

34



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Johan Eyckmans, Denise Van Regemorter and Vincent van Steenberghe

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1 INTRODUCTION

On the 16th of February 2005, the Kyoto Protocol finally entered into force after its ratification, three months earlier, by the Duma, the Russian Parliament. However, since its signature in December 1997, several important events have occurred modifying substantially some key aspects of the Kyoto Protocol. Three of them are likely to seriously affect future greenhouse gas (GHG in the sequel), permit prices, signatories' compliance costs and overall World emissions.

First, during the spring of 2001, the president of the USA declared that his country would not ratify the Kyoto Protocol despite its earlier approval of the Protocol's text in 1997. It is well known that the USA has been, and still is, the major emitter of greenhouse gases both in relative and in absolute terms. Among the Annex B countries, the USA accounts for approximately 38% of total Annex B emissions in 1995. The 2001 USA withdrawal, therefore, brings a considerable weakening of the World's emission reduction objective under the Kyoto Protocol.

Second, the original 1997 Kyoto Protocol already contained provisions for the use of carbon sequestration activities, more commonly labelled "carbon sinks", to achieve emission targets. However, rigorous definitions of concepts like afforestation, reforestation and the like have only been settled during the subsequent Conferences of the Parties (CoP hereafter) in Bonn and Marrakesh in 2001. In addition, quantitative limits have been fixed for land use, land use changes and forestry (LULUCF in the UNFCCC jargon) activities. As many of these carbon sink projects are rather cheap, they are believed to decrease prices for greenhouse gas permits.

Third, following discussions on possible restrictions on the trading of permits, concerns about strategic behaviour of countries like Russia and Ukraine arose. Due to their relatively low emission reduction costs and their relatively generous

allocation of emission permits¹, these countries are likely to be the main and sole permit exporters. Their dominant position in future markets for trading permits has given rise to fears that they might abuse their market power: they might gain from increasing the permits prices through a restriction of their sales.

The main purpose of this chapter is to analyse and quantify the repercussions of these three issues for future GHG permit prices, signatories' emission levels and compliance costs. In terms of methodology, we use the MacGEM model.² MacGEM consists of a set of marginal abatement cost functions (MAC in the sequel) for carbon emissions originating from fossil fuel use. These functions are derived from simulations with a large, top-down general equilibrium model GEM-E3 World. The MacGEM model aims at evaluating compliance costs and permit trading equilibria for the first commitment period of the Kyoto Protocol. It allows for the introduction of trading restrictions, transaction costs and limited accessibility of the Kyoto flexible mechanisms like Joint Implementation (JI) and Clean Development Mechanism (CDM). Moreover, it can be used to assess market power by permit sellers and buyers.

The Kyoto Protocol also allows Parties to bank unused emission permits for use in subsequent commitment periods. This chapter does not deal with this issue because its focus is on the first commitment period. The issue tackled in detail in the next chapter.

This chapter is organised as follows. Section 2 introduces the MacGEM model and the reference scenario. This reference scenario represents the "original" 1997 Kyoto Protocol, which assumes the participation of the USA and does not account for sinks enhancement activities. Section 3 examines the effects of the US withdrawal on the world emissions reduction objective and on the efforts by each Party. In section 4, we approximate the net changes in carbon sinks that might be used by the Parties to meet their emission reduction objective. Section 5 emphasises the key role of Russia and Ukraine on the market and discusses the consequences of strategic behaviour by these countries. Finally, section 6 summarises our results and concludes.

2 MODEL STRUCTURE AND REFERENCE SCENARIO

2.1 MacGEM model structure

MacGEM³ is a numerical simulation model that aims at evaluating carbon emission abatement and permit trading equilibria for the first Commitment Period (i.e. 2008-2012) of the UN Framework Convention on Climate Change. The model distinguishes 15 main regions/countries in the world and simulates

¹ In fact, many of these countries are believed to have an emission permit endowment that exceeds their Business-as-Usual (BAU) emission levels. The surplus of permits over BAU emissions is often referred to as "hot air".

