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On the major proposals for carbon emission reduction and some related issues

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We evaluated and ran simulations for seven proposals for the reduction of global CO_2 emissions (e.g., those of the Intergovernmental Panel on Climate Change (IPCC), United Nations Development Program, and Organization for Economic Cooperation and Development). All the proposals ignored the fact that the cumulative CO_2 emissions per capita for developed countries were 7.54 times those for developing countries in the historical period of 1900–2005. These proposals further deliberately allocate 2006–2050 emission quotas to developed countries that are 2.3–6.7 times those to developing countries. This will seriously violate the development rights of developing countries. This paper clearly states that proposals such as that of the IPCC are not suitable references for future international climate change negotiations as they violate the fundamentals of fairness and equity in international relationships and the UNFCCC principle of "common but differentiated responsibilities". Comparing estimates of emissions in China in the scenario of rapid development with low-CO_2-emission technology in the period 2006–2050 with estimates for other countries and groups, we find that China can logically and morally argue for equivalent emission rights even in the case of the strict CO_2 concentration target of 450–470 ppmv.

CO_2 emission reduction, cumulative CO_2 emission per capita, emission rights

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1 Introduction

There is global political consensus at present to control the atmospheric CO_2 concentration below an appropriate level within a certain period, although the scientific community has not yet drawn unanimous conclusions on several core scientific issues such as the sensitivity of the air temperature to the atmospheric CO_2 concentration [1–3]. To achieve exercisable control of the atmospheric CO_2 concentration, a comprehensive global responsibility system that focuses on the future allocation of emission rights to countries must be established and accepted by most countries. However, it is a great challenge to establish a fair and reasonable global responsibility system, and there is a hot debate on the benefits of emission reductions and rights of emissions among nations because (i) CO_2 emissions are a result of most common human activities, such as transportation, smelting, construction, power generation and daily living, (ii) it is difficult to widely apply low-CO_2-emission technologies around the world in a short time frame, (iii) most developing coun-

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tries have not completed their industrialization and urbanization, and (iv) it is difficult for people living in developed countries to give up lifestyles that have high energy consumption. Our understanding is that once an atmospheric CO_2 concentration target is established at a certain time node, the globally permitted CO_2 emission from the present to this time node is fixed, and there then must be an international agreement (proposal) for the assigning of emission reductions to individual countries to meet this target. Although many countries have acknowledged the need to respond to the challenge of global warming, none have committed to controlling emissions in terms of participating in a global responsibility system with a spirit of self-sacrifice.

To date, a number of proposals on how to allocate future emission quotas have been suggested, most of which select possible pathways of emission reduction, while only a few focus on the allocation of future emission rights. Impartiality is a key issue for both types of proposals. This paper assesses seven proposals [4–9] that have significant international influence, focusing on the differences in future emission rights per capita among countries. The evaluation criterion is simply that the larger the difference, the more unfair the proposal. This criterion is selected on the basis that a future emission right is a basic human right, which has been accepted through vigorous debate and demonstration. In addition, a future emission quota for China is suggested by considering the history of the cumulative emission per capita.

2 Outlines of the seven international proposals

The seven proposals selected in this study (five of which are concerned with reducing emissions and the other two with allocating future emission quotas) are listed in Table 1 and briefly introduced as follows.

The first proposal was made by the Intergovernmental Panel on Climate Change (IPCC) (Table 1) and appeared in the IPCC Fourth Assessment Report [4]. The focus of this proposal is to control global warming to within 2°C during the period from the Industrial Revolution to the end of this century. To achieve this target, the proposal suggested the equivalent atmospheric CO_2 (CO_2-e) concentration must be controlled below the level of 450 ppmv by 2050. The unit of CO_2-e concentration was not well defined. If the concentrations of all greenhouse gases (e.g., CH_4 and N_2O) were converted to CO_2-e concentrations, the current CO_2-e concentration would already be about 460 ppmv, so it is impossible to achieve the proposed target of 450 ppmv by 2050. According to the IPCC report, the cooling effect of atmospheric aerosols is approximately equal to the warming effect of greenhouse gases other than CO_2 [10]. Though this point is debatable, it indicates that the CO_2-e concentration reported by the IPCC is approximately equal to the CO_2 concentration. To achieve the CO_2-e target of 450 ppmv, the IPCC proposed the 40 Annex I Parties of the United Nations Framework Convention on Climate Change (UNFCCC) (Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden Switzerland, Ukraine, United Kingdom of Great Britain (GB) and Northern Ireland, and the United States of America (USA)) reduce their emissions by 25%–40% and 80%–95% from 1990 levels by 2020 and 2050 respectively. In addition, it was proposed that Latin America, the Middle East, Centrally Planned Asia, which are non-Annex I Parties (mainly developing countries), reasonably and largely reduce their emissions from the business-as-usual (“general scenarios”) levels by 2020 and 2050 respectively (i.e., these countries should greatly cut down their growth rate of CO_2 emissions, while the emission amount could still augment).

The second one is the G8 proposal (Table 1) by G8 countries (USA, GB and Northern Ireland, France, Germany, Italy, Canada, Japan, and Russia) at the Italy Summit in July 2009. This proposal suggests that the CO_2 emissions due to fossil energy generation and cement production should be reduced by 50% globally and 80% for developed countries by 2050. There was explicitly neither a base year nor a mid-term target or CO_2 concentration target for 2050 in this proposal.

The third proposal was developed by the United Nations Development Program (UNDP) [5] (Table 1). The proposed targets are (i) for the maximum global CO_2 emissions to occur no later than 2020 and (ii) a 50% reduction in emission from the 1990 level by 2050. To achieve these overall targets, the proposed paths of reducing emissions are different for developed and developing countries. Developed countries should reach their maximum emissions in 2012–2015 and reduce their emissions by 30% and 80% from 1990 levels by 2020 and 2050, respectively. Developing countries should reach their maximum emissions in 2020 and can increase their emissions by 80% before that time, but they must reduce emissions by 20% of the 1990 level by 2050. This proposal suggests a target CO_2 concentration in 2050 of 450 ppmv CO_2-e.

The fourth proposal was suggested by the Organization for Economic Cooperation and Development (OECD) [6] (Table 1). In the proposal, 2000 is set as the base year. With a CO_2 concentration target of 450 ppmv in 2050, it is proposed that the global emission reduction should reach 3% by 2030. To meet this target, OECD countries should reduce emissions by 18%, the four BRICs countries (Brazil, Russia, India, and China) could increase emissions by 13%, and other countries could increase emissions by 7%. In addition, it is suggested that global emissions are reduced by 41% by 2050. Consequently, the OECD countries, four BRICs countries, and other countries would need to reduce their emissions by 55%, 34%, and 25% respectively.

