International Carbon Emission Reduction Game of Low Carbon Development

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Abstract. Low-carbon development is the fundamental path to address climate change, and reducing carbon emissions is an inevitable requirement. There are differences between developed and developing countries and within developed countries on carbon emission reduction. Build a game model to analyse the strategies of international carbon emission reduction at different stages. In order to avoid the "prisoner's dilemma" of betraying each other and losing all parties in carbon emission reduction, developed countries should take the lead in emission reduction within the UN framework of climate change and help developing countries with carbon emission reduction through capital and technology, so as to achieve the win-win result of "deer hunting game".

Keywords: Low-carbon development, carbon emission reduction, strategies of international carbon emission reduction, a game model.

1. Introduction

Climate change is the most complex challenge facing humanity in the 21st century, not just an environmental issue, but also a political, economic and social one. International organizations, governments and the general public have all become active factors in tackling climate change. From the establishment of the Kyoto protocol to "Bali roadmap", to the Copenhagen conference on climate change, a climate change conference in South Africa, to the climate change conference in Paris, although the national interest demands, there are big differences in climate negotiations, but the ultimate goal is consistent, is to reduce global carbon dioxide emissions, save the human common homeland. High carbon consumption, pollution and emissions are not sustainable. Countries around the world are taking responsibility for reducing carbon emissions and looking for the right way to develop. In 2003, the British government first proposed the concept of "low-carbon economy", which aims to achieve more economic output through less consumption of natural resources and less environmental pollution. The development mode of low-carbon economy is in line with the requirements of emission reduction at the present stage, and it is an inevitable requirement to realize the harmonious coexistence of man and nature, man and environment. On low carbon development and carbon emission reduction policies and game research are: Tapio (2005) [1] the use of "decoupling" elastic (greenhouse gas emissions growth rate and the ratio of per capita GDP growth rate) concept, the decoupling index decouple subdivided into weak decoupling, the strong and weak negative decoupling, strong negative decoupling and expansion negative decoupling decouple, expansion connection, recession and decline 8 types of connection.

Through research, it is found that it is completely possible for developed countries to achieve strong decoupling between carbon dioxide emissions and economic growth. For developing countries, although there is a weak decoupling feature, it is very unstable. Therefore, relevant policy measures should be taken to make it more realistic to achieve relatively low carbon economic development. Galeotti et al. (2006) [2] found that the relationship between per capita carbon dioxide emissions and per capita income was inverted u-shaped. Pacala and Socolow (2004)[3] proposed the stable content of greenhouse gases in the atmosphere of the wedge cuts, analyzed the technology of the greenhouse gas emission reduction potential, and proposes the framework of technical solutions, points out that the large-scale application of low carbon economy technology can solve the issue of climate change over the next 50 years, global greenhouse gas concentration control at a low level. Hamin and

Gurran(2009)[4] believe that there should be policies to deal with these climate risks at all levels, from sustainable urban forms to alternative energy production and biodiversity conservation. Chen shiyi (2012) [5] evaluated and predicted the transformation process of low-carbon economy in China's provincial regions, and proposed that local governments should formulate reasonable economic policies and environmental policies to promote the transformation of low-carbon economy. Chai qimin and xu huaqing (2015) [6] analyzed four paths and scenarios for China to achieve total carbon emission control and peak carbon emission based on IMAC model.

2. The International Response to Climate Change and the Formation of Carbon Game Pattern

Carbon emission is an inevitable product of human society and economic development [9]. Developed countries are the major contributors to global greenhouse gas concentration. The United Nations framework convention on climate change (UNFCCC) was adopted at the United Nations conference on environment and development in Brazil in June 1992. In December 1997, the United Nations framework convention on climate change (UNFCCC) adopted the Kyoto protocol at three meetings in Kyoto, Japan. As a supplement to the UNFCCC, the goal is to "control the amount of greenhouse gases in the atmosphere at a reasonable level to prevent climate change from posing a threat to human existence". The Kyoto protocol follows the principle of "common but differentiated responsibilities" laid down by the United Nations framework convention on climate change (UNFCCC), requiring developed countries to take specific measures to limit greenhouse gas emissions, while developing countries do not undertake legally binding obligations to reduce greenhouse gas emissions. The Kyoto protocol established three flexible cooperation mechanisms -- the international emissions trading mechanism (ET), the joint implementation mechanism (JI) and the clean development mechanism (CDM) -- that allow developed countries to achieve emissions reductions flexibly through carbon trading markets, while developing countries have access to relevant technologies and funds. In December 2015, the Paris agreement was finally reached through negotiations and various disputes among various countries. Its main goal is to limit the increase of global average temperature in the 21st century to less than 2 degrees Celsius, set standards and requirements for global action to cope with climate change after 2020, and push countries to reduce greenhouse gas emissions.

