Scenarios for differentiating commitments : a quantitative analysis

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9. Scenarios for Differentiating Commitments: *A Quantitative Analysis*

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As emphasized in the latest Intergovernmental Panel on Climate Change (IPCC) report, stabilization of greenhouse gas (GHG) atmospheric concentrations is needed in order to delay and reduce damages from climate change (IPCC 2001d, Q6.9). The previous chapters in this volume qualitatively discuss paths toward future global participation in this effort to mitigate climate change. Various proposals are analyzed, ranging from principle-based allocation methods to more pledge-based, country-tailored approaches. All of them could contribute to achieving the ultimate goal of the 1992 United Nations Framework Convention on Climate Change (UNFCCC), which is to stabilize GHG concentrations at a safe level.

This chapter examines three worldwide scenarios of differentiated commitments from a quantitative perspective. Each scenario is drawn from a proposal analyzed in this volume. The Per Capita Convergence scenario allocates emission allowances to countries based on population. The Relative Responsibility scenario shares emission reductions according to the countries' respective responsibilities for climate change. The Emissions-Intensity Target scenario frames the mitigation effort on the basis of reductions in carbon intensity. Based on a long-term concentration stabilization goal, each scenario focuses on the period 2010 to 2030. The POLES model (described in Appendix 9A) is used to investigate the carbon dioxide (CO_2) emission limitations needed to meet an intermediary environmental goal in 2030, and their distribution across countries.[1]

This chapter shows how differentiating commitments based on various proposals could be translated into operational terms and used to induce Annex I countries to further take the lead in a global participation framework to limit CO_2 emissions. It illustrates several issues raised in the previous chapters and may provide useful information for future climate change negotiations. The findings show how the three differentiation scenarios yield varying CO_2 emission allowances and abatement costs across countries.

Section I presents the assumptions and methodology used in the analysis throughout the chapter. Sections II, III, and IV discuss the distribution of emission allowances implied by each scenario. Section V compares the scenarios with respect to emission allowances and permit trading.

I. Assumptions and Methodology

The environmental goal at the center of this analysis is stabilization of atmospheric CO_2 concentration between 450 and 550 parts per million by volume (ppmv) by 2100. This long-term target range corresponds to the lowest CO_2 concentration targets adopted in the emission mitigation scenarios examined in the latest IPCC report (IPCC 2001c). This represents, at most, a *doubling* of CO_2 atmospheric concentrations compared to pre-industrial levels. Stabilization at such a level could still entail potentially serious damages attributable to climatic changes.

Consistent with a 450 to 550 ppmv CO_2 stabilization goal, an intermediary goal is set at 9.4 billion tons of carbon equivalent (GtC) for 2030. This constitutes the *maximum* level of annual world CO_2 emissions. The reason for this intermediary target stems from the trajectories for CO_2 emissions from fossil fuel combustion drawn in the IPCC Third Assessment Report, from 1990 onward (IPCC 2001c). To achieve concentration stabilization between 450 and 550 ppmv, most of the fossil fuel CO_2 mitigation scenarios reviewed by the IPCC show similar inverted U-shaped emission trajectories. The inverted U-shaped emission trajectories mean that, after a period of growth, emissions reach a maximum between 2020 and 2060, stabilize for a time, and finally decline at a different rate (IPCC 2001c, 130, 150). The maximum emission level ranges from 6 to 15 GtC per year in the IPCC review. The maximum emission level of 9.4 GtC in 2030 is in the lower range of these trajectories.

This analysis uses the POLES model, a partial equilibrium model of the energy sector, and the ASPEN software.[2] Thus, only CO_2 emissions from fossil fuel combustion are taken into account.[3] Countries are considered either individually or on a regionally aggregated basis. The assumptions for 2010 emissions are designed to reflect current conditions (Box 9.1), with global emissions reaching approximately 7.8 GtC in 2010. Between 2010 and 2030, CO_2 emissions increase from 7.8 GtC to nearly 12 GtC. This reflects a business-as-usual (BAU) trajectory, whereby no action is taken to mitigate CO_2 emissions.[4]

Box 9.1. Assumptions for 2010 Emission Levels

- All *Annex I countries* except the United States and the economies in transition are assumed to reach their Kyoto targets.
- *The United States* is assumed to achieve the Bush administration's target, which is to cut the greenhouse gas intensity of economic production by 18 percent between 2002 and 2012 (White House 2002).
- The emissions of the *former Soviet Union and other Eastern European countries* are assumed to equal the business-as-usual (BAU) projections (which are far below their Kyoto targets, due to economic slowdown).
- *Non-Annex I emissions* follow the model's BAU projections, because non-Annex I countries do not have binding targets under the Kyoto Protocol.

