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The Evolutionary Game of Electronic Seal Usage Behaviour Supervision From the Perspective of Credit and Penalty

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ABSTRACT The illegal use of electronic seals has the potential to harm both the contracting parties and the country's economy. This paper studies the phylogenetic relationship between government regulatory bodies and enterprise behaviors through the payoff matrix and an evolutionary game model. According to both the equilibrium point and stability of the game's dynamic replication relationship phase diagram, this paper analyzes the incentive effects of the legal use of management costs and the illegal use of economic penalties, government regulatory costs, and credit ratings on the use of electronic seals. The results show that the steady state does not exist as a time extension of government supervision and standardize the behaviors of electronic seal enterprises. In addition, the selection specification evolutionary path using electronic seals is different based on the different initial conditions. The use of the restricted speed and the evolutionary result not only depends on the choice of the enterprise's standard initial probability of usage behavior but also on the initial probability of government departmental supervision. This occurs without using any means of supervision and penalty measures under the conditions that all enterprises tend to choose not to regulate the use of the electronic seal. Due to regulation with a low probability of no significant effect of the standard, the need to reach a certain level of supervision to regulate the use of electronic seals was improved. The government simply increasing the penalty is not an effective solution since the electronic seal does not regulate the problematic use of credit rating factors. On the one hand, it reduces the probability of government regulations, and on the other hand, it greatly improves the standard probability of the use of electronic seals. Finally, conclusions are based on the governmental point of view to promote the use of electronic seal specification recommendations.

INDEX TERMS Electronic seal, corporate behaviour, government regulation, evolutionary game, credit rating.

I. INTRODUCTION

It is generally known that official seals are used by organs, organizations, enterprises and institutions. The electronic seal simulates the traditional physical seal with advanced digital technology, and its management and use conform to the custom and experience of the physical seal. The electronic document it covers has the same appearance, the same effectiveness and a similar use [1] as the paper file that is covered by the physical seal. Compared with traditional seals, the electronic seal is easier to use and has lower costs.

To prevent some unlawful persons from engraving the public seal privately, swindling, destroying the State Administration of public security management, and infringing on the legitimate interests of the organizations, groups, enterprises

and institutions, the state has incorporated the engraving industry into the management of special industries. However, we found that you can ''have'' the ''official seal'' at a moment on a flat platform such as Taobao and do not need to provide any material proof. If a counterfeit electronic stamp is sold on the Internet, one or more illegal results will occur in real society. If you search for the electronic seal on the Taobao home page, the data show that there are more than three or four thousand hits in the whole search history. The number of goods is 48985 in Taobao. Moreover, we live in a world were data are generated from a myriad of sources, and it is really cheap to collect and storage such data [2], [3]. The purchase of counterfeit stamps is simple and inexpensive, which reflects the potential hidden dangers brought about by the use of counterfeit stamps.

Only by establishing a comprehensive clean-up and penalty in accordance with the law can we guarantee the property and dignity of an ''official seal''. On April 1, 2005, China formally implemented Electronic Signature Law of the People's Republic of China [4]. However, in recent years, the economic losses and social effects caused by bad seal management and illegal use have seriously affected the economic order, people's normal production and lives, and sounded the alarm for seal managers and users. These massive forgery official seal information can easily be uploaded to the cloud and spread more and more harm to the company and the social [5], [6]. Furthermore, in May 2016, the office of the seven ministries and committees of the China National Development and Reform Commission jointly issued the ''notice on promoting the development of electronic commerce'' (the development and reform of high technology [2016]1284). The ''notice'' emphasizes the safety of the management of electronic seals and the promotion of their application.

Because of the strong concealment of the forged official seal and the imperceptible influence on the social equity, the influence of social equity is not easily detected. Therefore, the relevant government departments should not be in the spirit of ''the people do not tell the people, the officials do not study''. If people should choose to attack forged official seal actively, the government should not only punish the online shop and even the platform enterprises that have the private seal but also not to ignore the ''false chapter'' that has outflowed and has been studied deeply. The legal use of electronic seals is also a part of the legal formulation and implementation of the government and organization system. The study of the characteristics of the use of electronic seals by enterprises is of practical guiding significance for the government and organizations to design scientific and rational electronic seals to standardize the use of incentive mechanisms. The electronic seal can better serve the development of the economy and society.

From the point of view of the system, this paper studies the system's evolutionary relationship between contract signing and the main body of the government supervision department through a payoff matrix and the evolutionary game model, describes the standardization and effectiveness of the electronic seal under different conditions, and proposes some suggestions on the improvement of real electronic seal management.

II. LITERATURE REVIEW

The study of electronic seals began at the end of the twentieth century [7], [8]. A large number of literature studies occurred on the design of electronic seal systems [9]–[11]. The electronic seal system was born with the development of electronic signatures [4], electronic documents [12] and electronic archives [13]. The extensive use of electronic seals plays a great role in promoting social progress. The research has occurred in the fields of medicine [12], law [14], electric power [15], coal [16] and so on, and it is also researched in emerging fields such as network transactions [17], e-government [18], [19], electronic contracts [20], Internet gold melts [21] and others.

The early research of electronic seals mainly focused on the hidden dangers of the electronic seal system and the design and application of the electronic seal system. Kim *et al.* [22] addressed the design and implementation of an electronic seal protection system, implemented a new electronic seal system equipped with the eSeal Protection Protocol (ePP), and evaluated its performance using a real-world platform. Wang and Zhou [23] combined the various kinds of risks involved in the analysis of the seal and proposed a new model for the use of seal management. Zhou and Cao [24] proposed the electronic seal for the E-government to improve the security of electronic data based on digital watermarking in the design and application of an electronic seal system. Xu *et al.* [25] proposed general electronic seal system architecture. Wang *et al.* [26] designed a multi-user signature system based on the RSA ordered multiple signature scheme. Wang *et al.* [16] analyzed the application of an electronic seal in coal mine information management. Zhang [19] studied the application practice of the Zhejiang provincial government's electronic seal system in Zhoushan. Zheng [21] analyzed the application of electronic seals in financial service platforms. Tang [27] studied the application and practice of electronic seals in enterprises.