The fifth proposal (Garnaut's proposal) (Table 1) was proposed by Garnaut [7], a researcher from Australia. This proposal set 2001 as the base year and 2005 as the start year. To achieve the target of 450 ppmv in 2050, it proposed that global emissions could increase by 29% by 2020 while they must decrease by 50% by 2050. Six groups of countries with different responsibilities for emission reductions were suggested: Australia, Canada, the USA, Japan, the 25 countries of European Union, and developing countries. Among the first five groups, the ranges of suggested emission reductions were 25% (Australia) to 45% (Canada) by 2020 and 82% (the 25 countries of the European Union) to 90% (Australia) by 2050, while for developing countries, emissions could increase by 85% before 2020 but should reduce by 14% by 2050. In addition, this proposal set specific targets for China and India: China could increase emissions by 195% before 2020, but should reduce emissions by 45% by 2050, and India could increase emissions by 97% before 2020, but should reduce emissions by 90% by 2050.

The sixth proposal (CCCPST) (Table 1) was made by several scientists [8] from USA, the Netherlands, and Italy. This proposal emphasizes that, according to the principle of fairness, the task of emission reductions should be undertaken by high-income people around the world. The emission reduction required of a country is related to the ratio of the high-income population in the country to that around the world. The high-income population of a country can be calculated from the income distribution in the country. Four categories of countries were proposed: the USA, OECD countries other than the USA, China, and non-OECD countries other than China. It was suggested that the peak global emission approaches 9.03 GtC a^{-1} in 2020 (1 GtC is 1 billion ton of carbon), which breaks down to 1.39, 2.13, 2.32, and 3.19 GtC for the USA, OECD countries other than the USA, China, and non-OECD countries other than China, respectively. The global total emission was suggested to be 8.18 GtC in 2030, which breaks down to 0.87, 1.69, 2.24, and 3.38 GtC a^{-1} for the USA, OECD countries other than the USA, China, and non-OECD countries other than China, respectively. The base year in this proposal was 2003. The global CO_2 emission from the combustion of fossil fuel in this year was 6.95 GtC based on the data provided by the United States Energy Information Administration [11].

The seventh proposal (Sørensen's proposal) (Table 1) was supposed by Sørensen [9], a researcher in Denmark. The proposal directly allocates emission quotas to different groups of countries from 2000 to 2100. The basis of alloca-

Table 1 Main parameters of the seven proposals

Proposal	Mid-term target (2020)	Long-term target (2050)	Base year	Category
IPCC	Reduction of emissions by 25%–40% for Annex I Parties, and a great reduction of emissions from the base level for non-Annex I Parties (including the Latin America, the Middle East, Centrally Planned Asia)	Reduction of emissions by 80%–95% for Annex I Parties, and a great reduction of emissions from the base level for non-Annex I Parties	1990	Annex I Parties and non-Annex I Parties
G8	–	Reduction by 50%	–	Developed countries and other countries
UNDP	Approaching the summit of emissions	Reduction by 50%	1990	Developed countries and developing countries
OECD	Reduction by 3% (2030)	Reduction by 41%	2000	OECD countries, BRICs countries, and other countries
Garnaut's (Australia)	Increase by 29%	Reduction by 50%	2001	Australia, Canada, United States of America (USA), Japan, 25 European Union countries, and developing countries
CCCPST	Approaching the summit (9.03 GtC a^{-1})	Reduction to 8.18 GtC a^{-1} (2030)	2003	USA, OECD countries other than USA, China, and non-OECD countries other than China
Sørensen's (Denmark)	–	486.27 GtC (cumulative emissions during 2000 to 2100)	2000	13 categories, including USA, China, Western Europe, etc.

tion is "a convergence of future emissions per capita"; i.e., countries with high current emissions should make gradual reductions while countries with low current emissions could increase emissions gradually, and the emissions per capita of all countries would be equal by around 2100. The total emission from fossil fuel combustion and land-use changes was estimated to be 486.27 GtC from 2000 to 2100 in modeling simulations. This amount was suggested to be allocated among 13 groups of countries according to the principle mentioned above: 69.55 GtC for the USA, 12.00 GtC for Canada, Australia, and New Zealand, 17.73 GtC for Japan, 48.82 GtC for Western Europe, 9.27 GtC for Eastern Europe, 21.27 GtC for Russia, Ukraine, and Belarus, 43.91 GtC for the Middle East, 68.18 GtC for China, 49.91 GtC for India, 42.27 GtC for other Asian countries, 23.45 GtC for Latin America, 58.09 GtC for Africa, and 21.82 GtC for international aviation and maritime activity.

3 Evaluation of the seven proposals

To evaluate the above seven proposals, we first simulated scenarios for individual proposals on the basis of their proposed coefficients and then assessed their fairness according to the simulation results. In the course of the simulations, the emission rights per capita for the main emission bodies were highlighted. The basic data used were annual CO_2 emissions from fossil fuel combustion and cement production (obtained from CDIAC) [12] and the population in 2005 and the predicted future population [13]. The method of calculating the quotas of emissions from fossil fuel combustion and cement production using the atmospheric CO_2 concentrations in the start and target years has been introduced in the related literature [14].

It is worth mentioning that none of the seven proposals specified whether reduction calculations were based on a linear or non-linear process. Theoretically, reductions could be achieved in any of three ways: fast-then-slow reduction, slow-then-fast reduction, or linear reduction. The lowest and highest calculated emissions in a particular period were found for the fast-then-slow and the slow-then-fast reduction paths respectively. However, fast-then-slow reduction is almost impossible in practice and the most likely scenario is slow-then-fast reduction because the development and application of clean technologies require time. This can also be seen in the mid-term and long-term emission reduction targets for some countries. If there is no atmospheric CO_2 concentration target (e.g., as in the G8 proposal), the total emission in the case of slow-then-fast reduction is likely to be much higher than that in the case of linear reduction. Most of the proposals set targets for both the emission reduction and the CO_2 concentration, so it is critical to select an appropriate method of achieving both objectives. The emission reductions at different time points were simulated by assuming that the reduction is a linear process because most of the proposals suggest a linear reduction or a near-linear reduction pathway in an indirect manner. The simulation results of the total emissions can be understood as the minimum among all possible scenarios.

There are two important aspects of the IPCC proposal. One is the global concentration target and the other is the task of quantitative emission reductions for the 40 Annex I parties. For the non-Annex I parties, no emission reduction was specified. In this case, we assumed the difference between the total emission capacity to meet the atmospheric target and the emission assigned to Annex I parties was allocated to the non-Annex I parties. To meet the 450 ppmv target in 2050, the total CO_2 emission from fossil fuel combustion and cement production should be less than 255.11 GtC. Using the base year of 1990, to meet the mid-term and final targets, the total emission for the 40 Annex I parties would be 80.04–101.27 GtC from 2006 to 2050, which is 31.37%–39.70% of the total global emission capacity. However, the total populations of the Annex I and non-Annex parties were respectively 1.264 and 5.25 billions in 2005. The allocated emissions per capita for the Annex I parties would therefore be 1.9–2.7 times and 2.3–3.3 times the levels for the non-Annex I parties, calculated with the 2005 population and the predicted future population, respectively.

