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Original Research Paper

Game Theory Analysis on Agricultural Ecological Compensation in Rural Areas Around Beijing-A Case of Zhangcheng District

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ABSTRACT

The environment of Beijing, the capital of China, has deteriorated, which need to be managed in the areas of the city and the neighboring rural areas. Zhangcheng district is the main soil and water conservation area of Beijing. Agricultural-ecological environmental problems of Zhangcheng district are increasingly serious, because of conflict between different benefit of each main body in the agricultural ecosystem. Agricultural-ecological compensation, as an institutional arrangement to adjust the damage and the protection of agricultural-ecological environment interest relations, is an effective measure to protect the ecological environment. This paper takes Zhangcheng district as an example, using the game theory to study its agroecological compensation mechanism theory model, as well as the compensation policy decisions and behaviour process between subject and object in the compensation practice process. The analysis shows that: (1) The ecological compensation policy effect is not entirely depending on the amount of compensation in size, and only by improving the standard of compensation to protect environment is not wise; (2) Ecological compensation policy made by government should also be included in the scope of compensation limit policy; (3) The level of development of the third industry and the income of migrant workers directly affects the level of ecological construction project implementation effect.

INTRODUCTION

As the agro-ecological environment is deteriorating today, long-term excessive use of ecological resources will result into widespread phenomenon of ecological damage. The meaning of agro-ecological compensation is obvious, which can reduce the pressure on the agricultural economy by means of financial compensation in the fragile ecological areas and protect the environment (Jia 2014). On government and farmer behaviour, Douglas (2006) discussed that, the success of any agricultural development project must not only attempt to balance the economic costs and benefits for the participants involved in the change, but also take into account the political, agricultural, ecological, economic and cultural consequences of such change. Lack of eco-compensation system is an important reason for ecological degradation in China to solve the problem on conservation (Zhiwei 2011). On agro-ecological compensation issues, lot of researches have focused on the evaluation of the ecological benefits (Lebon et al. 2014), the source of the ecological compensation funds, compensation standards and remedies, etc. (Renard et al. 2012). Salla (2013) presents an analytical framework for studying the social impacts of conservation interventions, and factors affecting post-intervention livelihood rehabilitation. Li & Li (2013) and Dong et al. (2014) have analysed the acts of decision-making, of the participants, during agro-ecological compensation.

The two districts of Zhangjiakou and Chengde are located in the north-west of Hebei Province, and at the junction of four provinces of Beijing, Hebei, Shanxi, and Inner Mongolia. Zhangjiakou and Chengde districts, lying on the north of Beijing, and because of the low-lying northwest to the southeast, they form a natural ladder as a natural barrier to the Beijing-Tianjin area. Also, this district is rich in natural resources, and as Beijing's "reservoir", "vegetable basket" and energy supply base, has an important significance for Beijing. Due to the fragile ecological environment in Zhangjiakou and Chengde region, it is difficult to withstand large-scale development. Especially indiscriminate discharge of waste gas and water pollution from heavy industries, soil erosion caused by deforestation, which has led to outstanding environmental problems in the Zhangjiakou and Chengde districts. Therefore, there is a need to develop a reasonable and perfect agro-ecological compensation mechanism to promote ecological construction and social and economical coordinated development (Liu et al. 2012).

MATERIALS AND METHODS

In this paper, Zhangjiakou and Chengde districts are selected as the research objects, through game theory, taking returning farmland to forest policy as an example, to examine the

effect of the implementation of ecological compensation system, analyse the behavioural and decision-making processes of ecological compensation policy implementation process of the different benefit parties, in order to develop a reference of future development of relevant government agricultural compensation policy.

RESULTS AND DISCUSSION

The poor socio-economic environment and worrying ecological environment of Zhangcheng district: Zhangjiakou and Chengde region's economy progress lags behind at provincial average level. In 2014, there were 10 state-level poverty-stricken counties in 13 counties of Zhangjiakou, and 5 state-level poverty-stricken counties in 8 counties of Chengde, and many poor people, particularly concentrated in the adverse natural conditions of the dam area. The economy gross of Zhangjiakou and Chengde area is behind, over the years within the region, and the GDP and fiscal revenues are difficult to exceed 10% of the total in Hebei Province. Also, the industrial development is uneven, the major share of the primary sector, secondary and tertiary industries, especially the service sector, lag behind. In addition, there is a huge contradiction between the local regional economic development and ecological environment protection. Primary industry in Zhangjiakou and Chengde districts, mainly agriculture and animal husbandry, and the secondary industry is mainly mining industry. Over-development of mineral resources will destroy the ecological balance of the natural environment, cause soil erosion, land desertification and environmental pollution problems. The poor economic environment in Zhangjiakou and Chengde area has led to no financial resources for government to resolve the local environmental problems, and in order to accelerate the development of the regional economy, it will lead to further damage to the ecological environment. This vicious circle even affects the ecological environment and economic development of Beijing-Tianjin region.

