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Research Article

An Evolutionary Game Model of Knowledge Workers' Counterproductive Work Behaviors Based on Preferences

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Knowledge workers' counterproductive work behaviors (CWB) always cause great loss to enterprises, but it is hard to supervise these behaviors. Based on the analysis of the causes of these behaviors, this paper builds a theoretical model of knowledge workers' CWB and proposes that knowledge workers' CWB are influenced by both rational and irrational factors. Regarding contextual factors and individual factors as risk preferences of knowledge workers, this paper establishes an asymmetrical evolutionary game model of enterprise supervision. Then, multiagent modeling simulation is conducted to discuss the effect of both formal and informal constraints on knowledge workers' CWB and, based on it, the intervention strategies of enterprises are proposed. The simulation results show that the effect of informal constraints is bigger than the effect of formal constraints. The working environment and knowledge workers' personality traits are the key factors to produce CWB.

1. Introduction

For any type of organizations, it expects its employees to conform to organizational norms and behave as they are expected by the organizations. However, employees' behaviors are not always consistent with organizational expectations and sometimes they even exhibit some deviant behaviors. Fox et al. called such behaviors counterproductive work behaviors (CWB). They posited that the negative organizational contexts (such as organizational injustice and organizational constraints) may affect employees' CWB, which is mediated by negative emotions [1].

Counterproductive work behaviors (CWB) refer to a set of distinct acts that share the characteristics that they are volitional and harm or intend to harm organizations or organization stakeholders such as clients, coworkers, customers, and superiors [2]. Usually they are hard to be detected but can cause great destruction. CWB are very common in organizations so the research on CWB is an important issue for both academia and business circles. According to an American study, 75% employees have once stolen their employers [3]. It is estimated that 33%–75% employees have exhibited CWB [4]. Another study estimated that only employee theft could cause 200 billion dollars loss to American enterprises and not to mention the slackness, destroying work, or aggressive behaviors [5].

Although there are already some theories and empirical studies in the CWB field, most studies focus on common employees and ignore the study of knowledge employees. Compared with common employees, the nature of work of knowledge employees has changed significantly. It is harder to detect their CWB and the consequences they cause are more serious. Knowledge workers are the ones who directly participate in knowledge innovation activities. Compared with common employees, their CWB can cause greater destruction to enterprises [6]. Knowledge worker was first coined by Drucker (1959) [7]. He pointed out that "the most valuable asset of a 21st-century institution, whether business or non-business, would be its knowledge workers and their productivity." Knowledge workers are employees who have a deep background in education and experience and are considered people who "think for a living." They include software developers, doctors, engineers, lawyers, inventors, teachers, financial analysts, and architects [8]. Knowledge workers mainly work at technical and managerial positions, which can have great effect on enterprises. For example, for

knowledge workers at technical position, if they exhibit CWB, the minor effect may be the influence of quality of products while the severe effect may be the influence of technological innovation of enterprises or even the leak of core secrets. For knowledge workers at managerial position, if they exhibit CWB such as competing viciously with colleagues for benefits or performing cliquism, they also can bring fatal harm to enterprises. Furthermore, the nature of work of knowledge workers determines that they have more freedom and these CWB are harder to be detected, which increase the possibility of such behaviors [9].

From above analysis, it is easy to see that the destruction knowledge workers' CWB bring is huge. However, the studies on the intervention strategies of knowledge workers' CWB are rare. Based on literature review, we have sorted out the intervention strategies on employees' CWB and find there are mainly two perspectives: the first perspective is to explore the determinants and formation mechanism of employees' CWB by empirical studies and then further propose the control strategies. For example, based on the setback-attack hypothesis, Spector and Fox proposed the stressor-emotion model of CWB [10]. By regression analysis, Krischer et al. found that personality and organizational context were the two main factors influencing employees' CWB and provided some control measures such as building good organizational culture, implementing punishment, and controlling deviant behaviors [11]. By combining attribution theory and theory of planned behavior, Martinko et al. proposed the causal reasoning theory and recommended a series of control measures such as improving employees' self-efficacy and maintaining a fair and equitable ethical climate [12]. However, these studies have the following problems: these empirical studies are based on static cross-sectional data, the relationship among variables are simple linear and causal related, and it is hard to conduct quantitative analysis on the micro dynamic mechanism of CWB control. In addition, the studies are hardly conducted on knowledge workers. This is mainly because, compared with common employees, knowledge workers' CWB are quite hard to be detected. Usually they are more sensitive to their negative behaviors and tend to fill the questionnaires according to their social preferences or even concealing their CWB, which may result in incorrect information collected in survey.

Therefore, some scholars attempt to describe the dynamic decision-making process of employees' CWB from game theory perspective. Then, based on the analysis of the equilibrium points, the employees' behaviors can be predicted. For instance, Mao and Sun constructed a multistage game model of CWB control and proposed "timely punishment" and "moderate punishment" management mechanism of employees' CWB [13]. Despite the fact that these studies can quantitatively analyze the control of employees' CWB, there are three basic problems concerning conducting these studies to analyze knowledge workers: firstly, the hypothesis is that knowledge workers are complete rational and they can always make the decisions that best realize their benefits. Obviously, this does not match the reality and there are already scholars putting forward different opinions [14]. Secondly, these studies regard employees as homogeneous, which is also contradictory with the reality that knowledge workers have diversified personalities and characters. Some studies already showed that the individual differences of employees could affect the formation of CWB [15]. Thirdly, in different work context, employees' CWB may be different. Individuals may have different sensitivities to environment and some studies have proved it [12].

