

Retraction

Retracted: Prediction and Application of Computer Simulation in Time-Lagged Financial Risk Systems

Complexity

Received 23 January 2024; Accepted 23 January 2024; Published 24 January 2024

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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- [1] H. Wang, R. Liu, Y. Zhao, and X. Du, "Prediction and Application of Computer Simulation in Time-Lagged Financial Risk Systems," *Complexity*, vol. 2021, Article ID 5513375, 10 pages, 2021.

Research Article

Prediction and Application of Computer Simulation in Time-Lagged Financial Risk Systems

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Received 22 February 2021; Revised 20 March 2021; Accepted 7 April 2021; Published 15 April 2021

Academic Editor: Zhihan Lv

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Based on the existing financial system risk models, a set of time-lag financial system risk models is established considering the influence brought by time-lag factors on the financial risk system, and the dynamical behavior of this system is analyzed by using chaos theory. Through Matlab simulation, the bifurcation diagram and phase diagram of time-lag risk intensity and control intensity are plotted. The analysis shows that this kind of time-lag financial system risk model has complex dynamic behavior, different motion states will appear when different parameter values are selected, and the time-lag risk intensity parameter also has a very strong influence on the system motion. To ensure the operation of the financial system in a stable state, measures with certain delay effects must be taken to control the risk and to choose the appropriate time-lag control intensity, and too much or too little time-lag control intensity is not conducive to the benign operation of the system.

1. Introduction

The modern financial system is an important part of the modernization of the national governance system, and the stability of the financial system is essential for the economic development of the country. However, due to the complexity and vagaries of financial markets, financial risks are always present, and if they are too large and not handled properly, they can also affect the sustainable development of the national economy [1]. However, financial risks exist objectively in the financial market, and because of their uncertainty, high leverage, correlation, and contagiousness, they can easily lead to losses in financial institutions and, in serious cases, to the disruption of the social and financial system and financial crises [2]. Therefore, to maintain the stability of the financial system, it is necessary to adopt appropriate methods to predict and control financial risks.

Because of the complexity and variability of financial markets, traditional linear analysis methods have limitations in predicting financial system risk and cannot accurately measure when the risk occurs, what the consequences are,

and the presence of abrupt change behavior. Therefore, in this paper, a nonlinear analysis method based on chaos theory is considered to analyze the potential mechanisms of market volatility by viewing the entire financial system as a dynamic nonlinear system.

Chaos theory, currently one of the hot spots in frontier scientific research, has been widely applied to economic and financial fields in recent years, called chaotic financial systems, which can observe financial trends and reduce the occurrence of financial risks. M. Stutze first revealed the chaos phenomenon in Havells economic growth equation and proposed that economic models also have inherent stochasticity [3]. Zhou Guohong further refined the scope of chaos theory applications by applying it to the regulation and management of financial system risks [4]. Feichtinger et al. applied chaos theory to the field of management operations research and proposed that, under different management decision rules, queuing, inventory, and planning and scheduling systems also generate chaos in queues, inventory quantity, and planning and scheduling [5]. Zhang, Cai, and Fang analyzed the systemic risk of the capital

market using nonlinear dynamics theory, which in turn provided a rich nonlinear research model [6]; Hajipour and Tavakoli controlled the equilibrium point of the chaotic financial system by constructing a function approach, thus achieving synchronous control of financial system chaos [7]. Huang and Cao conducted a qualitative study to study the relationship between chaotic control of financial risk, investor sentiment, and market behavior following chaos theory [8]. Xin and Liu qualitatively studied the stability of equilibrium solutions of a class of fractional-order chaotic financial systems, applying fractional-order theory to the field of finance [9]. Wu et al. established a new risk model for financial systems and analyzed the stability of their equilibrium solutions and the conditions for the occurrence of Hopf bifurcation [10]. Based on this, Li et al. constructed a class of fractional-order nonlinear financial risk system models to study the chaotic dynamics behavior of this financial system risk model and analyze the operational stability of this system [11]. In the financial system, because there are many uncertain factors, some economic phenomena cannot be comprehensively described by general differential equations. Scholars often add time-delay factors to differential equations when studying economic dynamics, and all these studies focus on a fixed point [12–21]. In practical application, the influence of time delay is often distributed in an interval, so the introduction of continuous-distributed time delay can better describe the actual economic market [22]. The time-delay phenomenon introduces the new dynamic characteristics of the system. Since the state variables of the financial system can change with time, to explore the relationship between the two, Wang et al. added time delays to some state variables of the financial system, making them time-lagged, and then studied the chaotic characteristics of time-lagged chaotic systems [23].

Considering the possible lags of financial risks and regulatory measures, the article introduces a time-lag link based on the financial risk system model proposed by Xu Yuhua et al. in 2016, proposes a time-lag financial system risk model, applies chaos theory in nonlinear dynamics to analyze the potential mechanism of financial system volatility, finds the best combination of parameters to ensure the smooth operation of this system model, and provides avoiding high-risk financial behaviors by providing some theoretical basis.

2. Time-Lag Financial Risk Model

Xu Yuhua et al. proposed a circular structure financial risk system model that can contain three stages: the first stage is the destructive impact of external or internal shocks on the financial system; the second stage is the further damage to the stability of the financial system after the contagion effect among financial networks; the third stage is the financial institutions, regulatory system, and monetary policy in the face of systemic risk caused by the regulatory response [24], and the system model dynamics equation is as follows:

$$\begin{cases} \dot{x} = yz - (a+1)x, \\ \dot{y} = xz - (b+1)y, \\ \dot{z} = (c-1)z - xy, \end{cases} \quad (1)$$

where x is assumed to be the value of total systemic risk under the effect of external or internal shocks in the first stage, y is the value of total systemic risk under the effect of contagion in the second stage, and z denotes the value of systemic risk control in the third stage. Besides, a is the risk degree of current t risk, b represents the risk intensity of current t infection effect, respectively, and c denotes the degree of control over risk in the third stage.

