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Evolutionary game and simulation of management strategies of fallow cultivated land: A case study in Hunan province, China

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ABSTRACT

To achieve sustainable use of cultivated land in China, it is important to consolidate the achievements of the large-scale program to leave cultivated land fallow. However, conflicts of interest among the participants make it difficult to achieve the expected goal. In this study, we first analyze the differences in the interests of the three main participants in the process of protecting cultivated land, that is, the central government, local government, and peasants. Then, we construct two evolutionary game models to examine the dynamic changes of their strategies and we compare the impacts of external factors on their strategies under different conditions using simulation analysis. The results show that, to stimulate peasants to protect cultivated land, the government should apply a relatively advanced dynamic subsidy strategy, which is able to make peasants more enthusiastic about protecting cultivated land using less time and money. The central government should provide better promotion opportunities for well-behaved local government officials, and appropriately punish uncooperative peasants and officials.

1. Introduction

At the beginning of the 21 st century, grain production in China increased for 12 consecutive years, not only reaching a world record but also effectively protecting national food security and maintaining social stability (Song et al., 2016). However, in many regions across China, precious cultivated land resources face many serious problems, such as soil erosion, severe groundwater overdraft, soil degradation, and worsening non-point source pollution (Li et al., 2017a). This has posed severe threats to the sustainable utilization of cultivated land and agricultural development. Therefore, it might be a wise choice to suspend some cultivated land from agricultural production activities for a while, especially in regions with serious land pollution (Ribaudo et al., 1994; Fraser and Hone, 2001). The central government of China has been highly concerned about this issue. In particular, the 13th *Five-Year Plan for National Economic and Social Development in the People's Republic of China* has emphasized the importance of keeping the most stringent management system for fallowing cultivated land at regular intervals and improving the productivity of cultivated land (Deng et al., 2006). In contrast to previous related policies on the protection of cultivated land, which mainly focus on maintaining the amount of cultivated land above a basic line, protecting the quality of cultivated land and improving its productivity are now considered important goals in future agricultural economic development (Wu et al., 2017). However, many participants (e.g., local government officials and peasants) do not care about cultivated land protection, which has a huge positive externality, because they are more concerned about maximizing their own interests (Wang et al., 2015). Therefore, suspending surplus cultivated land that is not suitable for agricultural production activities is only the first step of China's large-scale fallow project. What is more important is how to protect cultivated land to maintain relatively high grain production capacity, so that the land can return to agricultural production at a critical time in the future. In addition, the failure of cultivated land protection plans for the last few decades in China has demonstrated the ineffective supervision of the central government on local governments and peasants, which arises mainly from conflicts of interest of different participants in the process of cultivated land protection (Xie et al., 2017). Therefore, finding effective ways to coordinate the conflicts of interests of the main participants is meaningful research to promote the effective protection of cultivated land.

As the practical executors of cultivated land protection, local government officials are often unwilling to implement the central government's plans perfectly owing to conflicts of interests between the central and local governments. This is mainly because local governments might suffer great economic losses from protecting cultivated land that would make it difficult to receive benefits in the short term (Wang

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et al., 2016). In particular, local government officials face enormous pressure in their political performance evaluations, including pressure to achieve high economic output. Thus, they are not likely to care about land that does not contribute to short-term economic growth but lies fallow to realize the long-term sustainable development of society and economy, for example, protecting cultivated land. In addition, as Liu and Zhao (2011) pointed out, asymmetric information between the central government and local governments has led to the failure to rectify local governments' behavior in a timely manner. Therefore, the land protection program is actually a process full of multi-participants' games, and the game relationship between the central government and local governments is the most important. Therefore, it is very important to find effective ways to coordinate the conflict of interests between the central and local governments.

In recent years, the huge income gaps between non-agricultural and agricultural production activities have stimulated more and more young peasants to choose to abandon cultivated land and engage in non-agricultural production activities in China's economically developed coastal provinces. This is a major reason why cultivated land protection work has not been fully implemented in past decades and precious cultivated land has even been abandoned in many regions (Xu et al., 2015). Unlike these young people, many old peasants have to stay in their villages because of their lower production skills and weaker market competitiveness, and their feelings for the land run much deeper (Wiles et al., 2009). Therefore, it seems a wise choice to encourage old peasants to protect their land over the long term. However, peasants have not received enough incentives in past decades owing to lack of considerable economic benefits, and they prefer to abandon their land to participate in jobs near their villages that require relatively low skills. Although the Chinese central government has increased its economic subsidies for peasants, and in some regions, the subsidy is nearly 1600 US dollars per hectare, the incentive seems to be very weak.[1] However, excessive compensation would undoubtedly increase the government's financial burden (Lu et al., 2017). Thus, the key points of this problem might lie in inappropriate incentives and regulatory measures of the government. It is urgent to find effective countermeasures to encourage peasants to protect their cultivated land without over-compensation.

