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Four-Party Evolutionary Game Analysis on Environmental Governance of Heavy Polluting Enterprises

Lin Wang* and Xinyuan Bai

School of Economics and Management (School of Tourism), Dalian University, Dalian 116622, P. R. China
*Corresponding author: wanglin2@dlu.edu.cn

Introduction

In order to improve the efficiency of environmental governance of heavily polluting enterprises, this paper researches the multi-body model of environmental governance of heavily polluting enterprises in China, and establishes a four-party evolutionary game model by placing the central eco-environment protection inspection team, local governments, heavily polluting enterprises and social supervisors under a unified framework.

Mathematical Formulas

$$\frac{\dot{x}}{x} = f_{A1} - \dot{f}_{A1} = (x-1)(C_1 - C_1\lambda_1 - Fu + Fv + Fuy - Fvy) \quad (1)$$

Research Questions

Reviewing the literature, the existing studies mostly focus on the two- or three-party games in the central and local governments, enterprises and society, but the real environmental governance involves multi-party subjects and lacks comprehensive research. This paper integrates central eco-environment protection inspection team, local government, heavily polluting enterprises, and social monitors into a unified framework. It constructs a four-party evolutionary game model and conducts theoretical analyses to address the shortcomings of previous studies.

Methodologies

In this paper, the method of evolutionary game is used to construct a four-party evolutionary game model, and numerical simulation analysis is carried out.

Conclusion

There are seven unstable equilibrium points in the benchmark model, and the remaining nine are conditionally stable equilibrium points, and there is no absolute ESS. The study suggests the following. (i) Heavily polluting enterprises with active pollution control are a necessary condition for local environmental governance to meet the standard. (ii) Local governments that implement strict regulatory strategies and heavily polluting enterprises that adopt active pollution control strategies bring about better operation of the environmental governance system. (iii) The impact of social monitors' participation is limited and cannot fundamentally shake the strategic choices of key players.

In order to improve and perfect the environmental governance of heavily polluting enterprises, the following policy recommendations are proposed. First, incentivize heavily polluting enterprises to actively treat pollution. Local governments can encourage heavily polluting enterprises to adopt environmental protection measures through economic incentives. Second, strengthen communication and coordination between the central and local governments to jointly promote environmental governance. Third, establish a diversified monitoring mechanism. The government encourages and supports the establishment of an anonymous online reporting system using the Internet and social media platforms.

Tables

Payoff matrix for the four-way game model of environmental governance.

