WHO WILL BE THE BENEFICIARIES OF RENEWABLE ENERGY SUBSIDIES IN CHINA? AN ANALYSIS FROM THE PROVINCIAL LEVEL IN CHINA

Fan Ye, China National Petroleum Corporation Economics & Technology Research Institute, (+86)15101186516, fanyecup@foxmail.com
Fang Ming, China University of Petroleum (Beijing), (+86)18810066372, sliverfrank@foxmail.com

Overview

Renewable energy is identified as an important way to cope with climate change, energy shortage and global warming. Many countries have been promoting the utilization and diffusion of renewable energy. Since China is a big country of energy production and consumption, it faces more severe task to increase energy supply and mitigate climate change. However, renewable energy just accounts for about 10% of the total energy consumption in China. In "China-US Joint Statement on Climate Change", Chinese government proposed the target of raising the share of non-fossil energy to 20% by 2030. Encouraging renewable energy investment is recognized as an important step to promote renewable energy in China. However, investors hesitate to invest renewable energy power generation project because of the investment recovery difficulty and high investment risk. It is essential to offer extra economic incentive to renewable energy investors. In order to improve the effectiveness of policies and avoid excessive incentive, governments have continuously adjusted the existing subsidy policies. For a different perspective, international environmental contracts are unstable, just like the member states of the Paris environmental agreement keep withdrawing *. However, China's socialist system is a very ideal and effective system for multi-regional cooperation to solve environmental problems. Each province in China is under the same social framework, subject to the same political constraints, and the implementation of policies is coherent. This article uses the provinces of China as the main body to establish a "Punishment-subsidy system"joint model to find the optimal form of subsidy to achieve the equilibrium of social "welfare-environment" utility maximization. This paper 1) builds the model; 2) discuss the model equilibrium; 3) discuss the model result with Chinese provincial level data.

Methods

Model assumptions:

Suppose China has N regions in total, i $(i=1,2,...,N)$ represents the i-th region, a region represents a province. Let $t(t=1,2,...,T)$ be the number of periods.

Objective function:

This problem is a dynamic game model. For each period t, the welfare function of a region i is

$$W_{i,t}=O_{i,t}-C_{i,t}(O_{i,t},\theta_{i,t},e_{i,t})-D_{i,t}(E_{1,t},...,E_{N,t})+x_{i,t}S_{i,t}-\mu_{i,t}S_t$$

Where $W_{i,t}$ is total economic welfare

For i regions, $O_{i,t}$ represents the economic output of its period. Let λ_i represent the energy efficiency of area i, that is, the energy consumed per unit output, then the energy consumed is $\lambda_i O_{i,t}$. Among them, renewable energy accounts for $\theta_{i,t}(0<\theta_{i,t}<1)$ in the total energy consumption, then renewable energy consumption is $R_{i,t}=\theta_{i,t}\lambda_i O_{i,t}$, and fossil energy consumption accounts for $F_{i,t}=(1-\theta_{i,t})\lambda_i O_{i,t}$. Assuming that the carbon emissions caused by unit fossil energy consumption are $e_{i,t}$, the total carbon emissions in the current period for region i is $E_{i,t}=e_{i,t}F_{i,t}$.

$C_{i,t}(O_{i,t},\theta_{i,t},e_{i,t})$ is the governance cost paid by district i for the emission rate to reach $e_{i,t}$ and the investment cost for the development of renewable energy.
$D_{i,t}$ represents the environmental negative effect of carbon emissions on area i. Taking into account the externalities of environmental impacts between different areas, emissions $E_{j,t}$ in other areas will also cause damage

to area i, $D_{i,t}$ is a function of $E_{j,t}(j=1,2,...,N)$ and $\frac{\partial D_{i,t}}{\partial E_{j,t}}>0$. For the sake of simplicity, let $D_{i,t}$ be a linear function of g $E_{j,t}$,that is $D_{i,t}=\sum_{i=1}^{N}\alpha_{i,j}E_{j,t}$.

"Punishment-subsidy system":

$x_{i,t}S_{i,t}$ and $\mu_{i,t}S_t$ represent the subsidies and obligations assumed by joining the "penalty-subsidy system", respectively. The subsidy is jointly provided by the central government and all members of the "penalty-subsidy system", which is called the carbon emission reduction dividend, for the carbon emission reduction brought by the development of renewable energy will benefit all other regions; the obligation is also due to other Regional carbon emission reductions have resulted in regional i dividends, so it is reasonable to pay other members. $x_{i,t}$ is called the degree of participation, and the degree of participation determines the proportion of each member's participation in distribution and commitment. The optional range of $x_{i,t}$ is given by the central government. Each region chooses the appropriate degree of participation, and $x_{i,t}=0$ indicates that region i does not participate in the system in period t. Under unit participation, the total subsidy received by member i for the development of renewable energy is $S_{i,t}=s_t\Delta R_{i,t}$, where s_t is the subsidy rate given by the central government and $\Delta R_{i,t}=R_{i,t}-R_{i,t-1}$ is the growth of renewable energy consumption at period i. At the same time, assuming that the obligation commitment coefficient of region i is $z_i(O_{i,t},E_{i,t})$, the ratio of the obligations undertaken by region i in the t period to the total obligations is $\mu_{i,t}=\frac{x_{i,t}z_i(O_{i,t},E_{i,t})}{\sum_{j=1}^{N}x_{j,t}z_j(O_{j,t},E_{j,t})}$, and S_t is the sum of the obligations of all members in the t period. Therefore, the subsidy received by the area i in period t is $x_{i,t}S_{i,t}$, and the obligation assumed is $\mu_{i,t}S_t$. Here, there is a binding relationship $\sum_{i=1}^{N}x_{i,t}S_{i,t}=S_t+S_t^*$ between S_t and $S_{i,t}$, which means that the sum of subsidies and benefits received by system members is equal to the sum of obligations plus central government funding, and S_t^* is central government funding, which is given in advance.

