGES WITH BM. In PLEDGES WITH CDM the leakage rate

Table 3.8 Economic welfare, GHG- and production leakage, fossil energy prices and global emisions, 2020

	AMBITIOUS PLEDGES	PLEDGES	PLEDGES WITH CDM	PLEDGES WITH BM	PLEDGES WITH FA
Economic welfare (%) [a)]					
Annex I	-0.32	-0.32	-0.24	-0.32	-0.32
EU-27	-0.46	-0.47	-0.37	-0.46	-0.47
USA	-0.16	-0.12	-0.09	-0.11	-0.12
Other	-0.32	-0.34	-0.24	-0.34	-0.34
Non-Annex I	-0.08	0.01	0.01	0.01	0.01
China	0.02	0.07	0.06	0.07	0.07
India	0.15	0.31	0.19	0.30	0.31
Other	-0.17	-0.06	-0.04	-0.06	-0.06
World	-0.25	-0.22	-0.17	-0.22	-0.22
Global GHG-emissions (in Gton CO_2-eq. deviation from baseline)	-2.09	-1.48	-2.04	-1.51	-1.48
GHG leakage rate [b)]	16	36	13	35	36
GHG leakage rate trade channel [c)]	0	2	-3	0	2
Energy intensive production leakage rate [d)]	54	64	64	53	65
Energy intensive production leakage as % of baseline level [e)]	0.7	1.4	0.7	0.9	1.3
Global fossil energy price (% dev. baseline)	-1.8	-3.2	-2.8	-3.3	-3.2

a) Economic welfare is measured in equivalent variation as a % of baseline national income

b) The GHG leakage rate is defined the leakage rate as the increase of GHG-emissions in non-Annex I countries as a percentage of the emissions reduction in Annex I countries; in the case of CDM the leakage rate is modified according to equation (4.2)

c) The GHG leakage rate as defined in b) when fossil fuel prices are kept at baseline levels

d) Production leakage rate is defined as the increase in energy intensive production in non-Annex I countries as a percentage of the decrease of energy intensive production in Annex I

e) Production leakage is defined as the increase in energy intensive production in non-Annex I countries as a percentage of baseline energy intensive production in Annex I

Source: WorldScan

falls to 13%, which reflects carbon leakage within CDM-supplying countries. If the leakage definition from equation 4.1 would have been used, leakage in PLEDGES WITH CDM would have been negative, -32%, because emission reductions from CDM reduce non-Annex I emissions below their baseline.

We assessed the importance of the price channel for the leakage rates in additional policy variants where we forced fossil fuel prices to remain at baseline levels.[6] The results show a predominant importance of the price channel rather than the trade channel. In PLEDGES, for example, the leakage rate of 36% drops to 2% if the price channel is eliminated in this way. These results are quite similar to those obtained by Böhringer *et al.* (2010). They report that for different climate policy scenarios, including various border measure variants, leakage is never reduced by more than 15%. Thus, as in their study, also in our simulations the main channel for carbon leakage appears to be the fossil fuel price channel, not carbon leakage through the trade channel. Due to the emissions ceilings imposed in Annex I fossil fuel prices decline and thus the use of fossil fuels is fostered in non-Annex I. In fact, also within some Annex I countries with non-binding emission ceilings such as Russia and Ukraine fossil fuel use increases in response to lower energy prices in four out of five scenarios.[7]

The production leakage rate for energy-intensive manufacturing is rather high in all policy cases, ranging from 54% in AMBITIOUS PLEDGES to 65% in PLEDGES WITH FA. However, when we look at the actual volume displacements of energy-intensive production (by multiplying the production leakage rate with the relative deviation of production from the baseline for the countries of Annex I) the picture becomes more varied. The range of production leakage outcomes in terms of % deviation from baseline production then is as follows: PLEDGES 1.4%, PLEDGES WITH FA 1.3% , PLEDGES WITH BM 0.9%, PLEDGES WITH CDM and AMBITIOUS PLEDGES BOTH 0.7%.

