Original Research

Analysis of Labor-Management Negotiation based on Chicken Evolutionary Game and Catastrophe Theory

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Abstract
This paper aims to conduct a research on the labor-management negotiation in a chicken evolutionary game models through catastrophe theory. Both players can compromise or not during the negotiation. The "no compromise" strategy for labor means threat to strike and for management is ignoring labors' demands. Since the model of this research is chicken game, if on player decides to dig in, the optimum decision for other is to compromise, however it is costly to be calling a chicken by the rivals. In the process of evolution, players reevaluate their options to update the payoffs in case of gradual and continuous changes which may happen in effective variables of strategy selection. The continuous changes could cause a catastrophic change in system's state and its collapse by a strike or lockout. ESS analysis and determining catastrophe threshold in the chicken evolutionary game will be done with the aim of giving managerial insights that help the players to prevent making decisions that could cause unsuccessful negotiation.

Keywords - catastrophe theory; evolutionary chicken game; labor-management negotiation

1. INTRODUCTION

The important issues such as wages or bad work conditions may cause labors' dissatisfaction and threat strike. Negotiation is a way that allows parties to settle a dispute; and it helps participants to attain their (Lewicki, Saunders, & Minton, 1999). Recent researchers have shown growing interest in developing bargaining models' applications, such as business and management (Chen and Hao, 2014).

The labor-management negotiating system ranges from strike to lockout. Figure 1 shows the behavior on the two positions of the surface as strike-prone or lockout-prone (Capdevielle, and Mary, 1979). A lockout is a temporary work stoppage or denial of employment initiated by the management during a labor dispute. While in a strike employee refuse to work.

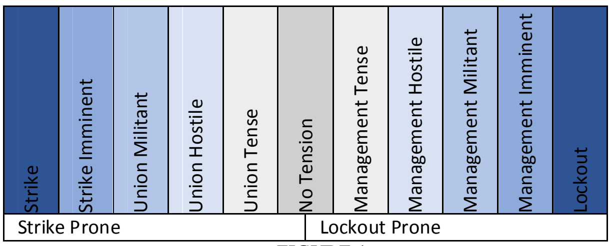

FIGURE 1
NEGOTIATION BEHAVIOR OF THE SYSTEM

The process of labor-management negotiation has some features which can be described by the catastrophe theory; two mode states, sudden jump. These features will be explained more in section 4. Catastrophe theory is a method to describe abrupt changes in the behavior surface. Strikes or lockouts in negotiation is a case in point. Catastrophe theory defines that small continuous changes in control parameters of a nonlinear models will lead to discrete jump in the system's state. Thom (1972) called such instability ‘‘catastrophes”.

Many researchers studied the application of catastrophe theory in behavioral science. Hu and Xia investigated labors' sudden behavioral changes through a hybrid qualitative–quantitative model of catastrophe theory (Hu and Xia 2015). Xu et al expanded the former model on the manufacturing enterprises to show fuzzy nature of human resource turnover (Xu et al. 2014). Wang et al. (2016) analyzed fuzzy catastrophe method for selecting suitable high strategy coincidence projects in a constrained resource environment. Hu and Hu (2018) evaluated the effectiveness of qualitative catastrophe method in modeling dynamics of group opinion. Dimas et al. (2018) did a research on managing labors' conflicts by the mentioned method.

As players' strategies evolve during the process of negotiation and they could learn by try and error, negotiation is a dynamic game. Evolutionary game is a way of monitoring behavioral traits of population. At first it was used in animals' evolution by Smith and Price (1973). Evolutionary stable strategy is a situation in which small changes in strategy selection of players could not invade the total result. This concept was introduced by Taylor and Jonker in 1978 (Hofbauer and Sigmund, 1998).

This study is intended to model the evolutionary negotiation in chicken games. The chicken game is associated with conflict in two players in games. It refers to analogy that two drivers speeding towards each other, with the potentially catastrophic result for both if they crash. If one side chooses straight strategy, the best strategy for the other side is swerves and vice versa (Figure 2), so it is necessary to choose different actions. The player who swerves is called chicken. The game may be played without disaster for few levels, but finally the moment will come when players prefer crash to the losing credit and being called as a chicken (Russell, 1959).

	Swerve	Straight
Swerve	Tie, Tie	Lose, Win
Straight	Win, Lose	Crash, Crash

FIGURE 2
A PAYOFF MATRIX OF CHICKEN

The previous studies did not investigate the labor-management negotiation as a chicken game in which the negotiation can suddenly fail by catastrophe such as strike or lockout. The gap will be filled by considering an evolutionary negotiation as a chicken game in which a discrete transition may occurs in proportion of the labors' strategies. This study set out to find out catastrophe set in which negotiation will collapse by a lockout or strike due to some continuous changes in control variables to warn participants to prevent it. The rest of this article is organized as follows: problem modeling in sections 2, equilibrium analysis in sections 3, reviewing a brief background of catastrophe theory in section 4 by exploring the possibility of catastrophe occurrence in the state of system, and finally the main conclusion to be drawn and suggestions is presented in section 5.