The intermediary environmental goal of limiting global emissions to 9.4 GtC by the year 2030 thus represents an overall reduction of emissions of nearly 2.6 GtC in 2030, relative to the BAU case. This chapter examines how this reduction may be distributed among countries according to the three differentiation scenarios and the associated economic outcomes. As with most models, the results in the following sections are best interpreted in relative terms rather than absolute figures.

II. The Per Capita Convergence Scenario

As pointed out in Chapter 8 of this volume, the distribution of emission allowances based on a per capita rule is a resource-sharing issue, namely, a global emission budget to be equally allocated among all the people of the world. The Global Commons Institute and the Center for Science and Environment have played important roles in developing and advocating per-capita-based approaches since the early 1990s (See Meyer 2000, Agarwal and Narain 1991).

Given the wide discrepancies among countries' current levels of per capita emissions, convergence to an equal per capita allowance level may require a few decades to become politically acceptable to today's high per capita emitters. The Per Capita Convergence scenario sets the emission convergence year at 2050, meaning that by then, per capita emission allowances will be the same in all countries: 0.95 tons of carbon equivalent (tC) per year. The transition period—2011 to 2049—is divided into three

Box 9.2. Countries' Emission Allowances Under the Per Capita Convergence Scenario

For each year, the calculation is completed in two steps:

1) Calculation of country i's emission share

The calculation is based on one of the equations proposed by the Global Commons Institute (GCI 2002) to achieve convergence to a standard value.[1]

$$S^i_y = S^i_{y-1} - (S^i_{y-1} - P^i_y)* \exp^{(-a*(1-t))}$$

where

S^i_y is the emission share of country *i* in year *y*.
P^i_y is the population share of country *i* in year *y*.
a is the "convergence coefficient" (set to 4). The higher the value, the later the convergence occurs. Setting *a* to 4 corresponds to a convergence trend beginning between 2020 and 2030.
t is the elapsed time ratio between starting year (2011, t=0) and convergence year (2050, t=1).

2) Calculation of country i's emission allowance

$$A^i_y = S^i_y * B_y$$

where

A^i_y is the emission allowance of country *i* in year *y*.
S^i_y is the emission share of country *i* in year *y*.
B_y is the global CO_2 emission budget of year *y*.

Source: Adapted from GCI (2002).

[1] The exponential convergence function was chosen in the present Per Capita Convergence scenario because it makes the transition smoother in the early years. GCI also proposes a linear convergence function, which is simpler and "removes the arbitrary and possibly contentious speed-of-convergence parameter 'a' from the model." See GCI (2002).

subperiods and reflects the most common curve identified by the IPCC for emission trajectories in concentration stabilization scenarios. From 2010 to 2030, global emissions grow in a linear fashion from 7.8 to 9.4 GtC. They stabilize for the next 10 years and finally decrease by 1 percent per year from 2040 to 2050. Thereafter, these yearly carbon budgets are then allocated to countries on the basis of population. The calculation of a country's emission allowance is described in Box 9.2.

Table 9.1. Emission Allowances in the Per Capita Convergence Scenario

	BAU	*Per Capita Convergence Scenario*	
Countries	**2030 Emissions (MtC)**	**2030 Allowances (MtC)**	**Reduction (–) or increase (+) in emissions relative to 1990 (%)**
Annex I			
United States	1,951	878	–34
European Union	1,067	598	–31
Japan	331	202	–31
Australia and New Zealand	158	64	–19
Former Soviet Union	944	466	–51
Other Economies in Transition	282	181	–34
Annex I, all others	210	90	–35
Non-Annex I			
Brazil	226	230	+322
Mexico	183	156	+93
India	1,180	1,333	+713
South Asia, excl. India	179	501	+2130
China	2,395	1,777	+173
South Korea	249	96	+48
Southeast Asia	921	789	+270
Africa	716	1,231	+626
Gulf States	473	293	+111
Non-Annex I, all others	516	516	+195
World	11,981	9,400	+66

Source: Calculated using POLES model.
Note: See Appendix 9B for the definition of geographic regions.
Abbreviations: Business as usual (BAU), millions of tons of carbon equivalent (MtC).

Table 9.1 shows the emission allowances by 2030 and compares them with BAU emission levels and the relative change since 1990. As expected, considering their current high emissions per capita, Annex I countries would have to considerably reduce their emissions relative to both the BAU case and 1990 levels.