In the G8 proposal, it is worth noting that (i) only long-term goals are proposed and a base year is not set and (ii) the main emission countries are distinguished into two groups: developed and developing countries. In our simulation, we assumed (i) the developed countries are the 27 high-income countries in the OECD (i.e., Australia, Austria, Belgium, Canada, Czech, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, South Korea, Luxemburg, Netherlands, New Zealand, Norway, Hungary, Portugal, Slovakia, Spanish, Sweden, Switzerland, United Kingdom, and the USA) and (ii) the years of 1990 and 2005 are the base year and start year of emissions respectively. The calculated total global emission was 2.9 GtC for 2050. If a linear reduction from 7.48 GtC in 2005 was achieved, the global CO_2 emission from fossil fuel combustion and cement production would be 231.21 GtC from 2006 to 2050. Taking into consideration of emissions due to land-use changes (supposing future emissions are similar to annual emissions of 1.5 GtC in the past 10 years [15]), the global atmospheric CO_2 concentration would be about 445 ppmv in 2050 (assuming ocean and terrestrial ecosystems absorb 54% of the total emission each year). Of the total emission quota of 231.21 GtC, according to the G8 proposal, developed countries would be allocated 84.23 GtC. The calculated emission per capita was 88 tC using the 2005 population of these countries, which was 3.3 times the value for developing countries. If the predicted future population was used in the calculation, the emission per capita for developed countries would be 3.9 times that for developing countries and would be close to the results of Fang et al. [16] (~ 3.5 times scenario).

In the UNDP proposal, we note two characteristics: (i) the concentration target is the same as that in the IPCC proposal and (ii) both developed and developing countries have increasing-then-decreasing emission pathways and the difference in the timing of the emission peaks is only 5–8 years. In our simulation, we assumed that the year 2014 is the emission peak for developed countries and that their emission growth rates linearly slow down from 0.93% averaged in 1990–2005 to 0 in 2014. Our simulation results are as follows. (i) Total emission for the 27 developed countries would be 3.36 GtC in 2014, which is slightly higher than that of 3.24 GtC in 2005. (ii) If a 30% reduction from 1990 levels was achieved by 2020, the total emission of developed countries in 2020 would be 1.97 GtC, which is only 58.63% that in the peak year of 2014 (it would actually be impossible for them to achieve more than 40% reductions within 6 years). (iii) If an 80% reduction from 1990 levels was achieved by 2050, the total emission would be 0.56 GtC; that is, the total emissions for the 27 developed countries would be 82.56 GtC in the period 2006–2050. This proposal suggests the emissions for developing countries in 2020 are 80% higher than those in the present year. The "present" year, however, was not explicitly defined. Considering the publishing date of the proposal, we assume the "present" was 2005. On this basis, the calculated total emissions for developing countries were 7.64 GtC in 2020. If a 20% reduction from 1990 levels was achieved in 2050, the emission would be 2.38 GtC. Therefore, the total emissions of developing countries would be 238.41 GtC in the period 2006–2050. The above simulation shows that the atmospheric CO_2 concentration would increase to 464.31 ppmv by 2050, which is much higher than the target concentration. The estimated emissions per capita for developed countries would be 2 and 2.3 times those for developing countries, calculated with the 2005 population and the predicted future population, respectively.

The OECD proposal suggests the establishment of a global goal that includes mid-term (2030) and long-term (2050) targets and it divides countries into three groups. If the global emissions reduced by 3% and 41% from levels of the base year of 2000 by 2030 and 2050, respectively, the global emissions from fossil fuel combustion and cement production would be 268.78 GtC in the period 2006–2050. The atmospheric CO_2 concentration, including emissions due to land-use changes, in 2050 would be 452.97 ppmv, which is close to the target concentration of 450 ppmv. Using the mid-term and long-term targets for the OECD, BRICs and other countries, our calculation shows that total emissions in the period 2006–2050 for these three groups would be 120.52, 83.86, and 60.42 GtC respectively. The sum emission is 264.80 GtC, which is close to the simulated global emission (268.78 GtC). In terms of emissions rights per capita, we found that the ratios of emissions rights for the three groups were 4.4:1.3:1.0 and 5.4:1.5:1.0, calculated with the 2005 population and the predicted future population, respectively.

For Garnaut's proposal with a target concentration of 450 ppmv, there is an issue of data self-consistency resulting from three different groupings of emission bodies: scenario I in which the world is considered as one, scenario II in which countries are grouped as developed and developing countries, and scenario III in which countries are divided into eight groups (Austria, Canada, the 25 EU countries, Japan, the USA, China, India, and other countries). In scenario I, if the emissions in 2020 are 29% greater than those in the base year of 2001, while those in 2050 are 50% less, the estimated global total emission from 2006 to 2050 is 289.70 GtC. In scenario II, if the emissions of the 27 developed countries are 31% and 86% less in 2020 and 2050, respectively, than in the base year of 2001, while the emissions for developing countries are 85% greater in 2020 and 14% less in 2050 than in the base year, the emissions from developed countries and developing countries in the period 2006–2050 are 78.18 and 211.95 GtC, respectively, and 290.13 GtC in total. In scenario III, the emission rights for the eight groups from 2006 to 2050 are 2.36 GtC for Austria, 2.97 GtC for Canada, 25.83 GtC for the 25 EU countries, 7.35 GtC for Japan, 38.34 GtC for the USA, 80.51 GtC for China, 26.41 GtC for India, and 132.99 GtC for other countries, totaling 316.77 GtC. The difference in the simulated global total emissions among these three scenarios is as high as 27.07 GtC, indicating that the data self-consistency is not entirely satisfied in this proposal.

The atmospheric CO_2 concentrations in 2050 are 457.51, 457.60, and 463.38 ppmv in scenarios I, II, and III, respectively. In terms of emission rights per capita, the average values in 2006–2050 for developed countries would be 2.1 times and 2.5 times those for developing countries, calculated with the 2005 population and the predicted future population, respectively. In scenario III, for example, of the eight groups of countries, the total emission rights per capita in 2006–2050 on the basis of the 2005 population would be 116.01 tC for Australia, 92.00 tC for Canada, 56.03 tC for the 25 EU countries, 57.51 tC for Japan, 127.88 tC for the USA, 61.32 tC for China, 23.28 tC for India, and 42.55 tC for other countries. The maximum is about 5.5 times the minimum and would be 6.2 times the minimum if the calculations were based on the predicted future population.

The CCCPST proposal directly allocates the emission rights for the main emission bodies at several time nodes and sets 2003 as the start year. Therefore, it is relatively straightforward to calculate the total emissions for the four main emission bodies in the period 2004–2030. The results show emission right of 36.23 GtC for the USA, 54.16 GtC for OECD countries other than the USA, 52.32 GtC for China, and 79.79 GtC for non-OECD countries other than China. The sum of these four groups is 222.50 GtC and the atmospheric CO_2 concentration would be 432.87 ppmv. Correspondingly, the emission rights per capita based on the population in 2005 would be 120.83 tC for the USA, 62.06 tC for OECD countries other than the USA, 39.85 tC for China, and 19.80 tC for non-OECD countries other than China. The ratio of these emission rights is 6.1:3.1:2.0:1.0. If based on the predicted future population, the ratio would be 6.7:3.6:2.2:1.0.

