Scholar Publishing Group
Academic Journal of Energy
https://doi.org/10.38007/RE.2020.010306
ISSN 2790-2714 Vol. 1, Issue 3: 42-50

Decision-Making Game and Policy Simulation of Biomass Energy Resources Based on Consideration of Behavioral Heterogeneity

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Keywords: Behavioral Heterogeneity, Biomass Energy, Evolutionary Game Model, Local Government

Abstract: At present, the biomass energy resource utilization projects carried out in many regions have suffered losses to varying degrees. The reason is that the supply of biomass energy raw materials is insufficient. The basis for this situation lies in the participation of farmers, biomass energy The degree of cooperation between enterprises and farmers and the implementation of policies by local governments. As a big agricultural country, my country is rich in raw material resources of agricultural biomass energy, which is economical and convenient, and has now become the main raw material of biomass energy. This paper takes agricultural biomass energy as the research direction, from the perspective of behavioral heterogeneity, considers the stakeholders involved in the development of agricultural biomass energy, and establishes the evolution of three biomass energy resource-based stakeholders: farmers, biomass energy companies and local governments. The game model explores the game behavior of different subjects in the process of biomass energy resource utilization, and simulates the changes in environmental protection subsidies through system dynamics simulation software, and makes decisions about biomass energy-related policies according to the simulation results. and provide a reference basis for improvement.

1. Introduction

Abundant energy supply is the basic guarantee for rapid economic development. The exhaustion and non-renewability of fossil energy prompts people to seek new energy supply. Biomass energy is naturally renewable and environmentally friendly, and it has huge reserves, and it has received increasing attention in the research of alternative energy [1]. Agricultural biomass is an important part of biomass energy, which has aroused the attention of various countries in the development and application of agricultural biomass energy. The Chinese government also attaches great importance to the development plan of its industry and has issued a series of supporting policy documents.

At present, the research on the main body game of biomass energy resources and related policies has achieved good results. For example, foreign agricultural biomass power generation has been in practical application for many years, and the technology is basically mature. The straw power generation technology of some western countries is at the leading level in the world, and some power plants can also use wood chips and garbage mixed to generate power, and there are the largest straw power plants in the world, which mainly use cotton straw pulverized and directly burned for power generation [2]. my country is a country rich in total biomass energy, but the resource per capita is relatively low. In the process of biomass utilization, Chinese scientists have developed a variety of biomass conversion and utilization technologies, including biogas, biodiesel, and fuel alcohol. The research on biomass energy industry policy in my country's academic circles is still in its infancy, and there is still a lack of in-depth and systematic research. There are few studies on biomass energy industrial policy, and there is no monograph on systematic research on biomass energy industrial policy. However, by summarizing the successful experience of developing the biomass energy industry abroad, the government's use of funds and policies to support the biomass energy industry at the technical level is inseparable [3-4]. A scholar pointed out the supporting role of the main international biomass energy policy indicators and guidelines on the sustainable development of the biomass industry, and combined the two to calculate and set the minimum greenhouse gas GHG emissions, which greatly improved the formulation of biomass policy. scientific and effective [5]. A certain scholar used the game method to simulate several straw supply modes in my country. The results show that the income of power plants will be different for different modes. Finally, in order to reduce the cost of straw supply, a hybrid collection mode that can be used in practical applications is discussed [6]. Whether it is the degree of perfection of biomass energy industry policies and measures, or the breadth and depth of research on biomass energy industry, my country still has a certain gap compared with foreign developed countries. It is difficult to promote the healthy development of the biomass energy industry if it relies entirely on the power of the market. Therefore, government support and guidance are essential.

This paper first studies the behavioral heterogeneity of farmers from three levels, and takes agricultural biomass energy as an example to conduct research on three main entities of biomass resource utilization, including farmers, biomass energy enterprises, and local governments, using VensimDSS software. Simulation experiments are carried out on the tripartite game system to analyze the impact of changing environmental protection subsidies efforts on the decision-making choices of the three parties. Finally, relevant policies for biomass energy are proposed based on the game simulation results.

2. Basic Theory

2.1. Research on the Behavioral Heterogeneity of Farmers

The heterogeneity of farmers' behavior means that due to differences in economic and social factors and different types of rural residents' preferences for time and wages, there is heterogeneity in the behavior of different types of farmers [7]. This heterogeneity is manifested in the obvious heterogeneity in the behavior of biomass raw materials that farmers are willing to provide under different labor-time costs under the condition that the government provides a fixed amount of ecological compensation [8]. Regarding heterogeneity, many scholars have carried out related research, which can be mainly divided into the following aspects:

First, subject heterogeneity. For example, in order to urge farmers to protect organic soil and reduce greenhouse gas emissions, a scholar developed a dynamic and frame-based economic experiment to represent farmers' decision-making on organic soil protection, and considered farmers' opportunity cost heterogeneity and Dynamic changes and incidental payments between participants [9].