After years of treatment, ecological environment of Zhangjiakou and Chengde region has been improved. Returning farmlands to forests, planting trees and grass, promoting forest grass, increase vegetation cover, preventing sandstorm, meadowland management, protection of water sources and other measures mitigates the environmental deterioration in Zhangjiakou and Chengde district, and achieved results in the construction of the Beijing-Tianjin green belt areas. However, considering the overview of the status of rural ecological environment, the situation is still worrying, the main environmental problems are as follows:

***Serious soil erosion*:** Zhangjiakou and Chengde area lies at Yellow River downstream, with serious problems of sparse vegetation, weak soil corrosion resistance, soil erosion, desertification, etc. Area of soil erosion in the region, accounts for about 50 percent of the mountain area, wetland area cuts more than half of the early days of about 60 years ago, which not only leads to low productivity of arable land, and produce sediment deposition problem, but also threats the water conservancy facilities of Miyun, Guanting, Panjiakou reservoirs.

***Severe sandstorms*:** Due to the large population, the land in this area cannot withstand the pressure resulting from unsustainable human activities, and the area faces serious desertification, currently desertification area accounts for more than 20% of land area. Zhangjiakou and Chengde therefore become a source of sandstorms and wind duct in Beijing and Tianjin. In the spring of 2010, in Beijing, blowing sand and dust storms have occurred 12 times, including four from Zhangjiakou and Chengde dam area, high frequency of occurrence, large scope, heavy intensity, which is rare in recent decades.

***Pollution of water source*:** Although Zhangjiakou and Chengde districts are severe water shortage areas, but are still committed to providing clean water to Beijing and Tianjin. From 2003, Zhangjiakou City has provided a total of 251 million cubic meters of water to Beijing (excluding natural water). Since the building of Miyun Reservoir and Panjiakou Reservoir, Chengde City has supplied a total of 79.1 billion cubic meters of water to the two reservoirs. However, due to the development of industry, the increase of the population and township enterprises in recent years, water and reservoirs in Zhangjiakou and Chengde areas have suffered a certain degree of pollution, water quality has eutrophication trend, particularly serious agricultural pollution caused from extensive use of fertilizers and pesticides. According to the statistics of pesticides and fertilizer use per year, the amount of usage growth is at 10% annually, which makes agricultural water eutrophication, and cause serious damage to the water. Without timely treatment, water pollution is a threat to the water security of the Beijing-Tianjin area.

Returning farmland to forest project of Zhangcheng district: Returning farmland to forest is the most favourable and major ecological compensation policy projects (Fu et al. 2013), a Chinese first major move in the cross-regional ecological compensation areas. Returning farmland to forest project began in 2000, the first pilot in Zhangjiakou and Chengde city dam areas, two years after being promoted to the whole Hebei province. 2002-2006 was a comprehensive construction period, and after 2006 the period was to consolidate the results. Zhangjiakou and Chengde regions as a key areas of returning farmland to forest project, has com-

pleted the forest green area of 2370000 hm², and completed with a total area of grassland management as 1300000 hm²; the average growth of the forest coverage rate is 3.77 percentage points, and has the good control effect in the prevention of sand and dust, prevention of soil erosion, local production and living environment in rural areas has improved.

Agro-ecosystem services provide significant economic value, which is the theoretical basis of ecological economics of agro-ecological compensation. Returning farmland to forest project promoted the adjustment of agricultural structure and increased farmers' income. For the Hebei province, the economic benefit is amazing from this project. Total area of the new fruit garden is more than three hundred thousand hectares in the province, the total area of fodder forest is more than two hundred and sixty thousand hectares, raw materials (paper) forest area is close to one hundred and thirty thousand hectares, and generates economic benefits of nearly nine billion RMB yuan. On this basis, the number of the province's agricultural and forestry products processing enterprises, surges to about five hundred, with an annual output amount per year close to four hundred million RMB yuan. The project has made important contributions to rural economic development. Project implementation makes a lot of rural labour force enter into the tertiary industry, related income generated close to four billion RMB yuan. Meanwhile, forestry, especially private forestry of Hebei province has made great progress. In the implementation of returning farmland to forest policy, government support private enterprise contract to invest in barren mountains and waste lands. As of 2012, there were more than six hundred thousand hectares private forests in Hebei woodland returning farmland to forest. Private enterprise contract reforestation projects, both achieve the aim to increase jobs, transfer the labours, increase farmers' incomes, and improve the quality of construction of returning farmland to forest project.

