APPLYING CLUB THEORY IN ACHIEVING REGIONAL CARBON NEUTRAL TARGET: ABATEMENT GAME IN CHINESE PROVINCES

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Overview

Like the whole world, China is experiencing severe climate change problems with the development of the economy, which is predominantly the result of increasing greenhouse gases (GHGs) in the atmosphere from fossil fuel consumption. It is generally accepted that carbon dioxide (CO2) is the main inevitable pollution externality that causes global warming. China's carbon dioxide emissions increased rapidly from 3515.8 million tons in 2002 to 9866 million tons in 2017, with a 2.8 fold increase. Meanwhile, China's annual air temperature has risen by more than 1.0 °C in the past three decades, higher than the global average (Lo and Cong 2017, Fang, Yu et al. 2018). In a situation like this, China faces growing domestic and foreign pressure to control its domestic carbon dioxide emissions.

Recently, China's leaders have laid out detailed rules for reducing carbon dioxide emissions. In September 2020, at the 75th Session of the United Nations General Assembly, China announced two crucial goals of reaching a carbon peak by 2030 and being carbon neutral by 2060. Some measures were set out in the nation's 14th Five Year Plan, which was regarded as formal and discreet commitments to global climate change. Different efforts to control carbon dioxide emissions in China have been well discussed in perspectives of the *carbon tax* (Liu, Wang et al. 2015, Liu and Lu 2015, Zhang, Guo et al. 2016, Zhang, Zhang et al. 2017, Lin and Jia 2018, Cao, Dai et al. 2021), *carbon emission trading system* (Wang 2013, Munnings, Morgenstern et al. 2016, Zhao, Jiang et al. 2016, Zhao, Wu et al. 2017, Lu, Ma et al. 2020), *cap-and-trade* (Liu, Guan et al. 2013, Pan, Yang et al. 2019), *Clean Development Mechanism (CDM)* (Resnier, Wang et al. 2007, Wang 2010, Maraseni 2013, Zhao, Li et al. 2014). All the policy tools listed above are adopted effectively to limit domestic CO2 emission under the existing trading system. Still, importantly, a system combining regional economic development and GHGs emissions is not well discussed, which affects regional equity of development. Therefore, this study introduces club theory inside China by applying provincial data to discuss a potential alliance mechanism to deal with climate change.

There has been a long road world tried to reach an effective international agreement on carbon dioxide reduction despite efforts from science, technologies, and politics involved. Under the guidance of the United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol was initially signed by 84 countries in 1999-1999 without the US and with Canada quit in December 2011, which leads to less global impact nowadays. Then the 2015 Paris Agreement attracted the world's primary carbon dioxide contributors limiting the globe towards 2 degrees of warming goal. But, even the US signed the Paris Agreement in 2016, the Donald Trump government quit the agreement for the sake of national economic interest in 2020, but the Joe Biden administration returned in 2021, which brought back public concerns over the uncertainty of international climate agreement. The fundamental reason for the global climate agreement's instability lies in that a country can receive the benefits of climate improvement without contributions, also called free-riding. The Westphalian dilemma gives sovereign nations the right of political freedom on operating internal affairs without outside intervention. So, it is legal to perform as free-riders in in the international climate issue, then how to deal with it? Climate club, which stems from the branch of club theory, can fit this problem perfectly.