² The MacGEM and GEM-E3 models are briefly discussed in the Appendix of this volume that surveys the models.

³ A Microsoft Excel version of the model is available at <http://www.climneg.be>.

the effects of the flexible mechanisms provided for in the Kyoto Protocol (Joint Implementation JI, Clean Development Mechanism CDM and International Emission Trading IET). The core of the model consists of a set of marginal abatement cost functions that were derived from simulations with the GEM-E3-World general equilibrium model (see Capros et al. (1997)). The MAC functions used in this paper were calculated under the assumption that emission abatement is allocated efficiently at the national level over the different economic sectors, i.e. marginal abatement costs are equalised across all sectors in every country. Implicitly, we also assume that the reallocation of abatement efforts between some countries has no significant effect on the MAC functions of other countries⁴.

The abatement costs in the top-down GEM-E3-World model include, among others, the costs of fuel switching, costs of investing in more efficient energy technologies, insulation costs to increase fuel efficiency in private houses and office buildings, etc. Since the MAC functions were estimated on data generated by a general equilibrium model, our approach incorporates indirect or general equilibrium effects. In this respect, our approach is similar to that of adopted by Ellerman and Decaux (1998); this uses MAC functions that are estimated on data generated by the MIT-EPPA general equilibrium model or den Elzen and de Moor (2002)--whose MAC functions were, in turn, based on the World-Scan model of the Dutch central planning office. A similar approach also underlies the "toy-simulation" model of the EU permit trading market by Böhringer et al. (2004) with MAC functions estimated on simulations with the PACE-EU model. However, Criqui et al. (1999) use the POLES partial equilibrium model to derive their MAC functions.

In the Kyoto Protocol, a market for carbon emission permits is created by assigning emission targets (Assigned Amount Units, AAU hereafter) to every region and allowing them to trade emission reductions. Every country can choose between reducing its emissions more than required by the AAU quatum and selling the surplus in the permit market, or reducing its emissions less than required and buying additional permits in the international market. Assuming price taking behaviour, a free trade market equilibrium for permit trading is defined as a list of emission reduction efforts such that every individual country maximises its expected GDP in 2010. This will be the case when every country reduces its carbon emissions up to the point where its marginal abatement cost is exactly equal to the unique market price⁵.

The intuition behind this behaviour is that countries should undertake all domestic emission abatement projects characterized by a unit cost lower than the market price. If the resulting emission level exceeds the specified ceiling, they should buy emission permits in the international market instead of undertaking more expensive domestic projects. If, on the contrary, the resulting emission

⁴ Simulation experiments with the GEM-E3-World model have shown that the estimated MAC function of a particular country is rather insensitive to the abatement efforts undertaken by the other countries. Hence, changes in the terms of trade as a result of different abatement effort allocations across countries affect the MAC curves only very little.

⁵ For a detailed description of the model, see Eyckmans et al. (2001), 5-7.

level stays below the ceiling, they can sell the surplus at the prevailing equilibrium market price. A graphical illustration of this intuition is provided in the next chapter (see sections 2.1 and 2.2, Chapter 6) that also illustrates the mechanism of banking emission permits.

2.2 Reference scenario: the 1997 Kyoto Protocol

By reference scenario, we mean a situation in which the USA is participating, the possible use of sinks is not accounted for and countries with potential market power do not act strategically. Each of these assumptions will be consecutively relaxed in the following sections.

Due to the unrestricted nature of emission trading within the Annex B group, marginal abatement costs are equalised and amount to 22.0 \$₁₉₉₅/tonCO₂ which is the equilibrium permit price in the first commitment period. However, the Annex B group buys some of its reduction in non-Annex B countries by means of CDM projects. The CDM mechanism is imperfect, however, due to assumed limited accessibility (30%) and transaction costs (20%). The accessibility restriction causes marginal abatement costs to differ between CDM host countries.