2. MODEL AND ASSUMPTIONS

This study deals with evolutionary labor-management negotiation, in which both players have two strategy of compromise and no compromise. Labors and management may both decide to compromise at a certain point. But this outcome cannot prevail either, because each side will rather raise its demands if he sees that the other side is ready to compromise. Thus, if labors decide on strike, it is better for management to compromise and if management takes the hard-nose approach, the labors would do best to compromise. The player who compromises will be called as a chicken. As times follows, the cost of being a chicken for the player will gradually increase and reach to a level that he prefers not to compromise to be a chicken. This time-dependent cost (dependent to the number of negotiation's iteration (n)) is reflected in players' payoff and according to the players' characteristics, it could be linear, ascending or descending. The strategies of the players are shown in figure 3.

		management: compromise	management: No compromise
labors	compromise	0,0	-b-f(n), b
labors	No compromise	b, -b-f(n)	-a, -a

FIGURE 3
THE STRATEGIES AND THE PAYOFF OF THE PLAYERS

3. EQUILIBRIUM ANALYSES

At the beginning level of game, the probability of compromise for the players is assumed to be x. The respective expectation values of “compromise”, “not compromise” and the average value are shown by U_c, U_n and $\overline{U}$, respectively.

$$U_c = (1-x)(-b-f(n)) \quad (1)$$

$$U_n = xb - a(1-x) \quad (2)$$

$$\overline{U} = x((1-x)(-b-f(n))) + (1-x)(xb - a(1-x)) = -xf(n) + x^2 f(n) - a + 2ax - ax^2 \quad (3)$$

4. REPLICATOR DYNAMICS EQUATION OF “COMPROMISE”

Replicator dynamic equation that is shown below, can investigate the growth rate of a specific strategy selection during the evolution by calculating its distant with the population's average payoff of (Esmaeili et al., 2018).

$$F(x) = \frac{dx}{dt} = x(U_1 - \bar{U}) = x(x-1)((a-f(n))x + b + f(n) - a) \quad (4)$$

- According to the above equation, if $x = \frac{a-b-f(n)}{a-f(n)}$, then $F(x) \equiv 0$, which means that all games are stable.
- If $x \neq \frac{a-b-f(n)}{a-f(n)}$, let $F(x) = 0$, then games are stable when $x = 0$ and $x = 1$.
- Evolutionary stable strategies are attained when $\frac{dF(x)}{dx} < 0$. If $x > \frac{a-b-f(n)}{a-f(n)}$ then evolutionary stable strategy is attained when x =0.
- The dynamic phase charts and stability of players are shown in figure 4.

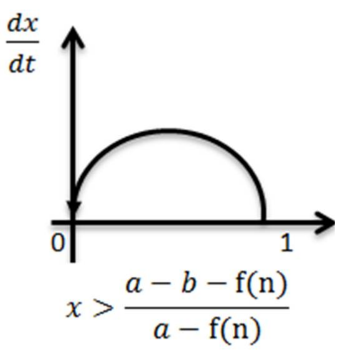

FIGURE 4
REPLICATOR DYNAMICS PHASE CHARTS

5. BRIEF REVIEW OF CATASTROPHE THEORY

René Thom introduced the catastrophe theory for the first time in 1960s. This method is used to explain abrupt mutations in nonlinear systems caused by continuous changes in control factors (Zeeman, 1976). The catastrophe theory equation is as below in which the potential function, dependent variable and control variable vector are $V(x(t), \vec{c})$, $x(t)$ and $\vec{c}$, respectively.

$$dx(t) = \frac{-\partial V(x(t), \vec{c})}{\partial x(t)} \quad (5)$$

Cusp catastrophe (Fig 5) is the most important kind of catastrophe among the other types (Thom, 1972). The nonlinear models such as negotiation in which there is two possible states (strike and lockout), and sudden probable transitions could be described by cusp catastrophe.

