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Post-2012 Climate Policies

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Abstract

After the decision of the United States and Australia not to ratify the Kyoto Protocol, the process of an internationally coordinated climate policy seems to be deeply stuck. In this situation, climate policy research can contribute by pointing out possible further steps and analysing their consequences. We contribute to this discussion by sketching a climate policy scenario for the period 2012-2020, building on the CPB-RIVM study of Bollen et al. (2005). We take the already existing climate change policies as a starting point and extend them where we consider this as politically feasible. The long-term 2°C objective is at the background of our discussion, but not directly used for deriving a set of emission restrictions. There are three important building blocks of our post-2012 scenario: The Annex-B countries, excluding the United States, form an abatement coalition in the form of a cap-and-trade system. The United States commit themselves to moderate emission targets, but not partake in the trading system. Non Annex-B regions contribute in the form of a system of Clean Development Mechanism (CDM) projects. As a variant we also consider the case where the US joins the permit trading club.

Key words: climate policy, Kyoto protocol, post-Kyoto policies, cap-and-trade system

JEL code: D58, D61, H3, Q25, Q48

1 Introduction

After the decision of the United States and Australia not to ratify the Kyoto Protocol, the process of an internationally coordinated climate policy seems to be deeply stuck. The Kyoto Protocol commits a group of industrialised countries - the Annex-B countries[1] - to reduce their emissions of greenhouse gases in 2008-2012 to approximately 5% below their 1990 level. This can be considered only a small step towards a stabilisation of the concentration of greenhouse gases in the atmosphere. A focal point in the discussion about climate change is a limit on the rise in global temperature of 2°C, which is commonly seen as a 'safe' temperature level limiting the possible catastrophic consequences of more severe changes (Eickhout et al., 2003). With such a target in mind, stricter emission ceilings for individual countries and an extension of the group of contributing countries are indispensable, which makes the non-participation of the United States even more worrisome.

In this situation, climate policy research can contribute by pointing out possible further steps and analysing their consequences. The discussion can be stimulated by contrasting possible paths of the future development, and singling out those that have the highest probability of gaining broad support. In this paper, we want to contribute to this discussion by sketching a climate policy scenario for the period 2012-2020, building on the CPB-RIVM study of Bollen et al. (2005). We take the already existing climate change policies as a starting point and extend them where we consider this as politically feasible. The long-term 2°C objective is at the background of our discussion, but not directly used for deriving a set of emission restrictions. There are three important building blocks of our post-2012 scenario: The Annex-B countries, excluding the United States, form an abatement coalition in the form of a cap-and-trade system. The United States commit themselves to moderate emission targets, but not partake in the trading system. Non Annex-B regions contribute in the form of a system of Clean Development Mechanism (CDM) projects. As a variant we also consider the case where the US joins the permit trading club.

The most visible consequence of the Kyoto process is the forming of the European Emissions-Trading Scheme (ETS), which establishes a mechanism to reduce the emissions of the EU's five most polluting industries. With the introduction of a common carbon market, the ETS also aims at a cost-efficient allocation of CO_2 emissions to the regions with the lowest abatement costs. Our post-2012 scenario assumes an extension of this common carbon market to all Annex-B regions, excluding the United States, and to all industrial sectors.

The role of the largest producer of greenhouse gases, the United States (about a quarter of global emissions), is particularly ambiguous and difficult to assess. The US did not ratify the Kyoto protocol because mandatory restriction of emissions was expected to having too severe

[1] The Annex-I or Annex-B group consists of Western and Eastern Europe, the USA, Canada, Japan, Australia, New Zealand and the former Soviet Union. However, the USA and Australia have decided not to ratify the Protocol. The Annex-B group can thus roughly be identified with the industrialised countries and the countries in transition; the non Annex-B group consists of the developing countries.

economic costs. However, the situation in the United States seems to be changing (Economist, 2006). Hurricane Katrina contributed to a shift in the public opinion towards more awareness of the possible consequences of a changing climate, and governments at the state level have started to take action in the form of greenhouse gas emission legislation[2]. Moreover, energy security considerations are becoming more urgent (Deutch, 2004). Therefore, as the most important deviation from the current situation, we assume in our post-2012 scenario that the United States set an emission target at the national level. With respect to the international integration of the US policy, we consider two variants. The first is inspired by the strong domestic orientation of the United States politics and assumes a stand-alone policy of the US. The second assumes an integration of the US into the abatement coalitions of the other Annex-B countries.

Although the United States are still at the top of the list of greenhouse gas producers, non Annex-B countries like China and India are catching up fast. A climate policy without these non Annex-B regions is doomed to fail. The Kyoto Protocol already allows for emission abatement through the participation in Clean Development Mechanism projects. A possible way for Kyoto regions to meet their emission targets is financing UN certified emission reduction projects in non Annex-B countries. These CDM projects are beneficial for Annex-B regions because of the low costs of reducing GHG emissions (partly below 1 € / t CO_2). CDM is also beneficial to non Annex-B countries if the technological renewing coincides with a reduction in regional pollution or if they succeed in generating income by establishing a mark-ups on these CDM through a tax or a regulated market. Our post-2012 scenario assumes a CDM market that covers 10 % of the emissions reductions in Annex-B countries. The United States is again treated differently in the two variants of the scenario.

This paper focuses on the macro-economic consequences of the post-2012 scenarios. We first describe the model and the baseline (Section 2). Section 3 contains further details about the post-2012 scenario assumptions. The results are described and discussed in Section 4 (basic scenario) and 5 (integrated permit trading in Annex B), with a short summary and conclusions in Section 5.

[2] E.g. California, lead by the republican Mr Schwartzenegger, legislated on August 31st 2006 for cuts in greenhouse gas emissions to the 1990 level, which amounts to approximately – 25 % compared with the baseline in 2020.

2 The model and baseline

2.1 The WorldScan model

WorldScan (Lejour et al., 2006) is a multi-sector, multi-region Applied General Equilibrium (AGE) model. It is developed to study long-term global issues, such as globalisation and climate change policy. The model builds upon neoclassical theory, has strong micro-foundations and solves for the equilibrium that maximizes welfare across the entire economy, subject to technological constraints, greenhouse gas limitations, etc. The model is calibrated on input-output tables and trade data from the GTAP6 database (Dimaranan and McDougall, 2005). The base year for the model is 2001.