The related research is limited to a certain aspect of the safety and design of an electronic seal. Yang and Li [28] presented the solution for electronic seals in electronic contract/document signatures. The system is based on cloud computing, PKI/CA and serial numbers, which can fuse the direct-vision of an electronic seal system with the security of a digital signature. Jiang and Sun [29] designed a security interface in an electronic seal system based on JNI using C + + and Java language directly. Shao [30] introduced a reusable electronic seal, logistics safety monitoring and real-time tracking system based on RFID technology. Rong-Lei *et al.* [31] studied and implemented the storage and usage of electronic seal data in safety and realized the signature and verification function of the OFD file according to the secure electronic seal cryptography technical specification's

latest release by the State Cryptography Administration that combined USBKEY technology and the ASN 1 standard.

Some researchers study the relationships among consumers' perceptions about online security, including awareness, privacy concerns, security concerns, and information quality. Kim *et al.* [32] found that educating consumers about the security and privacy dangers of the web, as well as the role of web assurance seals, does increase their awareness and perceived importance of the seals. Many online retailers display third-party seals on their website in order to signal their trustworthiness to potential customers. However, it is unclear whether and under what conditions such seals are effective in raising purchase probability. Van Baal [33] added to the literature by testing and comparing the efficacy of two third-party seals in the European electronic commerce market.

Nonetheless, the systematic analysis of the behaviors of electronic seals is rarely studied. The legal use of electronic seals is also a part of the legal formulation and implementation of the government and organization system. There are many aspects of the game between government supervision and enterprise behaviors [34], [35], including product quality [36], tourism standards [37], multilayer networks [38], new energy subsidies [39], populations cooperation [40], food safety [41], pollution emissions [42], Collective behavior [43], traffic specifications [44], disease transmission [45] and so on.

The study of the characteristics of the use of electronic seals by enterprises is of practical guiding significance for the government and organizations to design scientific and rational electronic seals to standardize the use of incentive mechanisms. The electronic seal can better serve the development of the economy and society. From the point of view of the system, this paper studies the system's evolutionary relationship between contract signing and the main body of the government supervision department through the payoff matrix and evolutionary game model [35], [36], describes the standardization and effectiveness of the electronic seal under different conditions, and proposes some suggestions on the improvement of the real electronic seal management.

III. MODEL AND ASSUMPTIONS

A. ASSUMPTIONS

In the process of managing and using electronic seals, many parties are involved, such as the government supervision department, the contract signatory of many enterprises, the independent enterprise's legal personnel, and the social natural person. In addition, there is a game relationship among all participants. This relationship is affected by the rewards and penalties, management costs and other factors. In essence, the participants in the electronic seal system are competing with each other in their pursuit of maximizing their respective interests. Therefore, this article makes the following assumptions.

1) In the whole game system, there are two main players, namely, the government supervision department (G) and the enterprise (S). The company includes the contracting parties, the seal making enterprises and the seal selling platform. The game players have limited rationality, and because of incomplete information, they cannot make a choice that maximizes their own interests. Each player has learning and imitating abilities and can adjust his own strategy according to experience.
2) The government regulator's strategy set is $G = \{g_1, g_2\}$, which represents the government's supervision and no supervision of the electronic seal. The enterprise strategy set is $S = \{s_1, s_2\}$, which represents enterprises' legal and illegal strategies in the process of contract signing, seal making and seal sales. There are 4 types of game combinations among the government and enterprises: (supervised, legal), (supervised, illegal), (unsupervised, legal), and (unsupervised, illegal).
3) In the initial stage of the two player game, suppose that the proportion of government departments selecting the supervision strategy g_1 is $p(0 < p < 1)$. Then, the proportion selecting the unsupervised strategy g_2 is $1 - p(0 < p < 1)$. Suppose also that the proportion of enterprises selecting the legal strategy s_1 is $q(0 < q < 1)$, and the proportion selecting the illegal strategy s_2 is $1 - q(0 < q < 1)$.
4) Enterprises need to pay the management costs. The costs of standardizing the use of electronic seals are SC. The use of electronic seals improves work efficiency, and the resulting benefits are SR. If enterprises illegally use electronic seals, the government will fine them SP. The government will pay a supervision cost of GC.
5) If the credit rating is considered, credit rating factors are regarded as intangible benefits that differ from material income. If the enterprise uses electronic seals illegally, the government supervision department assesses the impact on its credit rating, and the credit loss of the enterprise is recorded as c. The government may also unfavorably impact society due to the ineffective supervision of the illegal use of electronic seals and will accordingly pay a credit cost C.

B. GAME ANALYSIS WITH ONLY PENALTY

The payoff matrix among two players is established in Table 2. Supposing that Ug_1 represents the expected earnings of the government departments that adopt supervision, Ug_2 represents the expected earnings of government departments that are unsupervised. Moreover, U_G represents the expected earnings of the government departments that adopt the two strategies. Then, we have the following:

$$Ug_1 = q(-GC) + (1-q)(SP - GC) = SP - GC - qSP \tag{1}$$

$$Ug_2 = q \times 0 + (1-q) \times 0 = 0 \tag{2}$$

TABLE 1. Model parameters and connotations.

Parameters	Connotations
G	The government supervision department
S	The enterprises using electronic seals
p	The probability of government departments selecting the supervision strategy
q	The probability of enterprises selecting the legal strategy
SC	The costs of standardizing the use of electronic seals
SR	The benefit of enterprises legal use electronic seals
SP	The punishment by the government if enterprises illegally use electronic seals
GC	The government supervision cost
c	The credit loss of the enterprise
C	The credit cost of government

TABLE 2. Strategy combination and payoff matrix of two players.