The global fossil fuel price falls with 3.3% in PLEDGES WITH BM, exceeding the price fall in PLEDGES with 0.1%. Thus, border measures do not seem to address the fuel price channel and may in fact depress energy prices even further. The fossil fuel price declines least in AMBITIOUS PLEDGES (1.8%).

The decline in EU energy-intensive production is reduced by 15% if border measures are adopted (PLEDGES WITH BM 2.8% compared to PLEDGES 3.3%, Table 3.9). EU electricity production is slightly negatively affected by adopting border measures because residential electricity demand is decreasing as well as demand from the non-ETS production sectors.

[6] As instruments we used reductions of the natural resource stocks of fossil fuels. The stocks were reduced until fossil fuel prices returned to baseline levels.

[7] The exception being AMBITIOUS PLEDGES which effectively puts – by allowing full permit trade – a joint emissions ceiling on Annex I.

Table 3.9 EU production, by sector, 2020, in % deviation from baseline

	AMBITIOUS PLEDGES	PLEDGES	PLEDGES WITH CDM	PLEDGES WITH BM	PLEDGES WITH FA
Cereals (wheat and cereal grains nec)	-1.5	-1.8	-1.0	-1.9	-1.8
Oilseeds	-1.7	-1.9	-1.1	-2.1	-1.9
Sugar crops (sugar cane, sugar beet)	-1.1	-1.3	-0.7	-1.3	-1.3
Other agriculture	-1.5	-1.6	-0.9	-1.7	-1.6
Minerals NEC	-0.5	-1.4	-0.3	-1.4	-1.4
Oil	-1.9	-1.6	-1.0	-1.7	-1.6
Coal	-19.0	-15.6	-9.5	-15.8	-15.6
Petroleum, coal products	-3.8	-5.3	-3.2	-5.2	-5.3
Natural gas (inc. gas distribution)	-9.7	-5.1	-3.3	-5.1	-5.1
Electricity	-1.7	-9.6	-1.2	-9.7	-9.7
Energy intensive manufacturing	-1.0	-3.3	-1.1	-2.8	-3.2
Vegetable oils and fats	-0.9	-1.0	-0.6	-1.2	-1.1
Capital goods and durables	-0.7	-0.9	-0.6	-1.2	-0.9
Consumer food goods	-0.6	-0.5	-0.4	-0.6	-0.5
Other consumer goods	-1.0	-1.2	-0.7	-1.4	-1.3
Road and rail transport	-0.8	-1.0	-0.5	-1.0	-1.0
Other Transport (water and air)	-1.0	-0.8	-0.5	-0.9	-0.9
Other services	-0.4	-0.3	-0.3	-0.3	-0.3

Source: WorldScan

Border measures are more effective in curbing the decline of energy-intensive production in the EU than free permit allowances: in PLEDGES WITH FA the decline amounts to 3.2% (rather than 2.8% in PLEDGES WITH BM). However, in the 'what if' scenario where EU incumbents subsidize the price of energy intensive production by the full value of their permits energy intensive production rises slightly above baseline (+0.1%) at the expense of larger declines in production in the other production sectors of the EU.

Table 3.10 Average annual growth rates of GDP and emissions (2005-2020) and CO_2 intensity reductions in 2020 with respect to 2005, China and India, selected policy cases

	GDP	CO_2	GHG	CO_2 intensity 2020 % reduction below 2005
	Average % annual growth 2005-2020			
China				
BASELINE	8.2	4.0	3.5	47.3
AMBITIOUS PLEDGES	8.2	4.2	3.6	45.2
PLEDGES	8.2	4.2	3.7	45.9
PLEDGES WITH BM	8.2	4.1	3.7	45.9
India				
BASELINE	7.1	4.3	3.2	35.1
AMBITIOUS PLEDGES	7.1	4.9	3.3	28.9
PLEDGES	7.1	4.6	3.4	31.3
PLEDGES WITH BM	7.1	4.6	3.4	31.4

Source: WorldScan

In none of our policy cases the relative targets of China and India for CO_2-intensity have become binding (Table 3.10). In 2020 in all cases, the CO_2-intensity remained well below the most ambitious pledges of China and India (45% and 25% reduction below 2005 intensity). In terms of GHG-intensity the reduction performance of these countries is even better than for CO_2.