Although all countries are concerned about the issue of climate change, the process of the conference is often not smooth, with various countries involved in the dispute over carbon emission quotas, historical issues of carbon dioxide emissions and responsibility for emission reduction. According to interest demands and policies, it can be roughly divided into three interest groups. The first interest group is represented by the European Union, including Britain, Germany, Denmark, France and other countries. The EU group has a positive attitude towards emission reduction and is a promoter and leader of climate negotiations and low-carbon economic development, calling for effective measures to reduce carbon emissions. The second interest group is the umbrella group, including the United States, Japan, Canada, Australia and other countries. The group has taken a negative stance, emphasizing market-based policies and demanding that developing countries take responsibility for cutting emissions. The third interest group is developing countries, including the BRICS, small island states, Africa and Latin America. The group does not oppose emission reduction, but opposes mandatory quantitative emission reduction.

The current global differences and games on carbon emission reduction are mainly reflected in two aspects: First, the differences between developed and developing countries on carbon emission reduction is obvious. Developing countries want developed countries to take the lead in emission reduction, and help developing countries to voluntarily reduce emission through funds and technology. However, some developed countries, led by the United States, have a negative attitude towards emission reduction, and require China and other developing countries to undertake mandatory carbon emission reduction responsibilities at the same time. Second, there are differences among developed countries. It is mainly about the interests of the EU and the umbrella group led by the US. The EU

firmly promotes global carbon emission reduction and low-carbon development, believing that emerging industries with low carbon emissions have great development prospects. The United States leads the world in total energy consumption carbon emissions, per capita carbon emissions and cumulative carbon emissions. It fears that carbon emission reduction will affect its economic development, so it shows a negative attitude towards global carbon emission reduction and low-carbon development, and even exits from the contracting party of the Kyoto protocol.

3. Analysis of International Carbon Emission Reduction Game

3.1 Analysis of "Prisoner's Dilemma" Game before Carbon Emission Reduction

In terms of global CO2 emissions, each country is the main contributor. For the convenience of research and analysis, assume that there are only two countries in the world: A and B. The basic assumptions of the model are as follows:

First, both country A and country B have two strategic choices: emission reduction and non-emission reduction.

Second, there are several strategic combinations: when countries A and B reduce emissions at the same time, they will gain R; When A cuts emissions but B does not, A gains S and B gains T; When country A does not reduce emissions and country B reduces emissions, country A gains T and country B gains S. Both countries get the same P when they choose not to cut emissions.

Third, it takes money to reduce carbon dioxide emissions. If everyone cuts emissions, a better environment will benefit the whole world. So, $T > R > P > S$.

Based on the above assumptions, the payoff matrix shown in Table 1 can be constructed.

Table 1. The "prisoner's dilemma" game matrix before international carbon emission constraints.

		Country B	
		emission reduction	without emission reduction
Country A	emission reduction	R, R	S, <u>T</u>
	without emission reduction	<u>T</u>, S	<u>P</u>, <u>P</u>

