Sustainable endogenous growth model of multiple regions: Reconciling OR and economic perspectives

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ABSTRACT

By combining the two-sector endogenous growth model and the dynamic game of remediation (utilization) activities, we propose a theoretical framework to investigate conflict in the sustainable growth path of multiple regions. We analyze the effects of two types of activities that differ in externalities on other regions' stock of natural resources. In the case of inclusive remediation with a positive externality, the region that moves firstly will pass all the remediation responsibility to the other region and enjoy faster growth. However, in the case of exclusive utilization with a negative externality, both regions will experience the same growth rate, because each region could adopt exclusive utilization and reduce the stock of common resources available to the other region in the next period, which result in a symmetric equilibrium. We also find that regions have a stronger incentive to implement exclusive utilization than inclusive remediation. Although exclusive utilization seems fair to regions, it may deteriorate the social welfare, because regions may fall into a 'prisoner's dilemma' by using exclusive utilization. Three extensions of the model (i.e., increasing number of regions, asymmetric regions, and knowledge as a public capital good) are provided.

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1. Introduction

The motivation of this research comes from the conflict of utilizing water resources among regional governments around the Poyang Lake, China. Poyang Lake has been suffered a severe shortage of water resources in recent years. The following Fig. 1 shows the average, highest and lowest monthly water levels of Poyang Lake from 1983 to 2012.[1] We can see that all three indicators decreased, especially after 2000. Zhang, Wu, Wang, Dong, and Ren (2016) point out that the impounding activity of Three Gorges Dam, the largest operating hydroelectric facility in the world, may be the main reason. However, another possible explanation of such a shortage is the increasing demand of water form regions around the lake. Those regions utilize more and more water resources in a process of fast economic growth (the annual GDP growth rates of regions are about 10%) in recent years. We want to analyze the interactive decision making of constructing dams or impounding reservoirs among regions by using game theory, while regional

governments also target the sustainable economic growth path as the endogenous growth model suggests.

To deal with the shortage of water resources, some regional governments have started the construction of dams or impounding reservoirs, or asked permission of the central government to construct such projects, in order to increase their own stock of natural resources. However, these activities may worsen social welfare, because they are Beggar-Thy-Neighbor policies, in the sense of decreasing the stock of common natural resources available to other regions. We define this type of activity that causes negative externalities to other regions as exclusive utilization. There is also another type of activity, inclusive remediation, which increases the stock of common natural resources available to other regions. One possible example of inclusive remediation is planting trees for the water and soil conservation. Tree planting increases the stock of common water resources, and benefits all regions. Both inclusive remediation and exclusive utilization activities of some region increase its own stock of natural resources, but these activities are differ in the externalities on other regions. In fact, inclusive remediation is not the main policy adopted by regional governments to regenerate natural resources in real practice in China.

Why do regional governments have a stronger incentive to implement exclusive utilization than inclusive remediation? How can

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[1] We collect the daily observations of water levels from 10 stations around the Poyang lake and calculate the monthly water levels.
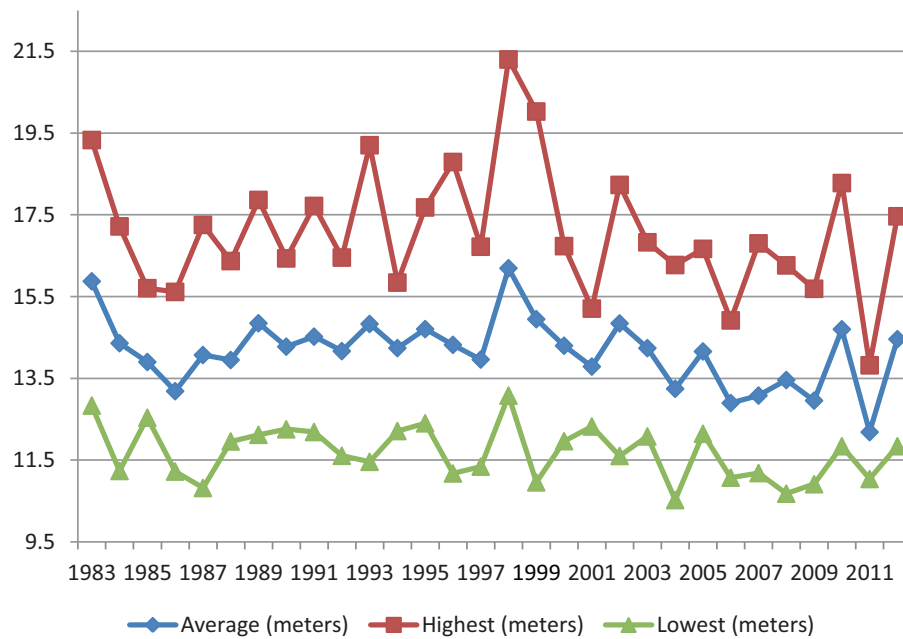
Fig. 1. Water levels of Poyang lake.
Source: Jiangxi provincial bureau of water resources, China.