Based on the above analysis, we can find that CWB are not only influenced by the rational factors such as payoffs but also influenced by working environment and individual preferences such as personalities. Influenced by these factors, knowledge workers' CWB are highly complex, dynamic, and evolutionary, which needs innovation and breaking through in methodology. Using evolutionary game theory, this paper studies the intervention strategies of knowledge workers' CWB. Based on literature review, firstly, we build a conceptual model of the formation of knowledge workers' CWB. Then, by combining rational and irrational factors, this paper constructs a multiagent model on the formation pattern and behavior rules of knowledge workers' CWB. By simulation, this paper reveals how knowledge workers' CWB are formed and proposes the intervention strategies on knowledge workers' CWB. The structure of this paper is as follows: Section 2 analyzes how knowledge workers' CWB are formed; Section 3 builds an asymmetrical evolutionary game model of knowledge workers' CWB and government supervision; Section 4 builds a multiagent model to simulate knowledge workers' CWB; Section 5 simulates the influences of various factors on knowledge workers' behaviors; Section 6 draws the conclusions.

2. Analysis of the Causes of Knowledge Workers' CWB

2.1. Determinants of Knowledge Workers' CWB. Negative contexts are the sources of most CWB. Different negative contexts may cause different psychological processing and further lead to different CWB. Recent studies also proved it [16]. Knowledge workers can perceive the unfair sources and then form corresponding CWB. Usually interactive injustice can lead to employees' CWB targeting on their superiors, while procedural and distributional injustice can lead to employees' CWB targeting on organizations. These two kinds of CWB are, respectively, related to the motives of retaliating superiors and retaliating organizations [17]. The current theories on CWB have noticed the effect of contextual factors on CWB [10, 12, 18]. Martinko listed 11 contexts including organizational context, working context, and individual living context. Spector posited that the organizational pressure factors such as organization constraint, organizational injustice, and interpersonal conflicts are the main contextual motivators of CWB. Some other studies showed that contextual factors not only can motivate CWB but also can control them. In a word, both theories and empirical studies indicated that the formation of CWB was more or less related to contextual factors.

However, not all CWB are caused by negative contexts. Some scholars pointed out that, due to personality tendency,

the possibilities of some individuals to exhibit CWB are greater than others [19]. Some studies showed that sometimes individuals exhibit CWB mainly due to helplessness such as incapability to finish performance goal, but sometimes they are intentional such as to gain bonuses [20, 21]. Due to individual differences, under the same context, the individual cognition may be different. The inconsistency between organization and employees in goals and values can lead to conflicts of role anticipation. Such conflict can lead to cognitive dissonance and then result in individual CWB. Individual deviant behavior is a kind of way for individuals to adapt to restore cognitive balance. After CWB are formed, individuals will rationalize them by self-representation [22]. Some other scholars posited that the violation of psychological expectation by either organization or individuals is the key of cognitive dissonance. If individuals attribute the cognitive dissonance to internal stable factors, it will lead to self-hurt CWB; if individuals attribute the cognitive dissonance to external stable factors, it will lead to retaliating CWB [12, 23].

Except for the above widely accepted factors, some other scholars proposed some other factors such as emotional factors, motivational factors, character factors, and cognitive capability factors [24–29]. There are many influencing factors of CWB. But, in the end, they can be generalized as individual factors and contextual factors. The emotional factors, motivational factors, character factors, and cognitive capability factors can be generalized as individual factors, while organizational factors, working environment factors, and living factors can be generalized as contextual factors.

2.2. The Theoretical Model of Knowledge Workers' CWB. Currently, there are abundant studies on CWB. The influential ones are the causal reasoning theory [12], self-control theory [18], stressor-emotion theory [10], and theory of planned behavior [28].

From cognitive process, the causal reasoning theory emphasizes the influence of employees' causal reasoning process on their CWB. This theory holds that CWB are the result of the interaction between individuals and environment. The cognitive process of causal reasoning is the internal motives of CWB. Such causal reasoning process has two important elements: individual perception to imbalance and individual attribution of imbalance. The imbalance refers to the working outcomes which are not consistent with expectations, such as rewards not matching expectations. Individuals can perceive these outcomes by comparison. The attribution of these imbalances will influence whether individuals perform CWB and their behaviors.

Self-control theory proposed a two-dimensional model to differentiate four types of antecedents of CWB. And they are excitation sources, opportunities, internal control, and character tendency. The four categories have covered the majority of the antecedents referred to by most CWB theories. In fact, this theory integrates the current environmental and individual perspectives in CWB field and changes the current research tendency that only centers on one perspective. Therefore, this theory contributes to comprehensive understanding of the influencing mechanism of CWB.

Stressor-emotion theory pointed out that CWB followed the causal chain "stress → emotion → CWB." In this chain, stress comes from different stimulus such as organizational constraints (including rule and procedure constraints, resource constraints, and colleague constraints), interpersonal conflicts (such as quarrels with colleagues and rude interactions), and organizational injustice (such as distributional injustice, procedural injustice, and interactive injustice). Not all environmental stimulus can cause individual sense of stress. Only when individuals subjectively regard environmental stimulus as perception of stress can sense of stress be aroused. Sense of stress can arouse individual corresponding negative emotions such as anxiety and anger and then CWB.

Theory of planned behaviors hold that behavioral intention refers to the extent of which an individual is willing to pay efforts and conquer difficulty to perform some behaviors. It is the nearest antecedent variable that causes individual behaviors. The stronger the individual behavioral intention is, the higher the possibility is to perform the behaviors. The behavioral intention consists of three relatively independent factors: behavioral attitude, subjective norm, and perceived behavioral control. According to the theory, when individuals hold positive attitude towards CWB, the influence of perceived subjective norm is weak and sense of control is strong, and the intention to perform CWB is strong.

