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Research Article

Stability and Complexity of a Novel Three-Dimensional Environmental Quality Dynamic Evolution System

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In this paper, a novel three-dimensional environmental quality dynamic system is introduced. Bayesian estimation was used to calibrate environmental quality variables, and Genetic algorithm (GA) optimized Levenberg-Marquardt Back Propagation (LM-BP) neural network method was used to effectively identify the system parameters for calibration of various variables and official data. The studies found that the effect of increasing investment in environmental protection on energy intensity and environmental quality is not obvious, and it also aggravates the economic instability. Adjustment of peak parameters of pollution emissions can accelerate the evolution of energy intensity and environmental quality to a stable speed and eventually stabilize with a certain value. But if the peak value of pollution emissions reaches too early, it will pose a certain threat to the environment. Although the speed of ecological environment self-repair is increased, it cannot effectively reduce energy intensity, improve environmental quality, and maintain economic growth; it can control the stability of the control system or effectively control pollution. Therefore, in order to improve the environmental quality, we need to take more measures in parallel, use more means and resources for environmental governance, and ultimately achieve "win-win" between environmental quality and economy.

1. Introduction

With the rapid development of economy and society, a series of problems such as shortage of resources, environmental degradation, and ecological destruction have become increasingly prominent. Since the evolution of the environment complex giant system follows the nonlinear mechanism, the new quality will be continuously innovated, and the world will become more diversified and complicated. It can be said that nonlinearity is the basic guarantee for the enrichment and complexity of the environmental system. Just because more and more new substances are produced, evolution continues, substances become more complex, and the amount of information contained increases and accumulates by nonlinear action. Only in this way can development be sustainable. The effect of complex nonlinear is common between the environmental system and the external and internal elements of the system, so that the system forms a relatively stable structure, organizational model, and control mechanism, which can stimulate or limit the evolution of the whole system. In addition, the exchange of matter, energy, and information in the cyclic motion of environmental systems and subsystems can lead to chaotic or disordered states, which requires humans to fully understand and guide the chaotic or disordered of environmental systems in a coordinated and orderly manner of orbit to evolve.

At present, the study of the complexity of the nonlinearity of ring systems has been more extensive. For example, Gudo Buenstor pointed out that the ecosystem is a self-organizing system, and its sustainable development is related to the self-organizing characteristics of the system. If various environmental problems will affect the process of economic development, then the thermodynamic changes of ecosystem (energy and entropy transformation) will have a guiding significance for the corresponding countermeasures of economic system [1]. Luis A et al. pointed out that there are relatively few studies on how human beings intervene in environmental systems and how natural phenomena lead to changes in ecosystems [2]. Ranjit Kumar Upadhyay and others believe that structural complexity is one of the most fundamental problems of dynamic complexity of ecosystems. The development and application of dynamic system theory are helpful to understand the complexity of ecosystem. It is pointed out that structural complexity and dynamic complexity are interrelated. Simple dynamic models of ecosystem show that simple structural systems can produce very complex and unpredictable dynamic behavior in some cases. However, the ecosystems with complex structures may not necessarily produce complex dynamic behaviors [3]. Sazykina and Milan demonstrated that the nutrient structure of ecosystem is a self-organizing process through dynamic analysis of ecosystem models [4, 5]. Bianciardi proposed an experimental model for quantifying the complexity and self-organizing characteristics of complex ecosystems. When the input variables of the system change, the complexity of the system changes, and the system needs to reorganize and continue to change to another equilibrium state [6]. Wu et al. expounded that environmental system is a typical complex system, which has the characteristics of nonlinearity, irreversibility, multilevel, openness, self-organization, and criticality [7]. For example, there are many species in the environmental system. There are complex relationships among species, such as parasitism, symbiosis, and natural enemies. There are direct or indirect connections among all species, which constitute a complex ecological network. Because the environmental system has the characteristics of nonlinearity, self-organization, nonnegotiability, dynamics, openness, multilevel, self-similarity and so on, it is a typical complex system, and it is a large system with many elements, levels, and complex relationships. If we want to solve the current environmental problems facing mankind, we must apply complexity theory to environmental problems making the structure of environmental system more reasonable and the balance of environment, economy, and society rebuilt.

