Evolutionary game analysis of coal miners' burnout intervention

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Abstract. In order to reduce the occurrence of miner burnout, a game model of miners and coal mine strategy selection was constructed from the perspective of bounded rationality. In-depth analysis of the key influencing factors in the choice of mining rig and coal mining strategy. It is found that there are 4 equilibrium points and 1 saddle point in the evolutionary game system. Miners and coal mines will adopt different coping strategies under the influence of each key element. At the same time, it is also verified that the evolution results of the two strategies depend on the initial value of (x,y), which provides ideas for how to implement intervention strategies to reduce miner burnout.

Keywords: Miner; evolutionary game analysis; job burnout

1 Introduction

In 1974, Freudenberger[1] first proposed the concept of burnout, and defined it as a phenomenon of psychological exhaustion caused by work. Scholars generally agree with Maslach et al. [2] and the three dimensions of burnout proposed by Maslach et al. (1981), namely emotional exhaustion, depersonalization, and low personal fulfillment. The survey[3] found that burnout has become a common psychological problem in various industries, seriously affecting the life and work of employees, and the concern about burnout in coal mines has also been strengthened.

With the intensification of China's "industrial transformation" [4] and the downturn in the mining industry, the wage level of miners has dropped sharply, and more and more miners have doubts about their occupations, which accelerates the generation of burnout and result in low production efficiency and safety performance, which has an adverse impact on coal mine safety production. In order to promote sustainable development , coal mines[5] need to pay more attention to miners and take measures to protect the mental health of employees, so that miners can avoid the formation of burnout. Therefore, this paper constructs an evolutionary game model[6] based on bounded rationality miners and coal mines, analyzes and discusses the evolutionary stability strategy of the game system, uses numerical simulation analysis to verify the game model

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and hypothesis, and puts forward targeted countermeasures and intervention suggestions.

2 Basic Assumptions and Model Construction of Evolutionary Game

The model basic assumptions are as follows:

Hypothesis 1: The two parties to the game is bounded rational. Coal mines can choose {Intervention; No intervention}. If the miner does not respond to the intervention of the enterprise, he needs to bear the performance loss caused by choosing burnout P, and he will get additional benefits when he does not choose burnout, and F represents the loss of the enterprise due to the miner's choice of burnout, but coal mines chooses not to intervene, and the miner's tendency to leave the job increases.

Hypothesis 2: Miners can choose the strategy as {do not choose burnout; Select Burnout}. Miners don't choose the benefits of increased productivity due to burnout. When miners choose burnout, D represents the loss incurred by the coal mines, and the risk loss caused by the coal mines's intervention policy and non-intervention policy. The matrix of the game gains between miners and coal mines is shown in Table 1.sic assumptions and model building

Table 1. Profit matrix of coal mines and miner game

Miners/Coal mines		Coal mines	
		Intervention;,y	No intervention,$1-y$
Miners	Do not choose burnout,x	E_1, E_2	E_1-J_1, E_2+J_2-F
	Select Burnout,$1-x$	$E_1+T-L_1-J_1-P$, E_2+P-D	$E_1+T-L_2-J_1$, E_2+J_2-D

3 Analysis of the Evolutionary Game Between the Two Sides

(1) The replication dynamic equation of the evolutionary game between the two sides

The expected returns and their average returns for miners choosing and not choosing burnout E_{11}、E_{12}:

$$E_{11}=yE_1+(1-y)(E_1-J_1) \tag{1}$$

$$E_{12}=y(E_1+T-L_1-P)+(1-y)(E_1+T-J_1-L_2) \tag{2}$$

$$E_1=xE_{11}+1-xE_{12} \tag{3}$$

In the same way, the expected returns and average returns of coal mining enterprises with and without intervention E_{21}、E_{22}.Then, according to the dynamic replication equation, the replication dynamic equation for both sides is as follows:

$$F(y)=\frac{dy}{dt}=y(1-y)(E21-E22)=y(y-1)(J2-P+x(P-F) \quad (4)$$

$$F(x)=\frac{dx}{dt}=x(1-x)(E_{11}-E_{12})=-x(x-1)(L_2-T+y(J_1+L_1-L_2+P)) \quad (5)$$