The model version used in this study distinguishes 13 sectors and 19 regions. These are listed in the table below. The model thus contains considerable detail at regional and sectoral level, specially the energy sectors, coal, oil, gas, petroleum and electricity.

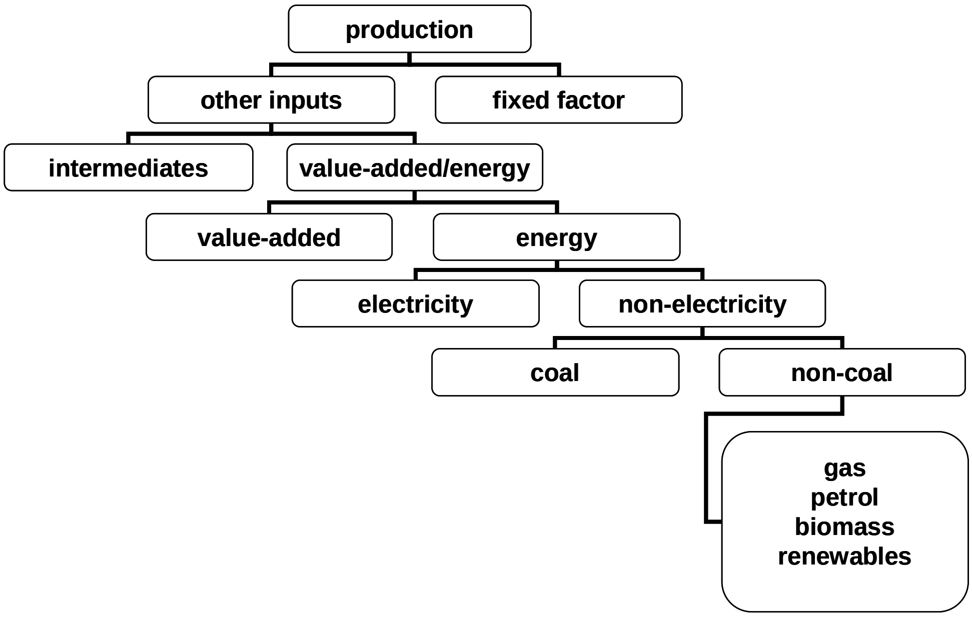
Table 2.1 Regions and sectors in WorldScan based on a GTAP mapping

Sectors	Regions
Agriculture	Germany
Coal	France
Oil	United Kingdom
Natural gas and gas distribution	The Netherlands
Petroleum and coal products	Italy
Minerals nec[a]	Spain
Chemical, rubber and plastic products	Rest EU-15
Other energy intensive sectors	Rest EU-25
Consumer good sector	Rest Europe
Capital goods and durables	Former Soviet Union
Electricity	Canada
Other services	Australia
Transport	Rest OECD (Japan, New Zealand)
	United States
	Latin America
	Middle East and Northern Africa
	China
	India
	Rest of the World

[a] nec: not elsewhere classified.

Sectoral production technologies are modelled as nested CES functions. The value of the substitution parameters determines the substitution possibilities between input factors. Figure 2.1 gives a representation of the WorldScan production tree. The top level, where the fixed factor is split off, is relevant only for the agricultural sectors and coal, oil, gas and other raw materials. This fixed factor nest has a substitution elasticity of .60. However, for the coal, gas and oil producing sectors this substitution elasticity is overwritten with the substitution elasticity implied by the supply elasticities of these sectors. For all manufacturing and service sectors we assume constant returns to scale in production. In the next level of the production tree, value-added plus energy carriers and material inputs are subdivided. This CES-function has a low substitution elasticity of .01, creating a Leontief structure.

Figure 2.1 Production structure of WorldScan



The nesting structure of the materials has a substitution elasticity of .90. In general, we assume relatively high substitution elasticities between value-added and energy carriers (.50), except for the energy sectors (.01). The value-added nest, containing labour and capital, has an elasticity of .90, creating a Cobb-Douglas like production function. For the energy nest, we assume a substitution elasticity for electricity of .25, for coal of .70 and for the other energy carriers of .50. The energy inputs biomass and renewables are produced by the agriculture sector and the service sector, respectively. Not explicitly shown in figure 2.1 are those capital inputs, which serve as a direct substitute for the energy inputs (substitution elasticity of 0.5).

Trade represents the difference between regional production and consumption. With respect to trade, WorldScan adopts an Armington specification, explaining two-way trade between regions and allowing market power of each region. . The elasticiy of substitution between products originating from different regions is set at 7.3 for manufacturing industries, agriculture and raw materials and at 3.8 for services (Hertel et al., 2003). Bilateral trade depends on consumer preferences for regional varieties of a good, and differences in relative prices. The demand by the consumer is modelled as a Linear Expenditure System.

On the capital market, WorldScan assumes imperfect capital mobility across borders. The savings in a region are determined by demographic composition, level and growth rate of the gross domestic product. On the labour markets, there are exogenous unemployment rates. The wage adjusts so that the remaining quantity of labour is fully absorbed by the production sectors.

2.2 The IIASA baseline

The impacts of policy interference are measured with respect to a baseline, which is a reference scenario usually termed business-as-usual (BaU), where no policy changes apply. In order to simulate the economic and environmental implications of our post-2012 scenario, information on the future BaU development of the global economy is required. The BaU projections forced upon the models determine how policy interference, such as carbon emission constraints under post-2012 climate policies, will bind the respective economies in the future. The compilation of the BaU projections is a key challenge for long-term climate policy analysis. For our simulations, we adopt the WEC/IIASA Scenario B “Middle Course” as our reference case (WEC 1998). Scenario B is based on a cautious approach to technological change and energy availability as well as modest economic growth (Jefferson 2000). Table 2.1 describes quantitatively the key features of the baseline scenario.