Within the non-Annex I countries, the situation is different: The 2030 allowances would be greater than the 1990 emissions, which would give them an opportunity to expand their economies and subsequent emissions to meet some of their development expectations. Some of the countries would need to reduce their emissions compared to 2030 BAU levels.[5] Others, currently low per capita emitters, would have allowances greater than the 2030 projected BAU emissions. In other words, they would be allocated more emission allowances than the model projects they will need. This is due to a combination of factors, such as their low current levels of emissions per capita, their future economic prospects as estimated in the model, their population growth pattern, and the level of the convergence target by 2050.

III. The Relative Responsibility Scenario

The Relative Responsibility scenario distributes required yearly emission reductions according to an indicator of relative responsibility for climate change. This scenario is similar to the variant of the Brazilian Proposal suggested in Chapter 7 of this volume; it defines responsibility on the basis of *cumulative* CO_2 *emissions*, rather than in terms of contribution to global warming, as in the original version of the Brazilian Proposal. Here, cumulative emissions since 1900 are used as a proxy to assess historical responsibility for global warming, partly because the CO_2 emissions estimates exist (from fossil fuel use only) and may be used with reasonable confidence.[6] In addition, as pointed out in Chapter 7, "expressing responsibility in terms of *cumulative emissions* over time... reduces the need for complex scientific models and associated uncertainties…." Relative to the Brazilian Proposal approach to determining responsibility, this scenario places a somewhat greater burden on countries that industrialized early.[7]

Several other features of this scenario are also consistent with modifications of the original Brazilian Proposal as suggested in Chapter 7. First, this scenario is applied to all countries of the world, not just industrialized countries. Second, it is based on emission reductions *relative to the BAU case* to reach the 2030 environmental target of 9.4 GtC. This target was chosen because the original Brazilian Proposal is only conducive to absolute emission *reductions* (not to increases), and the 2030 intermediary environmental goal used here leads to an *increase* in emissions relative to 1990.

The yearly global emission budgets are the same as those used for the Per Capita Convergence scenario.[8] This allows a comparative analysis between scenarios. The yearly global CO_2 emission reductions are thus the difference between the global BAU yearly emissions and these yearly global budgets. The yearly global reductions are then distributed to each country in proportion to their relative responsibility for CO_2 emissions since 1900 (see Box 9.3).

Box 9.3. Distributing Emission Reductions Based on Relative Responsibility: An Example

The following steps are used to calculate the emission reductions that the United States would have to achieve in 2030.

1) Calculating estimated 2030 global CO_2 reductions:

2030 business-as-usual (BAU) global emissions (POLES model) = 11,981 million tons of carbon equivalent (MtC)
2030 emission budget = 9,400 MtC
2030 global reductions = 2030 BAU global emissions – 2030 emission budget = 11,981 – 9,400 = 2,581 MtC

2**) Calculating 2030 U.S. relative responsibility:**

U.S. cumulative emissions from 1900 to 2020: 111.3 GtC
World cumulative emissions from 1900 to 2020: 421 GtC
U.S. cumulative emissions as percentage of the world cumulative emissions from 1900 to 2020 = 26. 43%

3) Calculating the U.S. emission reductions relative to BAU in 2030:

It is the product of global reductions and the ratio of U.S. relative responsibility = 2,581 * 26.43 % = 682 MtC

Relative responsibility is measured as the ratio of the cumulative emissions of a country to the world cumulative emissions. As in the original Brazilian Proposal, it is updated every 5 years. The 2005 responsibility ratio for a country accounts for emission reductions from 2011 to 2015, the 2010 ratio is used for reductions between 2016 and 2020, and so on. By using the 2005 ratio to define reductions from 2011 to 2015, the methodology reflects the lag between actual emissions and their official inventory and reporting.

Unlike the Per Capita Convergence scenario, this allowance allocation requires all countries to reduce their emissions below BAU by 2030 (Table 9.2). Annex I countries, however, bear a greater responsibility for cumulative emissions and thus have more stringent reductions to achieve. The earlier- and/or more heavily-industrializing countries bear the brunt of the required reduction. Simultaneously, the 2030 emission allowances for the non-Annex I countries are greater than their respective 1990 levels, giving them room to achieve development goals.

