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Global Climatic Cooperation and Emission Rights Allocation

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Authors' contributions

This paper was carried out in collaboration of all authors. Author GW presented valuable ideas and advices, supervise the study design and approved the final version. Author CL carried out the study design, material collection, and the writing.

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ABSTRACT

This paper demonstrates that cooperation is the way to solve emission problem and to find a better dynamic emission rights allocation. We present a model to analyze the difficulty in global climatic cooperation, and the tragic result if there is no cooperation. We preset a weighted formula of equal per capita emission and GDP to solve the dynamic emission rights allocation. We introduce a two-step mitigation path to the global climatic cooperation, and suggest that privatization and marketing may be a way to solve the green house gases emission problem. Game theory is the main method in this paper, theoretical analysis is the character of the paper, and we cited some literatures to demonstrate our standpoints. We discussed the universal of cooperation and a third party in our society, we believe that a court, a country, the United Nations and UNFCCC come into being because they are needed to be a third party that provide public service. Our conclusion is that we need get to a binding agreement to control green house gases emission.

Keywords: Global warming; climatic cooperation; emission rights; carbon markets.

1. INTRODUCTION

The influence of humanly induced green house gases (GHGs) on the climate is increasing with economic development, and one of the distinctive evidences is global warming, the

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atmospheric temperature is increasing since preindustrial times (1750 is the usual benchmark). Humanly induced GHGs emissions are mainly from fossil-fuel burning other than naturally in recent years, such as fire-powered electricity generation, automobile exhaust, cement production and so on, and the pace of global warming is likely faster and faster. Some scientists indicated that human activities are likely responsible for most of the increase of global temperature since the mid-20th century [1]. Since the mid 20th century the productive activities have elevated the temperature [2], The Intergovernmental Panel on Climate Change (IPCC) indicates that the global mean temperature over the 21st century will increase between 1.1ºC and 6.4ºC if no effort is taken to reduce GHGs emission [3].

Recent scientific evidence [4] demonstrated that widespread climate changes have emerged with an amazing pace, and climate models underestimated the size, speed, and extent of those changes [4]. IPCC [5] reported that the global average surface temperature has increased about 0.6ºC over the 20th century. Globally speaking, the 1990s is most likely the warmest decade and 1998 the warmest year in the instrumental record since 1861, and the temperature increase in the 20th century is likely the largest of any century over the past 1,000 years. CO_2 is one of the main anthropogenic sources, and it comes mainly from the burning of fossil fuels (about 75 percent) and changes of land use (mainly, deforestation). Research from IPCC shows that the concentration of co_2 in the atmosphere has increased 31% since 1750, human being has altered the atmosphere in ways that affect the climate since preindustrial times. Methane is of secondary importance in the atmosphere, and the concentration of methane has increased 151% since 1750. A little more than half of current emissions are anthropogenic (e.g., use of fossils, cattle, rice agriculture and landfill). Molecule for molecule, co_2 lasts about 5-200 years, and methane lasts about 12 years [5].

Some scientists indicated that the global temperature will increase 0.2℃ every 10 year in the coming 20 years, the increase of temperature will reduce the absorption of co_2 in the soil and ocean, and the percentage of co_2 in the air will increase, the increase of co_2 in the air will make the atmospheric temperature rise again. The feedback mechanism makes the climate temperature warmer and warmer [6].

The outline of the study is as follows: We reviewed the cooperative difficulties in global GHGs emission control in section 2. In section 3 a model of non-cooperation is presented to analyze prisoner's dilemma in the climatic cooperation, and the necessity of introducing a third party. We analyze the function of carbon taxes and emission rights allocation in section 4, indicate that emission rights allocation and carbon markets is a way to solve emission problem before clean-energy technologies break through. We present a two-step mitigation path in section 5, and analyze the importance of carbon markets. Section 6 is discussion and conclusion.

2. DIFFICULTIES IN THE GLOBAL COOPERATION OF EMISSION CONTROL

Public goods are often used to model social dilemmas of "tragedy of the commons" [7, 8], sociologists often link public goods to social capital, and social capital refers to social organization such as norms, social trust, and networks that facilitate coordination and cooperation for mutual benefit [9]. Prescriptive norms constitutes an especially important institutions of social capital within a collectivity, it is the norms that one should forgo self-interest and act in the interest of the collectivity [10], and the ability of a community to produce public goods is an important element of its social capital [11]. The cooperation in GHGs emission control is a norm that facilitates coordination and cooperation for the subsistence of the human.

Markets are likely optimal institutions for the production of private goods, but markets for common resources or public goods are not as efficient as private goods such as groundwater, national defense and global atmosphere. These markets are easy to fail because of non-excludability technically, and maybe the common resources or public goods can be privatized and traded if we can exclude other persons technically. Interests of an individual may conflict with its collective society, so sanction system has to be set up to protect the public goods or common pool resources because of conflicts between an individual and his collective [12]. A government, or an independent social organization, is set up to impose rules and force self-interested individuals to contribute necessary resources to provide public goods, such as taxes. Samuelson [13] classified commodities into two types according to their excludability and rivalry, one type is public goods, and the other is private goods. Ostrom [14] classified commodities into four types according to their excludability and subtractability, the first type is private goods, the second is toll goods, the third is common pool resources and the forth is public goods. Obviously clean air is a common resource, it is a public service to keep clean air from pollution, and it is just like the national defence and civil service.