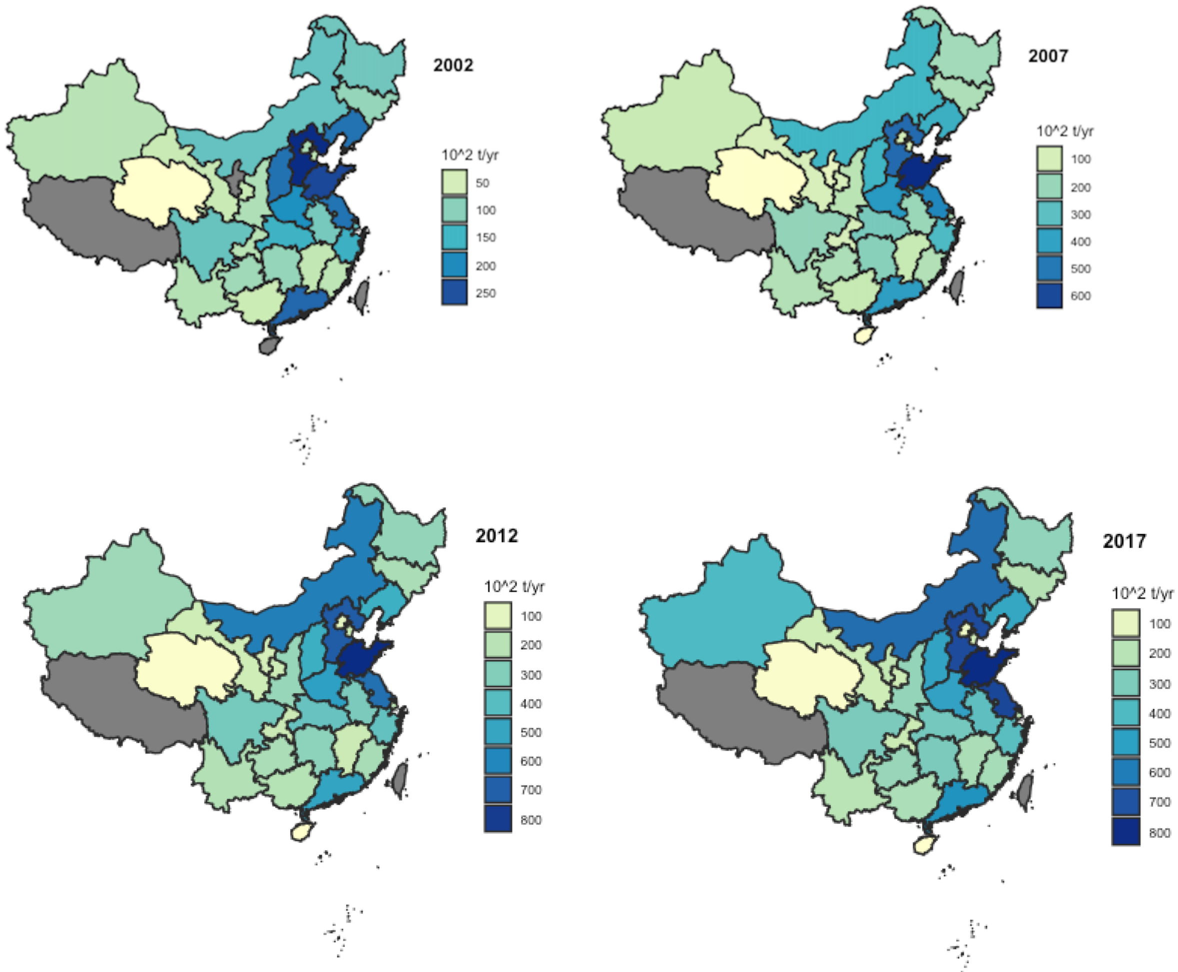


Figure 1 Distribution of carbon dioxide emissions in China

Club is a voluntary group deriving mutual benefits from the benefits costs of producing activity with public-good characteristics (Nordhaus 2015). Members in the climate club undertake harmonized emissions reduction efforts with nonparticipants are penalized for their benefits of climate improvement. The international climate club has gone through a long process, and there are still many difficulties until now, to no real international climate club exists in the real world. The determinants of climate club success are club design, incentive mechanisms, club good like low carbon technologies, level of sanctions, and side-payment. Different model designs from game theory (Nordhaus 2015, Nordhaus 2020) and agent-based model (Hovi, Sprinz et al. 2019) have been used in creating climate club model, but punitive and uncertain alliances in the international community make these studies problematic in practice. Namely, sovereign states can react to a punitive tariff with other sanctions, and trade tariffs for non-collaborators may be too small or ruinous without environmental utility improvement.