Table 9.2. Emission Allowances in the Relative Responsibility Scenario

	BAU	*Relative Responsibility Scenario*	
Countries	**2030 Emissions (MtC)**	**2030 Allowances (MtC)**	**Reduction (–) or increase (+) in emissions relative to 1990 (%)**
Annex I			
United States	1,951	1,269	–5
European Union	1,067	570	–34
Japan	331	236	–19
Australia and New Zealand	158	126	+59
Former Soviet Union	944	654	–32
Other Economies in Transition	282	173	–37
Annex I, all others	210	146	+6
Non-Annex I			
Brazil	226	199	+264
Mexico	183	152	+88
India	1,180	1,078	+557
South Asia, excl. India	179	165	+635
China	2,395	2,101	+223
South Korea	249	220	+239
Southeast Asia	921	830	+289
Africa	716	634	+274
Gulf States	473	408	+194
Non-Annex I, all others	516	439	+151
World	11,981	9,400	+66

Source: Calculated using the POLES model.
Note: See Appendix 9B for the definition of geographic regions.
Abbreviations: Business as usual (BAU), millions of tons of carbon equivalent (MtC).

IV. The Emissions-Intensity Target Scenario

Dynamic targets can be expressed in various forms (see Chapters 5 and 6). This chapter refers to emissions intensity, defined as the ratio of CO_2 emissions to gross domestic product (GDP). This scenario does not demonstrate how intensity targets reduce cost uncertainties (see Chapter 5), but rather illustrates how differentiated commitments can be defined in terms of intensity targets. The scenario is built on country-level targets expressed as relative changes to BAU emissions intensities, rather than absolute changes. If such a scheme were under discussion in the international climate negotiations, absolute levels of emissions intensities would not need

Table 9.3. Emission Allowances in the Emissions-Intensity Target Scenario

	BAU	***Emissions-Intensity Target Scenario***	
Countries	**2030 Emissions (MtC)**	**2030 Allowances (MtC)**	**Reduction (–) or increase (+) in emissions relative to 1990 (%)**
Annex I			
United States	1,951	1,257	–6
European Union	1,067	584	–33
Japan	331	198	–32
Australia and New Zealand	158	83	+5
Former Soviet Union	944	623	–35
Other Economies in Transition	282	186	–32
Annex I, all others	210	102	–26
Non-Annex I			
Brazil	226	205	+275
Mexico	183	166	+105
India	1,180	1,068	+551
South Asia, excl. India	179	161	+620
China	2,395	2,167	+233
South Korea	249	225	+248
Southeast Asia	921	833	+291
Africa	716	648	+282
Gulf States	473	428	+209
Non-Annex I, all others	516	467	+167
World	11,981	9,400	+66

Source: Calculated using the POLES model.
Note: See Appendix 9B for the definition of geographic regions.
Abbreviations: Business as Usual (BAU), millions of tons of carbon equivalent (MtC).

to be compared across countries, obviating the need to agree on an international measurement unit for GDP (see Chapter 5). GDP could be measured in national currencies, rather than U.S. dollars or by using purchasing power parities.

Many simulation options achieve the 2030 emissions target of 9.4 GtC. For example, Annex I countries could improve emissions intensity by 4 percent annually relative to BAU, allowing non-Annex I countries to follow their BAU paths. However, this does not meet the initial assumption that all countries participate in the mitigation effort.

A simulation that meets this participation criterion is one in which Annex I countries improve their emissions intensity by approximately 2 percent[9] annually from their BAU activities, while non-Annex I countries improve their emissions intensity by 0.5 percent. This would amount to a 34 percent improvement in emissions intensity from BAU levels for Annex I countries, and almost 10 percent for non-Annex I countries by 2030.

Improving emissions intensities by 2 percent yearly relative to their BAU levels would imply an approximate 3 percent annual reduction in carbon intensity for most Annex I countries. Intensity changes required to meet the targets in non-Annex I countries would vary more widely, ranging from a 0.5 percent annual intensity increase to a 2 percent decrease. Still, on average, most countries would have to reduce their emissions intensity by around 1 percent annually.

The emission allowances for each country based on this scenario are outlined in Table 9.3. As in the Relative Responsibility scenario, all countries would have to reduce their emissions compared with their BAU levels by 2030. Annex I countries, except Australia/New Zealand, would need to reduce their emissions below 1990 levels,[10] whereas non-Annex I countries could allow their emissions to grow, but at a lower rate than the BAU path.

V. Comparative Assessment

Although the 2030 global emission budget remains unchanged (9.4 GtC), the three scenarios yield different distributions of emission allowances between Annex I and non-Annex I countries (Table 9.4). Namely, Annex I countries would be allocated one quarter of the total global emission budget under the Per Capita Convergence scenario, whereas they would receive approximately one third of all allowances under the other two scenarios. Given the assumptions adopted for each scenario, in all cases Annex I countries need to achieve a greater reduction in their emissions than non-Annex I countries.