2.1 Different Opinions on Climate Change

Accurate relationship between GHGs emissions and temperature increase are not fully understood, it is the same with the influence of sunspot, volcanic forcing and aerosols on temperature increase [15]. After the publication of IPCC-AR4, some scientists brought forward different opinions [16, 17], the Nongovernmental International Panel on Climate Change (NIPCC) brought forward questions on the conclusions of IPCC, one of the main reasons that America withdrew the Kyoto protocol is the uncertainty relation between GHGs emission and global warming. Gardiner [18] intended that climate change is basically an ethical issue both in moral philosophy and humanity. Gundermann [19] questioned the DICE model of William Nordhaus, “the model is extremely simple-so simple that I once, during a debate, dubbed it a toy model”.

Some scientists indicated that the change of sunspot is positively related with the climate change [20], but the global climate change cannot be explained by the sunspot change since 1960s [21]. Lean and Rind [22] indicated that the volcanic eruption can make the global temperature go down, and offset the greenhouse effect. Some scientists [23] indicated that the co_2 emissions from the human activity and the continent vegetation are 9-10 Pg C, accounted 1/22 to 1/26 of the total sum from the nature (including oceans and continents). So it is still not clear whether human’s activities are the main cause for the rise of temperature.

2.2 Conflicts between Developed and Developing Countries

Threatened by global warming, most countries agree with reducing greenhouse gas emission, but conflicting opinions continue on mitigation and emission rights allocation. Developing countries challenge historical and current inequalities in per capita emissions. Developed countries worry that the emission abatement will do their economy harm in the future and emphasized common responsibilities. For example, the United States intended that developed and developing countries share common challenges in meeting their economic, social and environmental needs [24]. So all countries have a common responsibility to take actions promoting clean development [25], meanwhile, Australia considers that if mitigation commitments of some important developed countries were separated from commitments and actions relating to non-Parties to the Kyoto Protocol and advanced developing economies, it would be difficult to assess comparability of effort [26]. Table 1 indicates the order of GHGs emission of top 10 countries in 2005.

Table 1. The top ten countries of GHGs emission in 2005

Ranking sequence	Country	Percent (%)	Per-capita emissions	Units of tons of ghgs per-capita
1	China	17%	5	8
2	United States	16%	24	1
3	European Union-27	11%	10	6
4	Indonesia	6%	12	9
5	India	5%	2	1
6	Russia	5%	14	9
7	Brazil	4%	10	0
8	Japan	3%	10	6
9	Canada	2%	23	2
10	Mexico	2%	6	4

Resource: Wikipedia, Kyoto Protocol, see MNP (2007), "Greenhouse gas emissions of countries in 2005 and ranking of their per capita emissions", Netherlands Environment Agency website. Accessed 16 July 2012. Available: http://en.wikipedia.org/wiki/Kyoto_Protocol.

Developing countries emphasize differentiated responsibilities, asking developed countries to keep leading in the fight against climate change. Brazil indicated that significant steps should be taken by the developed countries to prevent the climate change along with the development of developing countries [27]. Tuvalu stated that the allocation of responsibility for emissions reductions should be based on historical emissions. Colombia indicated that developed countries should lead the emission reduction in order to avoid dangerous climate calamity, to reflect their historical responsibility for the causes of climate change, and to respect the principles of equity and common but differentiated responsibilities in accordance with the United Nations Framework Convention on Climate Change (UNFCCC) [28]. Economic regulation in developing countries for the environmental concern is generally much weaker than developed countries [29]. The emerging economies are having an increasing proportion in the global GHGs emission, and they haven't taken effective methods to reduce GHGs emission.

There are 191 states that have signed and ratified the Kyoto Protocol by September 2011. The remaining signatories that have not ratified the protocol are United States, Afghanistan, Andorra and South Sudan. China refused to accept the Kyoto Protocol at the 10th meeting of the COP to avoid high cost commitments relating to emission reductions in November 2004, and joined the Asia-Pacific Partnership (APP) in July 2005. Canada renounced the Kyoto Protocol in December 2011.

Durban's Accord presents a new treaty with binding targets for all countries to take effect in 2020, but Canada, Japan and Russia are reluctant to take it. Canada pulled out from the Kyoto Protocol at the Durban talks on December 12 2011, and withdrew formally invoking Canada's legal right. Canada was committed to cutting its greenhouse emissions to 6% below the 1990 levels before 2012, but its emissions in 2009 were 17% higher than the 1990 level [30].

3. A MODEL OF NON-COOPERATION IN GHGS EMISSIONS CONTROL

Although the increasing co_2 concentration in the atmosphere is one of the causes of climate change [31], but the influence of global warming upon different areas is different, and different countries may have different result, some countries may benefit from or adapt to global warming, while some countries may suffer loss from it. Countries that benefit from it may feel that the global warming is acceptable, while those who suffer losses from it may feel that it cannot be accepted. Different impact of global warming on different countries is preventing the cooperation of nations in the GHGs emission control [32].

The atmospheric temperature will increase with the increase of GHGs concentration, and the concentration is positive with the increase of cumulative GHGs emission according to the study of some scientists [6]. We assume that atmospheric temperature has a positive relation with the cumulative GHGs emission, we take the average atmospheric temperature function as g(x), x is the GHGs emission, $g'(x)>0$, $g''(x)>0$, g(x) is convex, that means the first order of the function is positive, the second order is also positive. The relationship of temperature and GHGs is indicated in Fig. 1.

