

Equity rules for burden sharing in the mitigation process of climate change

Miki Yanagi, Yosuke Munesue, Yasuko Kawashima

Abstract Although international negotiation on the mitigation of climate change is a process of determining burden-sharing rules between countries, there has been no clear agreement on equity principles for burden sharing. During the negotiating process up to the Kyoto Protocol, various proposals were made on such burden-sharing rules, but an agreement on emission targets for Annex I countries was achieved without explicitly agreeing to any rules. In the next phase of the negotiation, debates on emission targets are likely to shift from those between developed countries to those between all parties to the convention. In such a phase, debates on burden-sharing rules will be revisited. The purpose of this paper is: (1) to determine implicitly a formula for the rule for burden sharing between Annex I countries that was considered to be underlying the emission targets of the Kyoto Protocol, and (2) to examine plausible emission targets and timing of commitments for non-Annex I countries in the future by using the result of the analysis on the Kyoto Protocol. A multi-regression method is used for this purpose. It was concluded that the burden sharing between Annex I countries in the Kyoto Protocol

can mostly be explained by three variables: the increase in the rate of CO₂ emission during the years 1990 to 2010, the increase in the rate of afforestation between 1990 and 1995, and the GDP per capita at the time of negotiation. The timing of future commitments of developing countries and the levels of targets differ widely, depending on which index or formula is agreed as “equitable”. Some of the developing countries would have to start limiting their emissions within several years if GDP per capita or CO₂ per capita were chosen as the burden-sharing indicator. Developing countries would not have to make commitments until the mid-late 21st century if population growth rate were chosen. If the inferred formula of the Kyoto Protocol were applied to developing countries, they would have had to start mild limitation from 1990.

Introduction: purpose of the study

Although international cooperation is essential to stabilize the global climate, no general agreements have been made on equity rules for sharing the burden between countries for reduction in the emission of greenhouse gases (GHGs).

In 1992, the United Nations' Framework Convention on Climate Change (UNFCCC) was adopted for the purpose of mitigating global climate change. In Article 3.1 of the FCCC, it is stated that “the parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibility”. The Article, however, does not indicate any specific rule for “common but differentiated responsibility”. In Article 4.2 (a) of the Convention, all the developed countries and economies in transition (EIT) countries (Annex I countries) were urged to return their emission to 1990 levels by 2000. No emission targets were set for developing countries. This rough burden sharing between developed and developing countries could be seen as the only crude, primitive equity rule that was agreed at that time.

The next international agreement on GHG emissions was the Kyoto Protocol, which was adopted at the Third Conference of the Parties to the FCCC (COP3) in December 1997. There, again, emission targets were set only for the Annex I countries, but not for the developing countries. A difference between the FCCC and the Kyoto Protocol was the method of burden sharing between the Annex I countries. Rates of reduction in emission were the same for all the Annex I countries in

Received: 2 March 2000

M. Yanagi (✉)
The Institute of Energy Economics, Japan, 10F Inui-bld.,
Kachidoki, 1-13-1, Kachidoki, Tyuo-ku, Tokyo, 104-0054 Japan
e-mail: yanagi@edmc.ieej.or.jp
Tel.: +81-3-55470215
Fax: +81-3-55470226

Y. Munesue
Tokyo Institute of Technology, 2-12-1, Ookayama, Meguro-ku,
Tokyo, 152-8552 Japan

Y. Kawashima
National Institute for Environmental Studies, 16-2, Onogawa,
Tsukuba, 305-0053 Japan

This paper is based on Miki Yanagi's thesis submitted to acquire master's degree at Department of Social Engineering, Tokyo Institute of Technology. The authors are indebted to Professor Shuzo Nishioka of Keio University, Graduate School of Media and Governance, Professor Tsuneyuki Morita, Tokyo Institute of Technology. This research would not have been possible without their advice. Finally, I would like to thank Dr. Toshio Masui, National Institute for Environmental Studies, who provided valuable data, as well as two anonymous referees. Remaining errors are responsibility of the authors.