As a result of deeper emission reductions in Annex I countries, and despite faster population growth in non-Annex I countries, the 2030 per capita CO_2 allowance for Annex I countries would diminish in all scenarios relative to 1990, while that of non-Annex I countries would increase (Table 9.5). For example, the European Union's per capita allowance would be about 1.6 to 1.7 tC in any of the scenarios, whereas it was 2.4 tC in 1990 and would be 2.8 tC in the BAU case by 2030. In contrast,

Table 9.4. Distribution of CO_2 Emission Allowances Under Three Allocation Scenarios

	1990	2010	2030	2030 allowances		
	Actual Emissions	Projected Emissions	Projected Emissions (BAU)	Per Capita Convergence Scenario	Relative Responsibility Scenario	Emissions-Intensity Target Scenario
Annex I (%)	69	51	41	26	34	32
Non-Annex I (%)	31	49	59	74	66	68
Total (MtC)	5,679	7,832	11,981	9,400	9,400	9,400

Source: Calculated using the POLES model and ASPEN software.
Abbreviations: Business as usual (BAU), millions of tons of carbon equivalent (MtC).

India's 2030 per capita allowance would range between 0.8 and 1 tC in all scenarios, compared with 0.2 tC in 1990 and 0.8 tC in the 2030 BAU case.

From large divergences in projected per capita emissions in 2010, the three scenarios exhibit a trend toward convergence. This result constitutes evidence that per capita convergence may be achieved through various emission-limitation patterns.

The analysis also compares the three scenarios using emission permit trading (Table 9.6). Based on the respective marginal abatement costs of the various countries, and assuming the market in emission permits has opened by 2030, the model calculates a permit price of $97 per ton of carbon equivalent.[11] Countries with marginal abatement costs higher than the permit price would buy allowances to meet their target, while countries with lower marginal costs would sell allowances up to the level at which their marginal cost equals the permit price. The "trade volume" in Table 9.6 refers to the number of allowances (in millions of tons of carbon equivalent) that would be traded. The "total cost to meet the target" corresponds to the cost of reductions achieved domestically and the value of allowances traded. The total cost at the world level is the same in the three scenarios because the global emission target (the environmental goal by 2030) is the same.

The "gains from trade" represent the costs avoided (or, in some cases, benefits generated) with trading. They stem from the difference between the costs that the countries would bear if they achieved their targets solely by reducing emissions domestically and the cost of meeting their targets using emissions trading ("total cost to meet target" in Table 9.6).

Table 9.5 Per Capita CO_2 Emissions Under Three Allocation Scenarios

tons of carbon per capita

	1990	*2010*	*2030*			
				Allowable amount of CO_2 emissions		
	Actual Emissions	**Projected Emissions**	**Projected Emissions BAU**	**Per Capita Convergence Scenario**	**Relative Responsi-bility Scenario**	**Emissions-Intensity Target Scenario**
Annex I						
United States	5.1	5.6	5.8	2.6	3.8	3.7
European Union	2.4	2.4	2.8	1.7	1.6	1.6
Japan	2.4	2.4	2.8	1.7	2.0	1.7
Australia and New-Zealand	3.0	3.1	3.8	1.6	3.1	2.0
Former Soviet Union	3.3	2.0	3.2	1.6	2.2	2.1
Other EITs	2.2	1.9	2.5	1.6	1.5	1.6
Annex I, all others	3.5	3.8	4.1	1.7	2.8	2.0
Non-Annex I						
Brazil	0.4	0.6	1.0	1.0	0.9	0.9
Mexico	1.0	1.1	1.4	1.2	1.1	1.2
India	0.2	0.5	0.8	1.0	0.8	0.8
South Asia, excl. India	0.1	0.2	0.3	0.8	0.3	0.3
China	0.6	1.1	1.6	1.2	1.4	1.5
South Korea	1.5	2.8	4.7	1.8	4.2	4.3
Southeast Asia	0.4	0.6	1.2	1.0	1.1	1.1
Africa	0.3	0.3	0.5	0.9	0.5	0.5
Gulf States	1.2	1.6	1.9	1.2	1.6	1.8
Non-Annex I, all others	0.6	0.7	1.0	1.0	0.9	0.9
World	1.1	1.1	1.5	1.2	1.2	1.2

Source: Calculated using the POLES model and ASPEN software.
Note: See Appendix 9B for the definition of geographic regions.
Abbreviations: Business as usual (BAU), economies in transition (EITs).

Table 9.6 shows that, in general, Annex I countries would buy allowances, while non-Annex I countries are the sellers in each scenario. The total cost to meet the target is typically higher in Annex I countries than in non-Annex I countries, be it in absolute terms or expressed as a percentage of GDP. Annex I countries are required to undertake more stringent reductions and frequently face higher marginal abatement costs than non-Annex I countries.