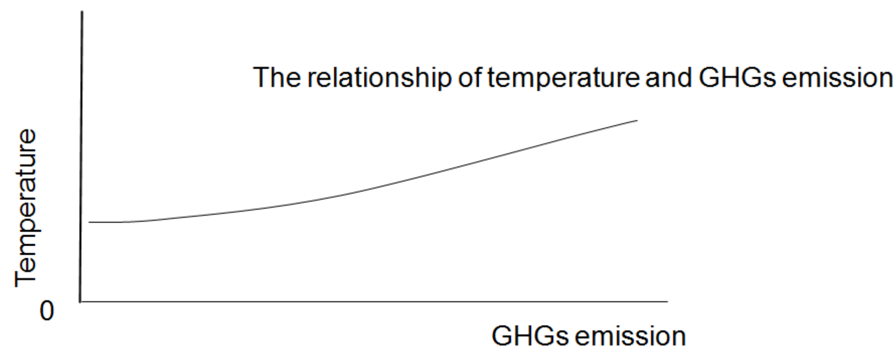

Fig. 1. The relationship of temperature and GHGs emission

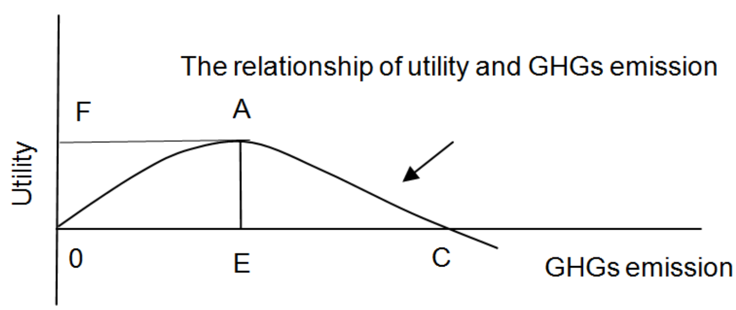

Fig. 2. The relationship of utility and GHGs emission

We know that people get utility by consuming goods, such as food, oil, coat and so on, and release GHGs, so we take the utility function as u(x), x is the emission of GHGs. Because of the rise of temperature and air pollution, the utility curve goes up at first and comes down when the temperature reach an point, such as 22°C, so we suppose that the utility function is concave, and it is an inverted U shape curve, that means u″(x)<0 (x>0). Fig. 2 demonstrates the relationship of utility and GHGs emission.

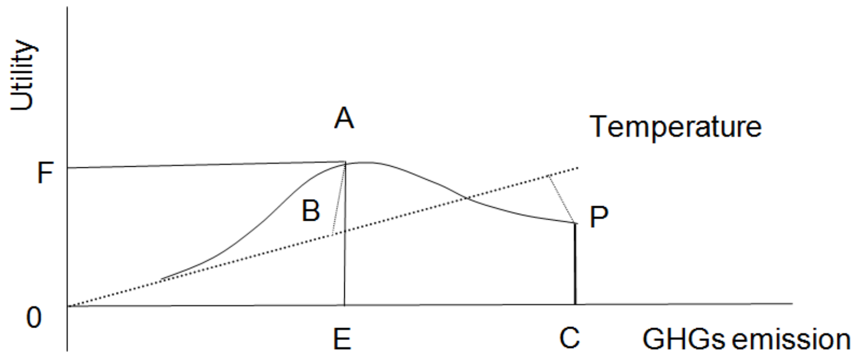

Fig. 3. A three-dimension figure of the relation of utility, GHGs emission and temperature

At point A, the utility of u(A) from the emission q_E is the biggest, the emission q_E is optimal, and it is a critical value, beyond point E, if the total GHGs emission continues to rise, temperature will rise too, but utility will go down because of the rise of temperature. The utility u(P) at point P is zero, its corresponding emission is q_C, both the emissions and air temperatures at point P are bigger than that at point E. The relationship of utility, GHGs emission and temperature is demonstrated in Fig. 3. Temperature fluctuates within a normal range when GHGs emission is less than q_E, there are few or even no severe weather changes. Temperature fluctuates severely when GHGs emission is beyond point E, and climate disasters rise quickly. Here we suppose that emission q_E is the biggest value that the natural environment can deal with.

We have got the maximum utility u(A) and its emission q_E, suppose that the number of people in the world is n, everyone will get an emission quota $\frac{q_E}{n}$ and a piece of utility $\frac{u(A)}{n}$ if the emission rights are equally distributed. The total utility is going down from point A to point P, we do not know the utility function exactly, we suppose that the utility function is $\frac{u(A)}{2^t}$ from point A to point P, the average utility is $\frac{u(A)}{2^t n}$, "t" is the sequence or time that GHGs emission gets bigger and bigger from A to P (or from E to C).

If people agree to accept the emission quota, and the total emission is less than q_E, there is no need to introduce a third party to manage the emission rights. The question is many people need more than their quotas, and the total emission is more than q_E, clean air is a common resource and is becoming scarce, we need to introduce a third party to manage emission rights if people do not obey the quota management.

If people do not obey the quota management as a whole, the total emission will rise, the GHGs concentration will rise too, temperature goes up, and the rise of temperature will make the utility of everyone decrease. If the total emission is bigger and bigger as we have supposed from A to P, they form an array of numbers that are demonstrated as below.

$$\frac{u(A)}{2^0}, \frac{u(A)}{2^1}, \frac{u(A)}{2^2}, \ldots\ldots, \frac{u(A)}{2^{t-1}}.$$

“t” is the time in the array of numbers, for instance, a year. As the numbers demonstrate that utility decreases while time t increases if people do not obey the quota management as a whole, and their utility will be half in the next time. The average utility is $\frac{\mathrm{u(A)}}{2^{\mathrm{t}}\mathrm{n}}$, and it also form an array of numbers as below:

$$\frac{u(A)}{n}, \frac{u(A)}{2n}, \frac{u(A)}{4n}, \ldots\ldots, \frac{u(A)}{2^{t-1}n}.$$

3.1 A Triggering Mechanism of Non-cooperation

Suppose that there are n persons, and everyone has a GHGs emission quota $\frac{\mathrm{q_E}}{\mathrm{n}}$ if the emission rights are distributed equally, and it is calculated annually. If everyone obeys the quota management, the total GHGs emission will be less or equal to $\mathrm{q_E}$, the GHGs concentration does not rise because of the natural carbon recycling, and temperature fluctuates within a normal range. But if someone needs more than his quota, and he cannot buy it from the market, or there is no other compensation mechanism such as clean development mechanism (CDM), he will have to break quota limit. If one breaks the quota management without being punished, other persons will follow, and the total GHGs emission will be more than the critical value $\mathrm{q_E}$. If the total GHGs emission is always bigger than the critical value, the GHGs concentration will become higher and higher, temperature will rise continuously, and the total utility will become smaller and smaller, until it comes to zero. We take the process as a triggering mechanism.