G / S	supervised g_1	unsupervised g_2
legal s_1	$(SR-SC,-GC)$	$(SR-SC,0)$
illegal s_2	$(SR-SP,\ SP-GC)$	$(SR,0)$

$$U_G = pUg_1 + (1-p)\,Ug_2 = p\,(SP - GC - qSP) \tag{3}$$

The replicator dynamics equation of the proportion p for the government is

$$\begin{aligned} F(p) &= dp/dt = p\,(Ug_1 - U_G) \\ &= p\,(1-p)\,(SP - GC - qSP) \end{aligned} \tag{4}$$

Suppose that Us_1 and Us_2 represent the expected earnings for the 'legal' and 'illegal' strategies of enterprises, respectively, and that U_S indicate the expected earnings of companies that adopt the two strategies. Then,

$$Us_1 = p\,(SR - SC) + (1-p)^*\,(SR - SC) = SR - SC \tag{5}$$
$$Us_2 = p\,(SR - SP) + (1-p)^*\,(SR) = SR - pSP \tag{6}$$
$$U_S = qUs_1 + (1-q)\,Us_2 = SR - pSP - qSC + pqSP \tag{7}$$

The replicator dynamics equation of the proportion q for the enterprises is

$$F(q) = dq/dt = q\,(Us_1 - U_S) = q\,(1-q)\,(pSP - SC) \tag{8}$$

Eqs. (4) and (8) are the continuous frequency dynamic systems for the government and enterprise, respectively. In the above replicator dynamic system, by setting the replicator dynamic Eqs. (4) and (8) equal to zero, the equilibrium points of the replicator dynamic system are obtained.

$$(p, q) = (0,0),\ (0,1),\ (1,0),\ (1,1),\ \left(p_1^*, q_1^*\right) \tag{9}$$

Regardless of the condition, $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$ are its four fixed equilibrium points. If $0 \le \frac{SC}{SP} \le 1$ and $0 \le \frac{SP-GC}{SP} \le 1$, the point $\left(p_1^*, q_1^*\right)$ is another equilibrium point. Then,

$$p_1^* = SC/SP \tag{10}$$
$$q_1^* = SP - GC/SP \tag{11}$$

Proof. The four points in (9) are clear. According to the stability theorem of different equations [36], if the point is the equilibrium point, it should satisfy$F(p) = 0, F(q) = 0$. As $p \in [0,1]$, $q \in [0,1]$, we can obtain $\left(p_1^*, q_1^*\right)$. Then,

$$\left(p_1^*, q_1^*\right) = \left(\frac{SC}{SP}, \frac{SP - GC}{SP}\right)$$

The supervision probability of the government supervision department on the use of the electronic seal standard is $p_1^* = \frac{SC}{SP}$. When $p > p_1^*$, according to the maximum profits, the system strongly urges the electronic seal's standard usage. Otherwise, when $p < p_1^*$, the regulatory authorities of the government are reluctant to regulate the nonstandard behaviors of the electronic seal, and some enterprises will be involved in irregularities in order to save the standard costs of use. The standard usage probability of the electronic seal is $q_1^* = \frac{SP-GC}{SP}$. When $q < q_1^*$, the policy of government regulators should advocate strengthening supervision. When $q > q_1^*$, government regulators can appropriately ease supervision.

C. GAME ANALYSIS BASED ON PENALTY AND CREDIT

The earnings matrix among two players is established in Table 3. Supposing that Eg_1 represents the expected earnings of the government departments that adopt supervision, Eg_2 represents the expected earnings of government departments that are unsupervised. EG represents the expected earnings of government departments that adopt the two strategies. Then,

$$Eg_1 = q\,(-GC) + (1-q)^*\,(SP - GC) = SP - GC - qSP \tag{12}$$

TABLE 3. Strategy combination and payoff matrix of two players.

G / S	supervised g_1	unsupervised g_2
legal s_1	$(SR-SC,-GC)$	$(SR-SC,0)$
illegal s_2	$(SR-SP-c,\ SP-GC)$	$(SR,-C)$

$$Eg_2 = q \times 0 + (1-q)^* (-C) = qC - C \quad (13)$$

$$EG = pEg_1 + (1-p) Eg_2 = p(SP - GC - qSP - qC + C) + qC - C \quad (14)$$

The replicator dynamics equation of the proportion p for the government is

$$H(p) = dp/dt = p(Eg_1 - EG) = p(1-p)(SP - GC - qSP - qC + C) \quad (15)$$

Suppose that Es_1 and Es_2 represent the expected earnings for the 'legal' and 'illegal' strategies of enterprises, respectively, and ES indicates the expected earnings of companies that adopt the two strategies. Then,

$$Es_1 = p(SR - SC) + (1-p)(SR - SC) = SR - SC \quad (16)$$

$$Es2 = p(SR - SP - c) + (1-p)(SR) = SR - p(SP + c) \quad (17)$$

$$ES = qEs_1 + (1-q) Es_2 = SR - p(SP + c) - qSC + pq(SP + c) \quad (18)$$

The replicator dynamics equation of the proportion q for the enterprises is

$$K(q) = dq/dt = q(Es_1 - ES) = q(1-q)(pSP + pc - SC) \quad (19)$$

Eqs. (15) and (19) are the continuous frequency dynamic systems for the government and enterprise, respectively. In the above replicator dynamic system, by setting the replicator dynamic Eqs. (15) and (19) equal to zero, the equilibrium points of the replicator dynamic system are obtained.

$$(p, q) = (0,0), (0,1), (1,0), (1,1), \left(p_2^*, q_2^*\right) \quad (20)$$

Regardless of the condition, $(0,0), (0,1), (1,0), (1,1)$ are its four fixed equilibrium points. If $0 \le \frac{SC}{SP+c} \le 1$ and $0 \le \frac{SP-GC+C}{SP+C} \le 1$, the point $\left(p_2^*, q_2^*\right)$ is another equilibrium point. Then,

$$p_2^* = SC/(SP + c) \quad (21)$$

$$q_2^* = (SP - GC + C)/(SP + C) \quad (22)$$

Proof: The four points in Eqs. (20) are clear. According to the stability theorem of different equations [47], if the point is the equilibrium point, it should satisfy $H(p) = 0, \frac{\partial H}{\partial p} < 0$, $K(q) = 0, \frac{\partial K}{\partial q} < 0$. Since $p \in [0,1], q \in [0,1]$, we can obtain $\left(p_2^*, q_2^*\right)$. Then,

$$\left(p_2^*, q_2^*\right) = \left(\frac{SC}{SP + c}, \frac{SP - GC + C}{SP + C}\right)$$