Sørensen's proposal directly assigns emission rights (for both fossil fuel combustion and land-use changes) according to the "Principle of Convergence" to the 13 main emission bodies for the period 2000–2100 and the annual emission quotas per capita for 164 countries. In the period 2006–2050, for example, the assigned emission rights per capita for the USA, Germany, UK, China, and India are 178.74, 111.49, 94.32, 31.76, and 16.79 tC respectively. We note that the emission rights per capita for China and India are respectively only 17.77% and 9.39% that for the USA.

The main simulation results for the seven proposals are summarized in Table 2.

As mentioned above, we assessed whether or not a proposal is fair on the basis of the suggested emission right per capita, or in other words, the larger the difference in the assigned emission rights per capita among countries, the more unfair the proposal. The simulation results for these seven proposals based on the predicted population show that the difference of assigned emission rights between developed and developing countries is varying by a factor of 2.3–6.7 (excluding Sørensen's proposal). Therefore, none of the proposals reflects the principles of fairness and equity. We further reveal their lack of fairness from five aspects as follows.

First, the seven proposals did not take into account the huge historical differences in actual emissions among countries. It is well known that the atmospheric CO_2 concentration increased from 270 ppmv (before the Industrial Revolution) to 380 ppmv in 2005, about 60% of which was contributed by the 27 developed countries with less than 15% of the world population in 2005. Using the cumulative emission per capita as an indicator, we have quantitatively calculated the emission histories of countries and regions with populations of more than 0.3 million during the period 1900–2005 [14]. The cumulative emissions per capita for developed and developing countries were respectively 251.17 and 33.33 tC during this period, which is a difference of a factor of 7.54. On the country scale, the cumulative emissions per capita for the USA, Australia, China, and India were 467.88, 260.62, 24.14, and 10.79 tC respectively, and their ratio was 43.4:24.2:2.2:1.0. UNFCCC stated the principle of "common but differentiated responsibilities", but did not explain in detail why it emphasized responsibilities as being "differentiated" among countries. Our under-

Table 2 Simulated results of the seven emission control proposals

	Global emissions (GtC) (2006–2050)	Projected concentration (ppmv) (2050)	Cumulative emission per capita (tC) (2006–2050) (2005 population)	Cumulative emissionper capita (tC) (2006–2050) (predicted population)
IPCC	255.11	450	63.31–80.10 (Annex I countries) 29.32–33.36 (Non-Annex I countries)	61.23–77.28 (Annex I countries) 23.15–26.22 (non-Annex I countries)
G8	231.21	444.81	88.00 (Developed countries) 26.45 (Other countries)	82.88 (Developed countries) 21.47 (Other countries)
UNDP	321.06	464.31	86.34 (Developed countries) 42.90 (Developing countries)	81.56 (Developed countries) 34.75 (Developing countries)
OECD	268.78	452.97	102.78 (OECD countries) 30.19 (BRICs) 23.57 (Other countries)	95.07 (OECD countries) 26.35 (BRICs) 17.65 (Other countries)
Garnaut	289.70	457.51	81.68 (Developed countries) 38.14 (Developing countries)	77.03 (Developed countries) 30.78 (Developing countries)
CCCPST	222.50 (2004–2030)	432.87 (2030)	120.83 (USA) [a)] 62.06 (OECD countries other than USA) [a)] 39.85 (China) [a)] 19.80 (Non-OECD countries other than China) [a)]	115.34 (USA) [b)] 61.96 (OECD countries other than USA) [b)] 38.10 (China) [b)] 17.22 (Non-OECD countries other than China) [b)]
Sørensen	486.27 (2000–2100)	507.46 (2100)	–	178.74 (USA) [c)] 31.76 (China) [c)] 16.79 (India) [c)]

a) Cumulative emissions per capita for countries or groups from 2004 to 2030 calculated on the basis of the population in 2003; b) cumulative emissions per capita for countries or groups from 2004 to 2030 calculated on the basis of the predicted population; c) the proposal presented the annual emissions per capita based on the predicted population from 2000 to 2100, whereas here we recalculated the emissions for the 2006–2050 period.

standing is that the basis for it is that the huge historic differences in emissions among countries should be taken into fair account when allocating future emission rights among nations. Base on the above analysis, we conclude that all the seven proposals violate the principle of common but differentiated responsibilities.

Second, the seven proposals allocate far greater future emission rights to developed countries than to developing countries. This overrides the legitimate rights of developing countries. To date, no country has avoided increases in CO_2 emissions per capita when the energy consumption per capita has increased in the processes of economic development and national welfare improvement. Countries that have low-carbon economies are the least developed and there has been no case of low-carbon development in the world. Even if there is substantial progress in low-carbon technology in the future, it is not possible to avoid the growth of CO_2 emissions in developing countries resulting from the construction of public facilities, cement production, industrialization, and urbanization because it is difficult to develop actual pragmatic low-carbon technologies for cement production, metal smelting, and long-distance transportation over a long period of time. In addition, the development and production of equipment for the generation of solar energy, wind energy, nuclear energy, and other low-carbon energy forms result in the emission of a large amount of CO_2. A core issue is what principle should be followed for the allocation of emission rights in the future? Our answer is that developing countries should receive greater emission rights than developed countries in the future to ensure their right to development rather than the reverse because emissions per capita for developed countries have historically been much higher than those for developing countries. We further believe that it is essential to distinguish emission rights from actual emissions. The emission right of a country should be calculated on the basis of fairness and equity, while the actual emissions of a country during a certain period should be determined by its historic and current emissions, stage of development, economic pattern, life style of its population, and other factors, and thus, a country's actual emissions could be more or less than their emission rights. The regulation of emissions will be manipulated through a fair trading system, which could be consistent with a domestic "cap and trade" system, to achieve total emission reductions. Once a strict target for the global CO_2 concentration is determined, the global amount of emission is fixed. The emission rights for all the countries would become limited goods. The imbalance between the emission rights and the actual emissions for individual countries can then be adjusted through international trade.

Third, the seven proposals did not particularly consider the great differences in development among countries when establishing the year of peak emissions. They set 2020 as the peak year of global emissions; that is, most developing countries are required to begin reducing emissions from 2020. However, the total emissions of the 27 developed countries have continued to increase in the past 10 years and they will not peak until at least 2010. The UNDP proposal established a peak year for developed countries between 2012 and 2015, which is only 5–8 years earlier than that for developing countries. Ding et al. [14] reported that on the basis of their simulations and in terms of cumulative emissions per capita, some developed countries reached their emission peaks in the 1970s or 1980s, by which time their industrialization and urbanization had been finished for several decades or even a century. In addition, the drop in emissions after peaking was related to transferring of energy-consuming industries to other countries. The total emissions in the USA, Australia, Canada, Japan, and other developed countries have continued to increase in recent years despite this transferring. However, industrialization and urbanization in many developing countries are still at low levels, and the construction of large-scale infrastructure has not even begun in some countries. Increases in emissions are inevitable in these countries even if there are great breakthroughs in low-carbon technologies because (i) the transferring and spreading of these technologies cannot be completed within one or two decades and (ii) there are no available low-carbon technologies for the construction of infrastructure. In short, the seven proposals do not take account of the development gaps between developed and developing countries of several decades and even centuries, and of the increasing populations of developing countries as well.

