Tripartite Evolutionary Game and Simulation Analysis of Healthcare Fraud Supervision under the Government Reward and Punishment Mechanism

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Introduction

- Healthcare fraud, or abuse, refers to the intentional deception or an unintentional mistake made by a person or entity to deceive the health care system to receive unlawful benefits or payments.
- The provision, usage and management of healthcare involves many sectors and stakeholders, including the local government, the hospital, and patients. The hospital is the main fraudster due to the their information advantages.
- In order to ensure regulatory professionalism, local governments have introduced third-party supervision. However, during the supervision process, third parties may be driven by interests and accept bribes from hospitals.

Research Question

- What are the behavior strategies of hospitals, third parties and local governments under the government's reward and punishment mechanism?

Literature review

- **Supervision of healthcare fund:**

Research on supervision subject;
Research on the supervision method;
Research on the supervision legalization; and
Research on the reason of healthcare fraud.

- **Evolutionary game model:**

The Origin of Evolutionary Game
Application fields of evolutionary game

Model construction

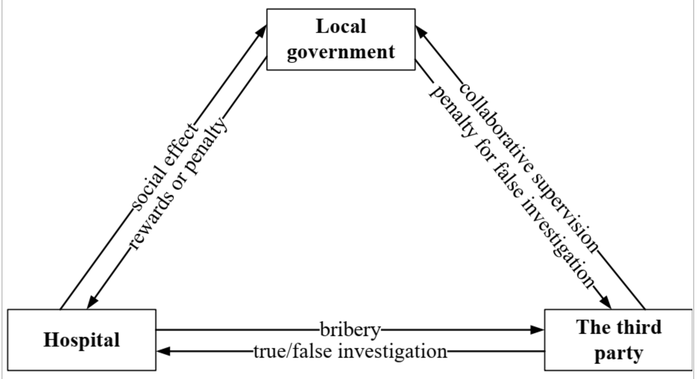

Fig 1 relationship of game players

Methods

Game theory-- Tripartite Evolutionary Game

Assumption 1

• hospital as participant 1; third-party as participant 2; local government as participant 3.

All three parties are participants with limited rationality, and of which the strategy selection gradually evolves and stabilizes to the optimal strategy over time.

Assumption 2: The strategy spaces are as follows:

• hospital : compliant operation (x); illegal operation (1- x), $x \in [0,1]$
• third-party: true investigation(y); false investigation(1- y), $y \in [0,1]$
• local government： strict supervision （z); non- supervision(1- z) ,$z \in [0,1]$

Assumption 3: Cost.

• Hospital: compliant operation ,C_{h1}; illegal operation , C_{h2} ($C_{h1} > C_{h2}$);
• Third party: true investigation ,C_{t1}; false investigation , C_{t2}($C_{t1} > C_{t2}$);
• Local government: strict supervision ,C_g ; non-supervision is 0 (C_g >0).

Assumption 4: Incomes.

• Hospital: compliant operation , I_{h1}; illegal operation , I_{h2}($I_{h2} > I_{h1}$)
• Third party: true investigation, I_{t1} ; false investigation, I_{t2}($I_{t2} > I_{t1}$);
• Local government: $social$ benefits, I_{g1} (hospital's compliant operation); I_{g2} (hospital's illegal operation), ($I_{g1} > I_{g2}$)

Assumption 5: Reward and punishment .

• Hospital: A_h ($A_h < C_{h1}$). Conditions: hospital compliant operation & local government strict supervision. P_h. Conditions: hospital illegal operation & local government strict supervision or & third party's true investigation.
• Third party: P_t. Conditions: local government strict supervision & third party's false investigation.
• Local government: A_g ($A_g < C_g$). Conditions: local government strict supervision.P_g. Conditions: local government non-supervision & hospital illegal operation & third party's false investigation.

Table 1 the payoff matrix for the evolutionary game model

		Third party	Local government	
			strict supervision (z)	non-supervision $(1-z)$
Hospital	compliant operation (x)	true investigation (y)	$I_{h1}+A_h-C_{h1}$, $I_{t1}-C_{t1}$, $I_{g1}-C_g-A_h+A_g$	$I_{h1}-C_{h1}$, $I_{t1}-C_{t1}$, I_{g1}
		false investigation $(1-y)$	$I_{h1}+A_h-C_{h1}$, $I_{t1}-C_{t2}-P_t$, $I_{g1}-C_g-A_h+P_t+A_g$	$I_{h1}-C_{h1}$, $I_{t1}-C_{t2}$, I_{g1}
	illegal operation $(1-x)$	true investigation (y)	$I_{h2}-C_{h2}-P_h$, $I_{t1}-C_{t1}$, $I_{g2}-C_g+P_h+A_g$	$I_{h2}-C_{h2}-P_h$, $I_{t1}-C_{t1}$, $I_{g2}+P_h$
		false investigation $(1-y)$	$I_{h2}-C_{h2}-P_h, I_{t2}-C_{t2}-P_t$, $I_{g2}-C_g+P_h+P_t+A_g$	$I_{h2}-C_{h2}, I_{t2}-C_{t2}$, $I_{g2}-P_g$

Results

①

$$\lambda 1 = C_{h2} - C_{h1} + I_{h1} - I_{h2} < 0,$$
$$\lambda 2 = C_{t2} - C_{t1} + I_{t1} - I_{t2} < 0,$$
$$\lambda 3 = A_g - C_g + P_g + P_h + P_t < 0$$

The strategy will evolve to (0,0,0)

②

$$\lambda 1 = C_g - A_g - P_g - P_h - P_t < 0,$$
$$\lambda 2 = C_{t2} - C_{t1} + I_{t1} - I_{t2} + P_t < 0,$$
$$\lambda 3 = A_h - C_{h1} + C_{h2} + I_{h1} - I_{h2} + P_h < 0$$

The strategy will evolve to (0,0,1)

③

$$\lambda 1 = A_h - A_g + C_g - P_t < 0,$$
$$\lambda 2 = C_{t2} - C_{t1} + I_{t1} - I_{t2} + P_t < 0,$$
$$\lambda 3 = C_{h1} - A_h - C_{h2} - I_{h1} + I_{h2} - P_h < 0$$

The strategy will evolve to (1,0,1)

Conclusions

- **In the process of compliant operation by the hospital, fines by the local government on the hospital are the key factor**.

The punishment mechanism exerted by the local government can drive the hospital to increase the probability of legal operation. The higher the fines, the faster the hospital tends to operate in compliance. In this situation the local government also tends to be strict in supervision, and the promotion of incentives for the hospital has less impact on the compliant operation of the hospital. Because excessive incentives for the hospital will increase the economic pressure on the local government, inhibiting the probability of strict supervision of the local government, thus the local government will offer fewer incentives to the hospital with the compliant operation. In this context, the punishment mechanism plays a major role.

- **The cost and benefit of the hospital are also the key factors affecting their strategic choices.**

The high supervision cost of the local government will restrain the probability of their strict supervision strategy, and the rewards from the superior government will encourage the local government to strictly supervise the behavior of hospital. Accordingly, the superior government needs to increase the incentives to the local government and encourage the local government to improve the level of supervision, so as to reduce the cost of strict supervision.

- **The cost and benefit of strict supervision by the local government are critical factors affecting their strategic choices**.

The high supervision cost of the local government will restrain the probability of their strict supervision strategy, and the rewards from the superior government will encourage the local government to strictly supervise the behavior of hospital. Accordingly, the superior government needs to increase the incentives to the local government and encourage the local government to improve the level of supervision, so as to reduce the cost of strict supervision.

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