However, the state variables in a chaotic financial system change with time, and the control of system risk in period i or the risk situation generated by the system may not take effect until after a period of time at $i + \tau$. Therefore, in this system risk model, the time delay is introduced to establish a time-lagged chaotic system, and the following system equations are obtained:

$$\begin{cases} \dot{x}(t) = y(t)z(t) - (a+1)x(t) - dx(t-\tau), \\ \dot{y}(t) = x(t)z(t) - (b+1)y(t) - ey(t-\tau), \\ \dot{z}(t) = (c-1)z(t) + fz(t-\tau) - x(t)y(t), \end{cases} \quad (2)$$

where $x(t-\tau)$ represents the value of systemic risk in period $(t-\tau)$ following shocks to the financial system from various factors and d represents the degree of risk of systemic risk in period $(t-\tau)$ in period t ; $y(t-\tau)$ is the risk caused by systemic risk in period $(t-\tau)$ following contagion effects; and e represents its degree of risk remaining in period t ; similarly, the risk control introduced in period $(t-\tau)$ may continue to have an impact in period t , and the parameter f represents its degree of control in period t and $d, e, f \geq 0$.

When $d=0$, $e=0$, and $f=0$, the system of time-lag differential equations (2) can be degraded to the system (1). Compared with system (1), the system of time-lag differential equations can better reflect the time-lag effect of various risks in the financial system on the financial market, as well as the possible long-term impact of various risk controls on the financial system, so it can more realistically reflect the real financial system state and better reveal the dynamic behavior and characteristics of the system model. In this study, we select appropriate d , e , and f parameters to construct various nonlinear models of financial risk to analyze the long-term effects of each link on the financial system, taking into account the time-lagged nature of the effects of various links on the financial system risk.

3. Chaotic Dynamical Behavior of Time-Lagged Financial Risk Systems

To better study the complex motion phenomena present in financial risks, the chaos theory of nonlinear dynamics can be used to predict and analyze financial risk systems. In the financial risk system, different combinations of parameters are chosen, and complex and variable dynamical behaviors can appear, such as motionless points, periodic motion, probabilistic periodic motion, multiplicative periodic motion, and chaotic motion. In general, periodic motion, probabilistic periodic motion, and multiplicative periodic motion are stable states that are more in line with the laws of the financial system. Reducing the number of periods while decreasing the amplitude of the motion can significantly improve the stability of the

financial system. And when the system motion is under chaotic transition, it indicates that the current financial system is in a state of loss of control, which may cause damage to the benign operation of the economic system.

The article uses the chaos theory of nonlinear dynamics to analyze the dynamical behavior of the time-lag financial system risk model by taking the initial values $(x_0, y_0, z_0) = (1, 1, 1)$, choosing different risk parameters d, e, f , and the hysteresis parameter τ and using Matlab to draw bifurcation and phase diagrams with $a=4, b=8$, and $c=2$ to propose effective prevention of financial risk effective means to prevent financial risks.

3.1. Hysteresis Link τ Effect on the System. Setting $d=1, e=0.5$, and $f=3$, the bifurcation diagram of the hysteretic chaotic system is plotted, as shown in Figure 1 for $\tau \in [0, 3]$.

From the bifurcation diagram, we can see that the lagged impact of each stage of risk and risk control on the financial system is not negligible, and the time-lagged financial risk system will show a complex motion state with the change in τ . As the time-lag parameter increases, the system will experience multiple chaotic to periodic state changes, and the system will finally enter the chaotic state when $\tau > 1$. Figure 2 shows the phase plane diagram and time course diagram of the system when the time-lag parameter takes different values.

Figures 2(a) and 2(b) show that when $\tau = 0.02$, the system is just introduced to the time-lag amount, the system is in the multiply periodic motion state, and the system is relatively stable, but as the time lag increases, the system enters the unpredictable chaotic state, as shown in Figures 2(c) and 2(d), at which time the system losses stability. When the time lag increases within a certain range, the system repeatedly enters the state of periodic motion and chaos, as shown in Figures 2(e) and 2(f). For $\tau = 0.5$, the system is in a very stable one-period motion, when the financial system can operate benignly and the financial risk can be better controlled, but at $\tau \in [0.55, 0.75]$, the system enters the disorderly chaotic state again, reflecting the complexity of the financial system. As can be seen from Figures 2(g) and 2(h), with the further increase in time lag, the financial system enters a period of one-period steady state, and the total system risk value is substantially reduced compared to the motion shown in Figures 2(e) and 2(f); this stage is the most ideal motion state of the financial system. However, after $\tau > 1$, the system enters the chaotic motion state again and the system stability is destroyed.

In conclusion, the stability of the financial risk system is closely related to the value of the time-lag parameter τ . In the initial stage of the increase in the time lag, the system presents a state of motion with changing circumstances, reflecting the complexity of the financial risk system, and the regulatory authorities should also take into account the first stage of the financial risk system in response to external or internal shocks or internal impact and the second stage transmission effect on the destruction of the financial system in the financial risk system. Accordingly, they should put forward some measures that can also lag in effect or increase the duration of supervision effect to deal with various situations. Also, this lag time is not longer better but should

be controlled within a certain range to ensure that the financial risk system operates in a stable state.