the FCCC, but they were differentiated in the Kyoto Protocol. Japan committed to 6%, the United States to 7%, and the EU to 8% reduction from 1990 levels by 2008–2012. These figures were again set without agreeing to any clear principles for the burden sharing. After the COP3, debates on burden sharing are likely to shift from those between developed countries only to those between all parties to the FCCC. In that case, further negotiation between developed and developing countries on equitable criteria for the burden sharing is expected. Developing countries, however, are likely to object to making a commitment, insisting that the point of the equitable burden-sharing rule be clarified first. Therefore, if developing countries take part in the commitment, the current burden-sharing rule should be examined.

The purpose of this paper is twofold. The first purpose is to detect the equity principle that governed the burden sharing between Annex I countries on the numerical targets in the Kyoto Protocol. The second purpose of this study is to indicate plausible emission limitation targets for developing countries in the future by applying several equitable rules including the rule that was derived in the first part of the paper. For the first purpose, the reduction target of the Kyoto Protocol is analyzed by using a multi-regression method, incorporating basic indicators (e.g. population growth rates, Gross Domestic Products) of Annex I countries, and the inferred formula is developed to explain the burden-sharing rule that was implicitly agreed in the Protocol. This inferred formula and several other basic indicators are then applied to the developing countries in order to achieve the second purpose of this paper.

It is often said that the figures for emission reduction targets that were agreed upon were based not on any kind of formula but on political bargaining, and only a few attempts have been made to prove that such a comment is correct. Although no consensus was reached explicitly at COP3 on a single burden-sharing rule or formula, it does not automatically mean that there was no consideration of equity. This paper assumes that an implicit agreement was reached on a burden-sharing rule when the agreement was reached on the emission target in the Kyoto Protocol. By assuming the implicit agreement on the agreed burden-sharing rule, it is possible to discover the rule that negotiators admitted as equitable. This will be an important indication when the negotiation starts in the future to set any emission goals for other countries in the long term.

A number of studies have dealt with an equitable burden-sharing rule concerning climate change negotiation. Rose and Stevens (1993) proposed ten equity principles that may be applied for determining tradable permits of carbon dioxide (CO₂). Kawashima (1997) analyzed the possibility of differentiation between Annex I countries in accordance with the equity rules, which were CO₂ emission per capita, emission per Gross Domestic Product (GDP), energy consumption per capita, and multi-criteria (population, GDP, carbon intensity, temperature, and size of area). On the basis of these rules, "minimum reasonable needs" were extracted. Ringius et al (1998) undertook a comprehensive review of

differentiation debates, and selected three criteria: CO₂ emission per capita, CO₂ emission per GDP, and GDP per capita. Then they evaluated the three criteria for OECD countries by looking at how much national income change might result from burden sharing under the criteria.

The burden sharing between developed and developing countries has also been examined. Smith (1993) pointed out that the responsibility for historical emission should be owed in accordance with historical emission, which was shown by the indicator of "natural debts". This was based on historical use of CO₂ assimilation capacity from 1950 to 1986. With the comparison of the United States and India, the disparity between developed and developing countries was shown. They proposed that the burden-sharing rule should be allocated according to per capita natural debts. Claussen and McNeilly (1998) introduced three criteria, as follows: (1) "The value standards of responsibility" evaluated from cumulative CO₂, total CO₂, CO₂ per capita, and estimated growth of CO₂ emissions; (2) "Standard of living" judged by GDP per capita; (3) "Opportunity" evaluated by energy intensity. As a result, 159 countries were divided into three groups: "Must act now", "Should act now but differently", and "Could act now".

Although many studies have been made on developed countries' burden-sharing rules and on developing countries' future timing to start commitment, there are not many that apply the current equity rule between developed countries to burden sharing between developed and developing countries. If developing countries were going to participate in commitments on the climate change problem, clear equity rules would be necessary. This study attempts to give a suggestion on necessary conditions for starting discussions on commitments of developing countries.