In terms of environmental effectiveness AMBITIOUS PLEDGES appears marginally to outperform the other four scenarios, lowering the global emissions by 2.1 Gton CO_2-eq. at costs that are similar to the costs in the other policy cases. Second comes PLEDGES WITH CDM, decreasing the global emissions by 2.0 Gton CO_2-eq.. Moreover, in this policy variant OECD production leakage of the energy intensive sector is lowest in absolute terms.

The growth of fossil energy use and of trade in energy-intensive products by non-Annex I has significantly raised the assessments by modelling teams of the rate of carbon leakage that goes with unilateral climate change policies in Annex I. There is no doubt that high leakage rates will lead to vigorous pleas that border measures are necessary to curb the leakages. Our simulation outcomes indicate that production leakage for the energy intensive sector will be relatively modest in absolute terms for Annex I, ranging from 1.4% (PLEDGES) to 0.7% (PLEDGES WITH CDM and AMBITIOUS PLEDGES) of baseline production. Our simulations also suggest that border measures are rather ineffective in reducing leakage – the leakage rate for energy-intensive production being reduced by a modest 17% and for carbon by only 4%. Moreover, the border measures in our analysis hardly affect economic welfare in Annex I. Finally, our simulations show that the fossil fuel price channel is by far the most important cause of carbon leakage. The border measures investigated in this report hardly affect leakage as they do not address this channel.[8]

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[8] These outcomes may depend on model parameterizations and specifications. Table A.3 in the Annex gives the Armington elasticities adopted in our study.

4 Conclusions

A major concern related to the interaction of climate change and trade is the adverse impact that climate policies might have on the competitiveness of countries which implement more ambitious climate policies compared to other countries. Differences in climate change policies will not only have an impact on trade, they can also lead to increased emissions in regions with no or less ambitious climate change policies, the so-called carbon leakage. This report discusses the impacts of the EU ETS and climate policies in other countries on competitiveness and on leakage in 2020.

The macroeconomic consequences of various climate policy scenarios have been quantified using WorldScan, a global applied general equilibrium model. The AMBITIOUS PLEDGES scenario is based on pledges in which countries set relatively stringent caps on GHG-emissions and allow free permit trade amongst each other. The other scenarios implement the more modest pledges made by countries up to the Copenhagen Climate Change Conference in December 2009. In these scenarios, there is no permit trade between Annex I countries with the exception of emission trading within the EU ETS and non-ETS.

The impacts of the policy scenarios have been assessed on the basis of the 2009 World Energy Outlook baseline. The only difference between the baseline used in this report and the WEO 2009 baseline is that the ETS has been removed from the baseline in order to establish a level playing field for our assessments of the mitigation pledges in an international context, resulting in a modest increase of GHG emissions in the EU and modest decreases Japan and the US. In the baseline, global population continues to expand. Combined with worldwide economic growth of 2.7% per year global demand for energy will be almost 30% higher in 2020 than in 2004. This expansion predominantly takes place in non-Annex I, thus partially reducing the gap in energy consumption per capita with the industrialized countries.

In terms of both environmental effects and economic costs, the scenario with ambitious pledges appears to perform best, lowering global emissions by 5% at costs similar to the costs in the other policy cases. Although emission reductions are more ambitious compared to the other scenarios, trading emission permits limits total costs. In the scenario with the Copenhagen pledges (without CDM), for example, global emissions are reduced with 3%, while costs are similar to those in ambitious pledges.

Increased carbon costs in countries which introduce climate change policies can affect not only trade, but can also lead to increases in emissions in countries without climate policies. This carbon leakage occurs because of two different mechanisms. First, due to loss of competitiveness energy intensive production and therefore emissions can increases in countries without binding emission limits. Second, climate policies will reduce demand for fossil fuels and therefore prices for fossil fuels will decline. This will increase demand and therefore raise emissions in regions without climate policies (the fossil fuel price channel).