The growth rates of GDP per capita are moderate in the IIASA baseline, roughly between 1 and 2 % per year. The energy intensity is declining with approximately 1 % per year; the Annex-B regions improve their energy intensity somewhat more than the non Annex-B regions. The emission intensity shows only a small decline, -0.1 % , caused by a shift in the use of coal to the use of less polluting energy carriers.

Table 2.1 Characteric growth rates (2001-2020) for the IIASA baseline scenario

	population	GDP per capita	Energy intensity[a]	Emission intensity[b]
	%	%	%	%
EU-25	0,3	1,5	-1,7	0,0
Germany	0,3	1,5	-1,8	0,0
France	0,3	1,5	-2,0	-0,1
United Kingdom	0,3	1,5	-1,3	0,0
The Netherlands	0,3	1,5	-0,7	0,0
Italy	0,3	1,5	-1,8	0,1
Spain	0,3	1,5	-2,1	-0,2
Rest EU-15	0,3	1,5	-2,0	-0,1
Rest EU-25	0,3	2,3	-2,0	0,0
Rest Europe	0,3	1,5	-1,5	-0,2
Former Soviet Union	0,6	2,2	-1,7	0,0
Canda	0,6	1,3	-1,5	0,1
Australia	0,2	1,2	-1,8	-0,2
Rest OECD	0,2	1,2	-1,7	-0,2
Annex-B excl. USA	0,4	1,3	-1,3	-0,1
United States	0,6	1,3	-1,1	-0,1
Latin America	1,3	1,5	-0,1	-0,3
Middle East and Northern Africa	2,3	0,9	0,0	-0,4
China	0,9	3,3	-2,2	0,0
India	1,4	1,9	-0,9	-0,2
Rest of the World	1,8	2,1	-0,9	0,0
Non Annex-B	1,5	2,1	-0,9	-0,2

a energy intensity is defined as energy use per unit GDP.

b emission intensity is defined as emission volume per unit energy use.

3 Characteristics of the post-2012 scenario

Constructing a plausible post-2012 scenario that explores the field between political plausibility considerations and the necessities of an effective limitation of greenhouse gas emissions, is a difficult task. Many parameters of the concrete policy implementation must be chosen from a range of alternatives, which form possible developments as well. In this section, we lay out our plausibility and consistency considerations for the choice of specific assumptions for the post-2012 scenario.

The period until 2010 is characterised by the commitments made under the Kyoto Protocol. The Kyoto Protocol commits a group of industrialised countries - the Annex-B countries - to reduce their emissions of greenhouse gases in 2008-2012 to approximately 5% below their 1990 level. The exact allocation of emission permits follows the agreements of Bonn and Marrakesh (Den Elzen and De Moor, 2001). The economic restructuring during the transition process after 1990 in Eastern Europe and the former Soviet Union has yielded an excess supply of emission permits in these countries, so-called “hot air”. The post-2012 scenario contains the assumption that the Soviet Union withdraws 75 % of their emission permits from the permit market for profit maximisation reasons. The corresponding withdrawing share for Eastern Europe is assumed at 25 %. These permits cannot be banked for use in later periods.

The long term objective of the European Union climate policy, adopted in 1996 the EU Council, is to prevent global mean temperature increasing by more than 2°C over pre-industrial levels. Given certain assumptions about the emissions targets of the non EU-regions (see below), this temperature objective corresponds to a reduction of the EU emissions to 20 % below their 1990 emissions level in 2020. No burden sharing will take place; every country of the EU-25 has to meet the 20 % reduction target independently of its welfare or emissions per capita level. The emissions target is linearly tightened between 2010 and 2020.

The non EU-25 regions of the Annex-B are divided, based on their emissions targets, into three subgroups: (1) Japan and New Zealand, (2) United States (USA), Canada and Australia, (3) the former Soviet Union and the Rest of Europe (including Romania, Bulgaria and former Yugoslavia). Japan, being the most ambitious region of this group with respect to climate policies, commits itself to a 10 % emissions reduction below the 1990 level. The United States, Canada and Australia set an emissions target of exactly the emissions level of 1990, which equals the emissions target set in California. For the former Soviet Union and the Rest of Europe, 1990 would not be plausible as a reference level because of their decline in production during the transition period after this year. Therefore, in our post-2012 scenario they use the emissions level of 2006 as the target for 2020.

The United States will follow a stand-alone policy, reflecting their strong domestic policy orientation. The rest of the Annex-B countries forms a cap-and trade abatement coalition, in which permits can be traded freely. Since these regions differ substantially in their marginal abatement cost curves, this coalitions lead to a shift in abatement efforts to the regions with the lowest marginal abatement costs, which reduces the overall costs of the climate policy. The consequences of the US joining the Annex B trading coalition are explored in a variant of the scenario (Section 5).

The fastest growing non-Annex-B regions - China, India, Latin America and the Middle East - are assumed to contribute to world climate policy by accepting targets that restrict their emissions to the baseline values until 2020. We see this as a plausible outcome if the Annex-B regions more forcefully require a level paying field for the fast developing non Annex-B regions with respect to environmental regulations. A commitment to not exceeding the baseline emissions will at least counteract the leakage of polluting activities from the Annex-B regions to the non-Annex-B regions. In the Region ‘Rest of the World’, i.e. the poorest parts of Africa and Asia, there are no emissions targets at all.

In the Annex-B countries, excluding the United States, firms are allowed to implement 10 % of the emissions reduction through the Clean Development Mechanism (CDM). CDM projects will be offered by firms in non-Annex-B countries, excluding the Rest of the World, at prices far below the emissions price on the Annex-B permit market. Buying these CDM credits from non Annex-B firms reduces the costs of compliance for Annex-B firms.

The difference between the emission permit prices on the Annex-B market and the CDM market is exploited by non Annex-B governments through levying an ad valorem tax rate of 150 % on the export of CDM permits. The supply of CDM credits is chosen proportional to the economic size of the region, i.e. Gross Domestic Product (GDP).

Table 3.1 Global CO_2 emissions indices (2000 = 1) for some climate change scenarios.