Applying game model in the study of agro-ecological compensation: Game theory is the study of the relationship that occurs when behaviour subjects make decisions and the balance of decision-making and behaviour, to solve practical problems that contradiction by a mathematical model. The purpose of game theory analysis is to use game plan to determine the balance of all participants involved in the optimal strategy combination. Ecological compensation belongs to the cooperative game, because ecological compensation is made on the perspective of the collective interest (Zhao et al. 2014), its implementation and the beneficiaries are all participants.

In an ecological compensation project of returning farmland to forest, farmers living in areas that need to return arable farmland, can choose to return farmland to protect the environment, and good ecological environment is the product of all residents to share, that all residents may get the benefit from returning farmland behaviour. "Clever Pig Game" story gives ideas for the weak (little pig) to wait in the competition as the best strategy. In practice, returning farmland areas are more in the economically under-developed regions, and those who obtain more ecological compensation benefits are residents in economically developed areas. This leads to lack of enthusiasm to return farmland to forest for farmers in economically under-developed regions. Also, the residents in economically developed areas do not understand sacrifices of other people, when they enjoy the ecological protection benefits, naturally there will be no sense of ownership for consciously safeguarding the ecological protection.

Construction and analysis of game model of compensation mechanism

Construction of the game theory model:

$G = \{P, S, I, U\}$,

the players: $P=Pi(i=1,2)$,

P1 stands for farmers,

P2 stands for the government.

During the agro-ecological compensation process, especially in the case of returning farmland to forests, farmers will choose the right "whether to carry out forest resources ecological protection in Zhangjiakou and Chengde area", according to the degree of government compensation made (Niu et al. 2010), specifically according to the government compensation standards for each hectare farmland. The government needs to pay a certain price in order to achieve the protection of the ecological value of the forest (Ulbrich et al. 2008), while the government's available resources are limited (Villarroya et al. 2014), so the government has the right to decide whether to compensate for forest conservationists in Zhangjiakou and Chengde area. The strategies collection is constituted as Table 1.

***Empirical function of various factors*:** Government usually follows some sort of compensation criteria established to develop compensation policy of returning farmland to forests (Wang et al. 2013). According to the compensation policy improved by the State Council in 2007, subsidy criteria of returning farmland to forests is 2250 kg grain (unprocessed) per hectare, equivalent funds of 3150 RMB Yuan, living allowance as 300 RMB Yuan, a total of 3450 RMB Yuan/ha. The returning ecological forest is eight years at the moment. After the expiry of the existing subsidies, according to the current subsidy standards (in Yangtze River and

Table 1: The strategies collection of the government and farmers.

		Government	
		Compensation Q_1	No compensation Q_2
Farmers	Returning farmland S_1	Returning farmland of farmers Compensation of government	Returning farmland of farmers No compensation of government
	No returning farmland S_2	No returning farmland of farmers Compensation of government	No returning farmland of farmers No compensation of government

Table 2: Government and farmers payment matrix.

		Government	
		Compensation Q_1	No compensation Q_2
Farmers	Returning farmlandS_1	(2379 + pI, -2379 + 0.61a)	(2379 + pI, -0.61a)
	No returning farmlandS_2	(3341.85, -0.61a)	(3341.85, -0.61a)

southern regions 1575 RMB Yuan per hectare of returning farmland every year, in the Yellow River and the northern regions 1050 RMB Yuan per hectare of returning farmland every year) add a cycle cash grant for returning farmland farmers, and 300 RMB Yuan living allowance per hectare per year will be linked to the management and protection tasks, direct subsidies to farmers. According to inspection results, the government pays cash subsidies.

According to the government's compensation policy, the government compensates for Zhangjiakou and Chengde district, the compensation amount for 3900x, in which x is the actual area of returning farmland to forests; at the same time, the ecological benefits of forests are value in return enjoyed by the public, this value in return has a huge economic benefits and ecological value, its value shown as A. A divided by the total area is ecological benefits of forest per unit area, and is denoted by a.