These generalizations do not apply to all countries in each group. A few exceptions may be noted. In the Relative Responsibility scenario, the Annex I countries of Australia/New Zealand would be sellers. In the Per Capita Convergence scenario, among non-Annex I countries, the Gulf

Table 9.6. Comparison of Economic Impact of CO_2 Emissions Trading Under Three Allocation Scenarios, 2030

Permit price: $ 97	**Per capita convergence scenario**				**Relative responsibility scenario**				**Emissions-intensity target scenario**			
	Trade Volume	Total cost to meet target		Gains from trade	Trade Volume	Total cost to meet target		Gains from trade	Trade Volume	Total cost to meet target		Gains from trade
	MtC	Billion $	% GDP	Billion $	MtC	Billion $	% GDP	Billion $	MtC	Billion $	% GDP	Billion $
Annex I												
United States	557	75.1	0.48	81.9	165	36.9	0.24	4.9	177	38.1	0.24	5.8
European Union	269	33.1	0.21	47.1	297	35.9	0.23	60.7	283	34.5	0.22	53.6
Japan	100	11.0	0.24	26.9	66	7.7	0.17	11.4	104	11.4	0.24	28.6
Australia and New Zealand	41	6.1	0.49	6.3	–21	0.1	0.01	0.6	22	4.3	0.35	1.3
Former Soviet Union	281	35.7	1.27	66.9	93	17.4	0.62	5.0	125	20.5	0.73	9.8
Other Economies in Transition	48	7.0	0.40	3.6	56	7.7	0.44	5.0	43	6.5	0.37	2.8
Annex I, all others	82	9.5	0.47	19.9	26	4.1	0.20	1.3	70	8.3	0.41	14.6
Non–Annex I												
Brazil	–28	–1.6	–0.06	1.6	4	1.5	0.06	0.0	–2	0.9	0.03	0.0
Mexico	–6	0.9	0.04	0.1	–2	1.3	0.06	0.0	–15	0.0	0.00	0.4
India	–415	–28.6	–0.35	28.6	–161	–3.9	–0.05	5.5	–150	–2.8	–0.03	4.8
South Asia, excl. India	–351	–32.9	–1.89	32.9	–15	–0.2	–0.01	0.5	–12	0.1	0.01	0.3
China	–42	24.2	0.13	0.2	–365	–7.2	–0.04	12.2	–431	–13.6	–0.07	16.5
South Korea	110	12.5	0.67	31.6	–14	0.4	0.02	0.3	–19	–0.1	0.00	0.5
Southeast Asia	–65	2.3	0.03	1.4	–106	–1.7	–0.02	3.4	–109	–2.0	–0.03	3.6
Africa	–613	–55.6	–1.38	55.6	–17	2.4	0.06	0.2	–30	1.1	0.03	0.6
Gulf States	97	13.0	0.63	13.6	–17	1.9	0.09	0.2	–37	–0.1	–0.01	1.0
Non–Annex I, all others	–66	–3.5	–0.05	3.5	11	3.9	0.06	0.1	–17	1.2	0.02	0.3
World	(1586)	108.2	0.11	421.6	(717)	108.2	0.11	111.4	(824)	108.2	0.11	144.7

Source: Calculated using ASPEN software. **Notes:** Monetary values are expressed in constant 1995 dollars, using purchasing power parities. A negative sign in the volume of trade corresponds to permit sales. A negative sign in the total cost corresponds to a benefit. See Appendix 9B for the definition of geographic regions. **Abbreviations:** Millions of tons of carbon equivalent (MtC), gross domestic product (GDP).

States and South Korea would be permit buyers and have the highest cost relative to their GDP.

Interestingly, both the Relative Responsibility and the Emissions-Intensity Target scenarios display similar gains from trading. The Per Capita Convergence scenario would induce the highest global volume of trade in emission allowances and therefore the greatest financial gains from trading. This is mainly because emission reductions required from Annex I (and some non-Annex I) countries are higher in this scenario than in the others. As the permit price is the same in all three scenarios, the level of domestic reductions is the same.[12] Thus, on the one hand, in the Per Capita Convergence scenario, these countries would buy more allowances on the permit market to achieve their more stringent reductions. On the other hand, some non-Annex I countries would have opportunities to sell surplus allowances (those beyond their BAU emission projections), thus providing the allowances needed by the buyers.