Although until now there are abundant theories and empirical studies in CWB field, the majority of studies focused on common employees and ignored the knowledge workers. Compared with common employees, the nature of work of knowledge workers has changed a lot. Their CWB are harder to be detected and the consequences are more serious. Although knowledge workers are the white-collar class and most of them have received good education, their professional backgrounds and knowledge structures are different. The personal experiences, characters, and self-control capability are different. What is more, the nature of work, work content, and work ways of knowledge workers are different. Most knowledge workers take on knowledge and innovative work and it is common for them to work in flexible time. In such working context, knowledge workers have more freedom. It is hard to supervise them and their work performance is hard to assess. Therefore, their CWB are more difficult to be detected and be supervised and controlled [30–33].

Based on the above analysis, this paper posits that knowledge workers' CWB is influenced by individual factors and contextual factors. The happening of knowledge workers' CWB can be divided into 3 stages: the first stage is knowledge workers' perceptions to surrounded environment (such as organizational injustice); the second stage is the processing and evaluation on the information perceived. Due to knowledge workers' different personalities, they may have different subjective cognition towards the same objective environment. So, at this time, knowledge workers may think they are treated unfairly and therefore produce negative feelings; in the third stage, knowledge workers with negative feelings will make all kinds of tries to balance their cognitions such as changing the attitude, reasonable attribution, or

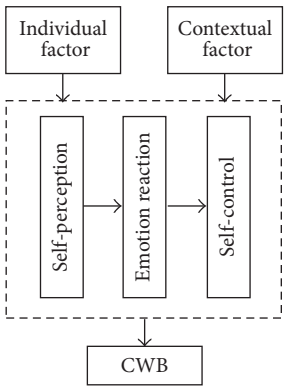

Figure 1: Theoretical model of knowledge workers' CWB.

Table 1: Payoff matrix of CWB.

Enterprise	Knowledge worker	
	Choose	Not choose
Supervise	$p - c - d + og$	$p - c$
	$w + e - og + (1 - o)t$	$w + t$
Not supervise	$p - d$	p
	$w + e$	w

"p" denotes the contribution of knowledge worker to enterprise; "w" denotes the salary that knowledge worker gets from enterprise; "e" denotes the extra payoff knowledge worker has when choosing CWB; "c" is the supervision cost of enterprise; "d" denotes the enterprise loss caused by knowledge worker's CWB; "o" denotes the observation capability of enterprise; "g" denotes the punishment to knowledge worker when enterprise supervises CWB; "t" denotes the increase of trust on knowledge worker when enterprise supervises but not does not find CWB.

performing CWB [34, 35]. Combining Spector, Martinko, Marcus, and He' views [9, 10, 12, 18, 34, 35], we integrate the influencing factors and processes of knowledge workers' CWB and get the following theoretical model. Please see Figure 1.

3. Evolutionary Game Analysis of Knowledge Workers' CWB

To control CWB, the most direct way is to supervise knowledge workers. Once there is CWB, then punish at once. Knowledge workers know that enterprises may supervise them. So they may decide whether performing CWB is according to their payoffs and preferences. Based on the analysis of above section, we can know that the nature of work of knowledge workers decides the supervision cost of enterprises is high. Even if there is supervision, constrained by the observable level, CWB still can not be detected by one hundred percent. Moreover, because knowledge workers mainly take on innovative work, too severe supervision may result in the decrease of knowledge workers' innovative capability [36, 37]. However, if enterprises do not supervise, it may lead to too many CWB. Therefore, enterprises will choose to supervise partly. For knowledge workers, according to the above analysis, their CWB are not totally depending on payoffs. They are also influenced by individual factors such as emotion, cognition, and characters and contextual factors such as working environment, organizational culture, and interpersonal relationship. In the same context, some knowledge workers may exhibit CWB but some not; for the same knowledge worker, in some contexts, he may exhibit CWB but in other contexts not. This is mainly because in different contexts different knowledge workers may have different perceptions to payoffs. These different perceptions may lead to different emotion reaction. When it exceeds the threshold of self-control, CWB happen [9, 10, 12, 18, 34, 35].

Based on prospect theory, some scholars proposed an improved value function, which can differentiate the perceptions of decision makers to payoffs by parameter setting. And experiments proved its effectiveness. Thus, this paper applies it to measure knowledge workers' perceptions to payoffs [38, 39]:

$$V(\Delta U) = \begin{cases} \xi (\Delta U)^{\alpha} & \Delta U \geq 0 \\ -\theta (\Delta U)^{\beta} & \Delta U < 0. \end{cases} \quad (1)$$

Parameters α, β denote the individual factors of knowledge workers. $0 < \alpha$, $0 < \beta$. The bigger α, β are, the riskier the decision maker tends to be, or in other words knowledge worker is easier to take CWB. When there is only one knowledge worker to game, then $\alpha = \beta$. ξ, θ denote the extent of knowledge workers' sensitivity to institutional punishment. When working climate is boring, compared with punishment loss knowledge workers are more sensitive to payoffs of performing CWB, then $\theta = 1$, $\xi > 1$; when work is full of challenges and satisfactory, knowledge workers may value work opportunities and care more about the punishment. Then $\theta > 1$, $\xi = 1$. ΔU denotes the changes of payoffs; V denotes decision maker's perception to changes of payoffs.

The game between enterprise and knowledge workers is a special one. The enterprise is in dominant position and it is very rational. We can regard it as rational participant, which make decisions based on the absolute payoffs of game strategies. On the contrary, knowledge workers are bounded rationality and they have preferences. They make decisions based on the compromising value of payoff and preference. Because one party of the game is bounded rationality, this paper adopts evolutionary game method to analyze it [40].

This game problem of CWB supervision is a 2×2 asymmetrical game between enterprise and knowledge worker. The strategy set of enterprise is {supervise, not supervise} and the strategy set of knowledge worker is {choose, not choose}. See the payoff matrix in Table 1.