Second, resource heterogeneity. For example, a scholar used the Biprobit model to construct the decision-making behavior equations of farmers' forestry production funds and labor input with heterogeneous resources, and studied the impact of forest reform policies on farmers' decision-making behavior [10].

Third, regional heterogeneity. For example, a scholar has studied how transboundary river pollution affects the WTP of river improvement projects. A survey of multiple cities in a watershed showed that downstream cities reported lower WTP when upstream pollution was more severe. This negative externality decreases with the distance and relative bargaining power of downstream cities [11]. Some scholars have used the STIRPAT model and the geographically weighted regression model to analyze the driving factors and spatial heterogeneity of ecosystem services in provinces and cities [12].

2.2. Evolutionary Game Theory

Game theory, also known as game theory, is to study the decision-making and the equilibrium of decision-making when the behavioral decisions made by game subjects interact with each other [13]. Evolutionary game theory is based on the assumption that the participating subjects are not completely rational people. Under the condition of information asymmetry, multiple participating subjects make corresponding behaviors according to the information they know and their own experience, and seek to maximize their own benefits process [14]. In the course of the game, the behaviors of the participants will affect each other, so the behavior of the players will change constantly, and when the behavior of one participant changes, the other participants will make the best response to their own interests. decision, thus changing the stability strategy of the player [15].

In the process of biomass energy resource utilization, the main players are farmers, biomass energy enterprises and local governments. The strategy choice of farmers is whether to participate, the strategy choice of biomass enterprises is whether to cooperate, and the strategy choice of local governments is whether to supervise [16]. The strategy game tree of the tripartite game between farmers, biomass energy companies and local governments is shown in Figure 1. The strategic choices of farmers, biomass energy enterprises and local governments mainly depend on their own benefits. When the strategy choice of the three parties is determined, when the external policies and environmental factors change, the three parties in the game will adjust their decision-making behavior according to the actual situation, so that the game system will continue to evolve dynamically and reach another equilibrium state [17-18].

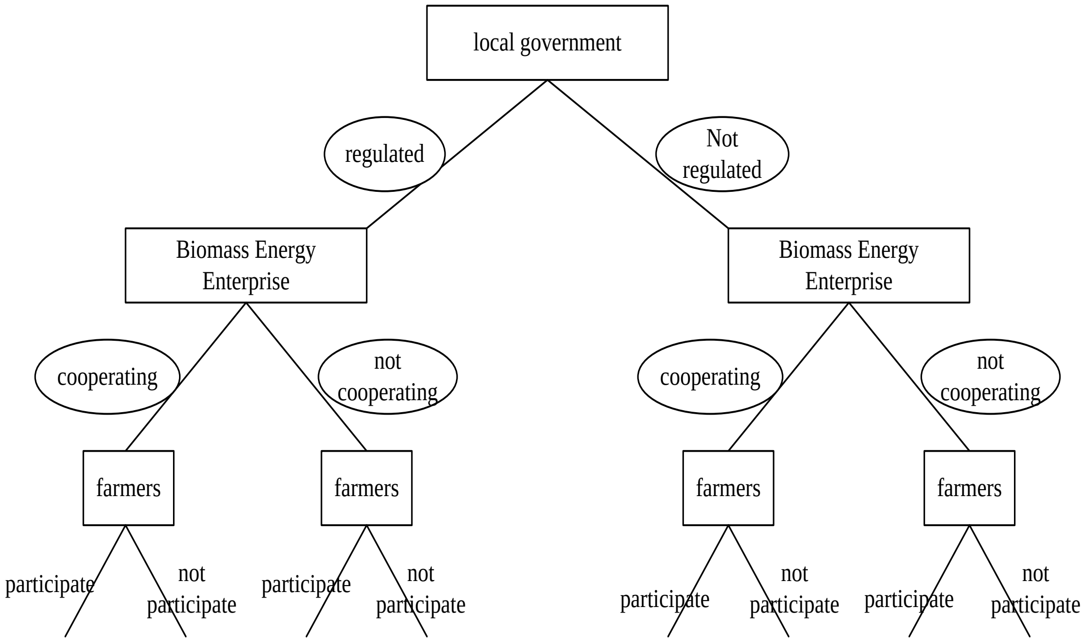

Figure 1. Strategy game tree for three-party game

3. Co-Evolution Simulation of Three Main Bodies of Biomass Energy Resource Utilization

3.1. Construction of SD Simulation Model of Three-Party Game System

In this paper, three subsystems of farmers, biomass energy enterprises and local governments are constructed by VensimDSS software, as shown in Figure 2, and the boundary of the system model is determined.