Within Annex B, only countries of eastern Europe⁶ (CEU hereafter) export permits (see Table 1). Their permit sales amount to more than 32% of their Kyoto assigned emissions. Approximately half of these sales stand for genuine emission abatement; the other half comes from hot air, i.e. the amount of emissions in surplus of their baseline emissions. Overall, CEU gain more than 2% of their 2010 GDP from engaging in emission trading. All other Annex B regions are net permit importers. High cost regions like Japan (JPN) and Other Europe (OEU) import more than 30% of their assigned amount. The USA and EU15 import approximately 20% of their Kyoto assigned amount. Compliance costs (i.e., abatement costs and the costs of the net purchase of permits/credits) for Annex B together amount to 35.3 billion US\$₁₉₉₅ which represents about 0.11% of 2010 GDP. Total world compliance costs amount to 24.6 billion US\$₁₉₉₅ or 0.058% of 2010 GDP. Annex B compliance costs prove to be larger than world compliance costs. The difference stems from the net benefits made by non-Annex B countries when implementing CDM projects.

⁶ These countries are Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovak Republic, Slovenia and former Soviet Union.

	E	$\Delta E/E0$	XS/AAU	MAC	AC	PC	TC
EU15	3.613	12.3	-22.046	21.963	0.033	0.122	0.155
OEU	0.099	26.3	-31.320	21.963	0.006	0.071	0.078
AUZ	0.327	12.9	-15.986	21.963	0.091	0.173	0.264
JAP	1.345	26.3	-34.359	21.963	0.011	0.103	0.114
CAN	0.500	16.1	-23.531	21.963	0.110	0.262	0.372
Annex B*	5.885	15.8	-24.568		0.029	0.120	0.149
CEU	2.997	-33.6	32.642	21.963	0.560	-2.674	-2.113
USA	5.370	9.4	-17.649	21.963	0.108	0.171	0.279
Annex B	14.252	-1.7	-3.739		0.073	0.035	0.108
MED	0.487	39.2	2.146	4.111	0.004	-0.045	-0.041
MEA	1.084	66.3	3.190	3.895	0.008	-0.096	-0.088
AFR	0.620	50.5	2.531	3.693	0.005	-0.062	-0.057
CHI	3.656	51.6	6.792	2.457	0.017	-0.400	-0.383
IND	0.941	56.4	7.353	1.904	0.010	-0.319	-0.309
ASIA	1.625	95.0	1.770	4.242	0.002	-0.026	-0.024
SAM	1.484	52.3	1.808	4.101	0.002	-0.022	-0.020
ROW	0.760	-7.1	6.575	2.083	0.010	-0.281	-0.271
World	24.908	15.6	0.000		0.058	0.000	0.058

$$p = 22.0 \text{ \$}_{1995}/\text{tonCO}_2 (= 80.5 \text{ \$}_{1995}/\text{tonC})$$

Table 1: the 1997 Kyoto Protocol⁷

3 NON-PARTICIPATION OF THE USA

The non-participation of the USA has a large impact on the permit market. First, global carbon emissions in 2010 would increase by almost 25% instead of 15.6% w.r.t. 1990 emission levels (see Eyckmans et al. (2001) for detailed figures). The global emission reduction objective is therefore drastically weakened by the US withdrawal since the emissions increase under the BAU scenario amounts to 30.1%.

Secondly, and consequently, the price of the permits decreases by more than 50% (10.0 versus 22.0 $\text{\$}_{1995}/\text{tonCO}_2$), since an important share of permit demand disappears. As the World's total emissions objective falls, it is no surprise that compliance costs for the Annex-B* countries (EU15, OEU, AUZ, JAP and CAN, i.e. countries with real emission reduction objectives) decrease by a factor of 2 (see Figure 1). Because of the sharp reduction in the equilibrium permit price, all permit exporting countries are losing revenues from the non-participation by the US. The biggest loser in absolute terms is CEU whose benefits decrease from 2.113% to 0.819% of GDP in 2010. Permit sales revenues of CDM hosting countries are even cut by a factor four. At the same time, world total costs decrease drastically, from 0.058 % to 0.008 % of 2010 GDP.