Derivation of a formula for the Kyoto Protocol

In this section we intend to detect a rule for burden sharing between Annex I countries agreed upon in the Kyoto Protocol. Although there was no explicit consensus on a burden-sharing rule in the actual negotiation, we assume in this analysis that an implicit burden-sharing rule was agreed upon when the reduction targets were agreed between Annex I countries. Such an assumption is supported by the work of Rose and Stevens (1993), who examined several equity principles for burden sharing in detail. They pointed out that diplomatic agreement was one of the equity values, and that a final agreement can be considered as an agreement on an equity rule if all parties agreed to it.

In this study, the determination of the implicit rule for burden sharing between Annex I countries was conducted using a multi-regression method. This formula included basic national indicators such as population growth rate and GDP growth rate.

For regressing, independent variables were selected mainly from proposals that were raised from countries during the negotiation meetings for the Kyoto Protocol, called the Ad Hoc Group on the Berlin Mandate (AGBM). The central debate during the process was the method to

Table 1. Proposals of countries on the differentiation of reduction targets (United Nations 1997b)

Country	Proposals of indices or principles for differentiation
Spain, France (EU)	Emission per capita Emission intensity of GDP
Japan	Emission efficiency Emission intensity of GDP
New Zealand	Cost-effectiveness Sink
Iceland	A "formula" considering each country's circumstance $Y_i = A[x(B_i/B) + y(C_i/C) + z(D_i/D) + w(E_i/E_i)]$ Y_i : reduction of emission of greenhouse gases (CO ₂ equivalents) by party i (%) B_i : carbon intensity of party i C_i : GDP per capita of party i D_i : emission per capita of party i E_i : shares of renewable energy of party i out of total energy demand of the Annex I parties B, C, D, E : average of each indicator A : a scale factor to ensure that aimed for reduction in emission is achieved x, y, z, w : weights (total is 1)
Iran	Economic growth (GDP) Historical share of greenhouse gas emissions Dependence on fossil fuels Access to sources of renewable energy Defense budget; population growth Special circumstances Share in international trade
Norway	Differentiated targets considering cost-effectiveness, and emission intensity $Y_i = A[x(B_i/B) + y(C_i/C) + z(D_i/D)]$ Y_i : reduction of emission of greenhouse gases (CO ₂ equivalents) by party i (%) B_i : carbon intensity of party i C_i : GDP per capita of party i D_i : emission per capita of party i B, C, D, E : average of each indicator A : a scale factor to ensure that aimed for reduction in emission is achieved x, y, z, w : weights (total is 1)
Poland	GDP per capita Emission per capita Emission intensity of GDP
Russia	Substantial decrease of emissions

set emission reduction targets for the Annex I countries. Countries made proposals on burden-sharing rules that they considered as the most appropriate. The proposals of these countries are summarized in Table 1. Consequently, Annex I countries and developing countries exchanged their views on the equity of these proposals, but they could not arrive at any agreement on an actual formula and criteria for differentiation. Some countries did not propose any specific indicators, but instead basic principles, such as the "principle of efficiency". In such cases, those basic principles were converted by the authors into indicators that were most likely to express that principle. For example, the "principle of efficiency" was converted into the indicators "CO₂ emission per primary energy consumption" and "CO₂ emission per GDP".

In the Kyoto targets, six gases (carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆)) are included. This analysis, however, considered only CO₂, because of the lack of data for the other gases. The Kyoto targets also include absorption of CO₂ by

forests (sinks) in a specific calculation, the so-called "net approach". In this analysis, an "increase in the rate of afforestation (average 1990–1995)" was used to include a part of a sink. Although this is not exactly the same as is written in the Protocol, the definition of Article 3.3 itself is still under consultation, and it was better to include part of a sink than not to include any. Altogether, 24 independent variables were extracted using this procedure. These variables are listed in Table 2.