3.2. Effect of the First Phase of Hysteresis Risk Degree d on the System. Setting $e=0.5, f=3$, and $\tau=1$, the bifurcation diagram of the hysteretic chaotic system is plotted for $d \in [0, 5]$, as shown in Figure 3.

It can be noticed that the motion of the financial risk system is always in a stable state when the degree of time-lag risk d increases over a period of time, as shown in Figures 4(a) and 4(b), which are the phase diagram and time course diagram of the system when d is taken as 0.5. When the value of d is taken as greater than 1, the system starts to bifurcate, and Figures 4(c)–4(f) show the phase diagram and time course diagram of the system when $d=2$ and $d=4$; the system is in a chaotic disorderly state, the motion is gradually complicated, the fluctuation of the financial risk system gradually increases, and the stability of the system gradually decreases until it is completely unpredictable.

It can be concluded that the impact on the stability of the financial system is small when the risk level of the lagged total risk caused by the shock of various factors in the first stage is controlled within a very small range, but if the risk level of the lagged total risk is larger, the more strongly the financial risk system stability is disrupted and ordered; therefore, the lagged effect of the total system risk caused by the first stage should be minimized.

3.3. Effect of the Second-Phase Hysteresis Risk Degree e on the System. Setting $d=1, f=3$, and $\tau=1$, the bifurcation diagram of the hysteretic chaotic system is plotted for $e \in [0, 10]$, as shown in Figure 5. The bifurcation diagram in Figure 5 shows that the risk brought by the transfer effect will also affect the sound operation of the financial risk system in the case of delay. As the degree of risk from the hysteresis effect increases in the second stage, the system moves from a chaotic state into a relatively more stable time-cycle motion, and as the degree of risk continues to increase, the system enters a completely disordered chaotic state, but when the degree of risk from hysteresis approaches 10, the system enters a stable cycle motion again, reflecting the complexity of the financial risk system. Figure 6 picks different values of e and analyzes the system motion state by combining the phase diagram and time course diagram of the system.

From Figures 6(a) and 6(b), it can be seen that, at $e=0.2$, the system is in a chaotic state, but there is a tendency to develop toward doubly periodic motion, and to a certain extent, the future development of the system can be predicted, but the stability is poor. At $e=1$, the system enters the state of periodic motion and presents a smoother motion, which can be predicted for the future, as shown in Figures 6(c) and 6(d). As e increases further, the stability of the system starts to decrease and enters a doubly cyclical motion again, as in Figures 6(e) and 6(f), which is very prone to financial crisis and will have an incalculable destructive effect on the whole economic system and is not the ideal motion state of the financial risk system. At $e > 2$, the system enters a chaotic state, as in Figures 6(g) and 6(h), where $e=6$, the system is in a chaotic motion and the

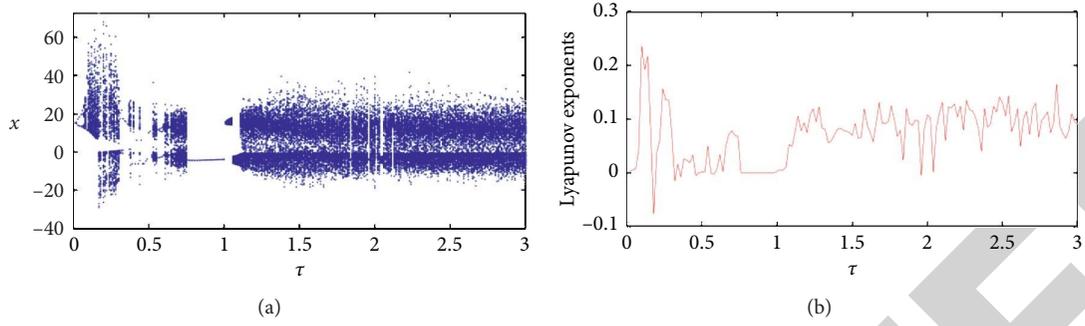


FIGURE 1: Bifurcation diagram (a) and Lyapunov exponents variation (b) of the total system risk x with the variation in the lag parameter τ .