The supervision probability of the government supervision department on the use of the electronic seal standard is $p_2^* = SC/(SP + c)$. When $p > p_2^*$, according to the maximum profits, the system strongly urges the electronic seal's standard usage behavior. Otherwise, when $p < p_2^*$, the regulatory authorities of the government are reluctant to regulate the nonstandard behaviors of the electronic seal, and some enterprises will be involved in irregularities in order to save the standard costs of use. The standard usage probability of the electronic seal is $q_2^* = (SP - GC + C)/(SP + C)$. When $q < q_2^*$, the policy of government regulators should advocate strengthening the supervision. When $q > q_2^*$, government regulators can appropriately ease supervision.

Obviously, by comparing the two games, we find that the two evolutionary equilibrium solutions are $p_1^* > p_2^*, q_1^* < q_2^*$. It is fully demonstrated that with the addition of credit rating factors, on one hand, the probability of supervision by the government supervision department is reduced and, on the other hand, the standard usage probability of the electronic seal is greatly improved.

IV. EQUILIBRIUM ANALYSIS OF THE EVOLUTIONARY GAME

For the five equilibrium points given in Eqs. (20), the following illustrates the stability of the evolutionary game. According to Lyapunov stability analysis [46], [47], the standard Jacobian matrix J is used to evaluate the asymptotic stability of the equilibrium strategy pairs. Any solution pair that satisfies the requirements detJ > 0 and trJ < 0 is asymptotically stable and hence is an ESS of the game. The stability strategy must be a disturbance rejection, which should satisfy:

$$H(p) = 0, \frac{\partial H}{\partial p} < 0, \quad K(q) = 0, \frac{\partial K}{\partial q} < 0.$$

The Jacobian matrix J is

$$J = \begin{bmatrix} (1-2p)(SP - GC - qSP - qC + C) & p(p-1)(SP + C) \\ q(1-q)(SP + c) & (1-2q)(pSP + pc - SC) \end{bmatrix}$$

The mathematical evaluations of these five strategy pairs are as shown in Table 4.

TABLE 4. The local stability of the game between governments and enterprises under the situation of dynamic subsidies.

Strategy	*DetJ*	*TraJ*	Result
$A(0,0)$	$SC(GC - SP - C)$	$SP - GC + C - SC$	Instability
$B(1,0)$	$(GC - SP - C)(SP$	$GC - C + c - SC$	Instability
$C(1,1)$	$GC(SC - SP - c)$	$GC + SC - SP - c$	Instability
$D(0,1)$	$-GC * SC$	$SC - GC$	Instability
$E\left(p_1^*, q_1^*\right)$	+	0	Central

As shown in Table 4, we obtain a central point $\left(p_2^*, q_2^*\right)$ and four saddle points. The signs of detJ and trJ at these four fixed points are uncertain since they may be greater than zero or less than zero, and we refer to them as saddle points. The point $\left(p_2^*, q_2^*\right)$ satisfies the basic conditions of the ESS, and so we call this point Lyapunov stable.

Because $0 < p_2^* < 1, 0 < q_2^* < 1, 0 < SC < SP + c, 0 < GC < SP + C$, and we obtain the signs of detJ and trJ. According to the signs of detJ and trJ, we can observe that there is no stable equilibrium point in the 5 local equilibrium points. The four strategies A (unsupervised, illegal), B (supervised,

illegal), C (supervised, legal), and D (unsupervised, legal) are not evolutionary stable strategies. The evolutionary path is shown in Figure 1.

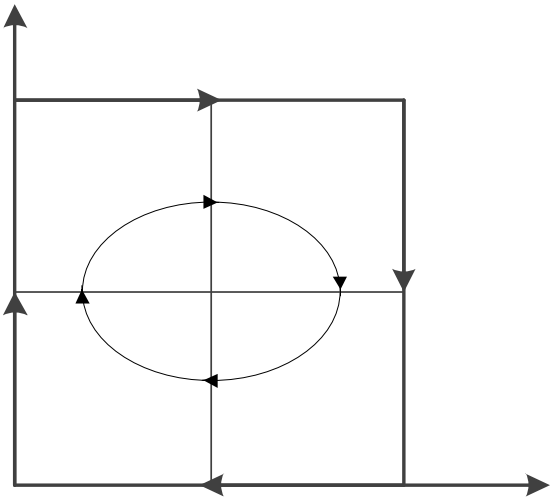

FIGURE 1. The evolutionary path in different payoff scenarios.

Therefore, the four fixed equilibrium points $(0, 0)$, $(0, 1)$, $(1, 0)$, $(1, 1)$ of the replicator dynamic systems are saddle points and they are all unstable, and the evolutionary game cannot reach stability at these points. The equilibrium point $\left(p_2^*, q_2^*\right)$ is a center point, meaning that the mutation strategy can obtain higher yields than the existing strategy during the process of the repeated game, but it is an indifferent equilibrium point for the evolutionary game. The trajectory of the evolutionary game approaches the trajectory of the point $\left(p_2^*, q_2^*\right)$, but cannot reach it. As Lyapunov stability has two stable properties, indifferent stability and asymptotic stability, we further discuss the stability nature of this central point combination with the properties of the saddle points. Strictly speaking, asymptotic stability is the ESS.