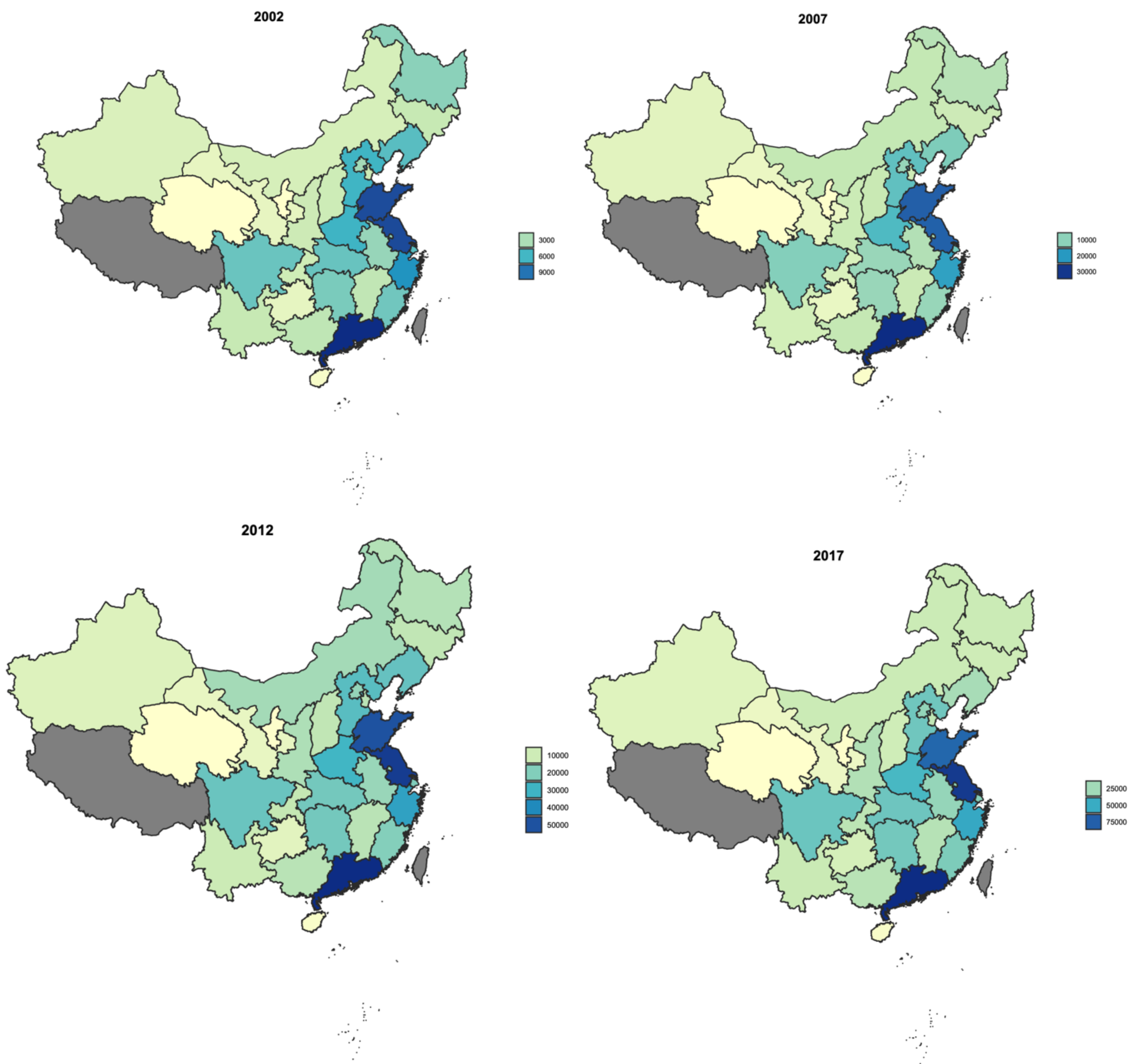


Figure 2 The distribution of provincial GDP in China

China is an ideal place to experiment with the climate club, and little attention has been paid to the related topic. Firstly, China has the characteristics of multi-region, which is similar to the nature of multi-country in the world. Secondly, the phenomenon of free-riding in the international climate governance also exists inside China at the provincial level, but it has not attracted widespread attention. Thirdly, China's carbon dioxide emissions vary in different regions and at varying levels of economic development, which means some parts have more significant potential to reduce emissions, while others have greater willingness to pay for environmental utility, and they have a need to complement each other. The distribution of carbon dioxide emissions, regional GDP distribution, and carbon dioxide emission intensity (CO2 emissions/GDP) can be seen in Fig 1. Fig 2. Fig 3 separately. Fourthly, the border carbon tariff can be modeled in Chinese provinces. China has a stable central government, and the socialist system gives a large government the possibility of coordinating public resources to improve the overall welfare of society. Stable clubs require homogeneity of participants, and China's provinces have such conditions. President Xi proposed a community with a shared future for humanity. The adoption of provincial-level carbon tariffs is consistent with the industry's high-quality development goals. Fifthly, local carbon tariff is equal to zero is consistent with the reality of low tariffs under the WTO trade agreement, which is important for promoting climate club to an international scale. Sixthly, Due to the limitation of land resources in China, the space for agricultural and ecological land has been squeezed, and the conflicts between urban, agricultural, and ecological spaces have intensified. The intensity of land development in areas such as Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta approaches or exceeds the carrying capacity of resources and the environment. Regions with better endowments still have greater potential. Taking China as a planning unit can manage the land in peak and non-peak areas in a unified way and promote carbon neutrality to the greatest extent. Seventhly, using the border carbon tariffs to invest in carbon-neutral development can solve green funding sources. Eighthly, social awareness of the environmental externalities arising from the consumption of goods is gradually increasing. For example, public willingness to pay for plastic bags is generally accepted, which will pressure the government to implement the climate club system. Ninthly, the central concern on the feasibility of climate clubs lies in political legitimacy. In terms of the carbon tariff return system we come out with in this study, Falkner argued that in the international economic world, the payments typically flown from developed countries to emerging economies have failed to roll back emissions in the developing nations. But the climate club inside China, we model the carbon tariff to be invested in the decarbonization industry, which is also workable under the central system of a country.