Effective independent variables were selected using a step-wise method. Combinations of variables were judged from the F value. The dependent variable in the assumed formula is the limitation and reduction rates agreed in the Kyoto Protocol (e.g. for Japan, -6 will be inserted for Y). As a result, the most explanatory formula is shown as follows:

$$Y = 0.31X_1 + 0.16X_2 - 0.0005X_3 + 0.51$$

(7.99) (3.50) (4.20) (t-value)

where the coefficient of determination adjusted for the degrees of freedom is 0.73, the F value is 33.48, Y is the emission targets agreed to in the Kyoto Protocol, X_1 is

Table 2. Variables for the regression

1	Increase in rate of CO ₂ emission 1990–2010 (%) (United Nations 1998)
2	CO ₂ emission 1995 (thousand tonne) (Carbon Dioxide Information Analysis Center 1998)
3	CO ₂ emission 1990 (thousand tonne) (Carbon Dioxide Information Analysis Center 1998)
4	CO ₂ emission/capita 1995 (tonne) (Carbon Dioxide Information Analysis Center 1998)
5	CO ₂ emission/primary energy consumption 1995 (coal equivalent tonne) (Carbon Dioxide Information Analysis Center 1998; United Nations 1997a)
6	CO ₂ emission/GDP 1995 (coal equivalent tonne) (Carbon Dioxide Information Analysis Center 1998; United Nations 1997a)
7	CO ₂ emission/GDP 1990 (coal equivalent tonne) (Carbon Dioxide Information Analysis Center 1998; United Nations 1995)
8	Primary energy consumption /capita 1995 (coal equivalent tonne) (United Nations 1997a; World Bank 1996)
9	GDP 1990 (M\$) (United Nations 1997a)
10	GDP 1995 (constant price 1990 M\$) (United Nations 1995)
11	GDP 1995 ppp, \$ (World Bank 1999)
12	GNP/capita 1997 (ppp, \$) (Atlas method) (World Bank 1999)
13	Ratio of GDP/capita 1990–1995 (\$) (United Nations 1995; 1997a)
14	International dependency rate of total energy use 1995 (%) (IEA/OECD 1998a; b)
15	Coal production 1995 (Mtoe) (IEA/OECD 1998a, b)
16	Primary energy consumption/GDP 1995 (coal equivalent tonne/\$) (United Nations 1997a)
17	Primary energy consumption 1995 (coal equivalent tonne) IEA/OECD 1998a, b)
18	Increase in rate of afforestation 1990–1995 (average %) (World Bank 1999)
19	Area of forest 1995 (100 ha) (World Bank 1999)
20	Population 1990 (thousand) (World Bank 1996)
21	Population 1995 (thousand) (World Bank 1996)
22	Projected population 2010 (thousand) (World Bank 1996)
23	Projected population growth rate 1990–2010 (%/year) (World Bank 1996)
24	Population density (persons/km ²) (World Bank 1999)

each party's projected increase in the rate of CO₂ emission (year2010/year1990), X_2 is each party's increase in the rate of afforestation (year1990 to year1995), and X_3 is each party's GDP/capita (year 1997) [purchase power parity international \$].

Each term in the above formula can be interpreted as follows. The first term in the inferred formula (X_1 : correlation coefficient 0.67), which has the highest correlation, is the projected increase in the rate of CO₂ emission in 2010, in comparison with that for 1990. This means that the emission limitation and reduction rates are mostly influenced by the business as usual scenario, or the status quo. Those countries expecting their emission to increase maintained their rights to do so. Differences between countries in the present situation or in the future were not taken into consideration.

The second term in the inferred formula (X_2 : correlation coefficient 0.5) is the increase in the rate of affores-

Table 3. The variables related to X_1 [the increase in rate of CO₂ emission (1990–2010)]

Variable	Correlation coefficient
Increase in rate of GDP/capita (1995/1990)	0.55
GNP/capita (PPP) in 1997	0.28
CO ₂ emission/GDP in 1995	-0.27
Primary energy consumption/GDP in 1995	-0.26
Population growth rate during 1990–2010	0.21

tation. The positive coefficient indicates that countries with a low increase in the rate of afforestation from 1990 to 1995 were willing to face strict limitation and reduction targets. Actually, during the negotiation, the United States, New Zealand, Norway, and Canada, whose afforestation rates during 1990–1995 were relatively high, insisted on including sinks in the emission calculation. It may be said that the figures in the Kyoto Protocol would have been very different if the sinks had not been included in the Protocol.