The saddle point has unstable singularities. It is stable along one direction (minimum value direction) and along another direction (maximum direction). (1) When the initial state of the evolutionary game system is in region I, Saddle point A is stable along the AD direction. Namely, the probability of using the electronic seal is not at the expected target and is decreasing. $(p < p*)$, and the government supervision department is increasingly more likely to supervise corporate behaviors. (2) When the initial state of the evolutionary game system is in region II, Saddle point B is stable along the BA direction. Namely, the probability of government supervision is not at the expected target and is decreasing $(q < q^*)$, and the probability of using an electronic seal is becoming increasingly less. (3) When the initial state of the evolutionary game system is in region III, Saddle point C is stable along the CB direction. Namely, the probability that enterprises use the electronic seal to achieve the expected goal is increasing continuously $(p > p*)$, and it is increasingly more likely that government regulators do not supervise corporate behaviors. (4) When the initial state of the evolutionary game system is in region IV, Saddle point D is stable along the DC direction. Namely, the probability of government regulations monitoring corporate behaviors to achieve the expected goal increases. $(q > q*)$, and it is increasingly more possible for enterprises to standardize the use of electronic seals.

From the point of view of government supervision, region III is the most ideal state. In the case of the reduction of the probability of government supervision, the probability of standardizing the use of electronic seals is still increasing. This is the inherent mechanism of the enterprise to use an electronic seal under the condition of social morality and high awareness of enterprise security, thus relying on its own subjective initiative. Therefore, the government supervision department will hope that the center E will gradually move to the bottom left side, thus expanding area III and decreasing $\left(p_2^*, q_2^*\right)$.

From the point of view of enterprise signing, region II and region IV are the ideal states. That is, under the condition of a certain level (middle and upper), the probability of government supervision can be reduced properly, which is a relatively comfortable development environment for enterprises, thus resulting in a higher q^* and smaller p^* when the standard usage probability of enterprises is low. Moreover, the government supervision department can appropriately increase the probability of supervision, raise the awareness of legal use and avoid the loss caused by inappropriate operations, which results in a smaller q^* and larger p^*.

V. SIMULATION

The software Matlab R2015b of the MathWorks, Inc is used for the evolutionary game model simulation [44], [46], [47]. Two scenarios were built to investigate how enterprises respond to different governmental policies. Section B assessed enterprises' responses to the different governmental incentive mechanism. Section C examined the mixed strategies chosen by players under different mechanisms.

A. ANALYSIS OF INITIAL STATE INFLUENCE

The initial values of the simulation are as follows: $SC = 1, GC = 1, SP = 1.5, C = 0.5, c = 0.5$.

When $p = q = 0.2$, the simulation results are as shown in Figure 2 (a). While keeping the other parameters unchanged, when $p = q = 0.4$ and $p = q = 0.7$, the simulation results are as shown in Figure 2 (b) and Figure 2 (c).

From Figure 2, as time passes, neither the government regulatory authorities nor the enterprise signatories have a stable evolutionary state. The evolutionary path of the use of the electronic seal is different in different initial states, and the constraint speed and evolutionary result of the use behavior does not only depend on the enterprise. The initial probability of selection behavior is also influenced by the initial probability of government regulators. In the case of the same initial probability of the use of electronic seals in the selection of enterprises, the better that the initial laws

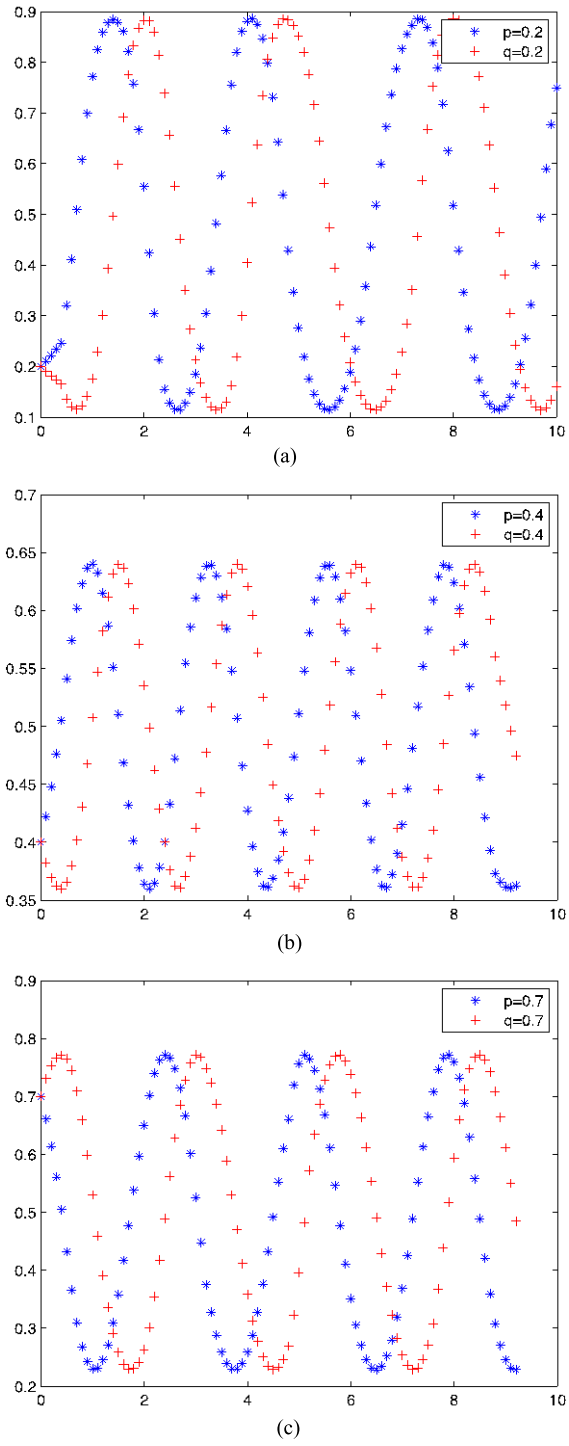

FIGURE 2. Behaviors of the government and enterprises with different initial values under a static mechanism. (a) System initial probability $p = q = 0.2$. (b) System initial probability $p = q = 0.4$. (c) System initial probability $p = q = 0.7$.

and regulations of the government supervision departments are, the greater the supervision and the greater the possibility of the evolution of the use of enterprises to the standard use of the stable state. Under the condition that the initial probability of government supervision is close to the ideal state, the greater that the initial probability of the enterprise choosing the standard usage behavior is, the faster it reaches the ideal state of standardization.