Fourth, the seven proposals do not reasonably consider the huge differences in the base year emissions among countries when allocating the quotas of emission reductions. The proposals of the IPCC and UNDP, for instance, set 1990 as the base year. The average emissions per capita in this year for the 27 developed countries and developing countries were 3.23 and 0.67 tC, respectively, the former being 4.8 times the latter. Even if the year of 2005 is set as the base year, the difference is still a factor of 4.4. The huge emission differences for the base year would definitely lead to significant differences in the allocation of emission rights in the future.

Fifth, each of the seven proposals has a clear preference for its respective position. For example, the CCCPST proposal was proposed by a scholar group from USA. The results calculated according to its "equitable principles" show that the emission right per capita for the USA is 3 times that for China, 6.7 times that for developing countries other than China, and 1.9 times that for other OECD countries. Garnaut's proposal was proposed by an Australian scholar. In this proposal, although Australia would have the largest long-term emission reduction target, its mid-term emission reduction target is lower than those of all other developed countries, and its emission per capita in the base year is 2.11 and 1.84 times that for the 25 EU countries and Japan, respectively. This proposal comparatively benefits Australia in terms of achieving mid-term emission reductions, although it is stricter in the long-term reduction. Sørensen's proposal made by Danish scholars applies the concept of future convergence in emission reductions. First, this so-called convergence is beneficial to developed countries with high current emissions. Second, the convergence is not achieved until around 2100, meaning that the annual emissions per capita for developed countries are higher than those for developing countries over the next 100 years. Furthermore, the proposal in general is beneficial to Western European countries. The strong tendentiousness of the above proposals by individual scholars can be understood. That the G8 and OECD proposals designed by developed countries tend to benefit developed countries can also be understood. However, it is difficult to understand the IPCC and UNDP proposals, which should be impartial in allocating emission rights and even be in favor of developing countries, to implement the policy of the United Nation's Millennium Development Goals. However, not only do these two proposals fail to take account into the huge differences in historic emissions among countries but they propose as well that the differences increase continually in the allocation of future emission rights. Therefore, it is natural to speculate that these two extremely unfair proposals were mainly designed by scholars from developed countries.

4 Future emission rights of China

It is understandable why China, as the world's most populous developing country, has received worldwide attention in terms of the amount and the trend of its long-term future emissions. Meanwhile, China has its own reasons to fight for greater emission rights: development differs among different regions in China, there is a high level of poverty, the country is only in the mid-stages of industrialization, and the urbanization ratio is only about 45%.

We believe that two questions about the long-term emission rights of China need to be addressed. (i) How much CO_2 does China need to emit in its green development until 2050? (ii) What emission rights should China have considering the response of the international community to climate change following the principles of fairness and equity?

There has been much research to address the first question. For example, the "China's Energy and Carbon Emission in 2050" study group simulated emissions required by China from the present to 2050 under different scenarios, including normal, the low-carbon, and intensified low-carbon emission scenarios [17]. One important conclusion of it is that even in the intensified low-carbon emission scenario, China needs to emit 90.0 GtC by 2050. Ding et al. [14] reported similar stimulation results by assuming that (i) China will reach its emission peak in the year 2035 (corresponding to the period when industrialization and urbanization are predicted to be mostly fulfilled), (ii) China's per capita emission in 2035 wil be 2.62 tC, equal to that of Japan in 2005, and (iii) the emissions per capita will begin to gradually decrease from 2035 to 1.69 tC (i.e., the emissions level of France in 2005) in 2050. The total annual emissions simulated on the basis of the predicted population are 3.82 and 2.38 GtC for 2035 and 2050, respectively. The cumulative emissions from 2006 to 2050 were calculated to be 126.97 GtC under the assumption of a linear change in emissions between the given time nodes (i.e., 2006 and 2035). However, this type of linear change is unlikely to occur. An actual scenario would be that the emission growth rate gradually slows down to zero from 2006 to 2035 and then negative growth begins. Using the more realistic assumption, a new numerical simulation was conducted on the basis of the average growth rate of China's emissions (6%) from 1996 to 2005. The simulation results are shown in Figure 1 (scenario I). The cumulative emission amount from 2006 to 2050 is 135.13 GtC and the cumulative emission per capita is 94.67 tC. The cumulative emission amount is 8.16 GtC higher than that simulated in the linear-change scenario because the emissions remain at a high level for several years in the non-linear scenario.

As shown in Figure 1, in the simulation of scenario I, we assumed that the emission growth rate decreases at 0.188% per year from 2006 and is zero in the period 2036–2037, when the emissions peak, after which the emissions decrease quickly to 2050 at a rate of 0.494% per year. However, it would seem difficult to achieve such a fast rate. In 2007, China's per capita emissions were 1.36 tC and the annual growth rate was 6.0% from 1996 to 2005. The growth rates in 2006 and 2007 were 10.7% and 7.5%, respectively [12]. This situation occurred against the background that China has been promoting the development of renewable energy, implying that China is still quite far from the decreased emission growth rate period.

We now discuss the absolute emissions per capita during the peak period. It is well known that Japan is the most energy-efficient country in terms of energy intensity, with its per capita emissions being 2.62 tC at present and the cumulative emissions per capita from 1900 to 2005 being 115.10 tC. Recently, the emissions per capita of several large cities in China have approached a similar level. The emissions per capita of Shanghai and Tianjin in 2006, for example, were 2.48 and 2.34 tC, respectively[1)]. It would therefore be a great challenge for China to keep its emissions per capita during the peak period to less than 2.62 tC. We now turn to the emissions per capita in 2050. The current emission per capita of France is only 1.69 tC because more than 80% of its total electricity production is from nuclear power and hydropower [18], whereas in China, 70% of electricity is currently from thermal power. It seems impossible for non-carbon electricity to account for 80% of the total electricity power in China by 2050. Similarly, it is difficult for China to keep the emissions per capita less than 1.69 tC in 2050. However, taking into account the potential development of low-carbon technologies in the coming decades and that the emissions per capita would be as low as 0.60 tC for the 27 developed countries in 2050, we should feel confident about China's long-term emission control.

Based on our simulations, the cumulative CO_2 emissions of China from 2006 to 2050 will not be less than 90 GtC and will very likely approach 130 GtC. If we consider the optimistic assumption that China's emissions decrease sharply after the peak years and the emissions per capita in2050 are as low as those for developed countries (i.e., 0.60 tC), the cumulative emissions of China from 2006 to 2050 would be 124.34 GtC (Figure 1, scenario II). Correspondingly, the cumulative emissions per capita during this period would be 87.09 tC on the basis of the predicted future population. To achieve this target, China's emissions after 2036 must decrease at a rate of 1.53% per year, which is even higher than the highest decrease rate of 1.23% during the period 1996–2005 among developed countries (i.e., the rate for Denmark).