An important result from our modelling exercise is the finding that carbon leakage due to direct loss of competitiveness via the trade channel is very small. Global competition distortions caused by the absence of a carbon price in countries with no binding pledges result in direct leakage effects of 1% or less. In other words, for every 100 ton CO_2eq emission reduction in the EU, emissions go up with 1 ton only in countries with no binding pledge. However, indirect leakage through the energy price channel is considerably more important. Measures taken by countries with binding pledges to reduce emissions reduce global demand for energy and thus reduce global energy prices. This actually increases energy consumption in countries that have no binding target and take no measures. It triggers high carbon leakage effects, ranging up to 36%, depending on the scenario.

Indirect carbon leakage through the energy price channel has increased significantly in this study, compared to the earlier studies. The carbon leakage rate in our study is 36 percent in the PLEDGES scenario, which is considerably higher than the 3-11 percent leakage rates reported in earlier studies. This is due to the increased importance of fossil energy use and trade in energy-intensive products by non-Annex I countries, as captured by the 2004 data (GTAP-7) used to calibrate this model (compared to 2001 data used in earlier models). Other modelling teams which use the same data also report comparably higher leakage rates.

Production leakage for energy intensive industries in developed countries is rather limited. Reductions in production levels for energy intensive industries compared to baseline are 1.4% or less, depending on the scenario. This is a very low impact, considering that in the simulations run with the WorldScan model, pledges for developing countries, such as for instance the carbon intensity target in China, under the Copenhagen Accord are non-binding. If those would be binding carbon leakage would be further lowered.

Carbon leakage can be reduced through the use of CDM, which reduces the costs of emission reductions and lowers the effect on fossil fuel prices. Another option is the use of border measures (BM) which introduce a carbon levy on imports and refunds on exports. Of the policy cases assessed CDM is the most effective option to reduce the leakage rate. CDM lowers the ETS carbon price from €31 to €9 per ton CO_2-equivalent. Hence, the effect on fossil fuel prices is relatively small and therefore also leakage through the fossil fuel price channel. BM are considerably less effective in reducing leakage. The effect of BM on leakage is also far more limited in our simulations compared with earlier studies. In these earlier studies, BM would reduce leakage with 30-60 percent, while in our simulations BM reduces carbon leakage by 1 percentage point only – from 36 to 35 percent. BM are much less effective in reducing carbon leakage because the fossil fuel price channel rather than the trade channel is the dominant cause of leakage. BM do not address this fossil fuel price channel.

Within the EU, the main climate instrument which has an effect on energy intensive business is the EU ETS. Free allocation or auction of the allowances do not differ in their effect on competitiveness as long as the allocation is lump sum and companies are assumed to incorporate the opportunity cost of free allowances into their price setting. However, updating and entrance and closure rules, which makes free allowances available to entrants and ends the free allocation to firms that stop producing, can mitigate the cost increase caused by the CO_2 price to some extent. The effect of these options is comparable to output-based allocation, in which firms receive allowances on the basis of their actual emissions. The effect of free allowances on production costs have been simulated on the assumption that the cost reduction for the energy intensive sectors is equal to the entrant reserve in the ETS of 5% of total allowances available in the period 2013-2020. The resulting cost reduction is limited and therefore the effects of this form of limited free allocation hardly differ from the case without free allocation.

Annex Tables in addition to section 3

Table A.1 Differences between WEO-scenario and baseline of average annual growth rates, 2004-2020