According to the above matrix, no matter country A chooses emission reduction or no emission reduction, the optimal choice of country B is no emission reduction. Whether country B chooses to reduce emission or not, the best choice of country A is not to reduce emission. Therefore, each player in the game model has a dominant strategy of not reducing emissions, which is the only Nash equilibrium of the game (no emission reduction, no emission reduction). This is a typical prisoner's dilemma game. The result of this game model reflects the contradiction between individual rationality and collective rationality, because the collective benefit of emission reduction is far greater than the collective benefit of non-emission reduction. But without external constraints, it is hard for individual countries to have the initiative to choose the strategy of reducing carbon emissions. This can also explain that before the concept of "low carbon economy" was proposed, countries consumed a large amount of fossil fuels in order to develop their economies, which led to the rapid increase of carbon dioxide emissions, and the climate change brought by the greenhouse effect had to limit the carbon emissions of each country. The "prisoner's dilemma" game model of climate change should be improved. For example, countries that do not reduce emissions should be punished from two aspects of political morality and economic punishment to increase the cost of not reducing emissions and thus reduce the benefits. This cost is denoted as C, and the constraints of C is shown as followed. The modified model is shown in Table 2

$$C > t-r \quad (1)$$

$$C > p-s \quad (2)$$

Table 2. International carbon emission reduction game matrix with punishment mechanism.

		Country B	
		emission reduction	without emission reduction
Country A	emission reduction	R, R	S, T-C
	without emission reduction	T-C, S	P-C, P-C

After the introduction of punishment, the dominant strategy of both parties changed from no emission reduction to emission reduction, and the Nash equilibrium was (emission reduction, emission reduction). The revised model suggests that countries can be incentivized to reduce carbon emissions if the penalty costs are large enough. But it is inappropriate for this model to put all countries in the same position to demand the same responsibilities. Because the historical cumulative carbon emissions of developed countries and per capita carbon emissions are much larger than the developing countries. In fact, when it comes to tackling climate change, developed countries play the role of big pigs, while developing countries play the role of small pigs.

3.2 Boxed Pig Game Analysis of Carbon Emission Reduction in the Implementation of Kyoto Protocol

The Kyoto Protocol follows the principle of "common but differentiated" responsibilities and gives specific requirements for developed countries to control greenhouse gas emissions. There are no specific emission reduction provisions for developing countries, but voluntary emission reduction principle is implemented. This stage mainly shows the boxed pig game between the carbon emission reduction of developed countries and developing countries. The basic assumptions of the model are as follows:

First, there are only two types of countries in the world, developed and developing, and each has two strategies: emission reduction and waiting.

Second, there are the following strategic combinations: when developed countries and developing countries reduce emissions simultaneously, developed countries gain R1 and developing countries D1; When developed countries reduce emissions while developing countries choose to wait, developed countries gain R2 and developing countries D2. When the developed countries choose to wait while the developing countries reduce their emissions, the developed countries get R3 and the developing countries D3. When both developed and developing countries choose to wait, the gains are R4 and D4 respectively.

Third, it is assumed that developed countries and developing countries have the same cost of emission reduction. Because developed countries have advantages in capacity, developed countries will benefit more than developing countries when both sides reduce emission. So R3 >, R1 > R2 > R4, D2 > D1 > D4 > D3.

Based on the above assumptions, the payoff matrix shown in Table 3 can be constructed.

Table 3. Boxed pig model of international carbon reduction

		Developing Country	
		emission reduction	await
Developed Country	emission reduction	R1, D1	R2, D2
	await	R3, D3	R4, D4

According to the above game matrix, no matter the developed countries choose emission reduction or waiting, the developing countries will choose waiting, so waiting is the dominant strategy of the developing countries, while the developed countries have no dominant strategy in this game, and the optimal strategy of the developed countries depends on the strategy of the developing countries. When

developing countries choose to cut emissions, the best strategy for developed countries is to wait; While developing countries choose to wait, the best strategy for developed countries is to cut emissions. Thus, the ultimate Nash equilibrium of the game is (emission reduction, wait). In the process of global climate change, the pig role of carbon emission reduction efforts of developing countries and motivation mainly depends on big pig role of developed countries, developed countries take the lead in emissions reduction, and then take the strategy of "free-rider", enjoy free carbon emissions in the developed countries bring positive externalities of global carbon dioxide reduction. However, due to the withdrawal of Canada, the United States and other developed countries from the Kyoto protocol, it is difficult for developed countries to fulfill their carbon emission reduction commitments. In this way, developed countries demand developing countries to undertake emission reduction obligations, so as to avoid the responsibility of big pigs. In order to stimulate the enthusiasm of developed and developing countries, the intellectual pig game model of carbon emission reduction can be improved. The most effective way is to increase the benefits of reducing emissions by reducing the costs. Assume that the increased revenue is the same, denoting as V, and increase the cost of waiting to reduce the free-riding revenue, assuming that the reduced revenue is the same, denoting as V', and the conditions are as followed. The improved boxed pig game model is shown in Table 4.