these activities influence the sustainable growth path of regions? How do we solve the conflict among activities of regions? To answer these questions, we combine the two-sector endogenous growth model with the dynamic game of remediation (utilization) activities, and propose a theoretical framework to investigate the sustainable growth path of multiple regions. We find that the region that moves firstly will pass all the remediation responsibility to the other region, and enjoy a faster growth in the case of inclusive remediation with a positive externality. In the case of exclusive utilization, both regions will experience the same growth rate, because each region could adopt exclusive utilization and reduce the stock of common resources available to the other region in the next period, which result in a symmetric equilibrium. We also show that if regions are able to choose inclusive remediation or exclusive utilization, both regions will choose the latter one, which implies that a 'prisoner's dilemma' will occur if no intervention from the central government is imposed. Finally, we provide three extensions of the benchmark model: if there are multiple regions, if regions are asymmetric, and if knowledge is a public capital good. These extensions provide several interesting results, and illustrate the applications of our theoretical model.

Many scholars have contributed to the study of the relationship between economic growth and environmental quality, and the effects of technological change on this relationship. (See the reviews of Brock & Taylor, 2005; Foray & Grübler, 1996; Löschel, 2002; Nijkamp & Van Den Bergh, 1997; Van Den Bergh & Hofkes, 1998) An important theoretical branch of this literature is the economic modeling of sustainable development using the endogenous growth model. Based on the work of Bovenberg and Smulders (1995), Lucas (1988) and Rebelo (1991) present a two-sector endogenous model in which the production of new technical knowledge in the knowledge sector will improve the effective use of renewable resources and reduce pollution. Hofkes (1996) introduces the concept of abatement into the two-sector endogenous model, which assumes that a proportion of final output can be used as abatement to reduce the level of pollution and recover the regenerative capacities of natural resources.

Current theoretical literature focuses on either optimal pollution/abatement choices (Breton, Sokri, & Zaccour, 2008; Byrne,

1997; Grimaud, 1999; Michel & Rotillon, 1995; Schou, 2000; Withagen, 1995) or the endogenous technical change and optimal environmental regulation (Acemoglu, Aghion, Bursztyn, & Hemous, 2012; Barbier, 1999; Bendoly, 2007; Groth & Schou, 2007; Hart, 2004; Rosendahl, 2004; Smulders & De Nooij, 2003). Though theoretical analysis of the optimal management of ground water resources has been provided (Esteban & Dinar, 2013; Roseta-Palma, 2002, 2003), it has not been in the framework of the endogenous growth model. Munda (2009) gives a conflict analysis approach for illuminating distributional issues in sustainability policy. However, the main methodology of Munda (2009) is the cost-benefit analysis, instead of game theory. Theoretical studies on the sustainable endogenous growth of multiple regions using game model are still lacking. Our study addresses this gap by combining the two-sector endogenous growth model and the dynamic game of remediation (utilization) activities.

Many empirical studies have investigated the relationship between economic growth and environmental quality (Brock & Taylor, 2010; De Bruyn, 2012; Färe, Grosskopf, Noh, & Weber, 2005; Zhang et al., 2017), including several on China (Choi, Oh, & Zhang, 2015; Sun, Lu, Wang, Ma, & He, 2008; Yang & Yang, 2015; Yu, 2015; Zhang & Cheng, 2009; Zhang and Xie, 2015; Zhang, Kong, & Choi, 2014, 2015). In the context of conflict between regions, Cai, Chen, and Gong (2016) analyzes the effect of pollution reduction mandates on the pollution location choices of regional governments. Olmstead and Sigman (2014) provide a study of conflict in dam location. However, the empirical study on the conflict in remediation activities between regions is still missing. For future research, we could give an empirical analysis on the conflict based on our theoretical model.

In this paper, we provide a theoretical framework that incorporates the regeneration of natural resources and the interaction of remediation activities between multiple regions with the sustainable endogenous economic growth model. We construct a dynamic game of regions' choices on natural resources (i.e., gross extractive use and remediation activities); meanwhile the region's decisions are subjected to the feasible condition of a sustainable economic growth path. Hence, the contribution of our study can be summarized as the combination of game model and sustainable growth