Let $F(x)=F(y)=0$, and obtain the four equilibrium points of the evolutionary game E_a (0,0）、E_b（1,0）、E_c（0,1）、E_d（1,1）and $E_e(x_0, y_0)$。$x_0=\frac{J_2-P}{F-P}$, $y_0=\frac{-(L_2-T)}{J_1+L_1-L_2+P}$。

(2) Stability analysis of the equilibrium point

Based on the research of Friedman[7], this paper used the Jacobian matrix to determine the stability of the equilibrium point:

$$J=\begin{bmatrix} -(2x-1)\left(L_2-T_1+y(J_1+L_1-L_2+P)\right) & -x(x-1)(J_1+L_1-L_2+P) \\ y(y-1)(P-F) & (2y-1)(J_2-P+Fx+Px) \end{bmatrix} \quad (6)$$

By judging the conditions[8], the analysis results of the stability point of the evolved game are obtained (Table 2).

Table 2. The results of evolutionary stability point analysis of both sides of the game

Equilibrium points	Conditions	Det（J）		Tr（J）		Results
$E_a(0,0)$	$L_2<T, P<J_2$	$(P-J_2)(L_2-T)$	+	$P+L_2-J_2-T$	-	ESS
$E_b(1,0)$	$F<J_2, T<L_2$	$(F-J_2)(T-L_2)$	+	$F+T-J_2-L_2$	-	ESS
$E_c(0,1)$	$J_2<P$ $J_2+J_1+L_1>T$	$(J_2-P)(J_1+L_1+P-T)$	+	$J_2+J_1+L_1-T$	-	ESS
$E_d(1,1)$	$J_2<F, J_2+T<F+L_1+P+J_1$	$(J_2-F)(T-L_1-P-J_1)$	+	$J_2+T-F-L_1-P-J_1$	-	ESS
$E_e(x_0, y_0)$	$P<F,$ $J_1+L_1+P<L_2$	$(F-J_2)(J_2-P)(L_2-T)(J_1+L_1+P-T)/(P-F)(J_1+L_1-L_2+P)$	-	0	0	Saddle point

4 Numerical Experiments and Simulations

In order to more intuitively reflect the results of the evolutionary stability analysis between coal mines and miners, according to the judgment conditions of the four equilibrium points and saddle points, the parameters are set as follows (Table 3):

Table 3. Parameter settings in different scenarios

Conditions	J_1	J_2	P	L_1	L_2	T	F
Scenario 1	8	10	5	4	3	5	2
Scenario 2	8	10	5	4	3	2	2
Scenario 3	2	3	4	2	3	10	2
Scenario 4	2	3	4	2	3	1	4
Scenario 5	4	6	3	4	2	6	10

In this paper, we drew a game diagram of the strategy evolution of coal mines and miners in different situations, as shown in Figures 1-5.

1) Under the conditions set by Array 1,Although the probability of safety managers choosing to switch to a positive mood initially increased, it then decreased rapidly, and eventually stabilized at choosing to maintain a negative burnout. Safety managers save a lot of time and energy due to job burnout, so they will show negative burnout in their actual work.

2) Figure 2 shows that over time, miners tend not to choose burnout, and coal mines tend not to intervene due to the high cost of taking measures and the low cost of miners' burnout levels.

3) Figure 3 shows that the increase in the number of miners choosing burnout over time leads to an increase in coal mine losses, and coal mines choose to adopt intervention policies, but the incentive income value of miners is not high, so they tend to choose burnout.

4) Figure 4 shows that over time, miners tend not to choose burnout, and coal mines tend to intervene, and the state of the evolutionary game system is ideal.