Supposing the probability of enterprise to supervise is x, the probability of not supervision is $1 - x$; supposing the probability of knowledge worker to choose CWB is y, the probability of not choosing is $1 - y$.

Then, the expected payoffs of enterprise supervision are

$$E_{11} = y(p - c - d + og) + (1 - y)(p - c). \quad (2)$$

The expected payoffs of enterprise not to supervise are

$$E_{12} = y(p-d) + (1-y)p. \tag{3}$$

The average payoffs of enterprise are

$$E_1 = xE_{11} + (1-x)E_{12}. \tag{4}$$

The replicator dynamics equation of enterprise is

$$F_1(x) = \frac{dx}{dt} = x(E_{11} - E_1) = x(1-x)(yog - c). \tag{5}$$

We take derivatives of both sides and can get

$$F_1'(x) = (1-2x)(yog - c). \tag{6}$$

The expected payoffs of knowledge worker to choose CWB are

$$E_{21} = x[w + e - og + (1-o)t] + (1-x)(w+e). \tag{7}$$

The expected payoffs of knowledge worker not to choose CWB are

$$E_{22} = x(w+t) + (1-x)w. \tag{8}$$

The average payoffs of knowledge worker are

$$E_2 = yE_{21} + (1-y)E_{22}. \tag{9}$$

The difference of knowledge worker choosing CWB and the average payoffs is

$$\Delta E_{21} = E_{21} - E_2 = (1-y)[e - (g+t)ox]. \tag{10}$$

The difference of knowledge worker not choosing CWB and the average payoffs is

$$\Delta E_{22} = E_{22} - E_2 = -y[e - (g+t)ox]. \tag{11}$$

Substituting (1) to (10) and (11), we can get the perceptive payoffs of knowledge worker:

$$\begin{aligned} V(\Delta E_{21}) &= \xi\{(1-y)[e-(g+t)ox]\}^{\alpha}, \\ V(\Delta E_{22}) &= \theta\{y[e-(g+t)ox]\}^{\beta}, \end{aligned} \tag{12}$$

when $\xi = \theta = \alpha = \beta = 1$, the above equation reduces to the general state, that is, not considering the contextual factors and individual factors of knowledge worker. At this time, the replicator dynamics equation is

$$F_2(y) = y(E_{21} - E_2) = y(1-y)[e-(g+t)ox]. \tag{13}$$

We take derivatives of both sides and can get

$$F_2'(y) = (1-2y)[e-(g+t)ox]. \tag{14}$$

Make the replicator dynamics equation equal to 0. Then, we can have five equilibrium points and they are $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$, $(e/(g+t)o, c/og)$. According to the method proposed by Friedman [41], the stability of the equilibrium state can be analyzed based on the local stability of Jacobian matrix. The Jacobian matrix is

$$J = \begin{pmatrix} (1-2x)(yog-c) & x(1-x)og \\ y(1-y)[(g+t)o] & (1-2y)[e-(g+t)ox] \end{pmatrix}. \tag{15}$$

By calculation, only when $og < c$, the determinant value of $(0,1)$ is bigger than 0 and the trace value is smaller than 0. So $(0,1)$ is an ESS. When $og > c$, and $e > (g+t)o$, the determinant value of $(1,1)$ is bigger than 0 and the trace value is smaller than 0. So $(1,1)$ is an ESS. The others are not ESS.

4. Simulation Analysis of Knowledge Workers' CWB Based on Multiagent Modeling

4.1. Model Description. Based on the above analysis, this paper simulates the dynamic evolution of knowledge worker's CWB by multiagent modeling. We use agent to describe knowledge worker and enterprise, while we use a series of constraint sets to describe enterprise management institutions and game rules. The definitions of the variables of the basic model are as follows:

(1) A is the agent set of knowledge workers, $A = \{\text{Agent}_1, \text{Agent}_2, \ldots, \text{Agent}_n\}$, n is the number of knowledge workers in the group.

(2) B is the current behavioral state of knowledge workers, $B = \{B_1, B_2\}$, B_1 is the state of knowledge worker choosing CWB, B_2 is the normal working state, F is the current behavioral state of enterprise, $F = \{F_1, F_2\}$, F_1 is the state of enterprise choosing to supervise, and F_2 is the state of enterprise choosing not to supervise.

(3) C is the management institution of enterprise, which consists of informal constraint C_1 and formal constraint C_2. From above qualitative analysis, we can know C_1 determines knowledge workers' decisions, $C_1 = (\alpha, \beta, \xi, \theta)$. C_2 consists of variables of the game matrix, $C_2 = (x, y, p, w, e, c, d, o, g, t)$. Organization can control the happenings of CWB by adjusting some variables in C_2.

4.2. Rule Description

(1) Initial Rule. Suppose that there are 100 knowledge workers in enterprise. At the initial stage, there is y probability to have CWB.

(2) Rule of Payoff Perception of Knowledge Workers. When enterprise supervises knowledge workers at x probability, then the perceived payoffs of knowledge workers who have CWB is $V(\Delta E_{22})$, that is, $\theta\{y[e-(g+t)ox]\}^{\beta}$, and the perceived payoffs of knowledge workers who do not have CWB is $V(\Delta E_{21})$, that is, $\xi\{(1-y)[e-(g+t)ox]\}^{\alpha}$. According to the estimates of Tversky and Kahneman [42], when the model is

in general state, that is, knowledge workers are risk neutral to CWB, $\alpha = \beta = \xi = \theta = 1$. When contextual climate is not good, $\theta = 2.25$, $\xi = 1$; when contextual climate is good, $\theta = 1$, $\xi = 2.25$; when knowledge workers prefer to be risky concerning CWB, $\alpha = 0.8$, $\beta = 1.5$; when knowledge workers prefer to be conservative concerning CWB, $\alpha = 1.5$, $\beta = 0.8$.