The triggering mechanism explains why non-cooperation happens and exists, non-cooperation is a better strategy for an individual, but it is not for a collective, that’s why a third party is introduced into a group of people (or a group of countries) to implement quota management. We take the quota management as a kind of public service, and the third party as a manager of public services, just as a state provides public services for its people, or the United Nations coordinates international affairs for its member countries.

Table 2. Strategies and payoffs with two players

Player1 \ Player2	**Obey the quota**	**Not obey**
Obey the quota	$(\frac{\mathrm{u(A)}}{2}, \frac{\mathrm{u(A)}}{2})$	$(\frac{\mathrm{u(A)}}{8}, \frac{1.5\mathrm{u(A)}}{2})$
Not obey	$(\frac{1.5\mathrm{u(A)}}{2}, \frac{\mathrm{u(A)}}{8})$	$(\frac{\mathrm{u(A)}}{4}, \frac{\mathrm{u(A)}}{4})$

We demonstrate the mechanism with a two-person game. Two persons mean n=2, and the average emission is $\frac{\mathrm{q_E}}{2}$, the average utility is $\frac{\mathrm{u(A)}}{2}$. We suppose that their payoffs are their utility in this paper. If one player does not obey the emission limit while the other one does, the person who emitted more than his quota will get one and half of his utility, the person who obey will get one fourth of his utility. If both of them obey the quota management together, their payoffs remain the same with the last time. If both of them break the quota limit, then both of them get half of the last time. Their strategies and payoffs are demonstrated in Table 2.

The total emission will be more than the critical value if both of them do not obey the management, and the GHGs concentration will increase next time, the temperature will rise too, and their utility will decrease. Their strategies and payoffs are indicated in Table 3. If both of them emit more than the quota limit every time, their utility will decrease every next time, until it is zero, just as the array of numbers below demonstrates:

$$\frac{u(A)}{2}, \frac{u(A)}{4}, \frac{u(A)}{8}, \ldots\ldots, \frac{u(A)}{2^t}.$$

Table 3. Strategies and payoffs with two players next time

Player2 / Player1	**Obey the quota**	**Not obey**
Obey the quota	$(\frac{u(A)}{4}, \frac{u(A)}{4})$	$(\frac{u(A)}{16}, \frac{1.5u(A)}{4})$
Not obey	$(\frac{1.5u(A)}{4}, \frac{u(A)}{16})$	$(\frac{u(A)}{8}, \frac{u(A)}{8})$

We can see that the equilibrium pure strategy of the two-person non-cooperation game is (not obey, not obey), the dominant strategy is "not obey" for both of them. If we want players to obey the quota management and cooperate, there have to be some institutions that make them obey the quota management and cooperate.

3.2 The Probability of Cooperation When n→ ∞

We suppose that the probability is "p", 1>p>0, with which a person will break the quota limit, and people are independent. If one person breaks the quota limit, others will follow, so the probability that the triggering mechanism is activated will be $1-(1-p)^n$, we can see that the probability is bigger and bigger with the increase of n, the triggering mechanism is certain to be activated when n→ ∞.

We have discussed the case when n=2, we want to see what it will be when n→ ∞. We suppose that if one person breaks the quota limit, one will get θ times what the utility at point A, and we want to see how much θ will be.

Table 4. Strategies and payoffs when n→∞

Group 2 / Group 1	**Obey the regulation**	**Not obey**
Obey the regulation	$(\frac{u(A)}{n}, \frac{(n-1)u(A)}{n})$	$(\frac{u(A)}{4n}, \frac{\theta(n-1)u(A)}{n})$
Not obey	$(\frac{\theta u(A)}{n}, \frac{(n-1)u(A)}{4n})$	$(\frac{u(A)}{2n}, \frac{(n-1)u(A)}{2n})$

To demonstrate the strategy and payoffs easily and clearly, we divide people n into two groups, person i (i can be anyone) who breaks the quota limit is group 1, the rest people is group 2. Person i has an emission quota $\frac{q_E}{n}$ and a share of corresponding utility $\frac{u(A)}{n}$, the rest people have an collective emission $\frac{(n-1)q_E}{n}$ and corresponding utility $\frac{(n-1)u(A)}{n}$. If one group obeys the quota limit while the other does not, the group that does not obey will get θ times of the quota, and the group that obeys will get one fourth of the quota. If both groups obey the quota, their payoffs remain the same. If both groups break the quota limit, both of their payoffs are half of the quota. Their strategies and payoffs are demonstrated in Table 4.

We know that in a prisoner dilemma game with characteristics of static perfect information, it is generally required:

$$\frac{u(A)}{n}+\frac{(n-1)u(A)}{n}>\frac{u(A)}{4n}+\frac{\theta(n-1)u(A)}{n}, \text{ and } \frac{u(A)}{n}+\frac{(n-1)u(A)}{n}>\frac{\theta u(A)}{n}+\frac{(n-1)u(A)}{4n}, \quad (1)$$

From $\frac{u(A)}{n}+\frac{(n-1)u(A)}{n}>\frac{u(A)}{4n}+\frac{\theta(n-1)u(A)}{n}$, we have $\theta<\frac{4n-1}{4(n-1)}$, When $n\to\infty$, $\lim_{n\to\infty}\frac{4n-1}{4(n-1)}=1$, we have $\theta<1$. From $\frac{u(A)}{n}+\frac{(n-1)u(A)}{n}>\frac{\theta u(A)}{n}+\frac{(n-1)u(A)}{4n}$, we have $\theta<\frac{3n+1}{4}$, when $n\to\infty$, $\theta<\infty$.