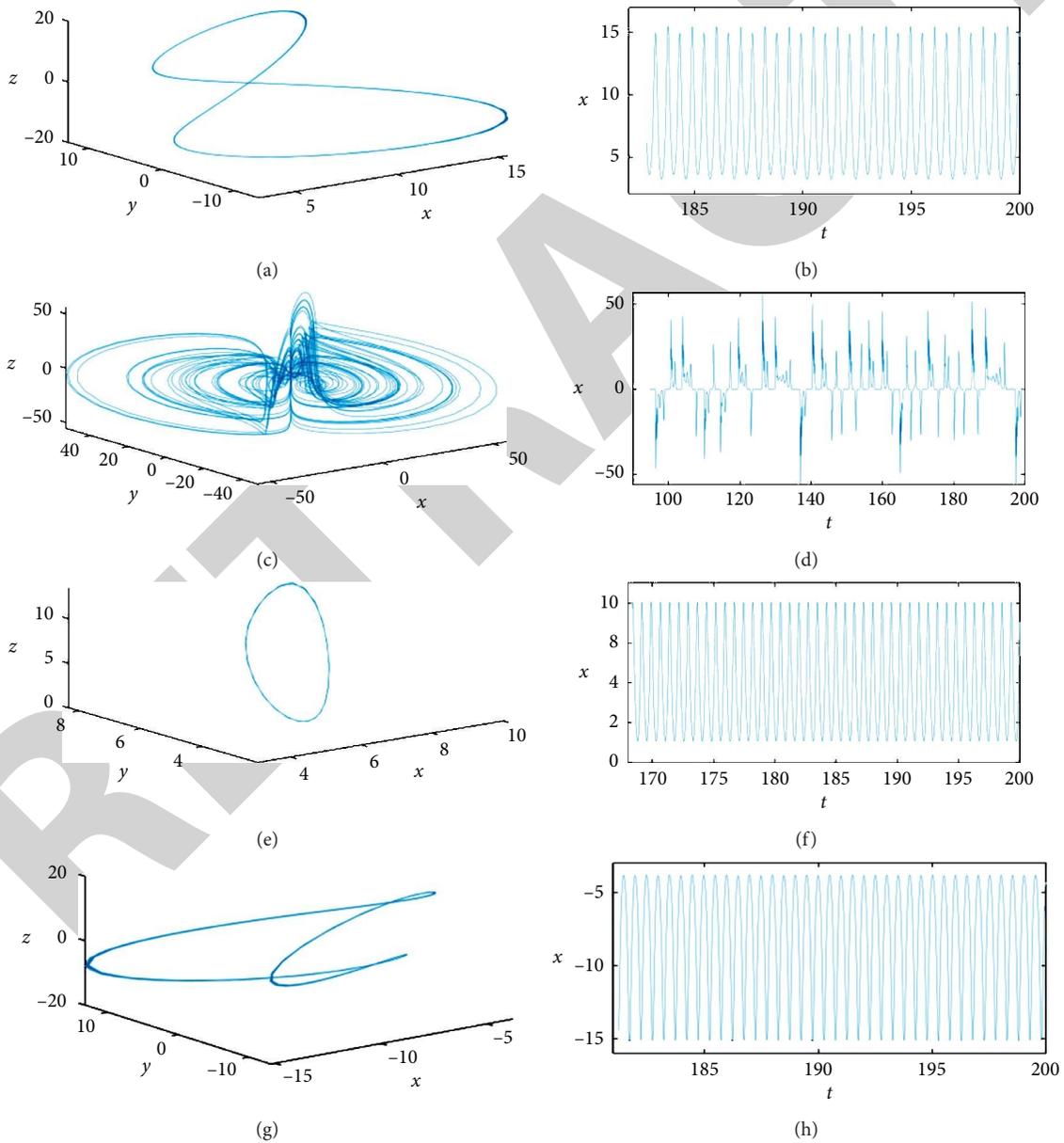


FIGURE 2: Continued.

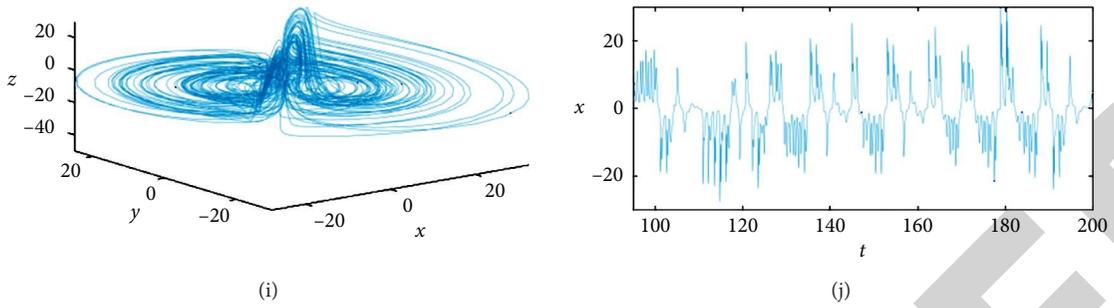


FIGURE 2: Phase diagram and time course diagram of the system when the delay value τ takes different values. (a) System phase diagram at $\tau = 0.02$. (b) Time course diagram at $\tau = 0.02$. (c) Phase diagram of the system at $\tau = 0.25$. (d) Time course diagram at $\tau = 0.25$. (e) System phase diagram at $\tau = 0.5$. (f) Time course diagram at $\tau = 0.5$. (g) System phase diagram at $\tau = 1$. (h) Time course diagram at $\tau = 1$. (i) System phase diagram at $\tau = 1.3$. (j) Time course diagram at $\tau = 1.3$.

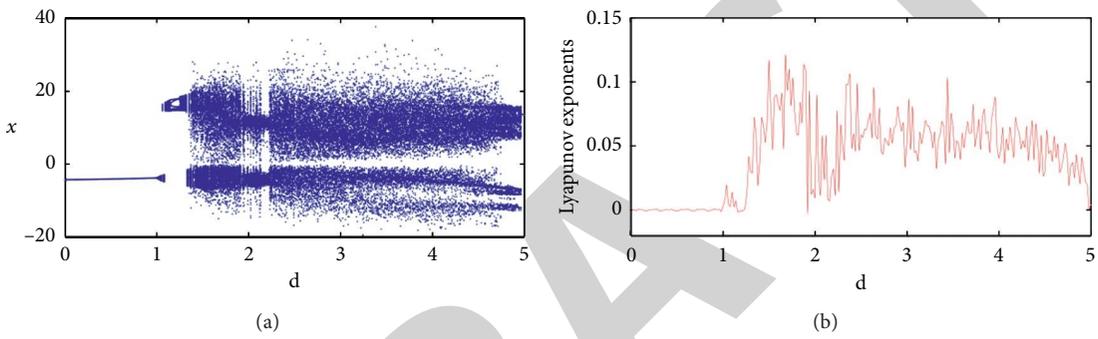


FIGURE 3: Bifurcation diagram (a) and Lyapunov exponents variation (b) of the total system risk value x with time-lag risk intensity d .