⁷ Legend for the table. For the name and the composition of the regions and countries, see Table 1 in Appendix. Annex B* includes all Annex B countries except USA and CEU. E denotes 2010 emissions (in GtCO_2); $\Delta E/E0$ denotes the change in emissions between 2010 and 1990, divided by 1990 emissions (in percentage); XS/AAU denotes excess supply for permit (exports (+) or imports (-)) as a fraction of Kyoto target emissions or Assigned Amount Units AAU (in percentage); MAC denotes marginal carbon abatement cost (in $\text{\$}_{1995}$ per ton of CO_2); AC stands for the abatement cost (in percentage of 2010 GDP); PC stands for the permit costs, i.e. the equilibrium permit price times the volume of permits imported or exported (in percentage of 2010 GDP); TC denotes total costs, i.e. $AC + PC$ (in percentage of 2010 GDP).

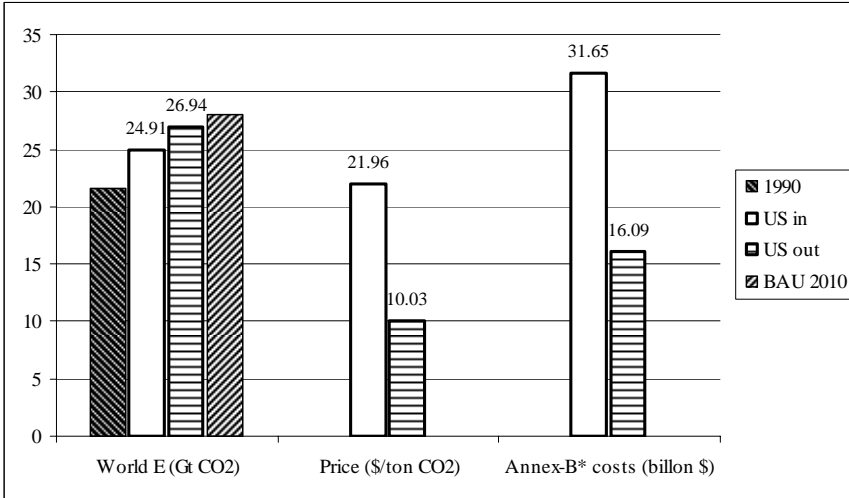


Figure 1: World emissions, permits price and total costs with and without US

For comparison, Böhringer (2001) reports equilibrium carbon prices of 16.9 \$₁₉₉₅/tonCO₂ when US participates and only 1.9 \$₁₉₉₅/tonCO₂ when it does not for the original Kyoto emission reduction targets. We will return to this later.

4 SINKS

The general principle that net changes in carbon sinks can be used by Annex B countries to meet their greenhouse gas emission reduction commitment was already accepted in the Kyoto Protocol (in particular the Articles 3.3 and 3.4). However, the precise definitions of carbon sinks and the way to account for them has been one of the major discussion points during CoP 6 (The Hague), CoP 6 Bis (Bonn) and CoP 7 (Marrakesh). In the final documents issued after the Bonn and Marrakesh meetings, different kinds of land use, land use changes and forestry (LULUCF) activities, which result in net changes in carbon sinks, are distinguished. Each of these activities is subject to different rules and constraints (for the essentials, see Eyckmans et al. (2001) or den Elzen and de Moor (2002)).