So we have two conditions, $\theta<1$ and $\theta<\infty$, we choose $\theta<1$ to meet both conditions. It means everyone should obey the quota management under the triggering mechanism when $n\to\infty$, or they will have to face worse result.

It is certain that GHGs emission will exceed the critical value q_E if everyone wants a little bit more than the quota when $n\to\infty$, then GHGs concentration and temperature will increase, in order to avoid non-cooperation and the rise of temperature, a third party should be introduced into the game as a public manager to punish persons who break quota limit.

On one hand the cost of providing quota management is increasing with the increase of population, on the other hand the probability that the triggering mechanism is activated is higher and higher. Cooperation of controlling GHGs emission will be very difficult if a third party is not introduced into the international climatic cooperation.

3.3 Introduction of a Third Party

A third party is introduced into the game to implement quota management, this is a kind of institutional arrangement, and we take the third party as a public service manager. The work of the third party is making party 1 and party 2 obey the quota limit. There may be many persons in party 1 and party 2 respectively, for convenience, we simplify the three-party game to a three-person game, player 1 and player 2 is party 1 and party 2 respectively, the three-party game becomes a three-person game, and we analyze the strategies and payoffs of them.

Player 1 and player 2 have a quota of GHGs emission, the third party also has a quota of GHGs emission, and his main work is supervising players and making them obey the quota management. The third party has an average emission and a share of utility as others do, as a manager the third party will punish the player who violates the quota limit by cutting his (or her) payoffs in half.

Here in a three-person game, M (manager) is a third party, P1 is player 1, and P2 is player 2, M is in charge of the quota management, M has two choices, quota management or not. Players have two choices, obey the rule or mot. We take “Q” as the quota management, and “NO” as no quota management, “O” as obey the quota management, and “N” as not obey the management. We take an extensive form to show a three-person game as indicated in

Fig. 4, and Table 5 is a pure strategy form of the game.

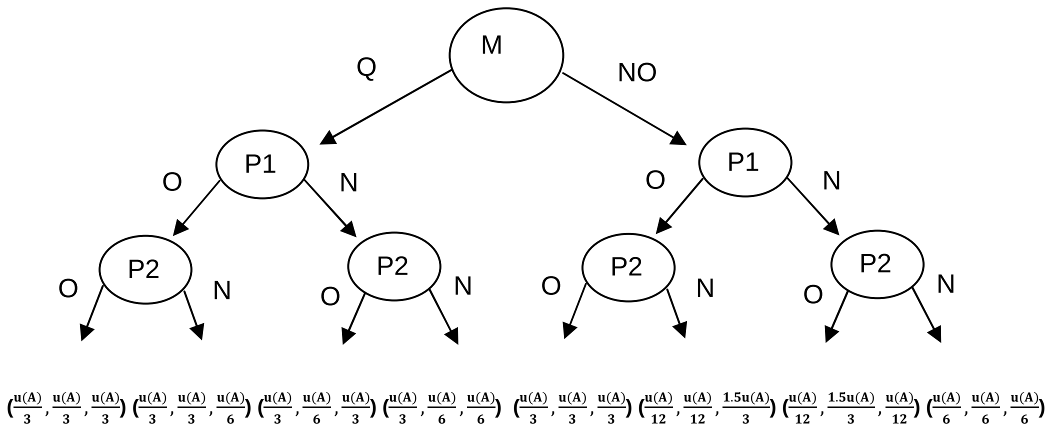

Fig. 4. Strategies and payoffs with a manager (a third party)

Table 5. Strategies and payoffs with a manager (a third party)

	A manager (a third party)				
	Q (quota management)			**NO (no quota management)**	
Player2 / Player1	**O (obey)**	**N (not obey)**	Player2 / Player1	**O (obey)**	**N (not obey)**
O (obey)	$(\frac{u(A)}{3},\frac{u(A)}{3},\frac{u(A)}{3})$	$(\frac{u(A)}{3},\frac{u(A)}{3},\frac{u(A)}{6})$	O (obey)	$(\frac{u(A)}{3},\frac{u(A)}{3},\frac{u(A)}{3})$	$(\frac{u(A)}{12},\frac{u(A)}{12},\frac{1.5u(A)}{3})$
N (not obey)	$(\frac{u(A)}{3},\frac{u(A)}{6},\frac{u(A)}{3})$	$(\frac{u(A)}{3},\frac{u(A)}{6},\frac{u(A)}{6})$	N (not obey)	$(\frac{u(A)}{12},\frac{1.5u(A)}{3},\frac{u(A)}{12})$	$(\frac{u(A)}{6},\frac{u(A)}{6},\frac{u(A)}{6})$

The optimal equilibrium strategies under the management of a third party are different from the strategies without management of a third party, the optimal strategy is (quota management, obey the rule, obey the rule) under the management of a third party, and the optimal strategy is (no quota management, not obey, not obey) without quota management. The efficiency (or payoffs) can be improved by cooperation, and a third party ensures the cooperation, that is why a third party comes into being, the third party may be any kind of international organization, such as a court, a country, the United Nations, UNFCCC or other organizations. The public manager will be publicly selected to prevent corruption in a modern democratic society, but the position of public management is grabbed by force and violence in old dictatorial societies, and corruption prevails. Maybe that is the main difference between a democratic society and a dictatorial society.