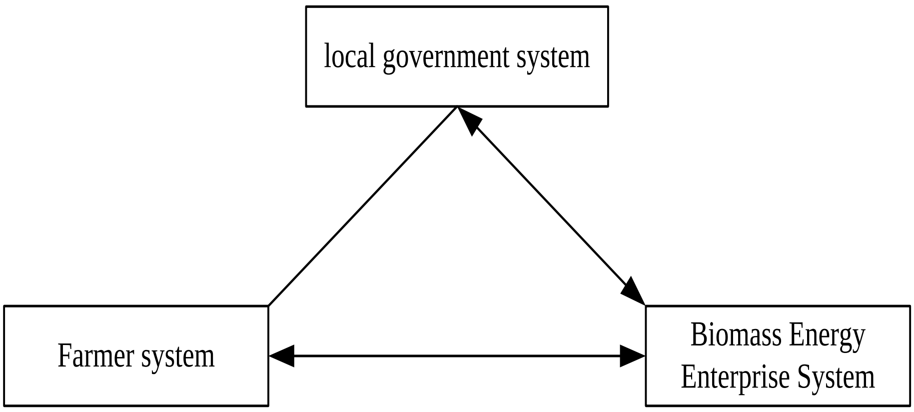

Figure 2. SD model framework

3.2. Calculation of Biomass Energy Resources

Crops are abundant biomass energy resources in my country, and the formulas for calculating crop stocks of different varieties in different regions are basically the same [19]. The calculation formulas are as follows:

$$Y_i = Q_i \times e_i \tag{1}$$

Among them, Y_i represents the resource amount of the ith crop, Q_i represents the yield of the ith crop, and e_i represents the yield of the ith crop.

The calculation methods for converting different biomass into standard energy are almost the same, and this calculation model can also be applied to the agricultural biomass energy studied in this paper.

$$E = M_i \times \lambda_i \tag{2}$$

Among them, E is the converted energy amount, AA is the biomass energy amount, and AA is the conversion coefficient.

4. Evolutionary Game Simulation under the Change of Environmental Protection Subsidy Policy

4.1. Analysis of Game Simulation Results

Under the condition that other conditions remain unchanged, the green environmental protection subsidies provided by the local government to biomass energy enterprises for the utilization of biomass energy resources under supervision are simulated at different environmental protection subsidy values (S=0, 1, 2, 3). Changes in the probability of farmers' participation, the probability of enterprise cooperation, and the probability of government supervision. The SD model of the three-party evolutionary game system for biomass energy resource utilization is simulated and analyzed, and the game results are shown in Figure 3, Table 1 and Table 2.

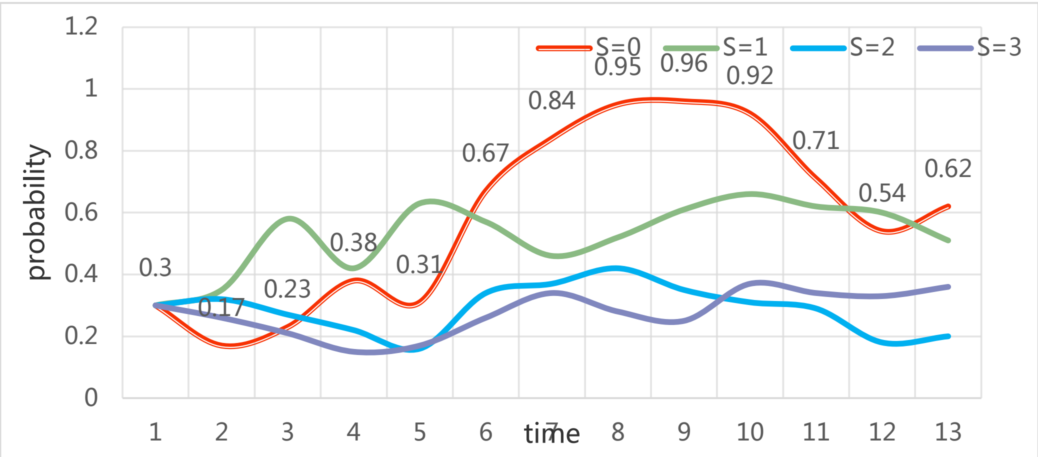

Figure 3. Impact on farmers' decision-making

As can be seen from Figure 3, as local governments increase the green environmental protection subsidies for biomass energy enterprises to utilize biomass energy resources under supervision, the probability of farmers choosing to participate in the strategy of biomass energy resource utilization continues to decline and The slower the rate at which the probability of participating in the strategy tends to 1. When the green environmental protection subsidy for biomass energy resource utilization of biomass energy enterprises under supervision is reduced, the probability of farmers choosing to participate in the strategy increases and the equilibrium is reached in a short period of time, and the volatility of the evolutionary game process becomes larger.