B. BEHAVIOURS OF PLAYERS UNDER DIFFERENT STATIC MECHANISMS

The initial values of the simulation are $SC = 1, GC = 1, SP = 1.5, C = 0.5, c = 0.5$, and the simulation results are as shown in Figure 3(a). In addition to the influence of the initial state of the system, the convergence speed and evolution of the enterprise's use of an electronic seal is also influenced by other factors. By keeping other parameters of the system unchanged, and $0 < SC < SP + c, 0 < GC < SP + C$, the simulation results are shown in Figure 3(b) to Figure 3(f) by changing the size of each parameter in turn.

The simulation result is shown in Figure 3 (b), which only reduces the costs of using electronic seals. In contrast to Figure 3 (a), it is found that the center point moves to the left side, and the areas III and IV that the government hopes will increase do increase. To increase the costs of government regulation only, the simulation results are shown in Figure 3 (c). Compared with Figure 3 (a), the center point is moved to the lower side, and area III that the government hopes will increase and area II that the enterprise hopes will increase are increased. The simulation results are shown in Figure 3 (d) in which only increases in the credit losses are generated by improper government supervision. In contrast to Figure 3 (a), it is found that the central point moves downward, and areas III and II that the government hopes will increase do increase.

Similarly, the only increase is in the credit loss of the electronic seal that the enterprise does not regulate, and the simulation result is shown in Figure 3 (e). In contrast to Figure 3 (a), it is found that the center point moves to the left side, and areas III and IV that the government hopes will increase do increase. The only increase is the economic penalty for enterprises not using the electronic seal correctly, and the simulation results are shown in Figure 3 (f). In contrast to Figure 3 (a), it is found that the center point moves to the left side, areas II and III that the government hopes will increase do increase.

In summary, we can conclude the following. (1) Only by reducing the costs of using electronic seals SC or increasing the credit loss c of the enterprise's nonstandard use of electronic seals can area III that the government hopes will increase and area IV that the enterprise hopes will increase are increased; then, the center can move to the left. (2) Area III that the government hopes will increase and area II that is desired by the enterprise are increased. This is done by increasing the costs of the government's supervision GC or increasing the credit loss C caused by improper government supervision, and it will promote the center point to move down to the lower side. (3) Increasing the economic penalty SP of the nonstandard use of an electronic seal by the enterprise will promote the center point to move to the