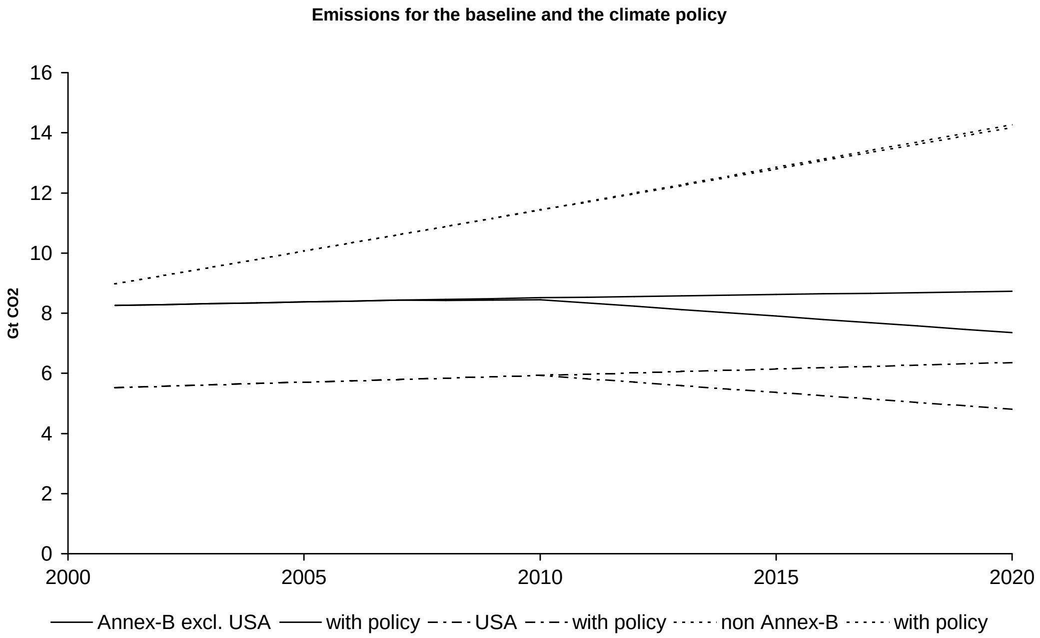
	2005	2010	2015	2020
WorldScan post-2012	1,08	1,15	1,23	1,31
Image-Timer 550 ppmv	1,11	1,23	1,28	1,24
Image-Timer 650 ppmv	1,11	1,23	1,34	1,43

Table 3.1 gives information on the compatibility of the post-2012 scenario with long term (2100) temperature stabilization. The global emissions pattern of the WorldScan post-2012 scenario is compared with two emissions profiles from the Image-Timer model of the RIVM (Eickhout et al., 2003). The results for 550 ppmv correspond to an expected temperature rise of 2.0°C in 2100, while the 650 ppmv correspond to an expected rise of 2.4°C. Until 2015, the WorldScan emissions lie below both of the Image-Timer emissions profiles. In 2020 the WorldScan emissions fall between the 550 ppmv and 650 ppmv stabilization emissions profiles, although closer to the 550 ppmv. Therefore, the WorldScan post-2012 scenario is consistent with scenarios which are expected to yield a temperature rise around the ‘safe’ level of 2°C.

4 Results of the basic scenario

We start our review of the scenario results with the CO_2-emissions in the baseline and in the post-2012 simulation for three aggregated regions: Annex-B excluding USA, the United States and non Annex-B:

Figure 4.1 CO_2 emissions (in Gt) from 2001-2020 for the baseline and the post-2012 scenarios



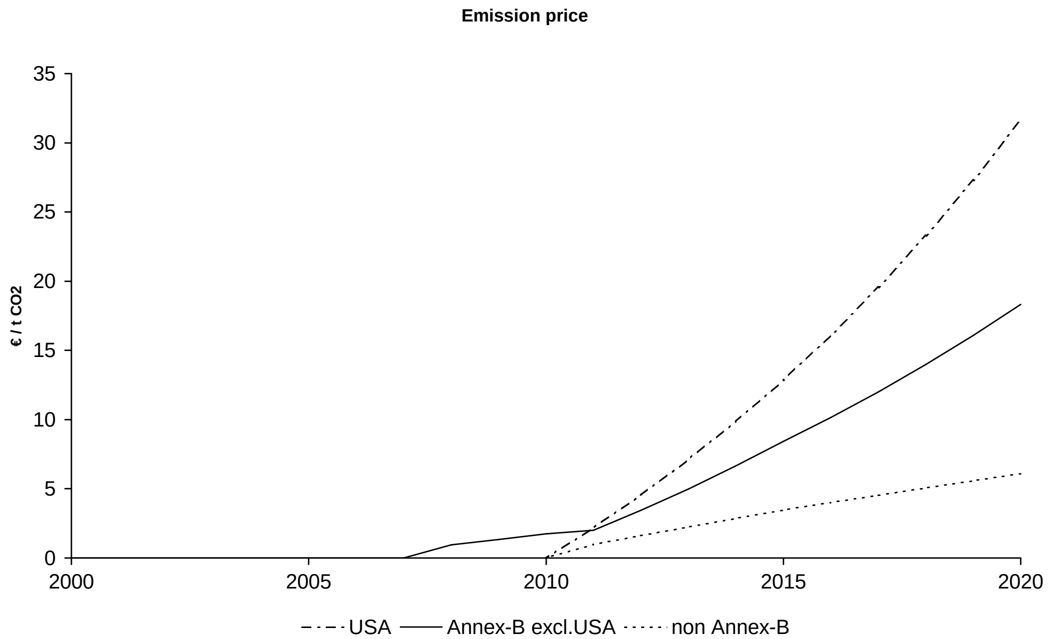
The baseline emissions are relatively stable for the Annex-B regions and rise steadily with 2.7% per year for the non Annex-B regions. Non-Annex-B countries like China and India will therefore become large emitters in the next decades.