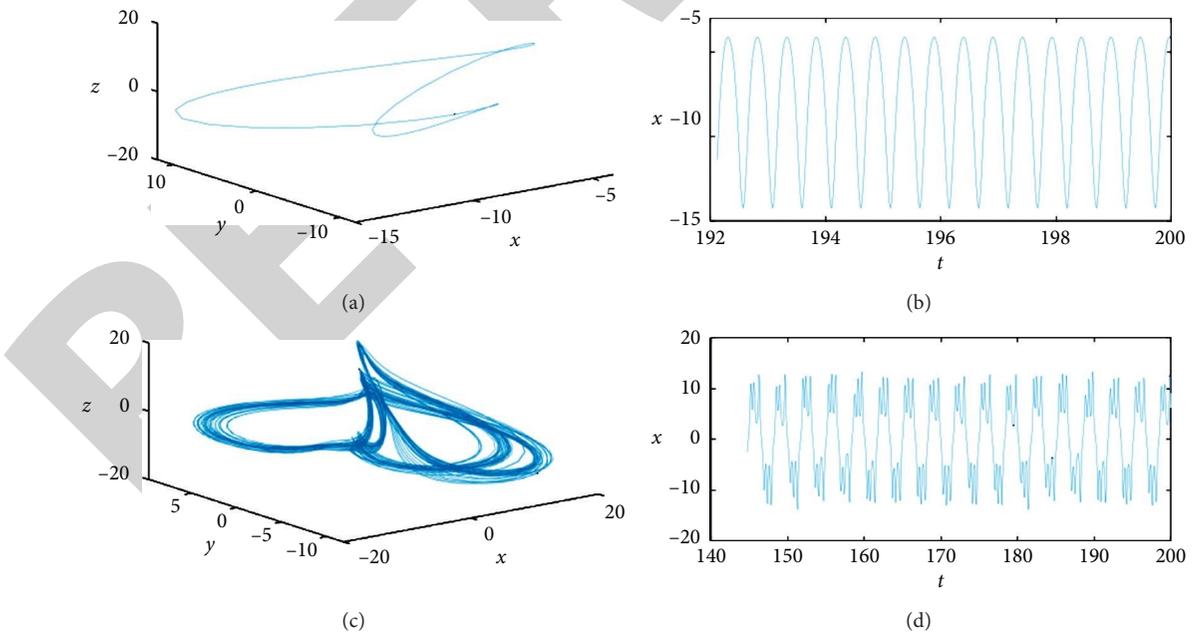


FIGURE 4: Continued.

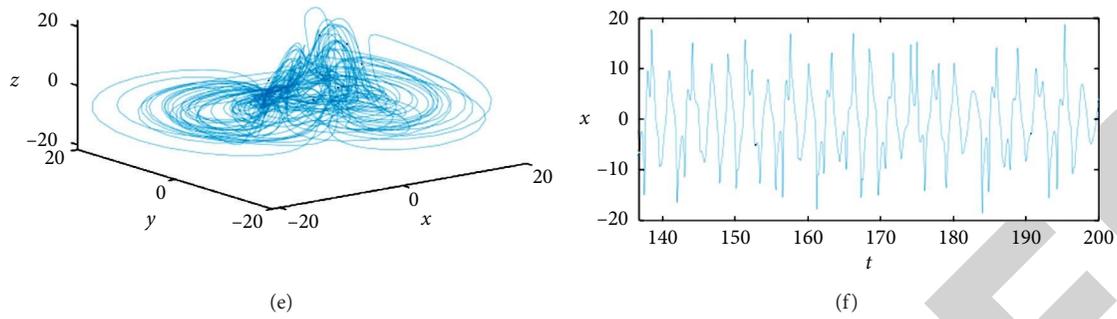


FIGURE 4: Phase diagram and time course diagram of the system for different values of time-lag risk intensity d . (a) Phase diagram of the system at $d=0.5$. (b) Time course diagram at $d=0.5$. (c) System phase diagram at $d=2$. (d) Time course diagram at $d=2$. (e) System phase diagram at $d=4$. (f) Time course diagram at $d=4$.

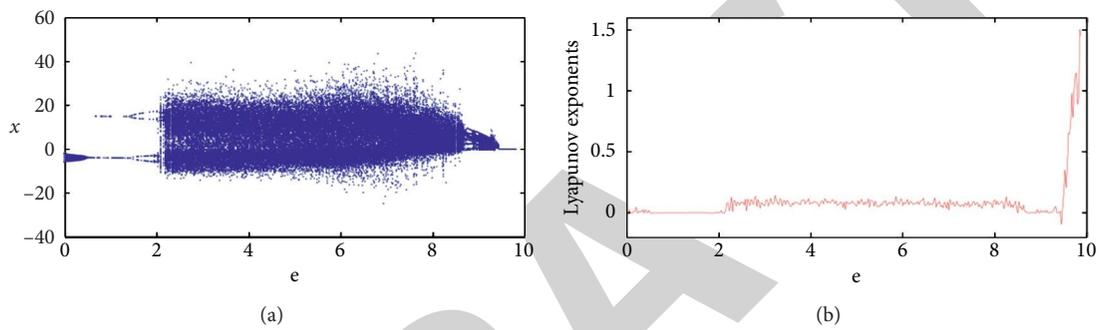


FIGURE 5: Bifurcation diagram (a) and Lyapunov exponents variation (b) in the total system risk value x with time-lag parameter e .