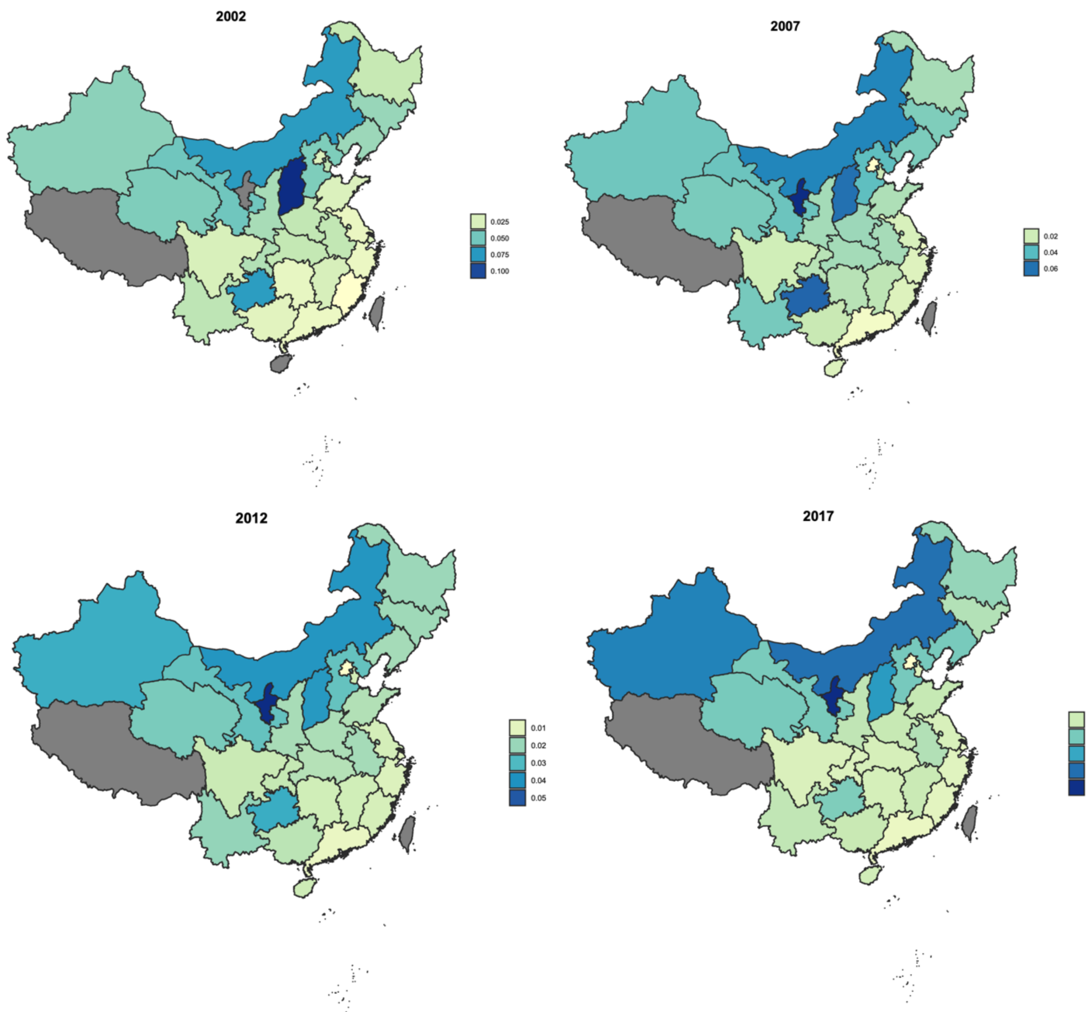


Figure 3 Distribution of carbon dioxide emission intensity in China (CO2 emissions/GDP)

According to the discussion above, we propose a game theory approach to testing stimulates the climate club system at the Chinese provincial level. The paper proceeds as follows. Section Method, we discuss the internal mechanism and model structure behind the Chinese provincial climate club. The following section presents the results and welfare gains from different carbon border tariffs and carbon tax scenarios. The final section presents the conclusion.

Methods

The model we prompt encouraging reluctant regions to become members if their payoff inside the club is greater than outside as free-riders, but for the enthusiastic club members, they stay in the club for the benefit is greater than withdrawal and abandon it only if staying generates negative net private benefits compared to the scenario without any club at all. The data for Chinese provincial carbon emissions and regional trade volume data are collected from CEADs (Carbon Emissions Accounts and Datasets for emerging economies, https://www.ceads.net.cn). Chinese provincial Gross Demastic Productions data and dgraphic Data are collected from China Statistical Yearbook.

We use non-cooperative game model:

Suppose there are a total of N regions in China, $i(i=1,2,...,N)$ represents the i*th* region.

To simplify, the utility of each region can be divided into four parts, economic output, trade tariff rewards and punishments brought by the club, abatement cost, and damage caused by the environment to the region. Specifically, the total utility of each area can be expressed as:

$$W_i = Q_i + \sum_{j\neq i} T_{ij} B(\Delta\tau, C_i, C_j) - \sum_{j\neq i} T_{ji} P(\Delta\tau, C_i, C_j) - A(E_i^*, E_i, C_i) - D_i(E_1, ..., E_N)$$

Where Q_i is the economic output of region i, which equals the GDP of region i.

C_i is the decision variable of whether area i joins the club, $C_i = 1$ means it joins the club, and it is equal to 0, means not joining. Because it is a single-period game, this article assumes that a region that has joined the club has no additional penalty for exiting. Therefore, a region is not a club member originally, and it should have the same effect as joining and then exiting. In other words, the utility of an area is only related to its current club membership status and has nothing to do with whether he was a club member before.