4. CARBON TAX AND EMISSION RIGHTS ALLOCATION

4.1 Carbon Taxes

Carbon taxes can elevate prices of the goods that are taxed, and generally make both the consumption and output go down. But carbon taxes cannot reduce consumption much if goods are necessities, and taxes will increase prices and make living cost go up. Industries of transport and electricity generation supply necessities, and they are main GHGs emission industries currently, so the carbon taxes may not reduce much of GHGs emission currently. We need to develop and invest in new clean technologies and control the GHGs emission technologies, so we levy carbon taxes on companies that produce carbon-emission goods, such as oil, gas and coal, or take taxes on goods of coal, oil and gas directly. These kinds of taxes can discourage the consumption of carbon-emission products, and reduce the GHGs emission, at the same time governments can encourage productions of clean energies and clean transports by favorite carbon taxes. For example we take high taxes on coal-fired power plants, gas-fired power plants or oil-fired power plants while we take no tax on wind-powered plants or other clean power plants. Technologies of solar energy and hydrogen energies have not been broken through currently, they are ideal energies but is not forthcoming [33], we need not take carbon taxes anymore if these clean energies can be used successfully. Carbon taxes are used to control GHGs emission, but carbon taxes only add living cost to our lives if there are not substitutable clean energies.

The way out to the emission problem is “breakthrough” of new technologies that supply clean energies, the carbon tax policy is a way to control GHGs emission technologies and encourage new clean technologies. But we are not sure whether clean-energy technologies can be broke through, and we need other ways to solve the emission problem if we cannot break through the clean-energy technologies for the time being, and one way is emission rights allocation.

4.2 Economic Cost of Emission Control

At the Berlin Talk of UNFCCC Conference, three questions were put forward: (1) developed nations are responsible for the most GHGs emission, and that is the main cause that elevated the current GHGs concentrations of the atmosphere; (2) per capita emissions in developing country are relatively low; and (3) emissions of the developing countries should grow to meet their development [34]. So developing countries were not subject to emission reduction commitments in the first Kyoto commitment period, but their potential GHGs emissions are tense issues, and the Clean Development Mechanism was passed to limit emissions in developing countries in the final agreement, it is recognized that developed countries will meet their first round commitments, developing countries will face quantitative commitments in a later period.

Schelling [35] is afraid that the costs to control GHGs emission will reduce productivity at two percent of GNP forever, and that seems politically unmanageable in many countries. Because of the difficulty of getting to a binding agreement in emission control, some scientists proposed that taking intensity targets as incentives for the voluntary participation of developing countries [36]. Lomborg [37] indicated it is far more expensive for some countries to adapt to the increased temperature than cut co_2 emissions

4.3 Allocation Principle for Emission Rights

It is deeply rooted in the old notions that fairness and equity should be based in dealing with the air pollution and climate change [38], and differential treatment between developed and developing countries started in the 1980s, it addresses problems such as air pollution, climate change [39]. Imposing equal obligations on subjects that have unequal capability is acknowledged as unjust during the 1972 Stockholm and the Rio conferences [40], this kind of obligation will exacerbate inequality and impose unfair burdens on those least able to bear. It is stated in the preamble of the Stockholm that developing countries need to safeguard and improve the environment while they develop their economies, and industrialized countries should make efforts reducing GHGs emission and reduce the gap between them [41].

Discussions on climate equality and justice started at the end of the eighties or early in the nineties of the last century [42], different principles have been presented ever since. There must be a standard to be based on when we talk about climate equity and justice, such as the per capita emission, economic welfare. Rose [43] proposed that economic welfare, population, land area, energy use, energy reserves and co_2 emission can be reference bases. The ultimate objective of the UNFCCC is to stabilize greenhouse gas concentration in the atmosphere at a safety level, and this means we should keep green house gas concentration below the safety level, which would prevent dangerous anthropogenic interference with the climate system. There are two justice principles, one is responsibility, which means developed countries are historically responsible for their contribution to the increase of green house gas concentration, and the other is emission rights equity to implement the common but differentiate responsibility [44].

Brazil stated that emission rights should be related proportionally to the historical responsibility in terms of accumulated contribution to the temperature rise, and the Brazilian proposal may be a better way to solve the conflicts between developed and developing countries [45]. Contraction and convergence has been proposed by the Global Common Institute [46], contraction means cutting back emissions in order to reach a co_2 concentration target, convergence means that allocation should be carried out on an equal basis to all countries. Emission rights could be allocated effectively once a global target has been defined.

There are different allocation principles, it is difficult to tell which one is better because of differences of preference, Müller [47] proposed a preference score method to reach a compromise solution between different principles. Rose indicated that philosophical distinction between different criteria may be mathematically equivalent, and have same welfare outcomes. Some economists indicated that the determination of international emission targets is the outcome of political bargaining rather than principled logic, and there is no principled logic for the determination of international emission targets [48, 49].

Many developing countries insist that the principle of grandfathering is a fair starting point for the global climatic negotiations, and emission rights allocation should be based on the equal per capita emission in this larger economically less homogeneous context [47]. Sadat [50] indicated that it will do nothing to benefit the atmosphere to meet obligations through emission trading unless a major share of the reductions is made within their territories. But Heil and Wodon [51] indicated that International emission trade may reduce emission inequality more than the targeted reduction by group countries.