The third term in the inferred formula (X_3 : correlation coefficient -0.09) is GDP per capita, which shows each party's wealth. It may be interpreted that the Annex I countries agreed that wealth could be considered partly when setting emission targets, meaning that high-income countries should have more severe emission targets than poorer countries.

These three variables are the key indicators for burden sharing in the Kyoto Protocol. This result does not conflict with the actual negotiation. Countries that expected higher emission growth were admitted. The sink issue was shown to be significant. Wealthier countries were asked to commit to more stringent reduction targets no matter how CO₂-efficient they were. In contrast, the result may be surprising for some of the negotiators. Of all the proposals on burden-sharing rules during the AGBM process, only GDP per capita was taken into consideration. Many of the proposals were not chosen for the determination of the Kyoto Protocol because they were beneficial for some countries but at the same time disadvantageous for others.

The strongest correlation coefficient between the three variables is the projected increase in the rate of CO₂ emission in 2010, in comparison with 1990. As seen in Table 3, it has a relation to other variables. The inferred formula does not include such indicators as population, carbon intensity, and energy intensity. Taking into consideration its correlation coefficient with other indicators, however, it can be said that such indicators are indirectly taken into account in the formula.

Examining plausible future emission targets for developing countries

Developing countries (non-Annex I countries) declined to set any emission targets in the Kyoto Protocol from the point of view of equity. In the long term, the climate change negotiation may start considering emission

targets for some of the developing countries. In this section, future timing and numerical targets for developing countries are examined by utilizing the result of the previous section. This section will use simple basic indicators proposed by Annex I countries during the negotiation, as listed in Table 2, and also the inferred formula that was developed in the previous section. Here, the targets for developing countries will not necessarily mean “emission reduction” but rather “emission limitation” targets, because countries may set emission targets that allow emission growth, as long as they make efforts to limit the growth.

As for the timing by which developing countries set first emission limitation targets, we assume three cases. These cases were selected under the consideration that developing countries have rights to emit as much CO₂ as they want until they achieve a certain level of today’s Annex I countries.

Case 1. The developing countries commit to emission limitation targets when their GDP per capita increases to a level of the lowest GDP per capita among those of all the Annex I countries today. This case was chosen because GDP per capita was determined as one significant part of the inferred formula in the previous section. The Annex I country with the lowest GDP per capita in 1997 was Latvia (U.S. \$3560/capita). Thus, we assume that a developing country has to set an emission target when it is as wealthy as Latvia was in 1997.

Case 2. The developing countries commit to emission targets when their population growth rates decrease to the level of the highest population growth rate among those of all the Annex I parties today. This case is chosen because of the availability of reliable data for future projection, and, as seen in Table 3, population growth rate was related to the projected increase in the rate of CO₂ emission, the most important variable in the inferred formula. The country that had the highest population growth rate during 1990–2010 among the Annex I

countries was Iceland (14.1%). Any developing country whose population growth rate falls below this rate is assumed to commit to an emission target in this case.

Case 3. The developing countries commit to emission targets when their CO₂ emission per capita reaches the level of the lowest CO₂ emission per capita among those of all the present Annex I countries. The Annex I country with the lowest emission per capita in 1990 was Latvia (1.0 t/capita). Thus, when a developing country produces more emission per capita than Latvia did in 1990, that country has to set an emission limitation target. Although this index is not related to the inferred formula of the previous analysis, it was selected in this section because developing countries have been proposing CO₂ emission per capita as the most important burden-sharing rule for climate change mitigation.

Data for future emission projections of developing countries which are necessary for this exercise were obtained from AIM (1997) on the basis of IPCC SRES A2 scenario (IPCC 2000), in which developing countries are grouped into five regions: Centrally Planned Asia, South East Asia, Middle East, Latin America, and Africa. The result of this simulation is shown in Table 4.