$\sum_{j\neq i} T_{ij} B(\Delta\tau, C_i, C_j) - \sum_{j\neq i} T_{ji} P(\Delta\tau, C_i, C_j)$ is the revenue (penalty) of the trade volume that region i receives (pays) to join (exit) the club. Where T_{ij} represents the total export trade volume from area j to area i. Region i will levy export taxes on this part.

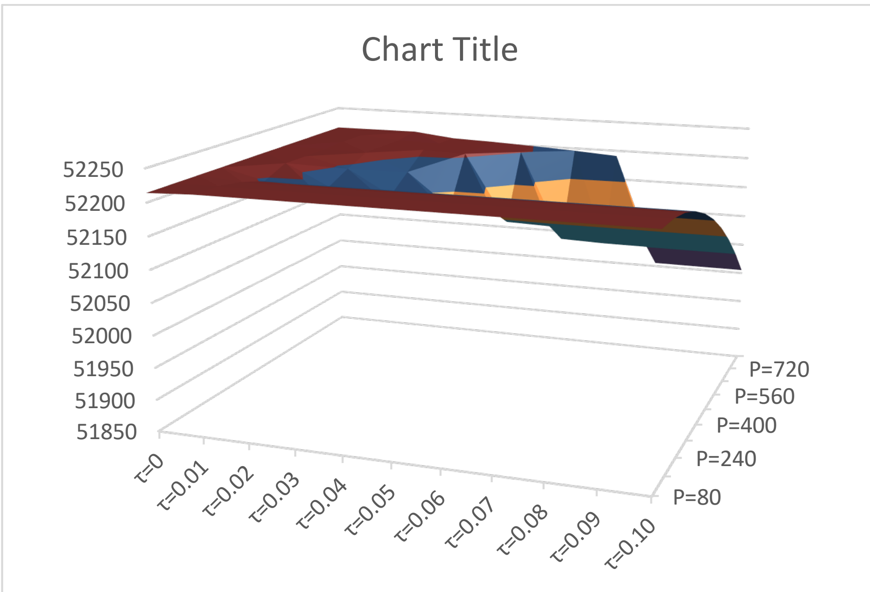
$T_{ij} B(\Delta\tau, C_i, C_j)$ represents the additional utility obtained by region i from levying export taxes on region j, where $B(\Delta\tau, C_i, C_j) = \Delta\tau - z_{ij}\Delta\tau^2$ when $C_i = 1, C_j = 0$; $B(\Delta\tau, C_i, C_j) = 0$, otherwise. Here $\Delta\tau$ represents the export tax rate charged by club members to non-club members. This article assumes that the tax rate charged by all club members to non-club members is the same. The segmentation hypothesis of $B(\Delta\tau, C_i, C_j)$ means that if and only if area i is a club member and area j is a non-club member, the partial utility is not zero. $B(\Delta\tau, C_i, C_j)$ is the revised tax rate item. This is because the additional tax rate will distort the trade price of the two regions and affect the utility of the relevant region. Therefore, it needs to be revised in the total utility. For the sake of simplicity, this article assumes that the correction term is a quadratic function of $\Delta\tau$. This term also implies that club members will not impose unlimited punitive tariffs on non-club members.

