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New evolutionary game model of the regional governance of haze pollution in China

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ABSTRACT

This paper constructs an evolutionary game model of haze cooperative control between the heterogeneity governments, which is used to analyze the dynamic evolution path of game system as well as evolutionarily stable strategy under the three different conditions: no constraint, the introduction of compensation mechanisms and the introduction of punishment mechanism. The results show that, due to the heterogeneity of governments, the stable model of cooperation cannot be formed between heterogeneous governments spontaneously, so the superior government should impose administrative penalties on the uncooperative governments to promote the formation and stability of cooperation control model. The conclusion of this paper can provide reference for the Chinese government to formulate environmental policies.

1. Introduction

As one of the countries with the most severe haze pollution in the world, China has listed the regional governance of haze pollution as an important part of the national ecological civilization construction [1].

Under the current political ecology civilization of China, “environmental regulation” [2], “restrictions on vehicle travel” [3], and “replacement of coal by natural gas” [4] have been the main ways to control haze pollution. Based on this, the local governments in the region will implement the above-mentioned environmental policies at the same time to achieve regional governance. However, under Chinese style decentralization [5], local governments have enough autonomy to choose cooperative strategy (enforcing environmental protection policies at the same time as agreed) or non-cooperative strategy (environmental policies are not implemented in time). On the other hand, the space diffusion phenomenon that haze pollution spreads from high concentration to low concentration, leads to the spread of haze pollution of the non-cooperative party to the cooperative party in the regional governance. This behavior of stealing environmental benefits by non-cooperative strategy is called “free-riding behavior” [6]. Because of the high degree of autonomy of local governments, free-riding behavior is widespread during the process of regional governance.

Moreover, the cooperating subjects are heterogeneous, which means the subjects have one or more different category parameters [7]. Differences in specific category parameters will cause that subjects choose different behavioral strategies, like motivational heterogeneity [8], preference heterogeneity [9], production costs heterogeneity [10], investment heterogeneity [11], strength heterogeneity [12] and so on. During the process of regional governance, governments in the region

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have certain differences in politics, economy, technology, and other aspects, such as different governance costs, environmental preferences, and management methods, so the benefits they can obtain are different. The differences between local governments are defined as government heterogeneity.

Free-riding behavior and government heterogeneity badly influence the formation and stability of the regional governance of haze pollution in China. In terms of promoting regional governance, along with the spontaneous cooperation agreements reached by local governments under unrestricted conditions [13]. Yang and Qiu [14] introduced fiscal cooperation into the regional governance, they proposed that high-yield side should pay compensation to the low-yield one, to coordinate multi-subject interests. Guo and Yang [15] analyzed the causes and impacts of cross-border environmental pollution incident in 2001 in Jiaxing and Suzhou, China, which showed that the supervision and punishment of superior governments on local governments would have played an important role in promoting regional governance. In addition, in this pollution incident, non-cooperative behavior of two local governments led to the failure of pollution to be treated in time, which resulted strong dissatisfaction and overreaction among citizens. This further revealed that the uncooperative behavior of governments would cause huge conflict cost.

The above-mentioned papers proposed three mechanisms for promoting regional governance, lacking theoretical justification for the effectiveness of the mechanism, though. The purposes of this paper are to put forward the feasible mechanism and necessary conditions for the formation of a stable cooperative control model between the heterogeneous local governments. Therefore, this paper constructs an evolutionary game model of haze cooperative governance under the perspective of government heterogeneity, discusses the evolutionarily stable strategy (abbreviated as ESS) [16] with three different mechanisms.

The remainder of this paper is organized as follows. The problem description and research hypotheses are presented in Section 2. Section 3 is to develop the evolutionary game model. Finally, the results and discussion of this study will be presented.

2. Problem description and research hypotheses

In this section, the topic of this research was further described. And four hypotheses of the research were proposed. Finally, the parameters involved in models were accurately defined.

2.1. Problem description

Because of the environmental externality caused by the spatial fluidity of haze, the game process that the local governments in the region compete for the public utility of environmental effects is similar to that of the classic hawk–pigeon game [17]. Hawk–pigeon game studies the strategic balance of internal competition and conflict, of which hawks and pigeons, respectively, refer to “aggressive type” and “peaceful type”. When the two sides of the game compete against each other for certain interests, the side adopting the aggressive strategy will obtain more benefits than that adopting the peaceful strategy. If both sides adopt “aggressive” strategy, then both will fail and lose resources. In the haze cross-border cooperation game system, both sides can evenly share benefits if both choose cooperative strategy; if one chooses cooperation and the other non-cooperation, the non-cooperative party can theft part of benefits from the cooperative party through free-riding behavior; if both sides choose non-cooperative strategy, there will be fierce conflicts and loss of benefits.

In this paper, the hawk–pigeon game model was used to establish a regional cooperative governance game system.

2.2. Research hypotheses

This study proposes that:

Hypothesis 1. *Based on the current severe haze pollution in China, local governments in the region will treat haze pollution in their territory. And based on China’s current control measures, the cost of local government managing haze will not change no matter whether they adopt cooperative strategy or treat separately.*

Hypothesis 2. *Both governments in the region have certain heterogeneity, and both game parties share benefits of cooperative governance and possible conflict costs in proportion to their heterogeneity differences.*

Hypothesis 3. *The environmental benefits that local governments can steal through free-riding behavior are the same.*

Hypothesis 4. *The impact of the atmospheric environment on the study area is not considered. That is to say, the area is a closed system, and haze will only flow within the area and will not spread out. The haze outside will not be diffused in. The max environmental effect of the area will remain unchanged.*

Hypothesis 1, Hypothesis 2 and Hypothesis 3 are the realistic basis for constructing the payoff matrix of Hawk–pigeon Game Model. At the same time, Hypothesis 2 reveals the way in which the important factor of “government heterogeneity” is used in this model. Hypothesis 3 simplifies the structure of the model. Considering the influence of free riding behavior on the dynamic evolution of the game system, it also facilitates the solution of the model. Hypothesis 4 excludes the influence of external factors of the system and clarifies the applicable preconditions for the conclusion of this paper.