(3) Decision Rule of Knowledge Workers. When $V(\Delta E_{21}) > V(\Delta E_{22})$, knowledge workers choose strategy B_2. On the contrary, knowledge workers choose strategy B_1.

(4) Decision Rule of Enterprise. When $E_{11} > E_{12}$, enterprise chooses strategy F_1. On the contrary, enterprise chooses strategy F_2.

4.3. Model Simulation. This paper uses netlogo to simulate the model. Netlogo is designed by UriWilensy in 1999. It is a programmable modeling environment which can simulate natural and social phenomenon. It is one of the widely used simulation tools. In this paper, we use netlogo 5.3 to simulate the model.

First, we suppose the contextual factor is moderate and knowledge workers are risk neutral to CWB, that is, $C_1 = (1, 1, 1, 1)$. In terms of C_2 variable, the author had interviewed Jiangling Motors Corporation, Huawei Technologies Corporation, and Zhongxing Telecommunication Equipment Corporation, where Jiangling Motors Corporation is a big automotive company, Zhongxing Telecommunication Equipment Corporation is a global leader in telecommunication industry, and Huawei technologies corporation is one of the three biggest mobile phone producers. All these three companies are knowledge-intensive enterprises which have lots of knowledge workers. So, from each of the three companies, the author had interviewed two directors of R&D teams and asked them about the quantitative relationship of CWB payoff matrix. The questions include "do you think the contributions made by knowledge workers are greater than the salaries paid to them?" and "do you think the punishment exercised on knowledge workers are greater than the salaries paid to them?" We summarized their answers and if the answers are not consistent, then we drop it. Then we can have the constraining condition: $p > w$, $e > w$, $d > e$, $w > g$; based on it, the author selected 50 MBA students of Jiangxi University of Finance and Economics who were engaged in knowledge-intensive jobs and sent questionnaires to them. They are asked to give values to C_2 according to their knowledge of the companies they worked in. The 50 graduates worked in different companies, where there were 7 working in machinery and manufacturing companies, 6 working in electronics manufacturing companies, 8 working in software companies, 14 working in finance companies, 5 working in medical companies, 4 working in education industry, and 6 working in law industry. The companies are distributed widely. There are 5 in Jiangxi province, 13 in Guangdong province, 7 in Jiangsu province, 6 in Zhejiang province, 6 in Fujian province, 5 in Hubei province, 4 in Hunan province, and 4 in Anhui province. Furthermore, half of them are multinational companies. Supposing $p = 10$, x, y, o all bigger than 0 and smaller than 1, the mean of variables is $C_2 = (0.16, 0.12, 10, 5.78, 7.06, 0.66, 13.56, 0.22, 2.78, 0.18)$; for the simulation results, please see Figure 2. The red line denotes the probability to select F_1, while the blue line denotes the probability to select B_1.

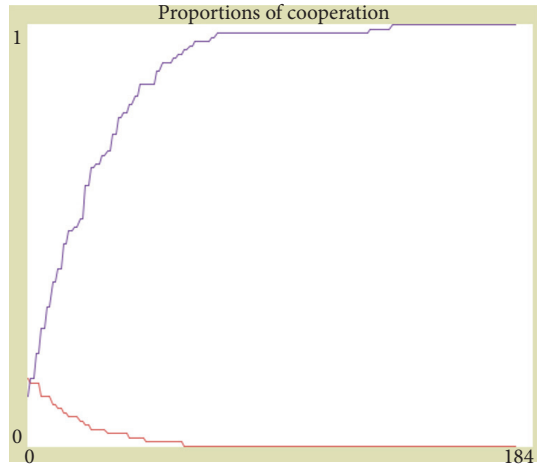

Figure 2: Simulation on evolution of knowledge workers' CWB.

From Figure 2, we can see the simulation curve finally converges at (F_2, B_1); that is, at current situation, the game reaches the equilibrium point: enterprise does not supervise and knowledge workers choose CWB. The simulation result matches the mathematical deduction of evolutionary game. This is because at this time $og < c$, $(0, 1)$ is the current ESS. This shows that at current state (when we use the mean of each variable) choosing CWB is the best strategy for knowledge workers. This explains why knowledge workers' CWB are more and more popular and also indicates the necessity and urgency to intervene [5, 34].

5. The Intervention Strategy on Knowledge Workers' CWB

According to the analysis of Section 3, there are many factors which influence knowledge workers' CWB. Some are individual factors such as knowledge workers' emotion, cognition, and characters. Some are contextual factors such as working environment, organizational culture, and interpersonal relationship. Others are managerial factors related to enterprise supervision. The purpose of intervention strategy is to reduce the happening of knowledge workers' CWB. Now based on the initial values of variables in C_2, we use simulation experiment to observe the effectiveness of the intervention strategies on CWB.

5.1. Influence of Enterprise Supervision on Knowledge Workers' CWB. Enterprise supervision is always the main means of organizational control. For managers, to increase the effectiveness of institution, firstly, they need to differentiate the influence of different managerial parameters on employees' states and find out the critical point or behavioral stable equilibrium point. In this subsection, we mainly analyze the

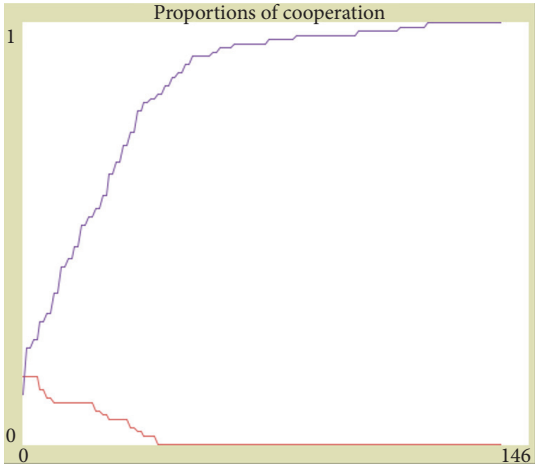

Figure 3: Influence of increasing knowledge workers' salaries on CWB.