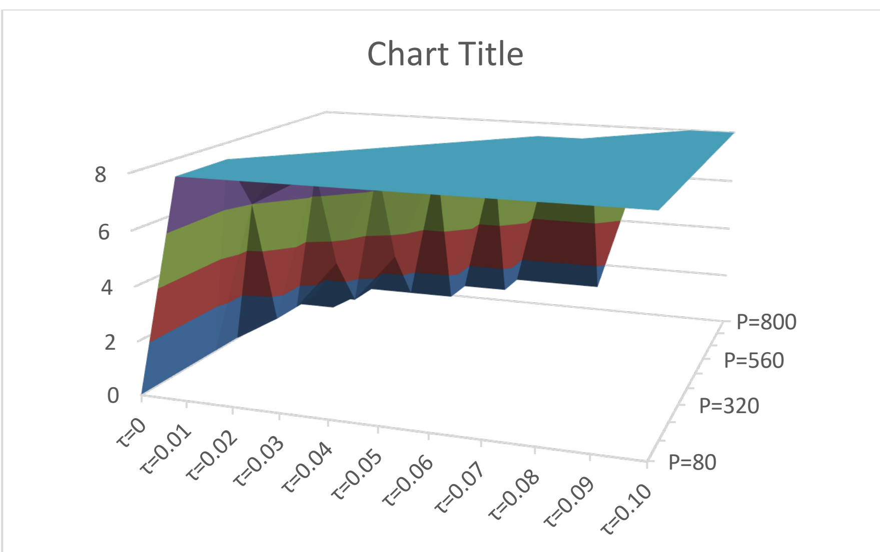
Similarly, $T_{ji} P(\Delta\tau, C_i, C_j)$ is the utility loss caused by area i as a non-club member paying punitive tariffs to other club members. Specific: $P(\Delta\tau, C_i, C_j) = \Delta\tau - x_{ij}\Delta\tau^2$, when $C_i = 0, C_j = 1$; $P(\Delta\tau, C_i, C_j) = 0$, otherwise.

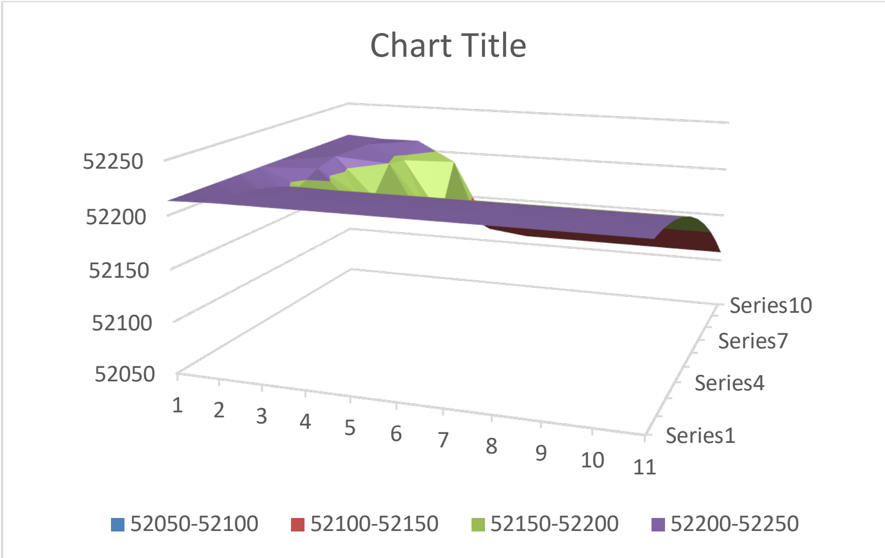
$A(E_i^*, E_i, C_i)$ is the cost of emission reduction in area i. Following Nordhaus's assumption, this article assumes that $A(E_i^*, E_i, C_i) = \alpha\mu_i^2 Q_i$ when $C_i = 0$. Here, $E_i^* = \sigma Q_i$ is the emission caused by no emission reduction measures, and σ is the emission factor. $\mu_i = \frac{E_i^* - E_i}{E_i^*}$ is the emission reduction ratio, and α is the unit emission reduction cost coefficient. When $C_i = 1$, because i is a member of the club, it must fulfill its emission reduction obligations. Therefore, the value of E_i (equivalent to μ_i) is limited, that is, μ_i must satisfy $\mu_i \geq \frac{P^*\sigma}{2\alpha}$ where $P_i = \frac{2\alpha\mu_i}{\sigma}$ is the marginal abatement cost of the emission reduction ratio of area i to μ_i, therefore, this requirement is equivalent to requiring that the marginal emission reduction cost of club members must exceed the agreed carbon price P^*, which imposes a requirement on the emission reduction ratio of each member.