Changzhutan in Hunan province in China is an important grain production region. However, because of the lack of government environmental regulation and longtime serious industrial pollution, a heavy metal land-pollution incident occurred in 2010, which significantly reduced the productivity of cultivated land, pollutes agricultural resources, and caused serious damage to neighboring ecosystems.[2] China's central government has been significantly concerned with the restoration and protection of cultivated land in this region and has listed it as a key pilot area for fallowing cultivated land (Zhang et al., 2014). In 2014, the Ministry of Agriculture and the Ministry of Finance, aiming to promote the immediate implementation of land restoration in Changzhutan, issued the *Pilot Program on Restoration of Cultivated land Contaminated with Heavy Metals in Hunan and Crop-Planting Structure Adjustment*.[3] In the same year, 1.7 million mu (0.113 million hectares) of cultivated land in Changzhutan area was included in the fallow plan.[4] In 2015, 6 thousand mu (400 ha) of the Wangcheng district in Changsha city was suspended from agricultural production activities.[5] This program has achieved a reduction of more than 60% of cadmium and received unanimous accreditation recognition from field experts. Furthermore, in May 2016, the State Council of China promulgated the *Soil Pollution Prevention Action Plan,* which laid out a detailed restoration task plan for the polluted cultivated land in the Changzhutan area to relieve its heavy metal contamination problem.[6] In the following month, the *Pilot Program on Exploring Implementation of Cultivated land Crop Rotation and Fallow System* was introduced, which clearly stated that mobilizing local government officials and peasants to protect cultivated land over the long term is the most important mission after the restoration of contaminated cultivated land.[7] As Xie et al. (2017) suggested, an appropriate economic subsidy would help to encourage peasants to cooperate with the government. To determine an appropriate rate of subsidy, we carry out a field investigation in dozens of villages in the Changzhutan area to obtain first-hand data. Based on the empirical results derived from the evolutionary game models, we suggest that improving the mode of subsidy might be a better choice than increasing the economic subsidy rate. We propose a dynamic subsidy strategy, which not only generates enough incentive for peasants to protect cultivated land, but also saves a lot of money to reduce the government's financial burden.

Therefore, the following research questions are addressed in this study.

(1) Who are the main participants in the process of cultivated land protection, what are their goals, and what conflicts exist between them?
(2) How can we illustrate the dynamic changes of the participants' strategies? How can we make the evolutionary game rapidly converge to an ideal stable state?
(3) How can we improve the current government incentives for peasants to encourage them to protect cultivated land without significantly increasing the government's financial burden?

The remainder of this paper is organized as follows. Section 2 reviews related studies and highlights the contributions of this study. Section 3 introduces the methods, indicators, and data used. Section 4 analyzes the evolutionary game between government and peasants and Section 5 analyzes the evolutionary game between central and local governments. Based on simulation analysis using a system dynamics model and Vensim PLE software, both Sections 4 and 5 propose effective measures to encourage peasants and local governments to protect cultivated land. Section 6 concludes with some policy implications based on the empirical results and provides some suggestions for future studies.

2. Literature review

In recent years, many scholars have carried out pioneering work on conflicts of interests among participants in protecting fallow cultivated land. Barham et al. (1995) argued that peasants are key participants in cultivated land utilization and protection. Conflict of interest between peasants and the government has always existed and has had negative impacts on the protection of cultivated land (Zhang et al., 2006). Regarding China's cultivated land protection, Skinner et al. (2001) and Li et al. (2009) believed that the government plays an important role and its attitude has a direct effect on the protection of cultivated land. Agreeing with this viewpoint, Zhong et al. (2012) conducted a case study in the Fuyang District of Zhejiang province in China, and found a certain degree of conflict of interests regarding cultivated land protection between local and central governments. In fact, many local government officials are reluctant to follow orders from the central government to protect cultivated land because they must simultaneously do their best to promote local economic development to achieve excellent political achievements, and do not care about protecting resources and the environment, as these cannot produce

[1] http://hn.rednet.cn/c/2016/07/08/4029646.htm
[2] http://hn.people.com.cn/n/2014/1201/c356328-23073747.html
[3] http://www.hunan.gov.cn/2015xxgk/fz/zfwj/szfzcbm_19689/sczt_19750/gfxwj_19751/201412/t20141218_1192097.html
[4] http://www.moa.gov.cn/govpublic/ZZYGLS/201709/t20170911_5811787.htm
[5] http://news.163.com/16/1102/11/C4S6D176000187VG.html
[6] http://www.gov.cn/zhengce/content/2016-05/31/content_5078377.htm
[7] http://news.xinhuanet.com/politics/2016-06/29/c_1119133589.htm