In the non-Annex-B regions, the post-2012 scenario only generates a modest reduction of the CO_2 emissions: -1 % in 2020 (see also Table 4.1). There is a small reduction, although the commitment of these countries is not stricter than the benchmark emissions, because CDM is taking place. However, the volume of CDM is small compared with the total emissions in the non-Annex-B area. Furthermore, some leakage of CO_2 emitting activities to the Rest of the World takes place; here the emissions increase by 1% in 2020 (see Table 4.1).

For the Annex-B regions, Figure 4.1depicts a more substantial reduction in CO_2 emissions compared with the baseline: -24 % for the USA and -16 % for the rest of the Annex-B in 2020 (Table 4.1). Differences in CO_2 reduction between regions exist according to their emissions target and level of permit trade. Detailed regional numbers are given in fourth column of Table 4.1.

Three markets for emission permits exist: the internal market of the United States, the common Annex-B market and the regional markets for CDM credits. Figure 4.2 shows the pattern of prices that lead to market clearing for these different types of permits. The emission price in 2020 for the United States is the highest: 32 € / t CO_2. The rest of the Annex-B has a lower emissions price: 18 € / t CO_2.. This higher price in the United States can be explained when we have a second look at the formation of the emission targets. If expressed as relative reduction compared to the 1990 emissions, it seems that the reduction target in the US is considerably less strict than in the rest of the Annex-B countries (no change vs. -26%, see Table 4.1). However, if this is translated into changes compared to the baseline emissions, the order is reversed, and the US end up with a stricter target (-24% vs. -20%), which results from the steeper increase in baseline emissions in the US. In addition, the US does not participate in CDM, so that the difference in domestic emission reductions is even enlarged to -24% vs. -16%. This translates into the permit price difference of 14 € / t CO_2 Joining the Annex-B permit market would thus be beneficial for the United States by lowering its emissions price. This option is explored in the following section.

Figure 4.2 Carbon emission price in € / t CO_2 (basic scenario)



For the Annex-B group, Figure 4.2 shows a positive permit price already in the Kyoto period (2008-2010). The price remains below 3 € / t CO_2, however.

Of the three permit markets, the market for CDM credits yields the lowest price: 6 € / t CO_2 (Table 4.2). This emissions credit price can be split up into marginal abatement costs (with a share of 40%, see Table 4.1) and the export tax on CDM credits (60%). Every non-Annex-B region gets a fixed amount of CDM allocated, depending on its GDP. Due to differences in marginal abatement costs across regions, CDM prices differ by region. The aggregate CDM price of 6 € / t CO_2 is a weighted average of these prices, which reflects the assumption that all Annex-B countries use the same mix of CDM supply regions.

The comparison of the first two columns of Table 4.1 (target compared with 1990 emissions and the baseline, respectively) is revealing because it tells us about the different development of the baseline emissions compared to 1990. Among the old EU member countries (EU 15), the reduction target is uniform. Compared to the baseline, however, the reduction targets show a considerable variation. The most ambitious target is in the Netherlands and Spain, while Germany and the UK are at the end of the list. This ranking results from the baseyear shares of the energy carriers. The Netherlands and Spain are already heavily relying on gas, so there is not much leeway for emission reduction through a switch between fossil fuel carriers. In Germany and the UK, with a higher share of coal, in contrast, this is the case (and also taking place in the baseline).[3]

[3] This effect is aggravated through the procedure used in WorldScan to disaggregate the baseline data from the IIASA scenario. The differences in the change of energy intensities therefore tend to be overstated and must be taken with a grain of salt.

Table 4.1	Results in 2020 for the climate policy scenario				
	Percentage CO_2 reduction			Emission price	National Income
	Target compared with 1990	Target compared with the baseline	Emissions in 2020 compared with the baseline		
	%	%	%	€ / t CO_2	% change compared to baseline
EU-25	-20	-21	-13	18	-0.2
Germany	-20	-9	-11	18	-0.1
France	-20	-21	-10	18	-0.1
United Kingdom	-20	-22	-14	18	-0.1
The Netherlands	-20	-39	-13	18	-0.4
Italy	-20	-26	-8	18	-0.2
Spain	-20	-38	-12	18	-0.2
Rest EU-15	-20	-27	-11	18	-0.2
Rest EU-25	-20	-11	-21	18	-0.1
Rest Europe	-28	-2	-15	18	0.0
Former Sovjet Union	-36	-16	-21	18	-0.6
Canada	0	-21	-14	18	-0.2
Australia	0	-19	-19	18	-0.2
Rest OECD	-10	-14	-12	18	-0.1
Annex-B excl. USA	-24	-20	-16	18	-0.2
USA	0	-24	-24	32	-0.1
Latin America	128	0	-3	4	0.0
Middle East and Northern Africa	141	0	-1	2	0.0
China	109	0	-1	0	0.0
India	159	0	-1	1	0.0
Rest of the World	177	0	1	0	0.0
Non Annex-B	137	0	-1	1	0.0

Comparing columns 2 and 3 of Table 4.1 (target vs. actual emission reductions), we can get information about the import and export structure for permits. In the trading block as a whole, reduction is less than the target (-16% vs. -20%) because of CDM imports. For the EU, the difference between targeted and actual emissions is even larger (-13% vs. -27%), indicating that the EU is a net permit importer. Within the EU, the relative reduction level is centred around the average of 13%, with Italy (-8%) and the new EU members (-21%) being at the extremes. Within the EU, all countries except Germany end up as net importers, with those countries that have the most ambitious targets (new members, Netherlands, Spain) at the top of the list (in relative terms). This is also reflected in the welfare consequences, which are most deteriorated in the Netherlands (-0.4%). An other region with negative welfare consequences is the former

Soviet Union: -0.6 %. This region is an exporter of energy carriers and therefore incurs terms of trade losses resulting from the lower energy prices in the post-2012 scenario.

Within the trading block, only the Former Soviet Union acts as a net exporter of permits, while all other countries also import. The import-export structure is further elucidated in Table 4.2, where we have the breakdown of the emission permits used in absolute terms (Mt CO_2).