As comprehensive data on carbon sinks and costs of LULUCF activities are rare and not reliable, we adopted a rough approximation by assuming that all parties will use sinks in CDM projects and forest management activities up to the maximal levels specified by the Bonn agreement and that this represents a zero cost abatement option.⁸

⁸ For a discussion of this assumption, see Eyckmans et al. (2001). Chapter 11 of this volume discusses the cost estimation of carbon sinks in Belgium.

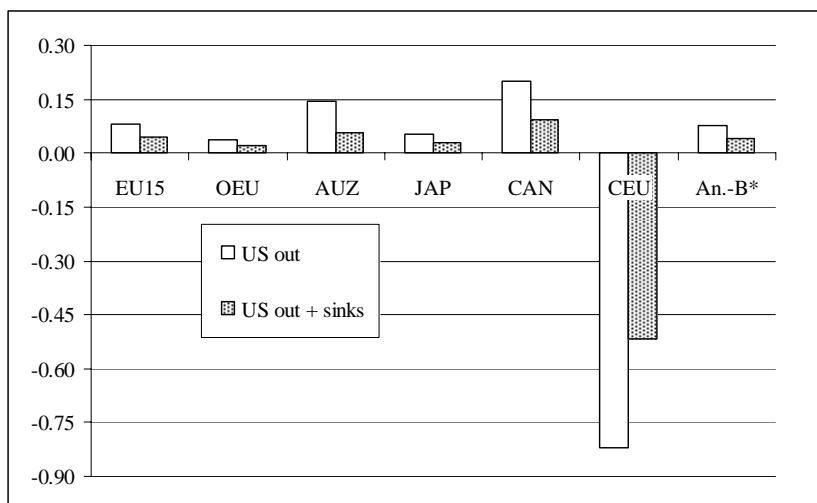


Figure 2: Total costs relative to 2010 GDP (%) for selected regions with and without sinks (US out)

As sinks represent very low cost carbon abatement options, their introduction in our simulation model causes the permits price to fall from 10.0 to 5.4 \$₁₉₉₅/tonCO₂. For very similar scenarios, den Elzen and de Moor (2002) obtain an equilibrium price of 9\$ per ton of CO₂, Manne and Richels (2001) a small but positive price, while Böhringer (2001) even obtains a zero equilibrium carbon price.

Figure 2 shows how this affects the compliance costs of some selected participating countries. Compliance costs for total Annex-B* are cut by half. Among these Annex B* countries, we observe that CAN, AUZ and to a lesser extent JAP, benefit proportionately more than the other countries from the inclusion of sinks. In our opinion, this reflects their strong negotiation power during CoP 6 Bis in Bonn, since their approval was absolutely indispensable to safeguard the future ratification of the Kyoto Protocol. Relative to their 2010 GDP, however, their abatement costs are still the highest of all Annex B countries. Finally, the gains of all permit exporters--hence also CDM revenues in developing countries--decrease as a consequence of the fall in permits price.

5 STRATEGIC BEHAVIOUR BY COUNTRIES OF EASTERN EUROPE

As mentioned in the sections above, Central and Eastern European countries CEU play a key role in the determination of abatement efforts since (i) their AAU are larger than their 2010 BAU emissions (hence they possess so-called “hot air”) and (ii) they are the only permit exporters among Annex-B countries. This raises the issue of strategic restrictions of permits exports by CEU.

As depicted in Figure 3, CEU can exert considerable market power by restricting its permit export if they can coordinate their actions. If CEU exports were to

completely restrict its permit exports, the equilibrium permit price reaches 34.5 \$₁₉₉₅/tonCO₂. Moving from left to right in Figure 3 is equivalent to gradually relaxing the export restriction. The equilibrium price progressively decreases and stabilises at 5.4 \$₁₉₉₅/tonCO₂ when the export restriction becomes non-binding. This occurs at an export limit of about 30% of CEUs AAU. We observe that CEU maximises its gains by selling only 15% of its AAU, which corresponds approximately to its hot air⁹. It would, therefore, be optimal for CEU to sell exactly all its hot air and not to engage in any additional costly emission reduction projects. It should be noted, however, that the overall magnitude of CEU's monopoly gains is relatively small. Furthermore, both trade gains of the CDM regions and compliance costs of permit importing regions increase monotonically because of the increasing permit price.