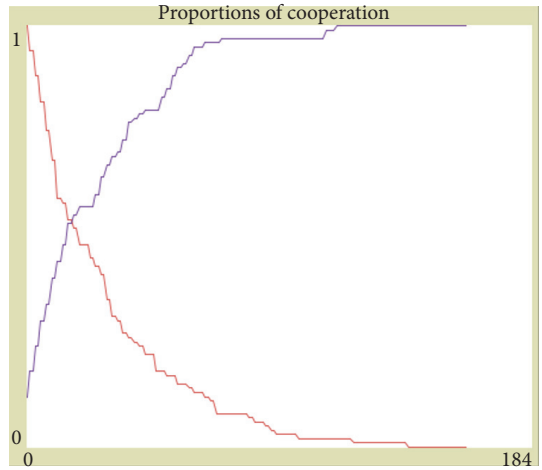

Figure 4: Influence of increasing frequencies of enterprise supervision On CWB.

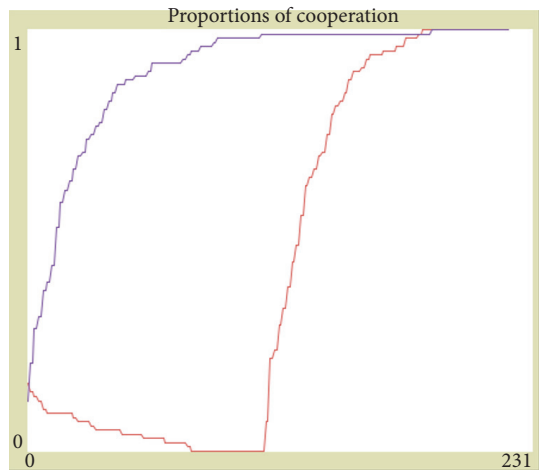

Figure 5: Influence of increasing enterprise observation capability on CWB.

influence of different institutional management parameters on employees' behaviors.

Firstly, we suppose enterprise substantially increases knowledge workers' salary. With $C_1 = (1, 1, 1, 1)$ is given, we give $C_2 = (0.16, 0.12, 10, 9.9, 7.06, 0.66, 13.56, 0.22, 2.78, 0.18)$ and salary is increased to the amount that is a little bit smaller than the contribution to enterprise and is bigger than the extra payoffs of performing CWB. This is the highest salary enterprise can pay knowledge workers. For the simulation result, see Figure 3.

From Figure 3, we can find when we increase knowledge workers' salary to the limit, knowledge workers will still choose CWB. So we can see increasing employees' salary has no direct relationship with the reduction of CWB and on the contrary it may increase enterprise's operation cost. Given other managerial measures, only paying employees high salary cannot decrease the probability of employees' deviant behaviors.

Next we increase the probability of enterprise supervision. We suppose the probability of enterprise supervision is positively proportional to the cost of enterprise supervision. We give the probability of enterprise supervision 100%; that is, enterprise spares no effort to supervise knowledge workers' CWB. So the cost of enterprise is increasing. At this time, $C_2 = (1, 0.12, 10, 5.78, 7.06, 4.125, 13.56, 0.22, 2.78, 0.18)$, of which enterprise supervision is to the highest extent. For the simulation result, see Figure 4.

From Figure 4, we can find even if enterprise conducts 100% supervision, it cannot prevent knowledge workers' CWB. It shows that only increasing the supervision level cannot reduce CWB but increase the supervision cost.

Finally, we increase enterprise's observation capability. The increase of observation capability is not necessarily increasing the supervision cost. It includes the rotation of sensitive positions and mutual supervision from different informal channels. All these can effectively save supervision cost and increase the supervision efficiency with the same input. We give $C_2 = (0.16, 0.12, 10, 5.78, 7.06, 0.66, 13.56, 0.24, 2.78, 0.18)$. For the simulation result, see Figure 5.

From Figure 5, we can find when increase the enterprise's observation capability, at this time, $og > c$ and $e > (g + t)o$. The simulation curve converges at $\{F_1, B_1\}$; that is, enterprise chooses to supervise, but knowledge workers choose to perform CWB. From Figure 5, we can see that the red line decreases to 0 from the start and then quickly increases to 1. This is because at beginning enterprise knows supervision cannot prevent knowledge workers' CWB. So it reduces the probability of supervision. But when the happening probability of knowledge workers' CWB approaches to 100% and the payoffs of punishment on knowledge workers' CWB is bigger than the supervision cost, enterprise chooses to supervise. We appropriately increase the values of "g," "t," and "o." $C_2 = (0.16, 0.12, 10, 5.78, 7.06, 0.66, 13.56, 0.9, 6, 4)$ and make $e < (g + t)o$. At this time, the simulation curve is seen in Figure 6.

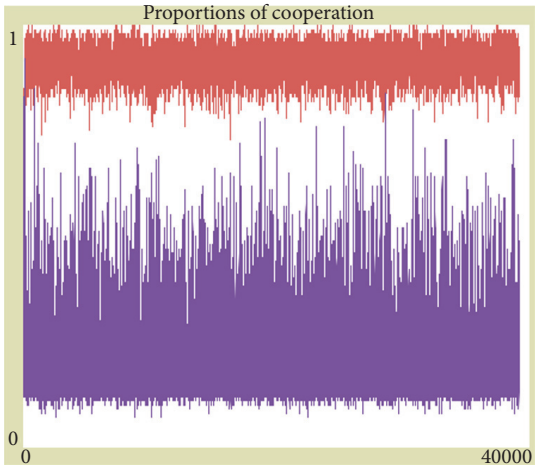

Figure 6: Simulation on knowledge workers' CWB when $e < (g + t)o$.