4.4 A Weighted Formula of Equal Per Capita Emission and GDP

The reason that we take equal per capita emission is to emphasize the importance of equity, and taking GDP is to emphasize the importance of economic welfare and productive efficiency. Suppose the total emission is q_E, the total population is n, GDP carbon emission intensity of person "i" is R_i, the income of person "i" is GDP_i, then we can get a weighted emission quota, as the following formula demonstrates. The emission quota of person "i" is as the following formula indicates:

$$\frac{R_i}{\sum_{j=1}^{n} R_j}\frac{GDP_i}{\sum_{j=1}^{n} GDP_j} q_E + (1 - \frac{R_i}{\sum_{j=1}^{n} R_j})\ \frac{q_E}{n} \quad (2)$$

$\frac{R_i}{\sum_{j=1}^{n} R_j}$ is a weight, $\frac{GDP_i}{\sum_{j=1}^{n} GDP_j} q_E$ is the emission of person "i" according to GDP principle, $\frac{q_E}{n}$ is the per capita emission. A person will get more shares of emission if his GDP is big.
Suppose t=$\frac{R_i}{\sum_{j=1}^{n} R_j}$, we have a general formula of emission:

$$(t\frac{GDP_i}{\sum_{j=1}^{n} GDP_j} + \frac{(1-t)}{n})\ q_E \quad (3)$$

"t" is weight, and $0 \le t \le 1$, we can change t according to the economic situations. If the economic is in depression, we take t as 1, the emission formula will be $GDP_i \frac{q_E}{\sum_{j=1}^{n} GDP_j}$; if developing countries have been as advanced as developed countries, equity is the only principle, we take t as 0, the emission quota will be $\frac{q_E}{n}$. The population, GDP, and the carbon emission intensity is not static, they change every year, so the emission quota changes every year.

Suppose we take n as the number of industries, GDP_i as the output of industry "i", R_i as the carbon emission intensity of the industry, we get emission quotas of different industries by the formula. Suppose we take n as the number of countries, GDP_i as the output of country "i", R_i as the carbon emission intensity of the country, we get emission quotas of different countries.

4.5 A Trembling Equilibrium

There are always some people who break quota limits, these people may be concealing true information or forget telling emission information to the quota manager, and the total emission will be more than the critical value q_E if many people emit more than the quota, and the result will be dangerous, there must be some precautious methods to cope with it. We suppose the percent of people who emit more than their quotas is "b", 0< b<1, the manager will have to subtract the percent of emission from the total emission, and the total emission that can be allocated will be q_E(1-b), and the average quota is $(1 - b)\frac{q_E}{n}$, then the weighted formula is:

$$(t\frac{GDP_i}{\sum_{j=1}^{n} GDP_j} + \frac{(1-t)}{n})\ (1 - b)\ q_E \quad (4)$$

The manager does not know exactly what a number the proportion is in the beginning or in a short time, but the manager will find out how many people and what kind of people are concealing the true emission in the long run by investigation carefully, and takes efficient methods to deal with it. By doing so repeatedly the proportion will be smaller and smaller until the percent of people is totally stochastic and relatively stable, and the emission management will come to a trembling equilibrium.

5. A TWO-STEP MITIGATION PATH AND CARBON MARKETS

5.1 A Two-step Mitigation Path

Berk and den Elzen [52] indicated that stabilizing co_2 concentration at 450 ppmv by 2100 requires the participation of major developing countries before 2050 in the global emission control, if emission rights take the form of regulated emission quota, and can be traded at international markets, member countries should reach an agreement on international emission levels and appropriate shares [51]. Jacoby and Schmalensee and Wing [53] proposed that an atmospheric concentration of 550 ppmv seems to be a moderate compromise.

Bode [44] indicated that three questions need to be discussed to allocate emission rights, (1) global targets (final and interim targets); (2) determination of time of participation; and (3) quantification of contributions to limiting GHGs emissions by participants. Bode proposed an approach of combining the equal per capita emission with the historical responsibility, as the Fig. 5 indicates, nations that have more emissions above the projected targets will have to reduce per capita emissions, nations that have less per capita emissions can increase per capita emissions.

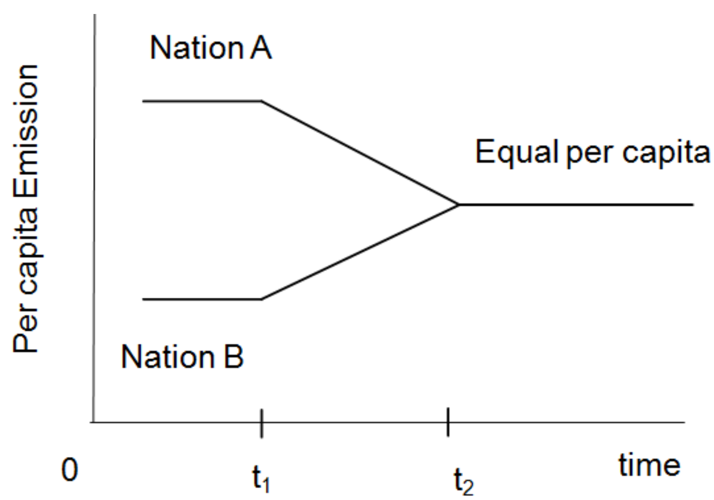

Fig. 5. Mitigation path of the model of Sven Bode

Source: Sven Bode (2003), Equal Emissions per Capita over Time-Proposal to Combine Responsibility and Equity of Rights

We have a two-step mitigation proposal for the GHGs emission, it is based on the model of Bode, and it is a little different from Bode. First, developed countries reduce their emissions to a historical level within a period of time, such as the emission level of 1990, 1970, or 1950 in 10 or 20 years. Developing countries constrain their emission within a certain rate, such as within 5% per year. The second step is allocating the emission rights according to some principles, and emission rights can be traded at carbon markets. In this paper, we allocate emission rights according to a weighted formula of population and GDP. We have a mitigation path to restore the global climate system, as it is indicated in Fig. 6.