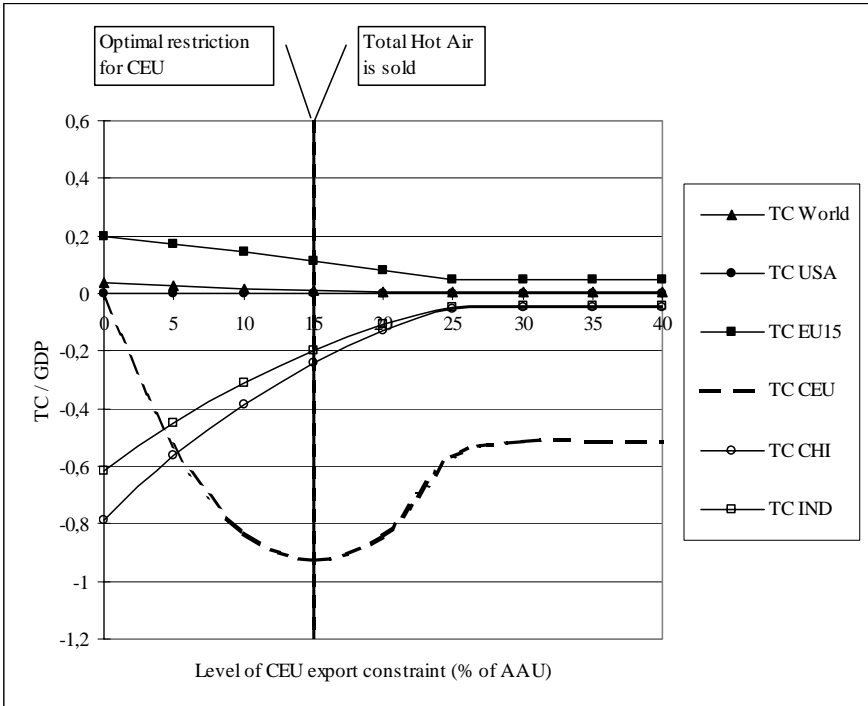


Figure 3: Total costs for different levels of CEU exports

Even if the CEU would sell all of its hot air, we find a positive equilibrium carbon price. In Böhringer (2001), however, the equilibrium permit price would fall to zero because the hot air of the CEU countries is sufficient to cover the reduction obligations of the other Annex-B countries in a scenario which takes into account the nonparticipation of the US and the use of carbon sinks. The

⁹ Sensitivity analysis, however, shows that this is a pure coincidence. For other BAU baseline assumptions for CEU, the amount of permit exports which maximises CEU gains may well differ from its hot air. den Elzen and de Moor (2002) find that the former Soviet Union should bank approximately 40% of their hot air in order to maximize their permit export revenues.

differences between our and Böhringer's results stem from the slightly higher BAU baseline projections we use for CEU.

6 CONCLUSIONS

This chapter assessed the permits prices and the compliance costs following the US withdrawal from the Kyoto Protocol and the Bonn/Marrakesh agreement. The analysis used the MacGEM model which is based on a set of marginal abatement cost functions derived from the GEM-E3-World general equilibrium model.

While in the absence of an agreement on CO₂ emission reductions, world carbon emissions would increase by about 30.1% compared to 1990, the 'original' 1997 Kyoto Protocol would have limited this increase to 15.5%. However, non-participation by the USA causes world emissions to increase by 25.5% in 2010. The equilibrium carbon permit price and Annex-B* (EU15, OEU, AUZ, JAP and CAN) total costs fall by 50%.