Table 4.2 Decomposition of emissions in the climate policy intodomestic permits, permits transfered from other Annex-B regions and CDM permits in 2020 in Mt CO_2

	Realization	Domestic	Permits Other Annex-B regions	CDM
EU-25	3301	3011	212	78
Germany	731	749	-26	8
France	324	284	32	8
United Kingdom	512	461	38	13
The Netherlands	186	130	48	8
Italy	380	305	65	11
Spain	226	159	58	10
Rest EU-15	444	362	68	13
Rest EU-25	498	562	-71	7
Rest Europe	267	310	-43	1
Former Sovjet Union	2087	2236	-191	42
Canada	472	432	29	12
Australia	263	261	-4	6
Rest OECD	964	951	-2	15
Annex-B excl. USA	7354	7201	0	153
USA	4805	4805	0	0
Latin America	1874	1935	0	-60
Middle East and Northern Africa	2432	2464	0	-32
China	4599	4646	0	-46
India	1450	1465	0	-15
Non Annex-B excl. Rest of the World	10356	10510	0	-153
Rest of the World	3820	NA	0	0
Permit price in € / t CO_2			18	6

Table 4.2 reveals that the supply of emission permits in the trading block is predominantly from the “hot air” regions Former Soviet Union (191 Mt CO_2), the new EU member countries (71) and the Rest of Europe (43). Smaller contributions are from Germany (26), Australia and the Rest of the OECD. On the importer side of the market, the Rest of the EU 15 (68 Mt CO_2), Italy (65) and Spain (58) are at the top of the list.

The allocation of CDM permits (last column of Table 4.2) is limited to a fixed proportion of emission reduction relative to the baseline. For instance, the amount of CDM in EU-25 can be calculated as 0.1 · 3011 · 0.21 / (1 - 0.21) (with some inaccuracy doe to rounding). A high level of CDM permits in an individual country can therefore either result from a high relative emission target (as in the new EU members, Netherlands or Spain, see Table 4.1) or from a overall high level of emissions (as in Germany, the rest of the OECD and, particularly, the former Soviet Union). The consequence of this construction is that the former Soviet Union is at the same time the largest exporter of permits and the largest importer of CDM measures. The share of CDM in actual emission reduction shows a considerable spread across regions, from 34% in the UK to 17% in the Netherlands.

While the import structure of CDM is fixed in proportion to the baseline emissions, the export structure is determined by GDP shares. Over all participating countries (excluding the rest of the world), the share of CDM in total emission volume is about 1.5%. In China and India, the share is at a low 1%, while it is considerably higher in the Middle East and especially in Latin America (more than 3%). This reflects a lower emission intensity of GDP in the latter region.

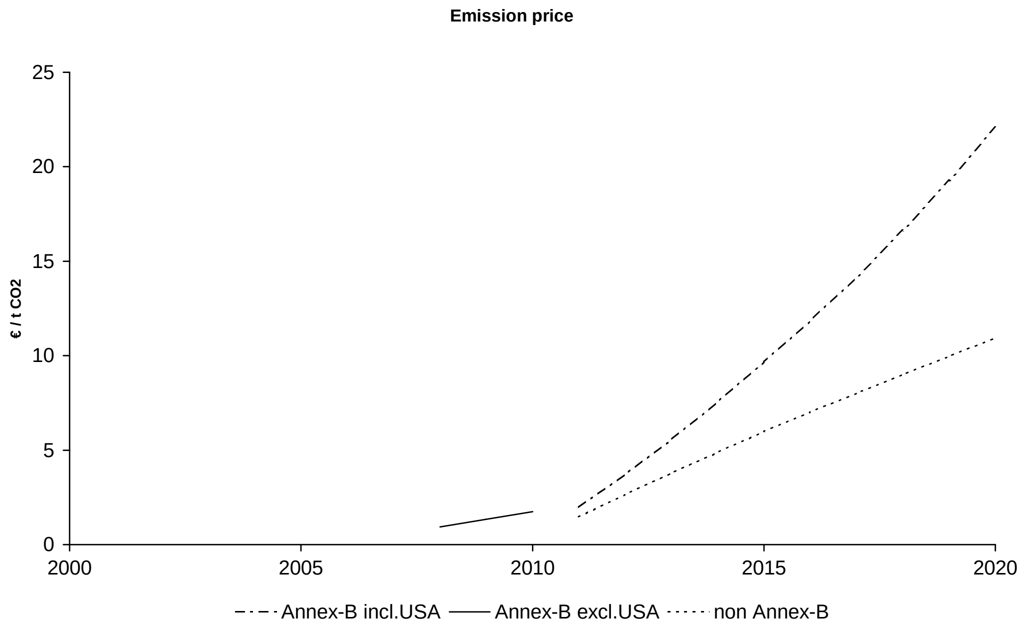
5 Integrated trading block in Annex B

The results of the basic scenario in Section 4 suggest that there is some scope for efficiency gains through an integration of permit trading in the US and the rest of Annex B. We saw that the permit prices are more and more diverging over time (Table 4.1), with a final difference of 18 € / t CO_2 (34 in the US vs. 14 in the rest of Annex B). Integrated trade would thus lead to a considerable adjustment of marginal abatement costs in the Annex B countries.

We explore this option in a variant of the basic scenario, where we allow permit trade between the US and the rest of Annex B. The individual emission targets are the same as before, and the assumptions about the non-Annex B countries are unchanged as well. The only further difference with the basic scenario is that the US now also participates in CDM. Here, we apply the same rule as for the rest of Annex B before: The amount of CDM is 10% of the emission reduction with respect to the baseline emissions.

Figure 5.1 (as an analogue to Figure 4.2 for the basic scenario) shows the development of traded permit prices and CDM measures over time. The values for the Kyoto Period are unchanged, whereas, after 2010, we now have only one permit price in Annex B, which increases over time from 2 to 22 € / t CO_2. As expected, these values are in between the spectrum in Figure 4.2. With respect to CDM, we now have a higher price (11 € / t CO_2 compared to 6 € / t CO_2 in Figure 4.2), which is mostly a reflection of the increased demand due to the US participation.