The equilibrium of this game is that when there are more members in the "penalty-subsidy system", new members are more motivated to join, because the more regional members, the new members receive the same subsidies while increasing their participation, and at the same time bear the smaller obligations. And the central government's funding guarantees that when the system has fewer members, its members can also enjoy renewable energy subsidies.

constraint condition

$\sum_{i=1}^{N}x_{i,t}S_{i,t}=S_t+S_t^*$ is the sum of the subsidies received by all members participating in the club equal to the sum of their obligations plus the central government funding. $\alpha_{i,j}>0$. $x_i\in\{0,1\}$. For the sake of simplicity, this article assumes that each region can only choose between non-participation and participation.

Model equilibrium:

The decision variable $\Delta R_{i,t}$ about the optimal scale of renewable energy in equilibrium, which meets

$$\frac{\partial C_{i,t}}{\partial \Delta R_{i,t}}+\frac{\partial D_{i,t}}{\partial \Delta R_{i,t}}=\frac{\sum_{j\neq i}x_{i,t}z_{i,t}}{\sum_{j=1}^{N}x_{i,t}z_{i,t}}x_{i,t}.$$

And $x_{i,t}$ in the the equilibrium can be shown in the table:

	$x_{i,t}$ in equilibrium solution 1 (or satisfy the equation)	$x_{i,t}$ in equilibrium solution 1 (or satisfy the equation)
$S_t^* = 0$	$x_{i,t} = 0 (i = 1, ..., N)$	$x_{i,t} = 0, (\frac{\sum_{j \neq i} x_{j,t} \Delta R_{j,t}}{\sum_{j \neq i} x_{j,t} z_{j,t}} > \frac{\Delta R_{i,t}}{z_{i,t}})$ $x_{i,t} = 1, (\frac{\sum_{j \neq i} x_{j,t} \Delta R_{j,t}}{\sum_{j \neq i} x_{j,t} z_{j,t}} > \frac{\Delta R_{i,t}}{z_{i,t}})$
$S_t^* > 0$	——	$x_{i,t} = 0, (\frac{\sum_{j \neq i} x_{j,t} \Delta R_{j,t} - S_t^*}{\sum_{j \neq i} x_{j,t} z_{j,t}} > \frac{\Delta R_{i,t}}{z_{i,t}})$ $x_{i,t} = 1, (\frac{\sum_{j \neq i} x_{j,t} \Delta R_{j,t} - S_t^*}{\sum_{j \neq i} x_{j,t} z_{j,t}} > \frac{\Delta R_{i,t}}{z_{i,t}})$

Results

In the game of deciding whether to join the “penalty-subsidy system” and determining the growth rate of renewable energy development (Under the premise of other parameters, the scale growth rate of renewable energy in each period and its proportion of total energy is a one-to-one relationship, so it is equivalent to choose which one as the decision variable. This article uses $\Delta R_{i,t}$ as the decision variable.) There are two possible equilibriums in this game model. When the central government funding S_t^* is zero, there is an equilibrium where all members' participation is zero. But when S_t^* increases, such an equilibrium will not exist; in the equilibrium state, several participants will have a non-zero participation degree. Whether or not to participate depends on the ratio of the renewable energy scale growth rate and its obligation coefficient in each region. The larger the ratio, the more motivated the member to participate in the club. Such a mechanism will make areas where renewable energy development is in its infancy more motivated to join the system. There is a positive correlation between the participation of each region in the equilibrium and the cost of reducing emissions and investing in renewable energy.

We are trying to use China's provinces as regions, use China's provincial data for numerical simulation, and run the model based on the proper prediction of future economic output and energy consumption. Based on the results of the current model calculations, we will find that A certain number of provinces have actively joined the renewable energy “investment-subsidy” system, and environmental negativeness will be reduced.

Conclusion

In this paper, we discuss one potential “penalty-subsidy system” model for different Chinese provinces which enrich the welfare of society and environment. Model equilibrium has been discussed and present the results. We also tried to use China's provinces as regions, use China's provincial data for numerical simulation, and run the model based on the proper prediction of future economic output and energy consumption. Based on the results of the current model calculations, we will find that A certain number of provinces have actively joined the renewable energy “investment-subsidy” system, and environmental negativeness will be reduced.

References

*Nordhaus, W., 2015. Climate clubs: Overcoming free-riding in international climate policy. American Economic Review, 105(4), pp.1339-70.