We now turn to question 2—what emission right should China reasonably have in the future? The answer to this question depends on two issues: (i) the level of the atmospheric CO_2 concentration to be controlled and (ii) the international system for allocating the emission rights among different countries. These two issues were considered in the seven proposals as mentioned above. Here, we choose the IPCC, UNDP, and OECD proposals to analyze the emission rights assigned to China. In the IPCC proposal, the total emission rights for the non-Annex I countries for the period 2006–2050 were 23.15–26.22 tC and the corresponding emission rights per capita were 0.51–0.58 tC a^{-1} (all calculations here and below are based on the predicted populations), which are 16%–26% lower than the averaged emission of the non-Annex I countries in 2005 (i.e., 0.69 tC). As one of the non-Annex I countries, we assume China would have an average emission right, and then its emission right would be used up by about 2019–2021 (Table 3). In the UNDP proposal, the cumulative and average annual emission rights per capita for developing countries for the period 2006–2050 were respectively 34.75 and 0.77 tC (Table 2). However, our simulation results (Table 3) show that China reaches this emission level before 2025. The OECD proposal assigns an emission quota of 26.35 tC per capita for the period till 2050 (i.e., 0.59 tC a^{-1}) to BRICs countries. Among the four BRICs countries, China's current emissions are lower than Russia's but higher than Brazil's and India's. The emissions per capita of Brazil and India in 2005 were 0.48 and 0.34 tC, respectively. It would also be very difficult for these two countries to control their future cumulative emissions below 26.35 tC per capita in view of their stages of development. We understand that there is no reason for China to have a higher emission rights among these four countries. However, our simulation results show that

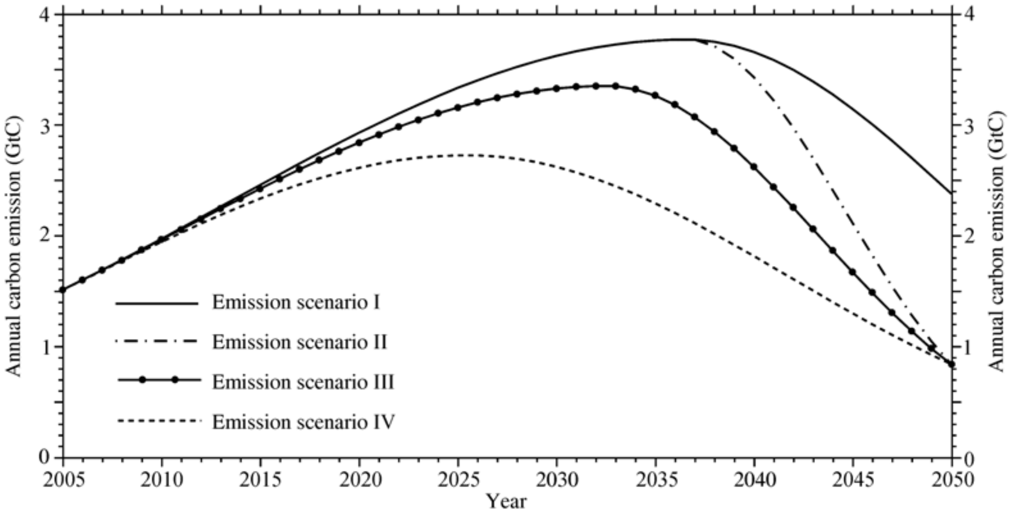

Figure 1 Emission scenarios for China from 2006 to 2050.

1) Qu J S, Wang Q, Chen F H, et al. Provincial analysis on the carbon dioxide emission in China (in Chinese). Quat Sci, 2010, in press.

China will use up its assigned emission right of 26.35 tC per capita by 2021 (Table 3).

In the seven proposals assessed in this paper, China is not allocated emission rights that will last for more than 20 years, implying that China would need to buy emission rights from other countries no later than 2026. Of course, China cannot accept such an arrangement because of the lack of fairness in the assigning of the emission rights. Much research conducted by Chinese scientists [19–21] in recent years on how to fairly assign emission rights has the common conclusion that the fairest method is based on the cumulative emissions per capita2). Ding et al. [14] reported that the global average of cumulative emissions per capita for the period 1900–2005 and the value for China were 79.58 and 24.14 tC, respectively. The difference between these two values could be considered as a historic surplus of emission rights for China. Using the simulation results for scenario II (Figure 1), we see that China's emissions per capita for 2006–2050 and 1900–2050 would be 87.09 and 111.23 tC, respectively (Figure 2). To meet the goal of controlling the atmospheric CO_2 concentration to less than 450 ppmv by 2050, the global averaged cumulative emission right per capita for the period 1900–2050 (based on the predicted population for 2006–2050) should be no more than 112.15 tC. If the targeted atmospheric CO_2 concentration increases to 470 ppmv by 2050, it grows to 123.01 tC. We also simulated the future emissions per capita for several developed countries on the basis of their emission reduction promises (Figure 2). The cumulative emissions per capita for the period 1900–2050 in the USA and OECD countries are 597.37 and 309.94 tC, respectively. The cumulative emission per capita for the period 1900–2050 in China (i.e., 111.23 tC) is only 18.62% that of the USA and 35.89% that of OECD countries. In fact, the cumulative emissions per capita were very high for some developed countries before 1900. According to the carbon emission data provided by CDIAC [12] and population data obtained from the Populstat website [22], the cumulative emissions per capita during the period 1850–1900 in the USA and UK, for example, were 48.58 and 122.83 tC respectively.

However, there is a problem with this comparison. Because the population of a country changes, the historic "surplus" of cumulative emissions per capita should be converted to a total emission surplus and added to the future emission rights of the country. The total emission surplus for China in the period 1900–2005 was 39.68 GtC [14]. If we assume the population in 2005 as invariable, to meet the targets of CO_2 concentrations of 450 and 470 ppmv, the emission rights for China for the period 2006–2050, including this "surplus", would be about 90 and 110 GtC, respectively, which are lower than values in scenarios I and II in Figure 1.