Figure 5.1 The emission price in € / t CO_2 (integrated trade scenario)



Tables 5.1 and 5.2 show the results for the individual regions (as 4.1 and 4.2 did for the basic scenario). Table 5.1 shows targets and emissions in relative terms, as well as the welfare indicator, while Table 5.2 decomposes the emissions into domestic permits, imported permits and CDM.

As the emission targets are the same in both scenarios, Table 5.1 shows no difference with Table 4.1 in the target-related columns. With respect to the actual emissions, however, the consequences of the integrated trading block can be seen. As was expected from the higher permit price in the US with no trade, the US now acts as a permit importer, while the rest of Annex B exports. Comparing the columns “Emissions in 2020 compared with the baseline” of Tables 5.1 and 4.1, we see that emissions decrease almost proportionally in the rest of Annex B. The total reduction is now 18% compared to 16% in the basic scenario. Accordingly, emission reduction in the US decreases from 24% to 19%. These differences between the scenarios are also reflected in Table 5.2 (to be compared with 4.2). Here, the columns “Domestic Permits” and “CDM” remain the same (except for CDM in the US), whereas “Permits from other Annex-B regions” adjusts. Here, again, we can see that permit imports decrease (or permit exports increase, respectively) for all Annex B countries except the US. The total trade volume amounts to about 200 Mt CO_2 in 2020.

Besides the integration of permit trading in Annex B, the two scenarios are also distinguished by the US now joining the CDM market. The most direct upshot of this is increased demand on the international CDM market and a corresponding increase in the average CDM price (11 € /

t CO_2 compared to 6 € / t CO_2 in the basic scenario). This almost proportionally affects the CDM prices in all individual non-Annex-B regions.[4]

Table 5.1 Results in 2020 for the integrated trade scenario

	Percentage CO_2 reduction			Emission price	National Income
	Target compared with 1990	Target compared with the baseline	Emissions in 2020 compared with the baseline		
	%	%	%	€ / t CO_2	% change compared to baseline
EU-25	-20	-21	-15	22	-0.2
Germany	-20	-9	-13	22	-0.1
France	-20	-21	-12	22	-0.2
United Kingdom	-20	-22	-16	22	-0.2
The Netherlands	-20	-39	-15	22	-0.5
Italy	-20	-26	-10	22	-0.3
Spain	-20	-38	-14	22	-0.3
Rest EU-15	-20	-27	-13	22	-0.2
Rest EU-25	-20	-11	-24	22	-0.0
Rest Europe	-28	-2	-17	22	-0.0
Former Sovjet Union	-36	-16	-24	22	-0.5
Canada	0	-21	-14	22	-0.3
Australia	0	-19	-21	22	-0.5
Rest OECD	-10	-14	-14	22	-0.1
Annex-B excl. USA	-24	-18	-18	22	-0.2
USA	0	-24	-19	22	-0.1
Latin America	128	0	-6	7	0.0
Middle East and Northern Africa	141	0	-3	3	0.0
China	108	0	-2	0	0.0
India	159	0	-2	1	0.0
Rest of the World	177	0	2	0	0.0
Non Annex-B	137	0	-2	2	0.0

Finally we turn to the welfare implications of the integrated trade scenario (last column of Table 5.2, to be compared with Table 4.2). Although there are overall efficiency gains to be reaped through the equalisation of marginal abatement costs in the US and the rest of Annex B, it is not clear, a priori, how these efficiency gains will be distributed between countries and whether

[4] Recall that the CDM market is not integrated, but the amount of CDM is distributed among the non-Annex-B regions in proportion to their GDM. Furthermore, we assume a tax of 150% on the value of CDM, so that non-Annex-B countries participate in the arbitrage gain. Table 5.1 reports the net-of-tax prices, whereas in Table 5.2, we show gross-of-tax prices.

each region will participate. Figure 5.2 actually shows that welfare is not increasing for all countries compared to the basic scenario. In fact, most of the EU countries are worse off in the integrated trade scenario than with a stand-alone policy of the US.

Table 5.2 **Decomposition of emissions in the climate policy intodomestic permits, permits transfered from other Annex-B regions and CDM permits in 2020 in Mt CO_2**

	Realization	Domestic	Permits Other Annex-B regions	CDM
EU-25	3224	3011	134	78
Germany	715	749	-41	8
France	317	284	26	8
United Kingdom	499	461	25	13
The Netherlands	181	130	43	8
Italy	374	305	58	11
Spain	221	159	53	10
Rest EU-15	434	362	59	13
Rest EU-25	481	562	-88	7
Rest Europe	260	310	-50	1
Former Sovjet Union	2013	2236	-265	42
Canada	456	432	13	12
Australia	254	261	-13	6
Rest OECD	943	951	-23	15
Annex-B excl. USA	7151	7201	-203	153
USA	5163	4805	203	155
Latin America	1811	1933	0	-121
Middle East and Northern Africa	2400	2464	0	-65
China	4553	4646	0	-93
India	1435	1465	0	-30
Non Annex-B excl. Rest of the World	10200	10509	0	-308
Rest of the World	3823	NA	0	0
Permit price in € / t CO_2			22	11

The negative welfare implications for European countries can be decomposed into two effects. First, although the region “rest of Annex B” might gain from permit trading with the US as a whole, there is a marked difference between countries that are permit importers and permit exporters in the basic scenario. As the consequence of integrated trade is an increase in the permit price in rest-of-Annex-B, permit importers are likely to gain, while permit exporters lose. The comparison of Tables 5.1 and 4.1 actually shows that all rest-of-Annex-B countries that gain from the integration are permit exporters.

The status of permit exporter does not, however, warrant gains from the integration. This is the case for Germany, although the difference is below the precision of Tables 5.1 and 4.1. As a second effect, the participation of the US in the CDM market raises the CDM price, which in turn increases the average abatement costs in the rest of Annex B. As always in this kind of analysis, there are also terms-of-trade effects that can blur the welfare outcomes. In the comparison of the two scenarios, we can assume, however, that these t.o.t. effects are small, as the overall level of emission reduction remains the same.