The payment function to all households in Zhangjiakou and Chengde area by government is:

$U2(Q1) = -3900x + A$

$U2(Q2) = -A$

This paper takes an example of individual farmer for analysis. In 2014 Statistical Yearbook of Hebei Province, actual arable area in Zhangjiakou and Chengde area was 992.88 thousand hectares, total rural population was 4883 thousand persons, which can be calculated as an average of 0.2 hectares of arable land per capita; if assuming the standard of an average 3.54 people per household, the average arable land per household is approximately 0.61 hectares. Therefore, the government payment function for single household in Zhangjiakou and Chengde area can be expressed as follows:

$$U_2^{'}(Q_1) = -3900 \times 0.61 + 0.61a = -2379 + 0.61a$$

$$U_2^{'}(Q_2) = -0.61a$$

Before farmers returning farmland, the value of labour is implied in total output per hectare: the main output crop in Zhangjiakou and Chengde region is the corn, the output was 4313.7 kg/ha, the total output was 5478.45 RMB Yuan per hectare; assuming there are two labours in every household, in which one labour needs to deal with family's daily life, and do preservation and maintenance for forests returning farmland, the other one labour may choose to go out to work or engage in other non-farming activities such as animal husbandry, etc. Assuming that the average income of migrant workers is I, the probability of obtaining migrant income chance is p, the farmer's payment function can be expressed as:

$U1(S1)=3900\times0.61+pI=2379+pI$

$U2(S2)=5478.45\times0.61=3341.85$

According to the above described analysis, a payment matrix (Table 2) is formed.

For the government, when farmers choose the returning farmland strategy for ecological protection, as the value of ecological compensation is a large positive value, namely:

$-2379 + 0.61a > -0.61$

At this point, the government will choose the compensation strategy. While when farmers choose no returning farmlands strategy without ecological protection, the government preference is same for the two strategies. So compared to non-compensation policy, the government is more willing to choose the compensation policy.

Because the government has ecological compensation preferences, and premise for farmers to returning farmland,

is clearly aware of the contents of the compensation policy, so in case the government chooses compensation strategy, the farmers will repeatedly compare their actual income that can be achieved with 3341.85 RMB Yuan to make decisions. That is, if the government wants to make farmers choose returning farmland, it must satisfy the condition as follows:

$2379 + pI \geq 3341.85$

Then, $pI \geq 962.85$

pI is a non-farming income of migrant workers or engage in cultivation, etc., that is, when migrant farmers' income is greater than 962.58 RMB Yuan, the farmers and the government will choose the strategy that farmers do return farmland and government do compensate, which is the game's dominant strategy.

In above dominant equilibrium, income plays an important role for farmers to choose the behaviour of returning farmland to forest, the specific impact is by the income that farmers work outside the home, including the level of income, and other efforts required access to income. Because the State Department grants for ecological forests allowance period is eight years, since it started in 2008, government allowance becomes 0 RMB Yuan from 3900 RMB Yuan per hectare. At this point, farmers returning farmland conditions change accordingly.

$pI \geq 3341.85$

Because if government subsidies stop, the necessary conditions for farmers to returning farmland adjust such that migrant farmers' income must be at or over 3341.85 RMB Yuan, which also reflects the important role of income factor for farmers to choose a strategy.

CONCLUSION

After the above analysis, researchers found that the implementation of ecological protection mechanisms of returning farmland to forests has a significant impact on farmland household income and rural economy. Specific features are as follows:

First, households have benefited from policy of returning farmland to forests, the income increases steadily. In addition to directly subsidize farmers in the choice of returning farmland, after returning farmland, the government implements basic food grain farmland, rural energy, ecological migration, skills training and other initiatives to consolidate the achievements of returning farmland to ensure an increase in household income.

The second is to promote the transfer of rural labour to urban areas or the secondary and tertiary industries, which stimulate the enthusiasm of households returning farmland, and is more favourable to promote the transfer entrepreneurship of farmers.

Except the above advantages of policy implementation of returning farmland to forests, there are some problems that need to be improved, such as the implementation of some projects do not implement a publicity system with opaqueness. In addition, there is a slow disbursement of project funds in some areas even insufficient funds situation and so on. These issues need to be addressed and settled.

Policy implementation of returning farmland gives a lot of inspiration and advice for the construction of other ecological compensation mechanism by government. First, the development of the project policy should consider the balance of interests of various actors of policy implementation, so that policy implementation can play to maximize effectiveness; secondly, in the process of policy implementation it should strengthen organization and leadership, improve the implementation and enforcement of policies; finally, the construction of ecological compensation mechanism is based on a long period, involving a wide range, it should increase the support efforts to ensure that investment funds play the biggest role.

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