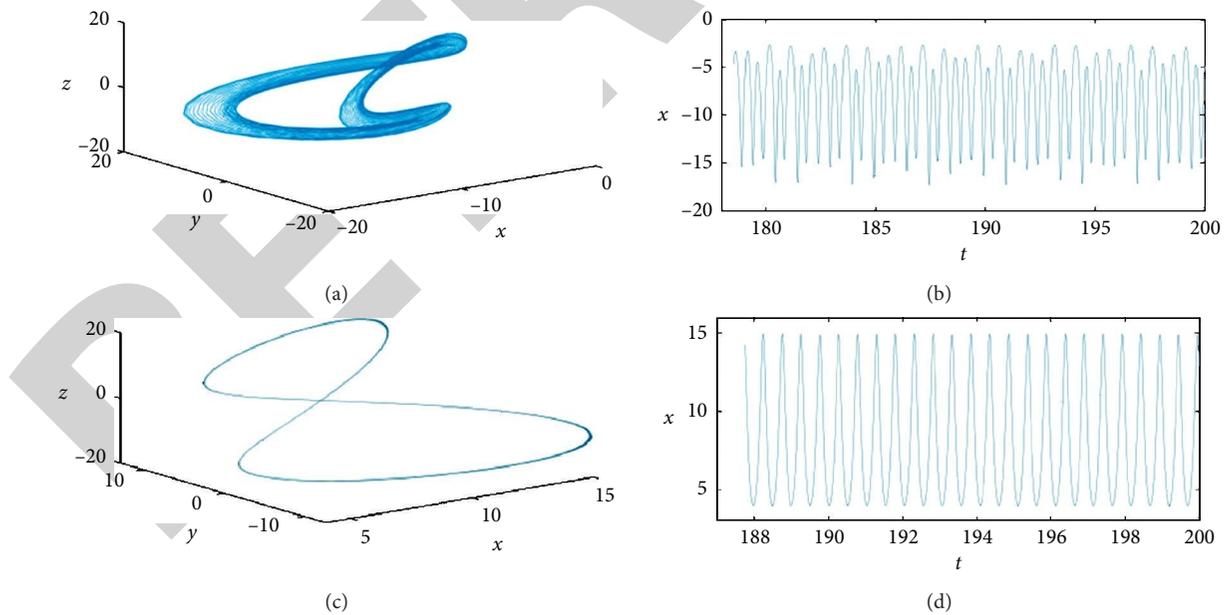


FIGURE 6: Continued.