Table 1. Impact on decision-making of biomass energy companies

	1	2	3	4	5	6	7	8	9	10	11	12
S=0	0.57	0.73	0.84	0.96	1	1	1	0.92	0.81	0.65	0.72	0.76
S=1	0.65	0.64	0.52	0.43	0.61	0.73	0.84	0.65	0.52	0.40	0.58	0.63
S=2	0.68	0.62	0.75	0.61	0.53	0.45	0.6	0.75	0.57	0.53	0.42	0.5
S=3	0.69	0.64	0.68	0.72	0.86	084	0.74	0.62	0.55	0.65	0.68	0.59

It can be seen from Table 1 that when the environmental protection subsidy is reduced, the probability of biomass enterprises choosing a cooperation strategy reaches an equilibrium in a short period of time, and at the same time, the volatility of the evolutionary game process becomes larger. When the intensity of environmental protection subsidies is reduced, the probability of biomass energy companies choosing a cooperative strategy is not feasible.

Table 2. Impact on local government decision-making

	1	2	3	4	5	6	7	8	9	10	11	12
S=0	0.63	0.59	0.65	0.68	0.73	0.94	0.97	1	1	1	1	1
S=1	0.42	0.57	0.35	0.30	0.34	0.37	0.41	0.43	0.36	0.33	0.28	0.32
S=2	0.34	0.31	0.28	0.24	0.19	0.12	0.07	0.02	0	0	0	0
S=3	0.27	0.24	0.20	0.18	0.15	0.09	0.03	0	0	0	0	0

It can be seen from Table 2 that under the intensity of green environmental protection subsidies, the probability of local governments choosing no supervision strategy continues to increase, and the greater the intensity of environmental protection subsidies, the faster the probability of the supervision strategy tends to 0. When the intensity of environmental protection subsidies increases to a certain extent , the probability that the local government chooses a regulatory strategy will eventually reach an equilibrium and stable state at 0; when the environmental protection intensity decreases, the probability that the local government chooses a regulatory strategy increases, and when the environmental protection subsidy intensity decreases to a certain level, the probability of the local government choosing a regulatory strategy finally reaches an equilibrium and stable state at 1.

4.2. Biomass Energy Policy

Biomass energy policy refers to a series of policies and measures formulated by the state to promote and ensure the sustainable development of the biomass energy industry, including laws and regulations, industrial planning and policy incentives.

(1) Strengthen supervision

The government should establish a monitoring and early warning system, strengthen the supervision of biomass energy enterprises, and formulate a dual mechanism of punishment and incentives to promote the utilization of biomass energy resources by biomass energy enterprises. Biomass energy enterprises are the key subjects in the process of biomass energy resource utilization, play a decisive role in the process of biomass energy resource utilization, and also serve as a bridge between the government and farmers. The government should increase the supervision of biomass energy enterprises, give full play to the supervision role of automatic monitoring data, electronically supervise the abnormal phenomena of biomass energy enterprises that exceed the standard, and establish a supervision complaint mechanism, formulate a accountability system, and conduct investigations on non-cooperative enterprises. Punishment, reduce the subsidy intensity and raise the subsidy application threshold of the enterprise, so as to urge more biomass energy enterprises to use biomass energy as a resource.

(2) Systematic incentive policies, making full use of economic means such as taxation and interest discounts

As a system designer, the government often removes obstacles to the development of emerging industries through system innovation. When the energy market cannot truly reflect the social cost, that is, when the market mechanism fails, the government must correct it through economic means and promote the development of the biomass energy industry through policy guidance.

5. Conclusion

Agricultural biomass has received extensive attention due to its abundant reserves and renewable nature, as well as the depletion of fossil energy. It itself is a part of the agricultural material cycle, making full use of it can reduce greenhouse gas emissions and effectively reduce environmental pressure. Actively developing and utilizing agricultural biomass energy can not only effectively solve my country's energy crisis, but also effectively solve the problem of environmental pollution caused by excessive consumption of petrochemical energy. In this paper, through the simulation results of the three-subject game of agricultural biomass resourceization, it is found that changing the environmental protection subsidy will have an impact on the decision-making behavior of the subject, and compared with the requirements of sustainable development, the relevant policies of the agricultural biomass energy industry still exist. In this regard, it is hoped that the policies proposed in this paper can promote the development of the biomass energy industry.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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