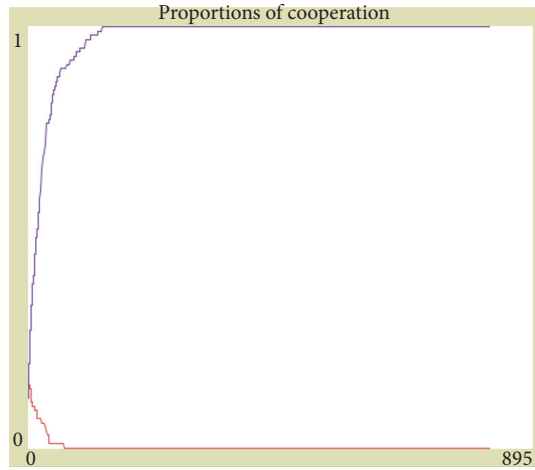

Figure 7: Simulation on knowledge workers' CWB when working environment is poor.

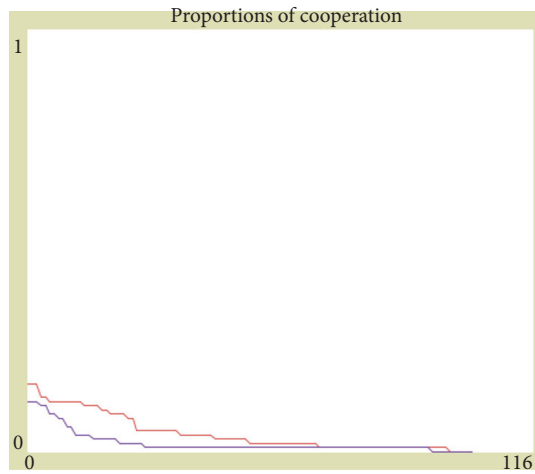

Figure 8: Simulation on knowledge workers' CWB when working environment is good.

From Figure 6, we can see when $e < (g + t)o$, the simulation curve does not converge. The probability of knowledge workers choosing CWB is significantly reduced. It remains at relatively low level of 0.1 to 0.4. The probability of enterprise supervision remains at 0.8 to 0.95. This indicates when enterprise increases the observation capability and increases the incentives of not finding CWB to certain level, that is, $e < (g + t)o$, it can effectively reduce the happening probability of knowledge workers' CWB.

5.2. Influence of Contextual Factors on Knowledge Workers' CWB. According to the literature review in Section 2, knowledge workers' CWB can be influenced by contextual factors. When the working environment is relatively poor or there are heavy tasks, knowledge workers have to keep tension state for long time. In addition, if the environment is boring and interpersonal relationship is cold, these can easily make knowledge workers have the negative and weary emotion on their work, which arouses their desire for the stimulation from CWB and make knowledge workers more sensitive to payoffs of CWB. So it can easily cause CWB. On the contrary, when jobs are full of challenges and passion, knowledge workers may value their work opportunities and be actively engaged in their work. At this time, they will be more sensitive to the punishment on CWB and hence will treat CWB with caution. Based on the empirical study [42], we suppose knowledge workers are risk neutral to CWB; that is, given $C_2 = (0.16, 0.12, 10, 5.78, 7.06, 0.66, 13.56, 0.22, 2.78, 0.18)$, when working environment is poor, $C_1 = (1, 1, 1, 2.25)$. When working environment is good, $C_1 = (1, 1, 2.25, 1)$. For the simulation result, see Figures 7 and 8.

From Figure 7 we can see when working environment is poor, simulation curve converges at $\{F_2, B_1\}$; that is, knowledge workers choose CWB and enterprise choose not to supervise. This is because when working environment is poor, knowledge workers tend to choose CWB to vent their dissatisfaction on enterprise. At the same time, through tries, enterprise knows supervision can not prevent CWB and therefore chooses not to supervise.

From Figure 8, we can see when working environment is good, simulation curve converges at $\{F_2, B_2\}$; that is, knowledge workers choose not to perform CWB and enterprise chooses not to supervise. This is because when working environment is good, knowledge workers will love their current work and value the current working state. They will not choose to perform CWB. In the game, enterprise finds employees not choosing CWB. So it chooses not to supervise. The equilibrium point $\{F_2, B_2\}$ is a win-win state for both enterprise and knowledge workers. On the one hand, enterprise saves the supervision cost and avoids the great loss caused by CWB; on the other hand, knowledge workers can work in better state, which not only brings better working performance but also helps them to get bonuses and share the payoffs of enterprise growth.

5.3. Influence of Individual Factors on Knowledge Workers' CWB. Based on literature review, we find that knowledge workers' CWB are closely related to individual factors such

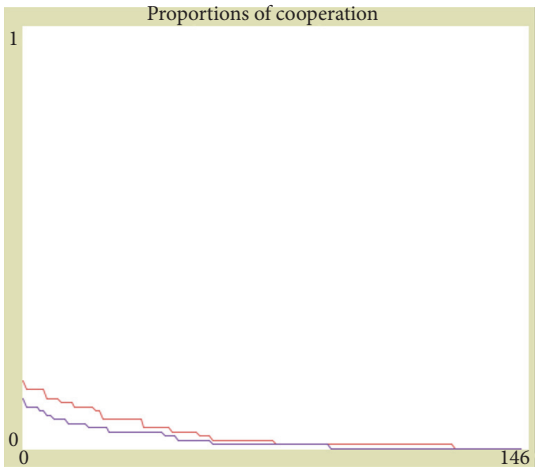

Figure 9: Simulation on calmness of knowledge workers' CWB.