6 Conclusions and discussion

We have presented two possible formulations of a worldwide post-2012 climate policy setup. The concrete mechanisms combined are meant as a rough indicator of possible developments and as a starting point for discussion of alternative scenarios and their consequences. In the formulation of the scenarios, the following aspects turned out to be crucial:

- The baseline development of energy use and emissions. Obviously, the same overall emission target is more demanding under a higher emission profile (or growth) in the baseline. Especially in comparisons of different scenario studies, the calibration to the same baseline is essential.
- The strictness of the individual countries' targets. In our study, we broadly apply stricter targets to countries that are more active in the Kyoto process (EU, Japan). However, depending on the standard of comparison (relative to 1990 emissions, or to the baseline path), targets that look loose at first sight can easily turn out to be quite restrictive in the end. This is the case with the US targets in our study.
- The scope of permit trading blocks. We work with cap-and-trade systems, either two separate ones in the US and the rest of the Annex-B countries, or an integrated one for the whole of Annex B. Whether the American tendency towards isolationism in climate policy is a sufficient reason for a cleavage might be discussed. From economic basic principles it is clear that there are efficiency gains from an integration.
- The initial allocation of permits within the trading blocks. In Europe, we have assumed a proportional reduction with respect to the 1990 emissions. Other allocation schemes would directly translate into different patterns of imports and exports, as well as changes in the welfare effects.
- The extent to which CDM contributes. We integrate CDM into the trading activities, but restrict its volume to a certain percentage of overall emission reduction. For a better empirical foundation of this quota both the technological and organisational feasibility of CDM and political restrictions (the signalling power of "doing something in your backyard") are important.
- The range of countries that contribute to the supply of CDM. We exclude the region "Rest of the World", because the organisation of CDM seems not to be feasible in the medium run in many of the countries included in this region.

The post-2012 scenarios we actually choose as a starting point for the discussion is characterised by relative ambitious targets in the EU and, less so, in the other Annex-B countries. The target for the US seems first not that stringent, if expressed relative to the 1990 emissions. Given the steep increase in the baseline emissions, the target turns out, however, to be quite ambitious and, with separate trading systems, leads to higher permit prices in the US than in the rest of Annex B after 2011. For this reason, we analyse a further integration of the trading regime between the US and the other trading countries as a variant of our basic scenario. From basic economic principles it is clear that there are efficiency gains from such a widening of the market for permits, but it is not clear whether each individual country will actually gain. Political resistance against an integration of permit trade can be expected to be strong in a situation in which the net trading position of the contributing countries are large (because of the abrupt change in net transfers this would imply). We therefore choose the point in time where permit prices are roughly equal (around 2011 in the basic scenario, see Figure 4.1) as a good candidate for a further integration step.

The outcome of the comparison of the scenarios with and without integrated trade is that in the integrated market the US will act as a permit importer, while the rest of Annex B exports. In terms of welfare, the US gains from the integration, while the outcome in the rest of Annex B is mixed. Most European countries lose because they are permit importers (although the rest of Annex B as a whole is an exporter) and are negatively affected from the increase in the permit price. Only regions that export permit individually can gain from the integration. As a second effect, the participation of the US in the CDM market drives the CDM price up, which is also detrimental for the rest of Annex B.

Although our model captures many important aspects of economic developments and climate policy, there are – as in any model – also a number of loose ends that deserve discussion. At the same time, these are the points that suggest themselves for further model developments and comparative scenario studies.

- We model only CO_2 emissions in a narrow sense. Other greenhouse gases do not enter the picture. This can be justified to a certain extent, because CO_2 has by far the largest share in the man-made greenhouse effect. Furthermore, the modelling activities required by the other gases are much broader than our energy-system focused approach. Nevertheless, the issue of "what"-flexibility is neglected in this way.
- Carbon sequestration, as an important option to reduce emissions at higher levels of permit prices, is not included in the model.
- Neither is there any other backstop-technology, which would deliver carbon-free energy at a certain, pre-determined level of costs. Depending on the cost level where one would expect the

backstop technology to enter, this might or might not be relevant for the scenario we describe in this paper.

- The permit price seems to be relatively low compared to other studies with similar scenarios. Partially this is an effect of the general equilibrium setup of the model. In such a model, with additional substitution possibilities in production and consumption, and thus more overall flexibility of the economic system, lower prices than in pure energy-system models are to be expected. However, even in the set-up of our model, differences in the steepness of the marginal abatement cost curves are possible (through adjustments in the elasticity of substitution between the energy carriers themselves and complementary equipment). Here a further systematic comparison with results from bottom-up studies is desirable.
- In the current setup, CDM is modelled as a uniform tax in the participating non-Annex-B countries. The corresponding assumption is thus that these countries follow an efficient abatement strategy. An alternative approach to CDM would be to treat it like a technological standard, so that the introduction of a shadow price of emission-producing inputs does not lead to a rise in the price of the goods produced.
- Another overall volume of CDM or another allocation pattern, both with respect to the country of origin and the importing country, might be experimented with.
- Without any complementary measures, the welfare gain from CDM would be unilaterally with the importing countries. Therefore we add a tax of 150 % on the value of CDM permits. which transfers part of the welfare gain back to the developing countries. Other values of this tax are possible, based either on the empirical evidence on CDM transactions or equity considerations.
- Permits are allocated according to independent targets by country. Here other, more interdependent schemes are conceivable. This, however, would bring the question of a worldwide fair distribution into the picture, which has often proved to be detrimental to progress in the negotiations. There is much in favour of circumventing it.
- Emission targets for the non Annex-B countries have only be introduced to avoid leakage. Those non-Annex-B countries that participate in the climate policy through CDM have committed themselves to not exceeding their baseline emissions (which might occur through leakage). For large non Annex-B countries like China, India or Brazil, tighter targets would make a considerable difference for worldwide emissions. However, this again would involve the discussion about a worldwide fair distribution of permits.
- The model is exclusively formulated in absolute emission targets. Given that relative targets (intensity targets with respect to GDP) play an important role in the policy discussion, one might think about implementing them in the model. However, this would only make a difference for the results insofar as growth is endogenous. As the growth effects of climate policy are moderate (at least for targets in the range that we explore in the scenario of this paper), the quantitative effect of the extension is most probably small.

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