These countries with surplus allowances gain a net benefit compared to a situation in which there is no climate change mitigation action (that is, their "total cost to meet target" is negative). In the Per Capita Convergence scenario, trading would lead to important monetary transfers to some non-Annex I countries that are less well off (South Asia and Africa). These results reaffirm Aslam's assertion in Chapter 8 that the "inclusion of trading is… deemed essential for the relative success and appeal of the [per capita convergence] approach." However, the comparative results show that emissions trading is important to reducing costs in all three scenarios examined.

Finally, Table 9.6 also shows that the three differentiation scenarios yield varying abatement costs across countries. Some countries would incur the lowest cost in the Per Capita Convergence scenario, others in the Relative Responsibility scenario, and the remaining in the Emissions-Intensity Target scenario.

Conclusion

This chapter illustrates how a few emission allocation proposals may be formalized. Based on the assumption that emission reductions from BAU are needed to reach a predetermined CO_2 concentration level, it shows how the various proposals can help in the near term to meet a long-term environmental outcome. The same emission reduction target from a BAU level is set to allow comparisons among the scenarios.

In the three scenarios considered, Annex I countries must make larger emission reductions than non-Annex I countries. In the Per Capita Convergence and the Relative Responsibility scenarios, this is due to the current and historically higher levels of emissions of Annex I countries, while in the Emissions-Intensity Target scenario, it is a result of how the model is formulated. Non-Annex I countries receive a larger portion of the carbon budget in all scenarios, enabling these countries to continue developing.

Emissions trading reduces abatement costs, allowing all countries to benefit from trading. In general, Annex I countries are the buyers and non-Annex I countries are the sellers. In terms of the costs (relative to GDP) incurred to meet the target, costs are higher in Annex I countries than in non-Annex I countries.

It must be remembered that these results are dependent on the assumptions adopted. First, they rely on the BAU assumptions of the model used, as well as on the model structure. Second, they relate only to CO_2 emissions from the energy sector. The overall picture would inevitably change if all GHGs were included. Furthermore, trade is assumed to occur in a perfectly competitive market at the international level. However, achieving a well-functioning trading market might be challenging (Baumert et al. 2002). The costs presented are only for emission reductions and do not include transaction costs from trading or costs associated with reporting and monitoring emission inventories. Finally, the regional coverage adopted in this chapter (see Appendix 9B) may hide large disparities across the countries that compose each region. For example, within Africa, the economic structures and the emission levels of oil-producing countries, such as Algeria and Libya, are very different from those of sub-Saharan countries. Adopting the more extensive regional disaggregation of the POLES model (38 countries/regions) would partially overcome this drawback.[13] Still, it may be necessary to undertake country-specific analyses for those countries not individually covered by the model, such as the analysis done for South Africa by Winkler et al. (2001).

Some issues were intentionally omitted from the analysis in this chapter; for example, the practical implementation of any of the scenarios or how countries would meet domestic emission reductions internally. The assumption is that these factors would not have changed the outcome of our analysis.

The results show that the three scenarios examined yield varying abatement costs across countries. This has important political implications, as countries tend to be more prone to accept the solution that is the least costly for them. The analysis provides information to countries on the order of magnitude of emission reductions and the associated costs, depending on the scenario used. This information may be helpful to countries in shaping their own negotiating positions. For some countries, none of the scenarios considered may be acceptable from a sustainability standpoint. Of course, the whole spectrum of options for global participation in a climate change mitigation effort is much wider than those analyzed here. Approaches such as Sustainable Development Policies and Measures or the Sectoral Clean Development Mechanism (addressed in Chapters 3 and 4) may also contribute to emission reductions in some countries, while bringing them other development benefits.

This analysis could be further developed to explore the consequences of exempting some countries from emission limitations. The exemption could apply to those countries whose emissions and GDP per capita are very low and that do not significantly contribute to the build-up of global CO_2 emissions.

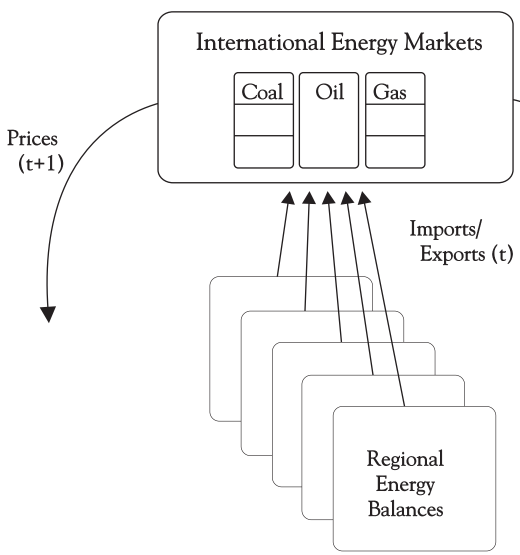
Appendix 9A

The POLES Model: Prospective Outlook on Long-Term Energy Systems

The POLES model was developed at Institut d'Economie et de Politique de l'Energie in Grenoble, France, under research programs funded by the European Union. Operational since 1997, it has been used for policy analyses by various European Commission's-Directorates General (e.g. DG-Research, DG-Environment) and by the French Ministry of Environment.