5) In Figure 5, When the probabilities of both sides of the game (x, y) take different initial values, and the final game evolution results also converge at different points. When the probability of burnout is less than x_0, the coal mines with the higher initial probability tend to intervene, while the coal mines with the lower initial probability tend not to intervene.

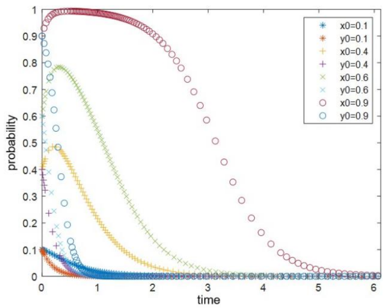

Fig. 1. The proportion of initial population change under scenario 1

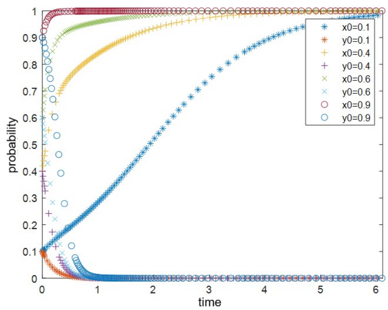

Fig. 2. The proportion of initial population change under scenario 2

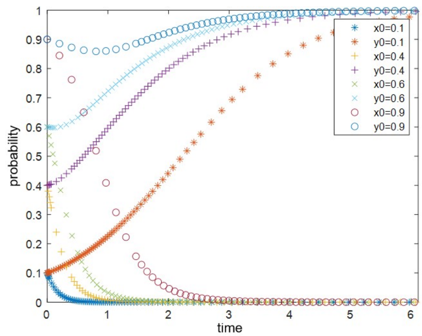

Fig. 3. The proportion of initial population change under scenario3

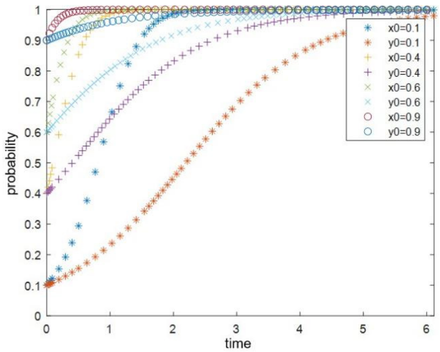

Fig. 4. The proportion of initial population change under scenario 4

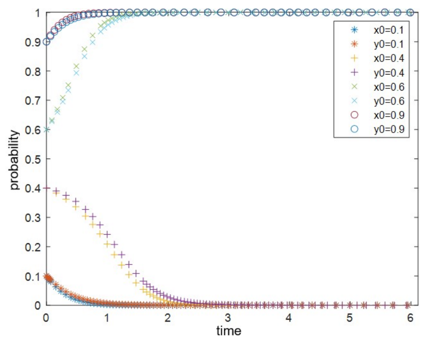

Fig. 5. The proportion of initial population change under scenario 5

5 Conclusion

The results of this paper show that there are four equilibrium points and one saddle point in the evolutionary game system, and miners and coal mines adopt different coping strategies under the influence of each key element set. Combined with the empirical analysis and evolutionary game analysis results of this paper, targeted intervention suggestions are given.

By optimizing the safety management evaluation mechanism, coal mines can make the performance rewards for miners far outweigh the benefits saved from burnout. At the same time, the improvement and improvement of work requirements and work resources[9] make miners feel that the risk loss due to burnout is far greater than the consideration of their choice of burnout. Enterprises should also comprehensively consider the possible losses caused by miners' burnout and non-implementation of intervention policies, so as to promote the healthy development of enterprises while assuming their due social responsibilities.

For the miners themselves, they can combine work and rest in their daily work, conduct questioning and analysis, review their work in a timely manner, save emotional resources[10] as much as possible, maintain self-esteem while feeling themselves, actively adjust their mentality and continuously improve themselves in their daily work, improve their core competitiveness, find the reason and excitement for their love for the industry and work hard, so that their physical and mental state can better engage in safety management.

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