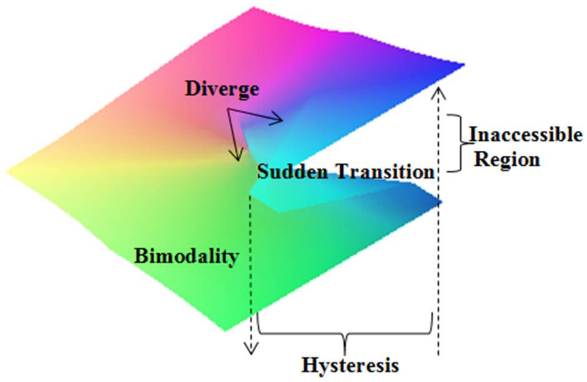

FIGURE 5
THE CUSP CATASTROPHE

The cusp catastrophe model consists of one state variable (Z) and two control variables (α, β). The potential function is represented in the following:

$$F(Z, \alpha, \beta) = \frac{1}{4}Z^4 + \frac{1}{2}\alpha Z^2 + \beta Z \quad (6)$$

The equilibrium surface and the catastrophe set expressed below (Eq. 7-8).

$$\frac{\partial F}{\partial x} = Z^3 + \alpha Z + \beta = 0 \quad (7)$$

$$27\alpha^2 = 4\beta^3 \quad (8)$$

In the following we will demonstrate that the replicator dynamic of our model could be described by cusp catastrophe and the managerial insights and an example will be presented.

6. THE EXISTENCE OF THE CATASTROPHE FOR THE POPULATION

The replicator dynamics equation for the labor population is presented below.

$$dx(t) = \left((a-f(n))x^3 + (2f(n) + b - 2a)x^2 + (a-b-f(n))x\right)dt = (Ax^3 + Bx^2 + Cx)dt \quad (9)$$

$$A = a - f(n);\ B = 2f(n) + b - 2a;\ C = a - b - f(n) \quad (10)$$

We assume α, β and Z as below and rewrite Eq. 9:

$$x = Z - \frac{B}{3A}, \alpha = \left(C - \frac{B^2}{3A^2}\right), \beta = \left(\frac{2B^3}{27A^3} - \frac{CB}{3A^2}\right) \quad (11)$$

$$dx(t) = A(Z^3 + \alpha Z + \beta).dt \rightarrow dx(t) = 0 \rightarrow Z^3 + \alpha Z + \beta = 0 \quad (12)$$

Eq. 12 is the equation of cusp catastrophe. Replacing the variables in the equation of catastrophe set allows us to investigate where the system's state undergoes a major discrete change duo to continuous changes of the control variables.

$$27\alpha^2 = 4\beta^3 \rightarrow$$
$$27(a-b-f(n)-\frac{(2f(n)+b-2a)^2}{3(a-f(n))^2})^2 = 4(\frac{2(2f(n)+b-2a)^3}{27(a-f(n))^3} - \frac{(a-b-f(n))(2f(n)+b-2a)}{3(a-f(n))^2})^3 \quad (13)$$

In this paper the control variables are the values of payoff matrix. The plot of catastrophe set is depicted in Fig 6. During the negotiation, the players should prevent choosing the strategies that leads to closing to the border of catastrophe threshold, because in this case negotiation will be failed by strike or lockout. In the following, the example aims to clarify the preceding points.

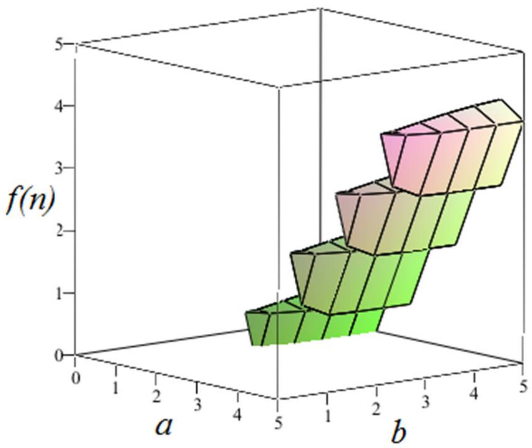

FIGURE 6
THE CATASTROPHE SET

Example: If $a = 10, b = 2$, (variables of payoff matrix), and $f(n) = 0.5n$ (credit cost in level n of negotiation), then the iteration in which the catastrophe occurs is iteration 19 (Obtained by equation 13). It means that after the 19 iterations of compromising and not getting the mutual compromise from the other side, because of the increasing cost of the losing credit, the player decides to not compromise anymore. If both players reach the catastrophe set, the system will collapse by strike or lockout. This prediction will help players to prevent system collapse through their strategy selection in the process of negotiation.

7. CONCLUSION

This paper was about chicken evolutionary game model of labor-management negotiation. Replicator dynamic equation is used to find out the stable strategies of population (the final proportion of choosing the strategies). Then it is proved that it is probable that the negotiation fails by abrupt collapse like strike or lockout in which the sides of the games choose to not compromise with each other anymore. The aim of these model was to mention the importance of paying attention to small changes in control variables such as increasing dissatisfaction to prevent huge disasters like strike and lockout. Whether or not a player has more power in the game, the catastrophe zones of labor-management relation should be considered to prevent negotiation failure.

The asymmetric matrix of players' payoff or different proportion of choosing the strategies could be an attractive issue for scholars in the future studies. The other forms of the game model such as leader- follower negotiation games could enrich the model.

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