In Case 1 with GDP/capita as well as in Case 3 with CO₂ emission per capita, many of the developing countries will have to commit to some level of emission targets at relatively early dates. For example, Centrally Planned Asia will set its emission limitation target using the year 2009 as the base year in Case 1, and the year 2016 in Case 3. Although the base years will be relatively early, developing countries in all regions will still be able to continue increasing their emissions at relatively high rates. This means that, in these cases, the developing countries will start early and with a less stringent commitment. In contrast, in Case 2 with population growth rate, the result indicated that developing countries do not have to commit to emission targets until relatively late. For example, under this assumption, Centrally Planned Asia will not have to commit to any

Table 4. Timing and numerical emission limitation targets for the developing countries (year). Note: in this calculation, countries are assumed to set emission growth rate for the next 20 years after the base year. For example, the column of Case 1

for Centrally Planned Asia reads the year “2009” and “16%”. This means the region is committed to limit its emission growth to 16% above the emission level of the year 2009 by 2029

Indicator for equity	The threshold Annex I country		Centrally Planned Asia	South East Asia	Middle East	Latin America	Africa
Case 1: GDP per capita (ppp)	Latvia \$3650/capita (1997)	Base year	2009	2008	1997	1997	2024
		Target	+16%	+20%	+37%	+16%	+11%
Case 2: The projected population growth rate	Iceland 14.1% (1990–2010)	Base year	2077	2039	–	2022	2047
		Target	+9%	+10%	–	+2%	+14%
Case 3: CO ₂ per capita (t)	Latvia 1.0 t/capita (1997)	Base year	2016	2024	1990	2000	2028
		Target	+7%	+8%	+32%	+16%	+11%
Inferred formula of the Kyoto Protocol	Annex-I countries	Base year	1990	1990	1990	1990	1990
		Target	+28%	+61%	+32%	+34%	+73%

emission target until 2077. Middle East countries will not have to set targets until far into the future, because their population growth rate is not likely to drop below that of Iceland during 1990–2010.

What if the same formula for the Annex I countries were applied to the developing countries? Here, a numerical reduction target for developing countries is estimated assuming that the developing countries agreed to commit to the burden-sharing rule of the Kyoto Protocol. This result is shown in the bottom row of Table 4. Under this rule, all the developing countries would also have had to start limiting their emission growth from 1990, because in the Kyoto Protocol basically all the countries with emission targets take 1990 as the base year, with only limited exceptions.

This result suggests that the timing for developing countries to commit to emission targets will differ markedly according to the equity indicator to be adopted. In the three cases considered here, the range of commitment years of developing countries would be from 1997 to 2024 if GDP per capita were considered as the equity index, from 2022 to 2077 if population growth rate were considered, and from 1990 to 2028 if CO₂ per capita were used. If the Annex I countries and developing countries wanted to agree on emission targets for the developing countries in the near future, there are basically three options that are suggested from this calculation. One suggestion is to use GDP per capita or CO₂ per capita as the equity principle, and each country starts limiting its emission when it reaches a certain level of GDP per capita or CO₂ per capita. The second suggestion is to use population growth rate as the equity principle. In this case, developing countries will not have to make commitments until mid–late 21st century. If the Annex I countries wished to demand earlier commitment by the developing countries, Annex I countries would have to assist developing countries to lower their population growth rates. The third suggestion is to use a similar formula to that inferred from the Kyoto Protocol, and to set loose emission targets from early stages. This is how the Annex I countries agreed to their targets. This process, however, may not solve climate change because the emissions will not be reduced enough to solve the problem.

There is another point to mention for all the cases examined in this study. In all cases and in the formula, the timing and level of emission targets differ from one region to another. This means that the debates will not only be between developed and the developing countries, but also be between developing countries. Since developing countries are afraid of losing their negotiating power over developed countries and have thus been coordinating their position under the name of G77 + China, developing countries will not have the desire to start any debate that may split the group into smaller groups. To overcome this situation, bargaining with other agenda items such as technology transfer and financial assistance may be necessary.