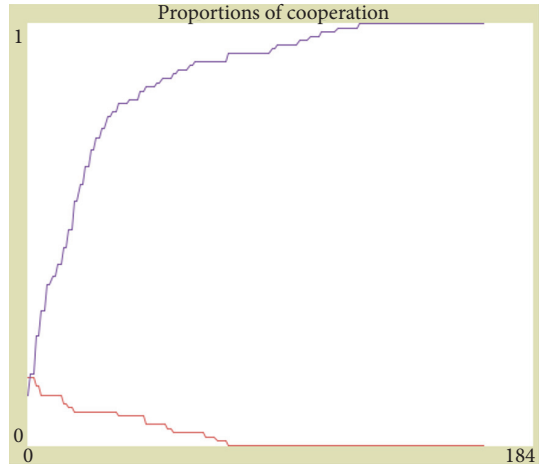

Figure 10: Simulation on neuroticism of knowledge workers' CWB.

as characters, emotions, or even values. By survey, some scholars divide knowledge workers into three categories: neuroticism, stability, and calmness [15]. Based on experimental data, some other scholars divide knowledge workers into three types: conservative, neutral, and risky. And the corresponding informal constraint parameters are $C_1 = (1.5, 0.8, 1, 1)$, $(1, 1, 1, 1)$, and $(0.8, 1.5, 1, 1)$ [43]. The neutral knowledge workers are the knowledge workers who are risk neutral to CWB in general state and we have simulated this condition. So in this subsection, we only consider the conservative and risky knowledge workers and we keep $C_2 = (0.16, 0.12, 10, 5.78, 7.06, 0.66, 13.56, 0.22, 2.78, 0.18)$ unchanged. For the simulation result, see Figures 9 and 10.

From Figure 9, we can see when knowledge workers are conservative, and simulation curve converges at $\{F_2, B_2\}$; that is, knowledge workers do not perform CWB and enterprise does not choose to supervise. This is because conservative knowledge workers' emotions are more stable and they hardly take risky behaviors such as CWB; furthermore, conservative knowledge workers' characters are more introverted and they are hardly influenced by other aggressive employees. As we have analyzed before, such equilibrium state is a win-win state for both enterprise and knowledge workers. And this is also the goal of enterprise intervention.

From Figure 10, we can see when knowledge workers are risky, and simulation curve converges at $\{F_2, B_1\}$; that is, knowledge workers choose to have CWB and enterprise chooses not to supervise. This is because risky knowledge workers are prone to emotional fluctuations and are easily influenced by other employees and various negative information. So they may perform CWB.

6. Conclusions

Aiming at the formation causes of CWB, the decisional process of CWB and organizational control, this paper combines game theory with agent modeling and builds a simulation model of knowledge workers' CWB. From organizational control perspective, this paper discusses the evolutionary rules of CWB under formal and informal constraints.

By simulation analysis, this paper mainly draws the following conclusions:

(1) Increasing knowledge workers' salaries cannot reduce the happening probability of knowledge workers' CWB.

(2) Increasing the probability of enterprise supervision cannot reduce the happening probability of knowledge workers' CWB.

(3) Increasing enterprise's observation capability and increasing the punishment of CWB and bonuses for not finding CWB to certain level, that is, $e < (g + t)o$, can effectively reduce the happening probability of knowledge workers' CWB with high probability of enterprise supervision.

(4) Contextual factors have important effect on knowledge workers' CWB. Positive working environment can make knowledge workers not to choose CWB, while passive working environment can lead knowledge workers to choosing CWB.

(5) Individual factors can have important effect on knowledge workers' CWB. Conservative knowledge workers choose not to have CWB, while risky knowledge workers choose to have CWB.

Based on the above conclusions, this paper provides some suggestions to effectively reduce knowledge workers' CWB:

(1) Improve Knowledge Workers' Working Environment. Knowledge workers may take use of working time to surf on the Internet and do nothing with work or choose to perform implicit CWB such as being slack. All these indicate they are tired of their repeated and boring work. In fact, due to their work nature, it is hard for enterprises to supervise knowledge workers and precisely tell whether they are working hard or not. Therefore, enterprises can regularly redesign the jobs of knowledge workers or implement position rotation to

enrich working content of knowledge workers and make their work more challenging. This helps to reduce the boredom of the job, increase the working efficiency, and reduce the happening probability of implicit CWB.

(2) Analyze Knowledge Workers' Personalities. The simulation result shows that, in the same context, knowledge workers with different personalities may have different choices of CWB. So the differences in knowledge workers' personalities can lead to irrational biases of knowledge workers' behaviors. Risky knowledge workers are impulse and more easily to have tension relationship with colleagues, superiors, and subordinates. When they perceive injustice, their emotional reaction is usually intense and their self-control capability is poor. Hence, risky knowledge workers easily perform CWB. Therefore, in allocating jobs and tasks, we need to consider knowledge workers' personalities and assign risky knowledge workers to the positions where the influence of CWB is relatively small so as to reduce the loss CWB brings to organizations.

(3) Standardize Enterprises' Formal Constraining Mechanism. Compared with informal constraints, the influence of formal constraints on CWB is relatively small, but it can also effectively reduce the happening probability of CWB. The simulation result shows when enterprise observation capability is high, punishment on CWB is severe, bonuses for not finding knowledge workers' CWB are great, and it can effectively reduce the happening probability of knowledge workers' CWB. On the basis of improvement of observation capability, clear and severe punishment can constrain and deter knowledge workers from taking CWB and make them more sensitive to perceived punishment. Similarly, clear and powerful incentives are the praise and encouragement for knowledge workers' good behaviors, which can make them more sensitive to the perceived incentives and therefore reduce the happening probability of CWB.

Competing Interests

The author declares no competing interests. The author has no financial and personal relationships with other people or organizations that can inappropriately influence the work.

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