Table 1. Payment matrix

		Heavily Polluting Enterprises: Active Treatment		Heavily Polluting Enterprises: Negative Treatment	
		Social Monitors: Active Participation	Social Monitors: Passive Participation	Social Monitors: Active Participation	Social Monitors: Passive Participation
Central Eco-environment Protection Inspection Team: Strict Regulation	Local Gov: Strict Regulation	$\Pi_1 = -C_1 + \alpha E - \beta C_0$ $\Pi_2 = -C_2 + E - C_0 + B + P - b$ $\Pi_3 = -C_3 + R + b$ $\Pi_4 = -C_4 + \omega_L + \omega_E$	$\Pi_5 = -C_1 + \alpha E - \beta C_0$ $\Pi_6 = -C_2 + E - C_0 + B + P - b$ $\Pi_7 = -C_3 + R + b$ $\Pi_8 = -\lambda_4 C_4 + \omega_L + \omega_E$	$\Pi_9 = -C_1 + \alpha E - \beta C_0$ $\Pi_{10} = -C_2 + E - C_0 + B - Q + pf + \xi(\Delta f - H_L)$ $\Pi_{11} = -\lambda_3 C_3 + R + R_E - p(f + \Delta C_3) - \xi(\Delta f + N)$ $\Pi_{12} = -C_4 + \omega_L - \lambda_3^{-1}\varphi_E + \xi(H_L + h\omega_E)$	$\Pi_{13} = -C_1 + \alpha E - \beta C_0$ $\Pi_{14} = -C_2 + E - C_0 + B - Q + pf$ $\Pi_{15} = -\lambda_3 C_3 + R + R_E - p(f + \Delta C_3)$ $\Pi_{16} = -\lambda_4 C_4 + \omega_L - \lambda_3^{-1}\varphi_E$
	Local Gov: Lax Regulation	$\Pi_{17} = -C_1 - \alpha L - \beta\lambda_2 C_0 + uF$ $\Pi_{18} = -\lambda_2 C_2 - L - \lambda_2 C_0 - uF + P - \lambda_2 b - \Delta C_2$ $\Pi_{19} = -C_3 + R + \lambda_2 b$ $\Pi_{20} = -C_4 - \varphi_L + h\omega_L + \omega_E$	$\Pi_{21} = -C_1 - \alpha L - \beta\lambda_2 C_0 + uF$ $\Pi_{22} = -\lambda_2 C_2 - L - \lambda_2 C_0 - uF + P - \lambda_2 b$ $\Pi_{23} = -C_3 + R + \lambda_2 b$ $\Pi_{24} = -\lambda_4 C_4 - \varphi_L + \omega_E$	$\Pi_{25} = -C_1 - \alpha L - \beta\lambda_2 C_0 + uF$ $\Pi_{26} = -\lambda_2 C_2 - L - \lambda_2 C_0 - uF - Q + q\lambda_2 f - \Delta C_2 + \xi\lambda_2(\Delta f - H_L)$ $\Pi_{27} = -\lambda_3 C_3 + R + R_E - q(\lambda_2 f + \Delta C_3) - \xi(\lambda_2 \Delta f + N)$ $\Pi_{28} = -C_4 - \varphi_L + h\omega_L - \lambda_3^{-1}\varphi_E + \xi(\lambda_2 H_L + h\omega_E)$	$\Pi_{29} = -C_1 - \alpha L - \beta\lambda_2 C_0 + uF$ $\Pi_{30} = -\lambda_2 C_2 - L - \lambda_2 C_0 - uF - Q + q\lambda_2 f$ $\Pi_{31} = -\lambda_3 C_3 + R + R_E - q(\lambda_2 f + \Delta C_3)$ $\Pi_{32} = -\lambda_4 C_4 - \varphi_L - \lambda_3^{-1}\varphi_E$
Central Eco-environment Protection Inspection Team: Lax Regulation	Local Gov: Strict Regulation	$\Pi_{33} = -\lambda_1 C_1 + \alpha E - \beta C_0$ $\Pi_{34} = -C_2 + E - C_0 + B + P - b$ $\Pi_{35} = -C_3 + R + b$ $\Pi_{36} = -C_4 + \omega_L + \omega_E$	$\Pi_{37} = -\lambda_1 C_1 + \alpha E - \beta C_0$ $\Pi_{38} = -C_2 + E - C_0 + B + P - b$ $\Pi_{39} = -C_3 + R + b$ $\Pi_{40} = -\lambda_4 C_4 + \omega_L + \omega_E$	$\Pi_{41} = -\lambda_1 C_1 + \alpha E - \beta C_0$ $\Pi_{42} = -C_2 + E - C_0 + B - Q + pf + \xi(\Delta f - H_L)$ $\Pi_{43} = -\lambda_3 C_3 + R + R_E - p(f + \Delta C_3) - \xi(\Delta f + N)$ $\Pi_{44} = -C_4 + \omega_L - \lambda_3^{-1}\varphi_E + \xi(H_L + h\omega_E)$	$\Pi_{45} = -\lambda_1 C_1 + \alpha E - \beta C_0$ $\Pi_{46} = -C_2 + E - C_0 + B - Q + pf$ $\Pi_{47} = -\lambda_3 C_3 + R + R_E - p(f + \Delta C_3)$ $\Pi_{48} = -\lambda_4 C_4 + \omega_L - \lambda_3^{-1}\varphi_E$
	Local Gov: Lax Regulation	$\Pi_{49} = -\lambda_1 C_1 - \alpha L - \beta\lambda_2 C_0 + vF$ $\Pi_{50} = -\lambda_2 C_2 - L - \lambda_2 C_0 - vF + P - \lambda_2 b - \Delta C_2$ $\Pi_{51} = -C_3 + R + \lambda_2 b$ $\Pi_{52} = -C_4 - \varphi_L + h\omega_L + \omega_E$	$\Pi_{53} = -\lambda_1 C_1 - \alpha L - \beta\lambda_2 C_0 + vF$ $\Pi_{54} = -\lambda_2 C_2 - L - \lambda_2 C_0 - vF + P - \lambda_2 b$ $\Pi_{55} = -C_3 + R + \lambda_2 b$ $\Pi_{56} = -\lambda_4 C_4 - \varphi_L + \omega_E$	$\Pi_{57} = -\lambda_1 C_1 - \alpha L - \beta\lambda_2 C_0 + vF$ $\Pi_{58} = -\lambda_2 C_2 - L - \lambda_2 C_0 - vF - Q + q\lambda_2 f - \Delta C_2 + \xi\lambda_2(\Delta f - H_L)$ $\Pi_{59} = -\lambda_3 C_3 + R + R_E - q(\lambda_2 f + \Delta C_3) - \xi(\lambda_2 \Delta f + N)$ $\Pi_{60} = -C_4 - \varphi_L + h\omega_L - \lambda_3^{-1}\varphi_E + \xi(\lambda_2 H_L + h\omega_E)$	$\Pi_{61} = -\lambda_1 C_1 - \alpha L - \beta\lambda_2 C_0 + vF$ $\Pi_{62} = -\lambda_2 C_2 - L - \lambda_2 C_0 - vF - Q + q\lambda_2 f$ $\Pi_{63} = -\lambda_3 C_3 + R + R_E - q(\lambda_2 f + \Delta C_3)$ $\Pi_{64} = -\lambda_4 C_4 - \varphi_L - \lambda_3^{-1}\varphi_E$