Conclusion

This paper is intended to develop a formula based upon the rule of burden sharing between the Annex I countries in the Kyoto Protocol, and to show the timing and the rate of emission limitation targets for the developing countries assuming the same formula was applied to burden sharing of the developing countries. These analyses revealed the following findings.

Burden-sharing rule in the Kyoto Protocol

The burden sharing between Annex I countries in the Kyoto Protocol was mostly determined by three variables: the increase in the rate of CO₂ emission between the years 1990 and 2010, the increase in the rate of afforestation between 1990 and 1995, and the GDP per capita at the time of negotiation. From this result, it was shown that the Kyoto target basically accepted the current levels of emission of Annex I countries, as well as existing disparities in emission per capita and energy efficiency between Annex I countries.

Future targets for the developing countries

This study examined the timing and level of emission targets for developing countries under four different assumptions. If developing countries were to commit to emission limitation targets when their GDP/capita reached the level of the current Annex I countries, many of them would have to set a target by 2047. If they were to set emission limitation targets when their population growth rate dropped to the level of the current Annex I countries, they would be able to avoid setting emission targets until 2022 at the earliest. If they agreed to set their emission limitation targets when their CO₂/capita reached the level of the current Annex I countries, they would have to set emission targets by 2028. Assuming that the developing countries agree to set their targets by the inferred formula of the Kyoto Protocol, developing countries will have to limit their emission growth within a range of 28–73% compared with 1990 levels.

All equity indicators and the formula examined in this study could be the basis for setting emission limitation targets for developing countries, but none is perfect. It is important to realize the merits and demerits of each equity rule in order to reach an agreement that is also climate effective.

References

- AIM Project Team (1996) AIM interim paper, IP-95-05. Tsukuba
- Carbon Dioxide Information Analysis Center (1998) Revised national CO₂ emission from fossil-fuel burning, cement manufacture, and gas flaring: 1751–1995; <http://cdiac.esd.ornl.gov/ftp/ndp030/>
- Claussen E, McNeill L (1998) The complex elements of global fairness. Pew Center on Global Climate Change, Washington, DC
- IEA/OECD (1998a) Energy balances of OECD countries, 1995–1996. IEA/OECD, Paris
- IEA/OECD (1998b) Energy balances of non-OECD countries, 1995–1996. IEA/OECD, Paris
- Intergovernmental Panel on Climate Change (IPCC) (2000) Emissions scenarios. Cambridge University Press, Cambridge

- Kawashima Y (1996) The possibility of differentiating targets: indices and indexing proposals for equity. In: Report of a workshop held at the Royal Institute of International Affairs. Royal Institute of International Affairs, London, pp 61-70
- Ringius L, Torvanger A, Holtmark B (1998) Can multi-criteria rules fairly distribute climate burdens? OECD results from three burden-sharing rules. Working paper. CICERO, Oslo, p 6
- Rose A, Stevens B (1993) The efficiency and equity of marketable permits for CO₂ emissions. *Resource Energy Econ* 15:117-46
- Smith K (1993) The basics of greenhouse gas indices. In: Hayes P; Smith K (eds) *The global greenhouse regime: who pays?* UNU Press Earthscan, London, pp 20-49
- United Nations (1995) *Statistical yearbook 1993*, 39th issue. United Nations, New York
- United Nations (1997a) *Statistical yearbook 1995*, 42nd issue. United Nations, New York
- United Nations (1997b) UN Document FCCC/AGBM/1997/2. 31 January 1997. United Nations, New York, pp 39-45
- United Nations (1998) UN document FCCC/CP/1998/11/Add.2. United Nations, New York
- World Bank (1996) *World population projections 94/95 year 1990-2150*. World Bank, Washington, DC
- World Bank (1999) web site <http://www.worldbank.org/data/databytopic/databytopic.html>