$$D1+V > D2-V' \quad (3)$$

$$D3+V > d4-v' \quad (4)$$

$$R1+V > R3-V' \quad (5)$$

$$R2+V > r4-v' \quad (6)$$

Table 4. Improved Boxed pig game matrix of carbon reduction

		Developing Country	
		emission reduction	await
Developed Country	emission reduction	R1+V, D1+V	R2+V, D2-V'
	await	R3-V', D3+V	R4-V', D4-V'

According to the improved wisdom pig game model, no matter developing countries choose emission reduction or waiting, the best strategy of developed countries is emission reduction. In turn, whether developed countries choose to cut emissions or wait, the best strategy for developing countries is to cut emissions. Emission reduction is the dominant strategy of both sides. Therefore, the improved wisdom pig game has the only dominant strategic equilibrium (emission reduction, emission reduction).

3.3 Stag Hunt Game Analysis after the Paris Agreement

The parties to The Paris Agreement do not have the understanding of whether they need to reduce emissions or not, but how, how and how much they need to do so. The game of cutting emissions after the Paris agreement can be analyzed as a game of deer hunting. Deerstalking is the story of two men who go out hunting for a deer and a rabbit. If you choose a deer, you need another person to choose a deer as well, to produce cooperation in order to successfully hunt. Rabbits, on the other hand, can be successful without cooperation, but they are less profitable than deer. The basic assumptions of the model are as follows:

First, participating country A and country B have two strategic choices: strong emission reduction and weak emission reduction.

Second, there are the following strategic combinations: when country A and country B both make strong emission reduction, the benefits obtained are Q1 and W1 respectively; When country A is strong in emission reduction and country B is weak in emission reduction, the benefits of country A and country B are Q2 and W2 respectively. When country A is weak in emission reduction and country B is strong in emission reduction, the benefits of country A and country B are Q3 and W3

respectively. When country A and country B have weak emission reduction at the same time, the gains are Q4 and W4 respectively.

Third, according to the game of deer hunting, it satisfies the conditions Q1 > Q4 > Q3 > Q2, W1 > W4 > W2 > W3.

Based on the above assumptions, the following payoff matrix can be constructed (Table 5).

Table 5. Stag Hunt model of carbon reduction

		Country B	
		strong reduction	weak emission
Country A	strong reduction	Q1, W1	Q2, W2
	weak emission	Q3, W3	Q4, W4

According to the above strategies, when country A chooses strong emission reduction, the optimal strategy of country B is strong emission reduction. When country A chooses weak emission reduction, the optimal strategy of country B is weak emission reduction. When country B chooses strong emission reduction, the best strategy of country A is strong emission reduction. When country B chooses weak emission reduction, the optimal strategy of country A is weak emission reduction. In this model, neither party has dominant strategy, and the optimal strategy of each party depends on the choice of the other party. Therefore, the Nash equilibrium has two (strong emission reduction, strong emission reduction) and (weak emission reduction, weak emission reduction). In other words, the game results in either strong or weak emissions cuts. But it is clear that the collective benefits of choosing strong emissions cuts are far greater than those of choosing weak ones. This is different from the prisoner's dilemma game of carbon emission reduction between countries before carbon emission restriction. The prisoner's dilemma game is that although the emission reduction of both sides is pareto optimal, they still choose to betray each other for their own interests. Deer hunting game final results will appear full co-operation or full betrayal, according to national condition and the cost of economic development, especially the developed countries and developing countries during the game, to the developing countries and developed countries should be fully considered and unequal responsibility requirements, let developing countries choose strong reduction strategy when income is greater than the benefits of cooperation, so the developed countries and developing countries can achieve win-win results.

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