Table 3 China's emissions in scenario II from 2006 to 2050

Year	Annual emission (GtC a^{-1})	Annual emission per capita (tC a^{-1})	Emission from 2006 (GtC)	Annual emission per capita by 2006 (tC a^{-1})	Cumulative emissions per capita from 1900 (tC)
2006	1.60	1.21	1.60	1.21	25.35
2008	1.78	1.34	5.08	3.82	27.96
2010	1.97	1.46	8.93	6.68	30.81
2012	2.17	1.59	13.17	9.79	33.92
2014	2.36	1.71	17.79	13.14	37.28
2016	2.56	1.83	22.80	16.75	40.88
2018	2.75	1.95	28.20	20.58	44.72
2020	2.93	2.06	33.97	24.65	48.79
2022	3.10	2.17	40.09	28.93	53.07
2024	3.26	2.26	46.53	33.41	57.54
2026	3.40	2.35	53.27	38.06	62.20
2028	3.53	2.42	60.26	42.87	67.01
2030	3.62	2.49	67.46	47.81	71.95
2032	3.70	2.53	74.83	52.86	76.99
2034	3.75	2.57	82.30	57.98	82.12
2036	3.77	2.59	89.84	63.15	87.28
2038	3.71	2.55	97.32	68.29	92.43
2040	3.43	2.37	104.35	73.14	97.28
2042	2.98	2.06	110.55	77.44	101.57
2044	2.41	1.68	115.67	81.00	105.13
2046	1.83	1.28	119.61	83.76	107.89
2048	1.29	0.91	122.45	85.75	109.89
2050	0.84	0.60	124.34	87.09	111.23

2) Fan G, Su M, Cao J. An economic analysis on consuming levels and carbon emissions (in Chinese). Econ Res J, 2010, in press.

Reasonable emission-reduction pathways for China with emission amounts of 110 GtC (scenario III) and 90 GtC (scenario IV) were also simulated (Figure 1). Our simulation results for scenario III were (i) the emission growth rate slows down by 0.214% per year till to 0 from a rate of 6% in 1995–2006 and there is a peak emission of 2.30 tC per capita in 2033, (ii) the emission reduction rate keeps 0.857% per year from 2033 on and the emission per capita in 2050 is 0.60 tC, and (iii) the emissions per capita in China for 2006–2050 and 1900–2050 are 78.83 and 102.97 tC, respectively. Our simulation results for scenario IV were (i) the emission growth rate slows down by 0.286% per year till to 0 from a rate of 6% in 1995–2006 and there is a peak emission of 1.88 tC per capita in 2026, (ii) the emission reduction rate keeps 0.379% per year from 2026 on and the emission per capita in 2050 is 0.60 tC, and (iii) the emissions per capita in China for 2006–2050 and 1900–2050 are 66.27 and 90.41 tC, respectively. Among these four scenarios as shown in Figure 1, (i) it would be impossible for China to follow scenario IV as the peak year occurs too early and the peak value is too low and (ii) in scenario I, if the emissions per capita for the OECD countries in 2050 are only 0.60 tC, it would be unlikely for China to be allocated an emission right as high as 1.69 tC. From all the analyses, we conclude that the highest possible total emissions for the period 2006–2050 in China would be 110–130 GtC.

Recently, Hallding et al. (Swedish scientists) [23] claimed that China would reach the global average of cumulative emissions per capita in 2033 on the basis of the unpublished writing of a Chinese economist. We considered this situation and our results are shown in Figure 3. In our simulation, (i) the emission reductions for the OECD countries were based on their own promises, (ii) China's data were for scenario II in Figure 1, and (iii) the global data are

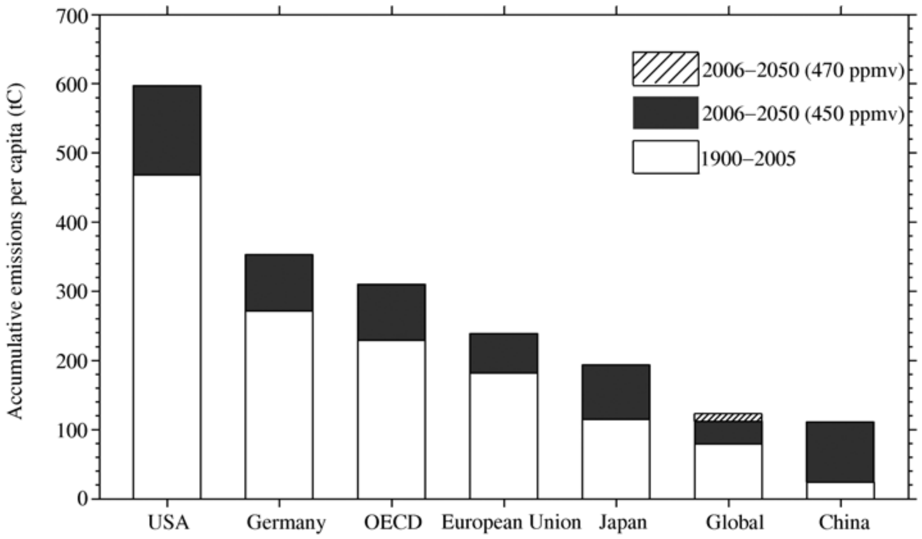

Figure 2 Changes in accumulative emissions per capita of the main parties.

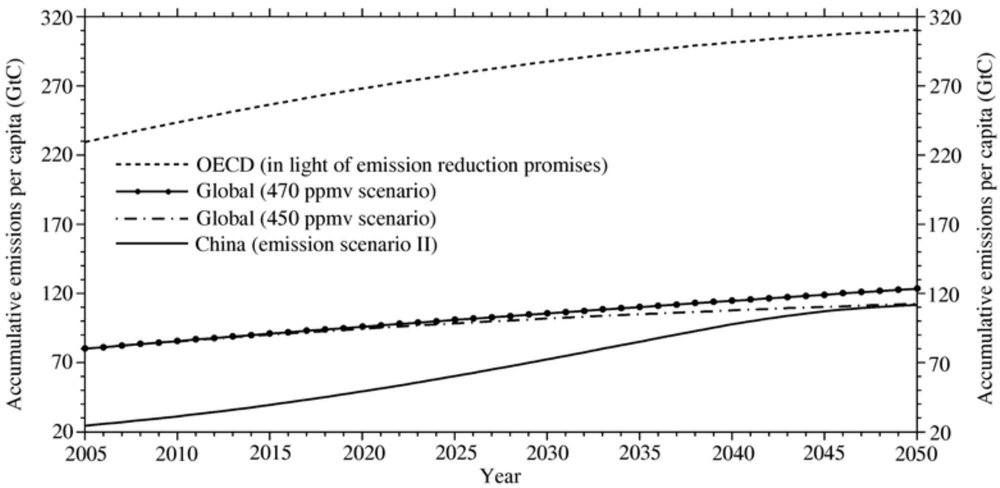

Figure 3 Annual accumulative emissions per capita from 2006 to 2050 under different emission scenarios.

based on two target atmospheric concentrations of CO_2 of 450 and 470 ppmv (i.e., the global total emission amount for 2006–2050 was calculated for a given concentration target, and this amount was allocated each year on the basis of averages of decreasing or increasing rates from 2006). As shown in Figure 3, for the target atmospheric concentration of CO_2 of 450 ppmv, China might reach the average level of global cumulative emissions per capita in the late 2040s, while for the 470 ppmv target, the cumulative emissions per capita for China would still be lower than the global average in 2050. China's cumulative emissions per capita from 1900 to 2050 would be 35.89% of the value for OECD countries. Therefore, with its dramatically fast development, application of low-carbon technologies, and the promotion of biosphere carbon sequestration, China has sufficient reasons from both logical and moral perspectives to be allocated cumulative emission rights of 110–130 GtC over the period 2006–2050.