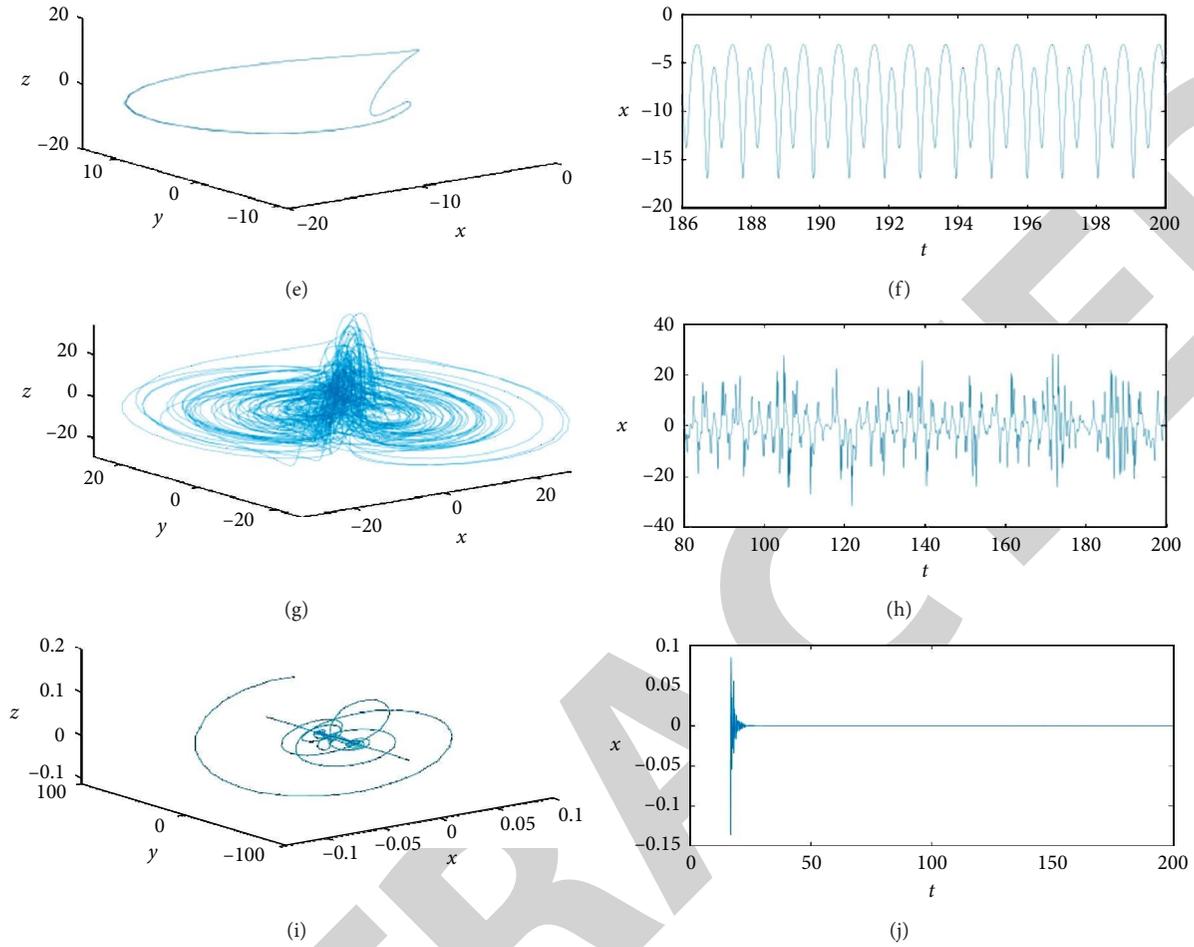


FIGURE 6: System phase diagram and time course diagram for different values of time-lag risk intensity e . (a) Phase diagram of the system at $e = 0.2$. (b) Time course diagram at $e = 0.2$. (c) Phase diagram of the system at $e = 1$. (d) Time course diagram at $e = 1$. (e) System phase diagram at $e = 1.8$. (f) Time course diagram at $e = 1.8$. (g) Phase diagram of the system at $e = 6$. (h) Time course diagram at $e = 6$. (i) System phase diagram at $e = 9.5$. (j) Time course diagram at $e = 9.5$.

system stability is destroyed. However, when e increases close to 10, the bifurcation begins to show a merging trend, as in Figure 6(i), and with Figure 6(j), with $e = 9.5$, the system risk enters the immobility point, which is more desirable and the financial system risk is close to 0, but Lyapunov exponents indicate that system operates in chaos. This is because the system risk caused by transmission effects enters in dispersing status.

In conclusion, the risk brought by the second-stage transmission effect is unpredictable in terms of the degree of risk caused to the system after the delay, and the stability of the financial risk system is higher under the reduced degree of risk.

4. Impact of Financial Management on the Intensity of Regulation of Financial Risk Regulation Policies on the System after the Time Lag

Through the analysis of the risk parameters d and e in the case of time lag, it can be known that the financial risk system will have different movements under different parameter

conditions, and the study hopes that the financial system can always operate benignly and stably, when the high-risk behavior will lead to the collapse of the financial system into an unstable state, such as chaotic motion, probable-cycle motion, or multicycle motion, during the movement of the financial risk system. We try to avoid these situations during the movement of the financial risk system. Since risk has a certain lag effect, regulators should also take into account the delayed impact of control measures when regulating systemic risk. Therefore, the choice of the time-lagged regulation intensity parameter f is crucial to mitigate high-risk financial behavior and promote the smooth operation of the financial risk system.

Setting $d = 1$, $e = 0.5$, and $\tau = 1$, the bifurcation diagram of the time-lag chaotic system is drawn, as shown in Figure 7, when the intensity f of the lagged effect generated by the regulation policy of the financial management varies in the interval $[0, 6]$.

From the bifurcation diagram of the system, it can be obtained that the motion state can be divided into three parts, which are $f = [0, 2.3]$, $[2.3, 3]$, $(3, 6]$. When the parameter f lies in the second interval range of variation, the

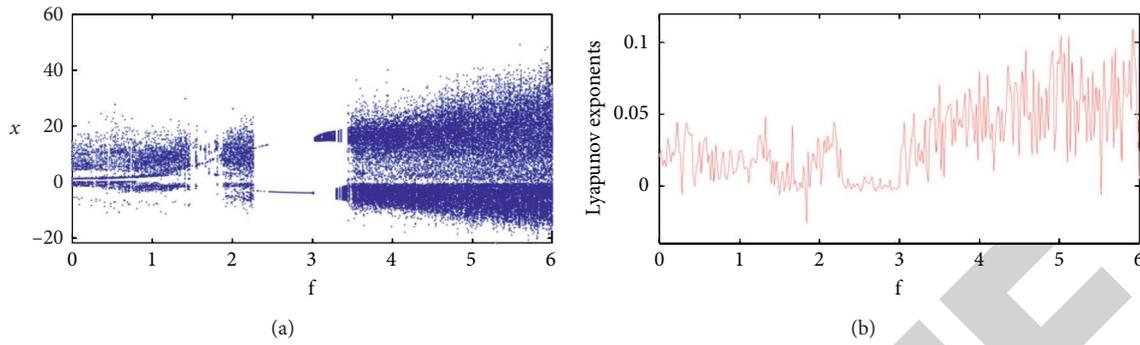


FIGURE 7: System bifurcation diagram (a) and Lyapunov exponents variation (b) in the total system risk value as the hysteresis modulation intensity f varies.