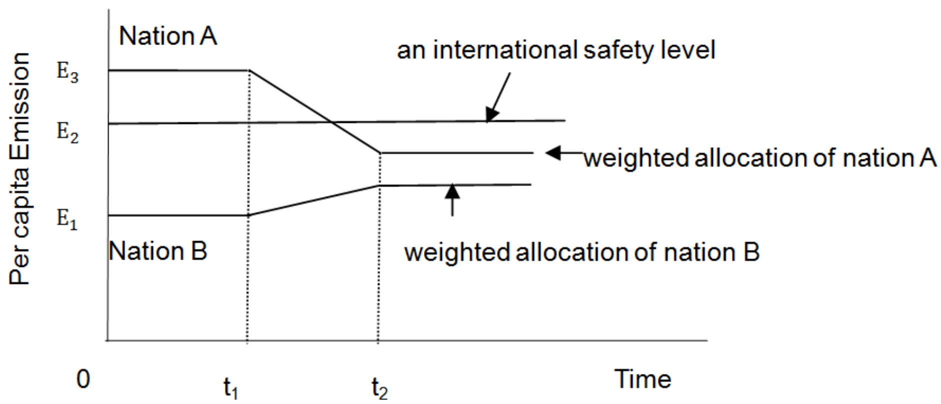

Fig. 6. A two-step mitigation path

5.2 Carbon Market

Suppose the cost of implementing quota management is positive with the number of persons, and they are linear related, the cost function c(n)=c×n=cn, n is the number of persons, c is a marginal parameter. Suppose emission managing can keep an amount of air clean from polluting, and the production function is y(n), suppose $y(n)=ae^n+a_0$, a>0, and a is a parameter, a_0 is a constant, n is the number of persons, y(n) is a mount of clean air. We see that y(n) is strictly convex, its first order is positive, and the second order is also positive, we have a increasing returns in the production of clean air.

Suppose p_y is the price of an unit of clean air, and we have a profit function R, $R=p_y y(n)-cn$. We can see that the quota management can be implemented effectively under the condition of $R \geq 0$. But the price p_y of clean air is important, and people will take effective methods to keep air clean if the price of clean air is high enough, or people attach enough importance to clean air. Otherwise, it is difficult for people to cooperate, and the air pollution problem would not be solved, so carbon markets are of most importance for prices formation of clean air.

Some people need more emission than their quotas, and some people need less, so carbon markets is in need to trade emission rights, carbon markets may be a best way to solve the emission problems, and people will find cost-effective GHGs abatements at carbon markets [54]. Emission rights can be traded easily at carbon markets once emission rights are allocated, and this is the base of “setoff” policies. The Environment Protection Agency took “setoff” policy to balance the stringent air-pollution control with the need for industrial growth in USA in 1976 [55], “setoff” policy helps people obey emission management. “Setoff” means a person can expand production scale by taking new energy-saving technologies, or set up new plants by purchasing old facilities and shutting them down while his total emission is within the quota limit, CDM (Clean Development Mechanism) can also be took as a kind of “setoff” policy.

Adam Smith demonstrated that specialization would increase the productive efficiency, and trading and markets would promote the specialization of people. That is the market mechanism and how people cooperate in the supply of private goods. We believe that privatization and marketing can also solve the emission problem in the protection of clean air.

5.3 Emission Rights Allocation and Institutional Arrangement

Clean air is a common resource, and it is the same with sun light and ground water. Common resources are subject to time or space, and their available amount is limited, there are conflicts among people when many persons chase after a limited common resource, and it is necessary to allocate the common resource among people to keep order and peace, because fights are easily triggered between individuals. Technically it is easy to allocate emission rights among people, but the difficulty is how to get the true emission information if people are concealing them. Is the investigation legal if a manager investigates emission information of a person, and will the person cooperate? Issues of investigation and punishment in the management of emission rights should be solved legally, and it is easy to manage the emission rights technically when the legal issues are settled, such as information investigation and punishment of the violator.

6. DISCUSSIONS AND CONCLUSION

We talk about the difficulty of cooperation in the international cooperation, and the necessity of a third party to promote the cooperation, and we take the responsibility of the third party as public services. Generally speaking there are many organizations acting as a third party, such as a court, a country, the United Nations, UNFCCC and other international organizations, they provide some kind of public service. Institutionalized arrangements are important for people to cooperate effectively in the GHGs emission control, and it is difficult for human beings to solve the GHGs emission problem if we cannot introduce a third party to implement quota management.

In fact, religion or culture is “a third party” that makes a group of people obey some rules, and keep the group of people cooperate and survive. For example, Jesus the son of God is a third party that make all of us do good things and help people who are in difficulty, and God will punish those who commit sins.

We know that property rights and patent laws have made the western world advanced in modern technology and industries, such as England and U. S. A. [56], and the eastern world has fallen far behind because of the lack of property rights and patent laws, such as China. Barrett [57] indicated the importance of institutions to eradicate epidemics, and being a global public goods, eradication of world epidemics pose problems for incentives and design of institutions worldwide, it is the same with the global emission control. We present a weighted formula of equal per capita emission and GDP, it is based on equity (per capita emission) and efficiency (GDP), and it is dynamic and changes along with technologies (carbon emission intensity) and GDP. We believe that clean-energy technology is the key to emission problem, and technology is a basic factor that promotes the development of human beings.

We present a two-step mitigation path to control GHGs emission, and we believe that emission allocation and carbon markets will bring a mechanism that solves the GHGs emission problem. Emission rights allocation is a kind of privatization, carbon markets are public platforms that provide incentive mechanism to promote clean-energy technology.

Carbon taxes will favorably promote clean-energy technology, but it will only add cost to our living if there is no substitutable energy, we are all looking forward to the breakthrough of clean-energy technology.

Feasibility and cost may be two important factors in the emission management, how to distinguish false information technically and how much is the cost, both of them are basic factors to implementing the emission control. To some degree, our freedom may be constrained for the emission control, is the emission control worth it, and are we ready to take it?

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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