	Population	GDP volume	Energy consumption [a]	GHG emissions	Energy intensity	GHG intensity [b]
Annex I	0.0	0.0	-0,6	-0,3	-0,6	0,4
EU-27	0.0	0.0	-2,9	-1,0	-2,9	1,9
Germany	0.0	0.0	-2,5	-1,1	-2,4	1,4
France	0.0	0.0	-4,4	-0,8	-4,4	3,6
United Kingdom	0.0	0.0	-2,7	-0,8	-2,7	1,9
Italy	0.0	0.0	-3,5	-0,9	-3,5	2,6
Spain	0.0	0.0	-3,5	-1,0	-3,4	2,5
Netherlands	0.0	0.0	-1,9	-0,5	-1,9	1,4
Other EU15	0.0	0.0	-4,2	-1,3	-4,1	2,8
Poland	0.0	-0.1	-2,1	-1,2	-2,0	0,9
Rest of EU-27	0.0	-0.1	-3,1	-1,1	-3,0	1,9
Norway	0.0	0.0	3,3	0,5	3,3	-2,9
Switzerland	0.0	0.0	0,1	0,2	0,1	0,1
Russia	0.0	0.0	0,3	0,1	0,4	-0,3
Ukraine	0.0	0.0	0,2	0,1	0,2	-0,1
USA	0.0	0.0	0,1	0,0	0,1	0,0
Canada	0.0	0.0	0,3	0,1	0,3	-0,2
Japan	0.0	0.0	0,1	0,1	0,1	-0,1
Australia	0.0	0.0	0,2	0,1	0,2	-0,1
New Zealand	0.0	0.0	0,0	0,0	0,0	0,0
Non-Annex I	0.0	0.0	0,1	0,0	0,1	0,0
Brazil	0.0	0.0	0,1	0,0	0,1	-0,1
Middle East and North Africa	0.0	0.0	0,2	0,1	0,2	-0,1
China (incl. Hong Kong)	0.0	0.0	0,0	0,0	0,0	0,0
India	0.0	0.0	0,0	0,0	0,0	0,0
Rest of the World	0.0	0.0	0,2	0,1	0,2	-0,1
World	0.0	0.0	-0,1	-0,1	-0,1	0,1

a) Total of coal, refinery products, natural gas, biofuels, commercial biomass and renewable energy

b) GHG-intensity represents the ratio of GHG-emissions and energy consumption

Source: WorldScan

Table A.2 **PLEDGES WITHOUT THE EU RENEWABLES TARGET, 2020**

	Percentage GHG reduction			Emission price a)	Economic welfare b)
	Target (*or 2020 emissions*) compared to 2005 emissions	Target compared to baseline emissions 2020	Emissions 2020 compared to baseline emissions 2020		
	(%)	(%)	(%)	€ / tCO_2	(%)
Annex I	-7	-7	-13	-	-0.3
EU-27	-9	-21	-21	45	-0.4
Germany	-15	-22	-17	11	-0.3
France	-15	-22	-20	11	-0.4
United Kingdom	-17	-21	-19	11	-0.3
Italy	-14	-34	-20	11	-0.5
Spain	-10	-29	-22	11	-0.5
Netherlands	-17	-17	-13	11	-0.4
Other EU-15	-14	-27	-26	11	-0.6
Poland	15	-1	-25	11	-0.4
Rest of EU-27	10	-5	-25	11	-0.2
Norway	-35	-27	-27	115	-1.4
Switzerland	-21	-10	-10	39	-0.2
Russia	33	17	4	0	-1.2
Ukraine	77	83	6	0	0.4
USA	-17	-12	-12	12	-0.1
Canada	-17	-19	-19	14	-0.5
Japan	-30	-18	-18	14	-0.2
Australia	-10	-20	-20	13	-0.7
New Zealand	-28	-30	-30	52	-0.5
Non-Annex I	*61*	-	3	0	0.0
Brazil	*53*	-	6	0	0.1
Middle East and North Africa	*26*	-	4	0	-0.5
China (incl. Hong Kong)	*72*	-	2	0	0.1
India	*66*	-	4	0	0.3
Rest of the World	*57*	-	6	0	0.0
World	*26*	-	-3		-0.2

a) For EU-27 ETS-price, for member states non-ETS-price, for other Annex-I countries national carbon tax

b) Equivalent variation as % of national income of the baseline

Source: WorldScan

Table A.3 Armington trade elasticities, by sector

Cereals (wheat and cereal grains nec)	5.4	Electricity	5.6
Oilseeds	4.9	Energy intensive sectors	6.5
Sugar crops (sugar cane, sugar beet)	5.4	Vegetable oils and fats	6.6
Other agriculture	4.7	Capital goods and durables	7.6
Minerals NEC	1.8	Consumer food goods	4.8
Oil	10.4	Other consumer goods	6.7
Coal	6.1	Road and rail transport	3.8
Petroleum, coal products	4.2	Other Transport (water and air)	3.8
Natural gas (incl. gas distribution)	20.5	Other services	3.8

Source: GTAP-7 database

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