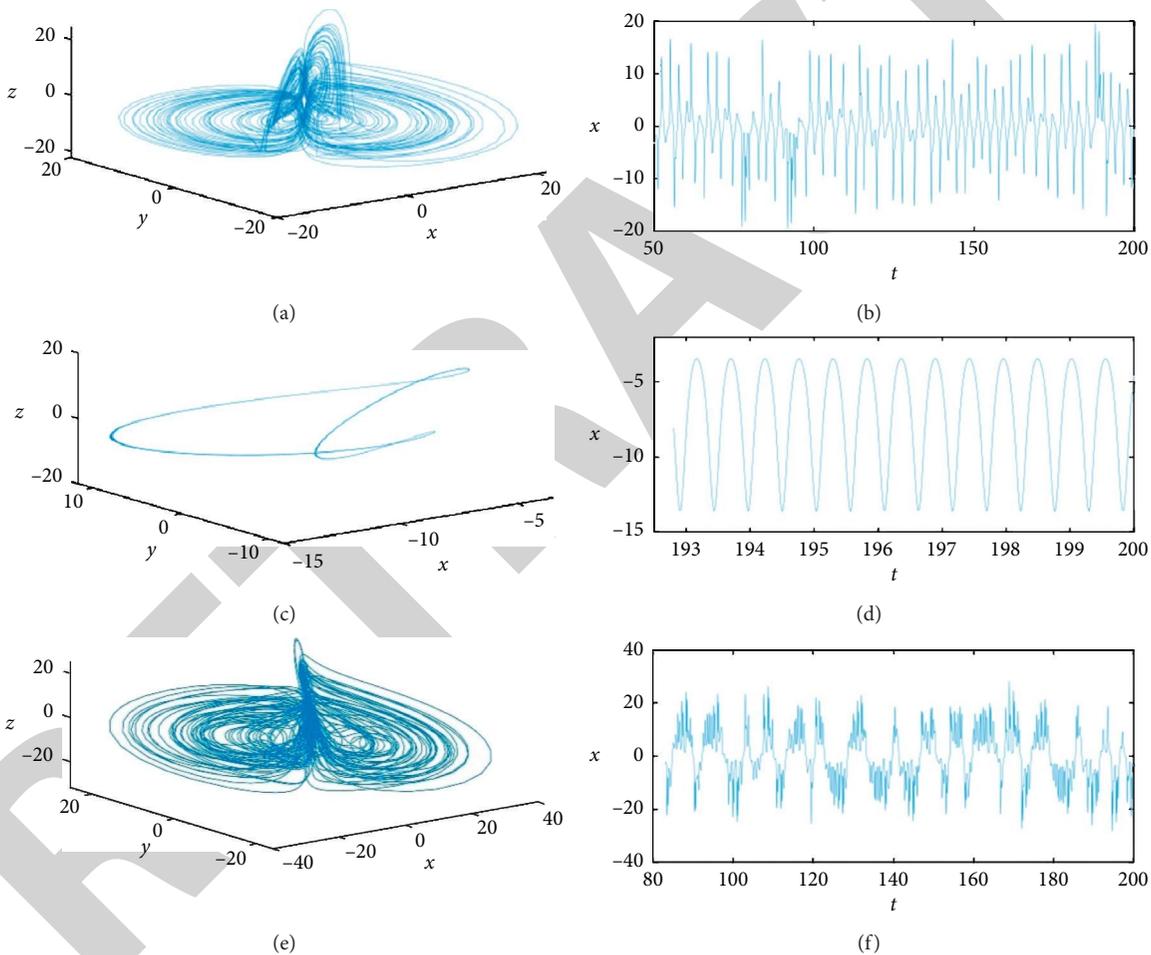


FIGURE 8: System phase diagram and time history diagram for different values of time-lag regulation strength f . (a) Phase diagram of the system at $f=2$. (b) Time course diagram at $f=2$. (c) Phase diagram of the system at $f=2.5$. (d) Time course diagram at $f=2.5$. (e) Phase diagram of the system at $f=4$. (f) Time history diagram at $f=4$.

financial risk system is more stable and can operate benignly, but the system is in a disorderly chaotic state for all other values of f . Figure 8 shows the system phase diagram and time course diagram for different values of f .

Figures 8(a) and 8(b) can be seen that, at $f=2$, the system is in a chaotic motion, at which time the system motion is

extremely unstable, and measures are needed to ensure the influence of the proposed regulation measures after one end of time and to enhance the size of the regulation strength of the time lag. After appropriately increasing the regulation intensity of the time lag, it can be concluded from Figures 8(c) and 8(d) that the system enters a periodic

motion state at $f=2.5$, which is a more stable motion state, and the financial risk system can operate benignly, so $[2.3, 3]$ should be taken as the value interval of the time-lag regulation intensity f in the study. After the parameter f increases further, the system enters the chaotic motion state again and becomes unstable and unpredictable, as in Figures 8(e) and 8(f), where the time-lag parameter $f=4$, the system changes randomly, and the financial risk system is turbulent.

It can be concluded that the intensity of regulatory measures after a delayed period has a crucial impact on the movement of the financial risk system. When proposing control measures, financial regulators should think far ahead, pay attention to the lagging impact they bring, and adopt some regulations that can maintain the effect for a longer period. Also, this maintenance time is not longer and the better control within a certain range can ensure the benign operation of the financial risk system.

5. Conclusion

In this paper, a financial system risk model is established, and the time-lag link is introduced in the risk model considering the lag of financial risk and regulatory measures, and the chaotic dynamics behavior of the time-lagged financial system is studied using chaos and bifurcation theory. The effects of the risk degree parameters d and e , the control intensity parameter f , and the time-lag parameter τ on the evolutionary behavior of the financial system complexity after considering the time lag are firstly explored. The time-lagged financial risk system studied in this paper produces different system motion states with the change in state parameters, while the ideal financial risk system should always operate in a smooth cycle. Therefore, the numerical simulation results obtained by computer simulation in this paper can provide some theoretical basis and decision-making reference for the government to regulate the financial system. In addition, the theoretical and numerical methods proposed in this paper are also applicable to the study of other financial systems.

In the next step, fractional differential equations can be introduced. Compared with integer order, fractional-order contains continuous information of time and is more universal. Besides, as chaotic systems are sensitive to initial conditions, the inclusion of attraction basins will be considered in future work, which will make it easier to identify the risk trend of the analyzed models.

Data Availability

All the data used in the study are generated through computer simulation, and the values of all parameters and models have been explained in the paper. Other scholars can reproduce or extend the simulation results according to the data mentioned in the paper. Some or all codes or other assistance related to the study are available from the corresponding author by request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This study was supported by the Research project of Humanities and Social Sciences in Anhui Universities (Grant nos. SK2020A0536, SK2020A0535, and SK2018A0477) and Excellent academic and Technical backbone of Suzhou University (Grant no. 2018XJGG05).

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