5 Discussion and conclusions

Four issues were discussed in detail in this paper and they are summarized as follows.

First, the results obtained in this paper revealed that various proposals for controlling atmospheric CO_2 concentrations, which were mainly proposed by scientists in developed countries, not only ignored the fact that developed countries accounted for the majority of historic emissions, but also assigned much higher future emission rights per capita to these developed countries than to developing countries. If the CO_2 emission right per ton of carbon is worth US$30, developing countries will lose more than 10000 billion dollars [14]. Accordingly, it is clear that these proposals are developed on the basis of fairness and equity. Moreover, these proposals were made in the name of emission reductions. As discussed by Ding et al. [14], the differences in both the historic emissions and the emissions per capita among countries will be obscured if the emission reduction ratios are defined as the criterion for establishing a global responsibility system to control the atmospheric CO_2 concentration. This will lead to the unjust allocation of emission rights. The following is an extended analysis of the trap hidden in the dialogue on emission reductions.

The "trap" referred to is created by (i) demonstrating the high sensitivity of the global temperature to the atmospheric CO_2 concentration, (ii) emphasizing the catastrophic impacts of global warming on biosphere and human society, (iii) making a value judgment to control the global warming to within 2°C in the period from the Industrial Revolution to the end of this century, (iv) calculating the atmospheric CO_2 concentration corresponding to the 2°C threshold (450 ppmv), (v) proposing that developed countries should take the lead in emission reductions and defining the reduction ratios for them, and (vi) defining the responsibilities of developing countries in terms of long-term emission reductions. The key point here is that once the concentration target of 450 ppmv is established, the permitted emissions from fossil fuel combustion and cement production from 2006 to 2050 are fixed accordingly. Even if the rate of absorbance by oceans and terrestrial ecosystems remains at 54% of the total emission, the total permitted emissions by human activity are no more than 255.11 GtC. Of this total amount, after designing the emission reduction shares for developed countries, there are little left for developing countries. In the IPCC proposal, for example, the Annex I parties are asked to define their mid-term and long-term targets while the non-Annex I countries are not. It seems fair, however, that the assigned emission rights per capita for the Annex I countries are 2–3 times those for the non-Annex I countries. This proposal hidden behind words is what we refer to as the trap. It is likely that the trap has not been fully recognized by the delegation of negotiators from developing countries. Some, for instance, still insist that a 25% reduction in emissions from the 1990 level by 2020 is not enough, and that the reduction proportion should be 40% of the emissions in 1990. It is still uncertain whether developed countries would accept such a high reduction. If they were to accept this suggestion, their emission rights per capita for the period 2006–2050 would decrease from 77.28 to 61.23 tC. As a result, the emission rights for the non-Annex countries would only increase from 23.15 to 26.22 tC. In this case, the emission rights of developed countries would still be as high as 2.3 times those of developing countries. That is, if developed countries only achieve an intermediate target of 25% reduction in the emission per capita from the 1990 level (as they themselves suggest), a developing country such as China would exhaust its emission right in 2019, and if the intermediate reduction target was increased to 40% as suggested by some developing countries, the emission rights would only last to 2021. It is clear that for the target of CO_2 concentration of 450 ppmv, though developed countries have taken the lead in defining their reduction goals, developing countries will eventually be deprived of their emission rights.

Second, we insist that future emission rights should be allocated on the basis of cumulative CO_2 emission per capita since a certain year can optimally reflect the principles of fairness and justice. Our previous research [14] demonstrated the rationality of this index through the high correlations between the cumulative CO_2 emissions per capita and socio-economic indicators such as the current industrial base, urbanization level, gross domestic product per capita, and national welfare of a certain country. In particular, because some developed countries already have emission deficits, we advocate that those countries should be able to trade future emission rights with their capital and technologies instead of having no emission rights in the future. Scholars have demonstrated the same viewpoints using the concepts of the carbon budget [19] and carbon emission accounts [21]. Some scholars have claimed that the high emissions of developed countries in the past were under the situation of unawareness of the harm of CO_2, and thus they should not be responsible for their past emissions. The above view has no foundation because (i) the warming effects of CO_2 have been recognized for about a century and (ii) the harm of CO_2 should be addressed from the point of view of "whoever causes pollution is responsible for its treatment" after understanding the harm. There is another view that it is unfair for contemporaries to have to take responsibility for the historical emissions of developed countries. However, it must be acknowledged that living conditions and lifestyles enjoyed by contemporaries in developed countries are a result of the construction of infrastructure by their ancestors, which is a process with high emissions, and thus, it is difficult to accept that historical high emissions have nothing to do with them. In addition, selecting a rational start year in calculating the cumulative CO_2 emission per capita in international climate negotiations is a serious issue.

Third, the target of 450 ppmv should not be rigid. The 450 ppmv target was defined by the IPCC in the light of the high sensibility of temperature to the CO_2 concentration and was mainly determined from numerical simulation instead of a strict assessment of climate records of the past century. Currently, it is inappropriate to set a higher or lower concentration target, and instead, an assessment mechanism with continuous adjustments to the target should be predetermined. Based on the assessment and data presented in this paper, a target concentration level of 450 ppmv for CO_2 is considered too high to be achievable. Achieving this target, even if developed countries keep their promises, requires developing countries to control their emissions below their current emission levels. This is absolutely impossible. And if that situation occurs, the current gap between the rich and the poor formed internationally would be immobilized, which goes against morality.

Fourth, several developed countries emphasized that their emission reductions should be combined with those of other countries when their target emission reductions are set, implying that they consider emission reductions of other countries as a precondition of their own emission reductions. This is reasonable if the term "other countries" refers to other developed countries, because most developed countries have huge historical emission deficits, and thus mutual promotion and supervision are required for future emission reductions. This is unfair if developed countries believe that developing countries should reduce their emissions at the same time. As shown in Figures 2 and 3, until 2005, the cumulative CO_2 emission per capita for China was about one-tenth that for OECD countries. For India, this ratio was about one-twentieth. The historical emissions and current emissions per capita are not comparable between developed and developing countries. As a result, developed countries will lose their basic moral rights if they insist that developing countries must reduce emissions synchronously with them.

The following are the four main conclusions of this paper.

First, proposals for controlling the CO_2 concentration that presently have an international influence, such as the IPCC proposal, allocate much greater future emission rights to developed countries than to developing countries and ignore the huge differences in historical emissions among countries. Thus, these proposals are not suitable to be references in future international climate change negotiations.

Second, the differences in both emission histories and emissions per capita will be obscured if emission reduction ratios are defined as the criterion for establishing a global responsibility system to control the atmospheric CO_2 concentrations, resulting in the violation of the development rights of developing countries.

Third, to best express the principles of fairness and justice, the cumulative CO_2 emissions per capita should be set as the criterion for allocating future emission rights. A global responsibility system to control the atmospheric CO_2 concentration needs to be established with this as the starting point.

Fourth, even for the strict target concentration level of 450–470 ppmv, China can logically and morally argue for emission rights of 110–130 GtC for the period 2006–2050.

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