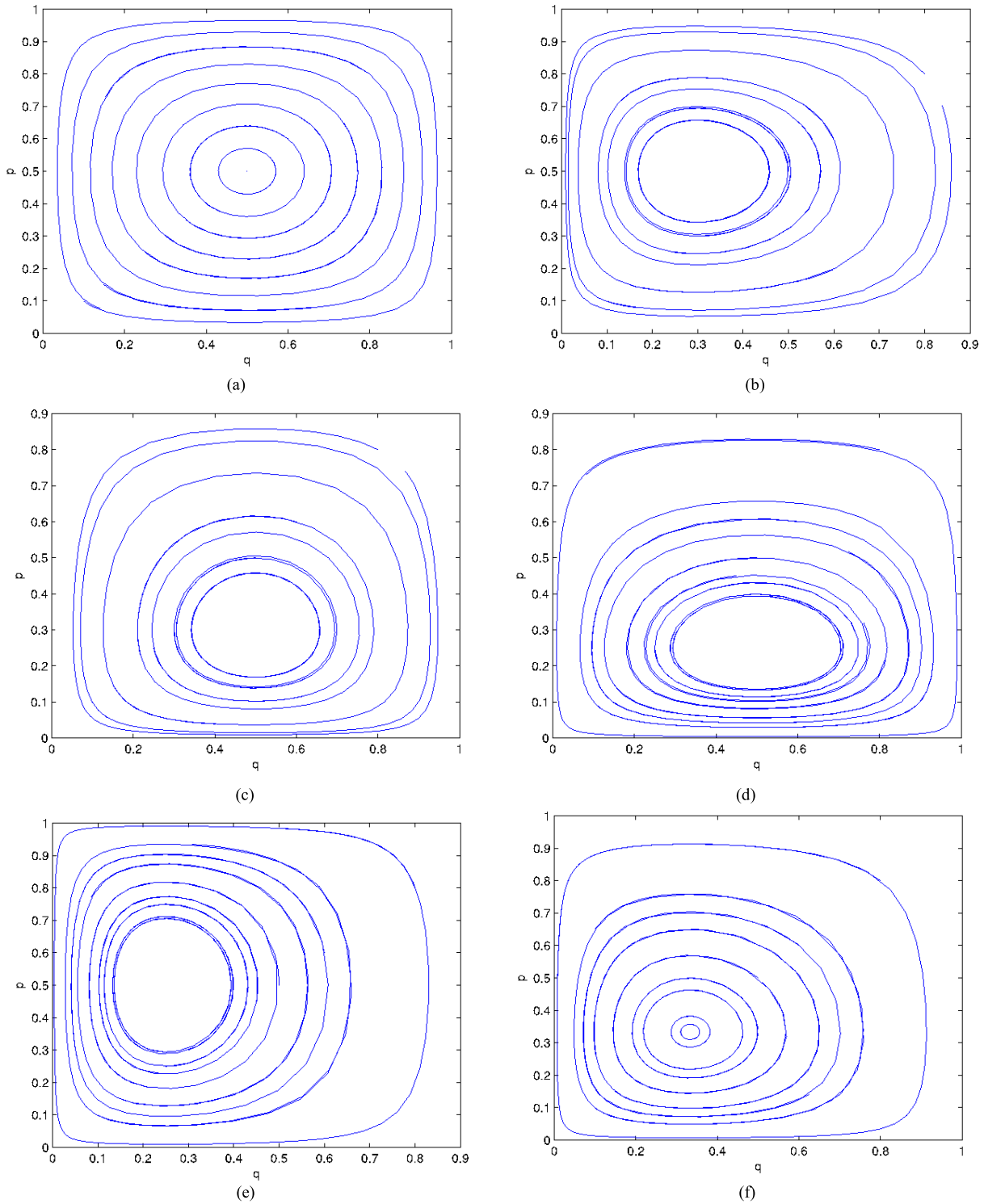

FIGURE 3. Players' behaviors in the evolutionary game under a static mechanism. (a) Initial values: $SC = 1, GC = 1, SP = 1.5, C = 0.5, c = 0.5$. (b) Increase the cost of use : $SC = 1 \Rightarrow SC = 0.6$. (c) Increase government costs: $GC = 1 \Rightarrow GC = 1.4$. (d) Increase government credit costs: $C = 0.5 \Rightarrow C = 2.5$. (e) Increase enterprise credit costs: $c = 0.5 \Rightarrow c = 2.5$. (f) Increase punishment: $SP = 1.5 \Rightarrow SP = 2.5$.

left side, and area III that the government hopes will increase and areas II and IV that the enterprise hopes will increase are increased. On the other hand, the area of the undesirable region increases.

C. THE MIXED STRATEGIES OF PLAYERS UNDER DIFFERENT MECHANISMS

The initial values of the simulation are $SC = 1, GC = 1, SP = 1.5, C = 0.5, c = 0.5$. Now, we synthetically

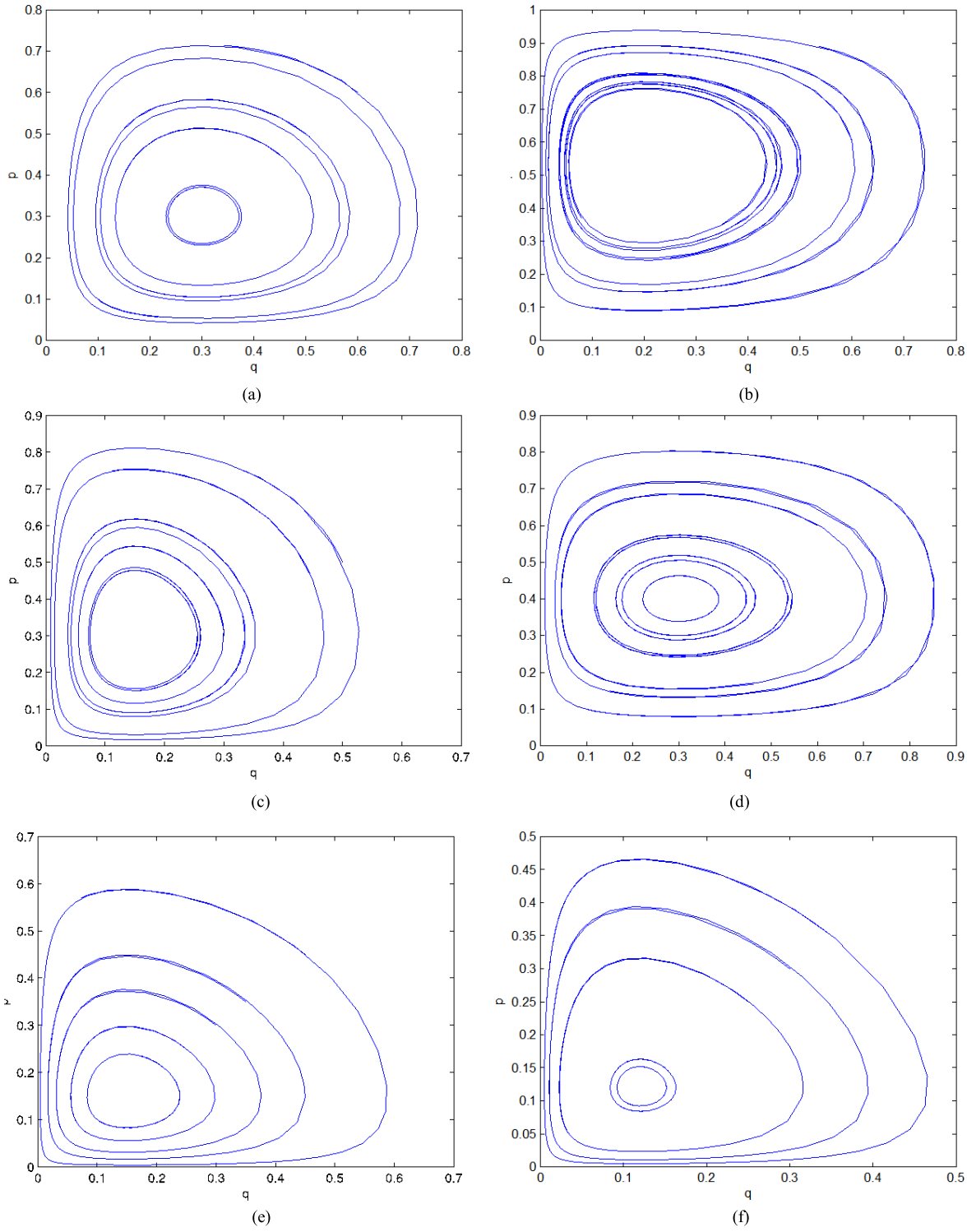

FIGURE 4. Players' behaviors in the evolutionary game under different mixed strategy mechanisms. (a) Initial values: $SC = 0.6, GC = 1.4, SP = 1.5, C = c = 0.5$. (b) Increase punishment: $SP = 1.5 \Rightarrow SP = 2.5$. (c) Increase enterprise credit costs: $c = 0.5 \Rightarrow c = 2.5$. (d) Increase government credit costs: $C = 0.5 \Rightarrow C = 2.5$. (e) Increase government supervision cost, government credit costs, and Increase enterprise credit costs: $GC = 3.4.c = C = 2.5$. (f) Increase punishment, government supervision cost, government credit costs, and enterprise credit costs: $SP = 2.5, GC = 4.4, C = c = 2.5$.

change the parameter values to $SC = 0.6, GC = 1.4, SP = 1.5, C = 0.5, c = 0.5$, which must fit in with $0 < SC < SP + c, 0 < GC < SP + C$. The evolutionary relationship between the government and the enterprise is shown in Figure 4(a). In contrast to Figure 3(a), it is found that the center point moves to the left and the lower side.