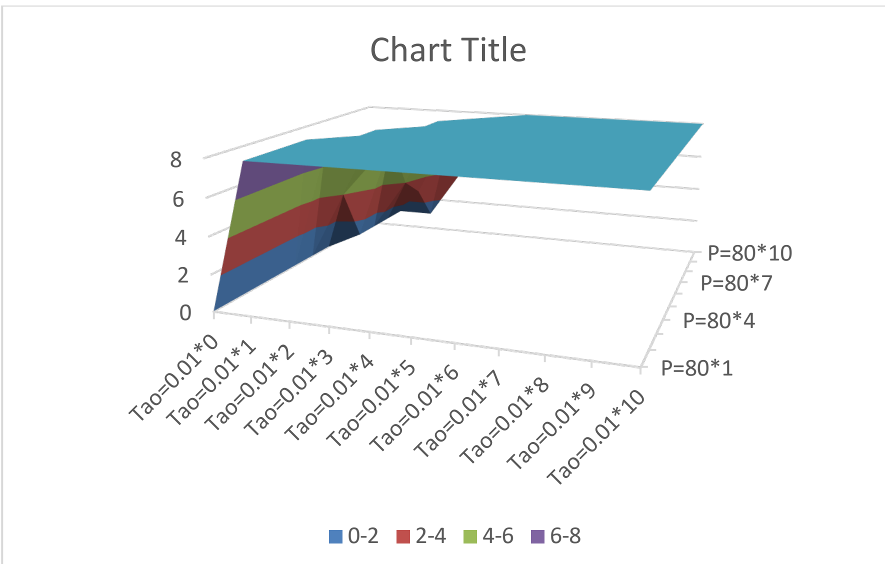
$D_i(E_1,...,E_N)$ is the environmental damage suffered by area i, following the Nordhaus assumption, this paper let $D_i(E_1,...,E_N) = \theta_i\gamma(E_i + \sum_{j\neq i} E_j)$, here γ is the national SCC (Social cost of carbon), that is, the sum of damage caused by each unit of carbon emissions to all regions. θ_i is the vulnerability index of area i, which represents the proportion of damage suffered by area i in the total, so it should have $\sum_{i=1}^{N}\theta_i = 1$. For the sake of simplicity, this article assumes that θ_i is proportional to the total economic output of region i.

Results









It can be seen that the number of club members increases with the increase in the punitive tariff rate, and there is no turning point when the tax rate reaches 10%. Decrease as the price of carbon increases.

Compared with carbon prices, the number of club members is more sensitive to punitive tariffs. And it is relatively more sensitive when the tariff is smaller. A 1% tariff is enough to make more than 6 member states join the club when the carbon price is less than US$200/ton. Therefore, setting a small penalty tariff appropriately is a very effective way to encourage various regions to join the club.

When the trade tax rate increases, the total utility of all regions will drop off a cliff. But when the tax rate is fixed, the total utility of all regions shows a gradual decline as the carbon price increases. And when the carbon price reaches a certain level, this rate of decline will increase.

Conclusions

In this paper, we first present the climate pressure in China with carbon emission and the commitments China has made for carbon abatement goal. The existing carbon reduction policies of carbon tax, cap-and-trade, clean development mechanism are not combining regional economic development and GHGs emissions, then we introduce club theory into China's case. After a briefing of international climate agreements on Kyoto Protocal and Paris Agreement, we found that the club is unstable because of free-riding. Climate club was then proposed. Then we pointed out the advantages of implementing environmental clubs in China. In the method part, we describe the climate system in details and provide two numerical simulation results under two scenarios finding number of club members increases with the increase in the punitive tariff rate, and there is no turning point when the tax rate reaches 10% and when the tax rate is fixed, the total utility of all regions shows a gradual decline as the carbon price increases.

With no doubt, China, like the rest of the world, is a long way from adopting a successful international and multilateral climate club system dealing with the climate crisis. Testing the climate club within the regime of a country will provide confidence to the world of implementing such procedure if it could, and hopefully a tiny cornerstone on the road for human carbon neutral target.

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