The introduction of activities enhancing carbon sinks should not, in principle, modify world net-CO₂ emissions since the discounts on emission reduction obligations are, in principle, compensated for by the uptake of CO₂ by sinks. Although this issue is still quite controversial, it is clear that the introduction of such activities leads to a further decrease of carbon emission abatement efforts. Given the non-participation of the US, our results show that accounting for carbon sinks enhancement activities will lead to a further decrease of Annex-B* total costs by more than 45%.

CEU has the opportunity to behave strategically by restricting its sales of permits. This causes an increase in the permit price of about 50% and, as a consequence, of the compliance costs (about 55% for all Annex B* countries taken together). This effect continues to be operative but is weakened if we assume that emission reductions can only take place via JI projects in CEU. Though the market power effect is relatively small compared to the consequences of the US withdrawal and the inclusion of sinks, our simulations suggest the need to pay attention to market behaviour and to the way emission reductions take place in the CEU countries.

Our analysis also suggests that these results are very sensitive to the performance of domestic abatement policies, the 2010 baseline emissions and the degree of CDM flexibility.¹⁰ When countries do not succeed domestically in equalising the marginal abatement costs of their carbon emitting sectors, the equilibrium permit price and Annex-B* total costs may increase by more than 25%. Sensitivity analysis on baseline emissions illustrates the role of Russia and Ukraine. Given the US withdrawal and the inclusion of sinks activities, lowering baseline emissions of all countries by 10% implies that no more emission reductions are needed to satisfy the Protocol's emission targets. Hot air does the whole job; the equilibrium permit price falls to zero.

¹⁰ For a detailed description of the sensitivity analyses, see Eyckmans et al. (2001).

Hence, the US withdrawal and the inclusion of sinks reduce total compliance costs to 0.037% of Annex B* countries 2010 GDP, while this number would reach 0.149% under the ‘original’ Kyoto Protocol. At the same time, world CO₂ emissions will rise to 26.943 GtCO₂ (plus 0.388 GtCO₂, which should in principle be absorbed by sinks) instead of 24.908 GtCO₂ if the ‘original’ Protocol were to come into force.

It should be clear that the non-participation of the US plus the rather generous way in which sinks can be used to meet one’s reduction commitment, have completely eroded the original 1997 Kyoto Protocol GHG abatement target for the first commitment period. However, together with many others (e.g. Grubb and Depledge (2001)), we believe that the Kyoto Protocol constitutes an important first step towards formulating more ambitious objectives for meeting the ultimate long-term goal of the UNFCCC, i.e. stabilising GHG emissions at a level that will prevent irreversible damage to natural and human ecosystems.

7 ACKNOWLEDGMENTS

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9 APPENDIX

Table 1: geographical coverage MacGEM

Label	Name	Composition
EU15	European Union	
OEU	other Europe	Iceland, Norway, Switzerland
CEU	Eastern Europe and former Soviet Union	Bulgaria, Czech-Rep, Hungary, Poland, Romania, Slovak-Rep, Slovenia, former Soviet Union
AUZ	Australasia	Australia, New Zealand
JAP	Japan	
CAN	Canada	
USA	USA	
MED	Mediterranean	Turkey, Morocco, Algeria, Egypt, Libya, Tunisia
MEA	Middle East	Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen
AFR	Africa	Angola, Benin, Botswana, Burkina-Fasso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Republic of Congo, Djibouti, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Kenya, Leshoto, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Senegal, Seychelles, Sierra-Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
CHI	China	China, Hong Kong
IND	India	
ASIA	Asia	South Korea, Indonesia, Malaysia, Philippine, Singapore, Thailand, Vietnam, Taiwan, Sri-Lanka, Bangladesh, Nepal, Pakistan
SAM	South America	Costa-Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Antilles, Nicaragua, Panama, Trinidad-Tobago, Venezuela, Colombia, Bolivia, Ecuador, Peru, Argentina, Brazil, Chile, Uruguay, Paraguay
ROW	rest of world	

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