Areas II, III and IV that the government hopes will increase do increase.

On the one hand, keeping the other parameters unchanged, the simulation results are shown in Figure 4 (b) after increasing the economic penalty *SP* of illegal use of electronic seals. In contrast to Figure 4 (a), it is found that the center point moves to the left side. Areas III and IV that the government hopes will increase do increase, while area II decreases. The simulation results are shown in Figure 4 (c) after only increasing the credit losses *c* of enterprises not using electronic seals properly. In contrast to Figure 4 (a), it is found that the center point moves to the left side. Areas III and IV that the government hopes will increase do increase while area II remains unchanged. The simulation results are shown in Figure 4 (d), which only increases the credit losses *C* caused by improper government supervision. In contrast to Figure 4 (a), it is found that the center point moves to the upper side. The government hopes that area IV of region III will increase and enterprises will remain unchanged, while area II will decrease.

On the other hand, the simulation results are shown in Figure 4 (e) after increasing the credit loss *c* of the unregulated electronic seal, government supervision costs *GC* and the credit loss *C* of improper governmental supervision. In contrast to Figure 4 (a), it is found that the center point moves to the left side, and areas II, III and IV that the government hopes will increase do increase. On this basis, the simulation results are shown in Figure 4 (f) after increasing the economic losses *SP* of the illegal use of electronic seals and continuing to increase government supervision *GC*. In contrast to Figure 4 (a) and Figure 4 (d), it is found that the center point continues to move to the left along the bottom side, and areas II, III and IV that the government hopes will increase do increase again.

In summary, we can conclude the following. (1) The mixed strategy can effectively control the government supervision probability and the enterprise standard use electronic seal behavior probability. (2) Under the control of a mixed strategy, the economic punishment cannot effectively affect the enterprise's standard use of electronic seal behavior. (3) Under the control of mixed strategy, the increase in enterprise credit loss is more effective than the increase in the government regulation. The effect of the credit loss on the supervision department is obvious. (4) Under the control of the mixed strategy, it is most obvious to strengthen the government's supervision within the scope of the double control of economic punishment and credit loss.

At present, the development of China's electronic seal market is in its infancy. The supervision of enterprises and markets is a state of negative supervision. On the one hand, it should effectively strengthen the management measures for punishing forged electronic seals and implement economic punishment. On the other hand, an effective corporate credit system and a third-party regulatory system should be established to strengthen the orderly development of the electronic seal market.

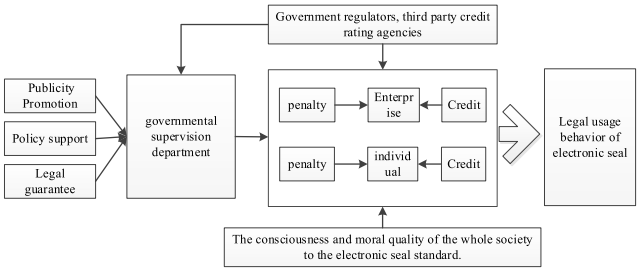

FIGURE 5. The formation mechanism of the legal use of electronic seals.

VI. CONCLUSIONS AND POLICY IMPLICATIONS

With the development of the Internet, the world market is still developing into the form of a binary market. The development of Internet technology has prompted the development and extension of the Internet market by the traditional industry and the entity enterprise, including the new application of electronic seals and electronic invoices, along with the new application of government supervision, management modes and moral hazard. It is in urgent need of extensive attention. This paper studies the relationship between the standard costs of use and management costs, and the relationship between the government supervision costs, the punitive measures and the credit rating. Economic punishment can improve the enterprise's awareness of the legitimate use of the electronic seal, thus avoiding the risks and unnecessary economic losses undertaken by the enterprise. However, in addition to the penalty measures such as economic fines, there are friendlier and more effective incentives such as reducing the costs of use and strengthening credit ratings to solve the problem. This reduces the regulatory costs of the regulatory authorities, enhances the understanding of the contractual parties to the legal effect of the electronic seal by strengthening the social supervision and raising public awareness, and further promotes the legal use of electronic seals by the contracting parties.

In this paper, it is believed that it is feasible to use the legal mechanism to shape the electronic seal at the core of the enterprise (as shown in Figure 5). A good ecological mechanism needs the government to establish a reasonable punishment mechanism and the costs of the electronic seal, with the external power of the third party or the public's credit rating constraints; the enterprise does not have power. The legitimate use of economic losses is the internal power. It includes the timely and rational use of government measures (such as promotion, policy support, and legal support) for new applications (such as electronic seals and electronic invoices), vigorously mobilizing enterprises' positive understanding and legal support for electronic seals and electronic invoices and promoting the initiative to enterprises for the legal use of electronic seals. This drives the moral literacy of the whole society and industries to legitimize the use of electronic seals.

Under the background of "Internet +" and artificial intelligence, the current country vigorously promotes the wide

application of electronic seals, electronic signatures, electronic invoices and electronic contracts. The legal use of electronic seals will have an important impact on individuals, enterprises and even the whole country and society in the future. Therefore, the following suggestions are proposed. (1) The government should attach great importance to the legal use of electronic seals, and enhance the legal awareness and legal guarantees of the electronic seal of individuals, enterprises and society as a whole. (2) The government should correctly guide the current use of electronic seals in accordance with the use of electronic seals in the enterprises and individuals in society. They should also adjust the strength of supervision and punishment for the use of electronic seals. (3) The government should formulate relevant policies scientifically and rationally in order to create a good legal environment for enterprises and individuals from the legal and cost perspectives. (4) The government should apply credit ratings and moral constraints in a friendly way to promote enterprises. Individuals should use electronic seals legally, and develop good habits for their legal use from the aspect of the whole social environment.

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