POLES is a world simulation model for the energy sector. It works in a year-by-year recursive simulation and partial equilibrium framework, with endogenous international energy prices and lagged adjustments of supply and demand by world region. GDP and population are the main exogenous variables.

POLES model structure



In the current geographic disaggregation of the model, the world is divided into 38 countries or regions. For each region, the model articulates four main modules dealing with the following:

- Final energy demand by key sectors
- New and renewable energy technologies
- The conventional energy and electricity transformation system
- Fossil fuel supply

The main outputs are the following:

- Detailed world energy outlooks to 2030, with demand, supply, and price projections by global regions.
- CO_2 emission marginal abatement cost curves by region, and emissions trading systems analyses.
- Technology improvement scenarios—exogenous or with endogenous features—and analyses of the value of technological progress in the context of CO_2 abatement policies.

The main advantages of the POLES model rely on the high disaggregation levels of energy demand sectors, energy technologies, and geographic regions. The detailed representation of the energy sector allows it to endogenously capture the various changes, such as the development and implementation of economically efficient new technologies. The geographic breakout delivers detailed insights on energy variables and CO_2-related emissions for many countries. This feature allows the model to better illustrate the challenges of many countries, and may be useful in the course of the climate negotiations.

See European Commission (1996) for a comprehensive description of the POLES model.

Appendix 9B

Regional Breakdown

The regional breakdown indicates how the 38 countries or regions of the POLES model are aggregated for the purpose of this chapter. A "+" sign means that the countries are grouped to constitute a single element.

United States: United States of America.

European Union: Includes Austria, Belgium+Luxemburg, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

Japan

Australia and New Zealand

Former Soviet Union

Other Economies in Transition: Includes Poland+Hungary+the Czech Republic+Slovenia, Rest Eastern Europe.

Annex I, all others: Includes Canada, Rest Western Europe.

Brazil

Mexico

India

South Asia, excluding India

China

South Korea

Southeast Asia

Africa: Includes North Africa non-OPEC, North Africa OPEC, Egypt, Sub-Saharan Africa.

Gulf States: Includes OPEC countries in the Persian Gulf.

Non-Annex I, all others: Includes Rest Central America, Rest South America, Rest Middle East, and Turkey.

Notes

1. "Countries" is used in this chapter as a generic term covering individual countries as well as geographic regions.
2. The Analyse des Systèmes de Permis d'Emissions Négociables (ASPEN) software was also developed at Institut d'Economie et de Politique de l'Energie (IEPE) in Grenoble, France. It computes regional CO_2 emission allowances according to a given differentiation approach. It then uses the POLES marginal abatement costs to compute the emission permit price and trade flows for any configuration of the emission permit market.
3. Thus, net CO_2 emissions resulting from land-use change activities as well as the emissions of other GHGs are not considered.
4. As in any model, the BAU case is built on many assumptions. For example, the projected GDP annual growth rate of each country, determined exogenously, leads to a worldwide average yearly GDP increase of 2.9 percent between 2010 and 2030.
5. South Korea would obviously have a tremendous challenge.
6. The data source used in the chapter is the World Resources Institute, gathered from EIA (2002b) and Marland et al. (2000).
7. This is because the method used in this scenario does not account for the decay of emissions over time. See Chapter 7.
8. As stated in the previous section, the budgets are defined so that from 2010 to 2030, the global emissions grow linearly from 7.8 to 9.4 GtC.
9. The precise rate is 2.059 percent.
10. Australia/New Zealand and the United States would be in a comparable situation by 2030. Their reductions relative to 1990 levels would not be as stringent as for the other Annex 1 countries because their assumed departure point in 2010 is above 1990 levels (as opposed to the other Annex 1 countries).
11. The permit price may seem high. This may be explained by the fairly high volume of emission reductions.
12. Buying countries will reduce their emissions domestically as long as the marginal cost of these reductions is lower than or equal to the permit price. They will turn to the international permit market for those additional reductions whose marginal cost, if taken domestically, would exceed the permit price.
13. Regional disaggregation results obtained using the POLES model are not presented in the chapter, but can be provided upon request.