Chaos theory is one of the key methods to study complex dynamics. It was originally developed under the background of physics. However, many scholars have found that social, ecological, and economic systems are all nonlinear, while nonlinear relationships evolve dynamically over time. Based on the hypothesis of participant's bounded rationality, a novel Cournot Duopoly game model of carbon emission reduction is established, and the dynamic adjustment mechanism of emission reduction on enterprises participated in is also analyzed [8]. Fang et al. obtained the attractors of energy-saving and emission-reduction by a series of energy saving and emission reduction system models. Using the energy intensity formula varying with time, the effectiveness of energy-saving and emission-reduction was evaluated [9–12]. Yuan et al. analyzed the relationship between energy intensity and technological progress based on Douglas production function [13]. Long used game theory to analyze the optimal strategies between the government and enterprises in the process of implementing energy-saving and emission-reduction actions and obtained Nash equilibrium solution of mixed strategies [14].

At present, China's environmental protection is still lagging economic and social development. The problem of multistage, multifield, and multitype pollution has accumulated on a long time. The environmental carrying capacity has reached or approached the upper limit, and the trend of ecological environment deterioration has not been fundamentally reversed. In the process of dealing with these problems, people gradually realized that how to deal with resource utilization problems and environmental problems and control pollutant emissions is the key to improving environmental quality. It is related to the sustained and healthy development of the economy and society. An important breakthrough in adjusting the economic structure and realizing the mode of economic growth is to establish a new economic competition and introduce a good opportunity for green development and environmental protection industry development.

In the process of further promoting environmental governance measures in China, the environmental problems left behind have become more complex and difficult to solve, and the work of further promoting environmental governance and quality improvement has become more arduous and complex. At present, with the acceleration of industrialization, urbanization, and modernization in China, the demand for energy is in a rapid growth stage. The sustained growth of fossil energy consumption and the prominent "high pollution" characteristic of "high emission" have become a major constraint on China's sustainable development. Although the quality of China's ecological environment has improved with active efforts, the complexity, urgency, and long-term nature of environmental issues have not changed. We must clearly understand and grasp the grim current situation of China's ecological environment, and we must rationally, objectively, and persistently promote the improvement of environmental quality. We should fully understand the complexity of the environment and the lag of environmental protection, reasonably reduce environmental pollution, and effectively improve economic growth to meet the people's pursuit of a beautiful ecological environment and higher quality of life. It plays an important role in alleviating the contradiction between human and nature and enhancing the effect of environmental protection. At the same time, the existing research extends from the focus on improving the effect of environmental governance to the idea of environmental governance system engineering, but the research on the mechanism of energy saving and economic growth to improve environmental quality needs to be improved. It is necessary to construct an environmental quality control system suitable for China's national conditions in this situation. Reasonably coordinate the relationship between various variables in the environmental quality management system, explore the vector sensitive to the environmental quality index in the environmental quality system, and find practical and feasible ways to reduce environmental pollution and have no significant impact on the economy. Provide theoretical basis and technical support for China to formulate policies and regulations to improve environmental quality and effectively promote the development of environmental management. This is the key to study the mechanism of improving environmental quality with strong theoretical expansion and practical application value.

This article is organized as follows. In Section 2, we have model building and interpretation, dynamic analysis, and showing the dynamic features of this system with numerical simulations, including bifurcation diagram, phase portrait, and sensitive dependence on initial conditions. In Section 3, we have data acquisition and processing of the model and LM-BP neural network is optimized based on genetic algorithm to identify system parameters. In Section 4, the depth of the key influential parameters is analyzed and studied in the identified model. Section 5 is the main research conclusion of this study.

2. Model Establishment and Analysis

2.1. Modeling and Interpretation. In this paper, we consider a new three-dimensional energy and economic growth system with environmental quality constraints, which can better simulate the actual situation and meet the requirements of practical development. The dynamic system is in the form of the following differential equations:

$$\begin{aligned} \dot{x} &= a_1 x\left(1-\frac{x}{F}\right)+a_2 y\left(1-\frac{y}{E}\right)-a_3 z \\ \dot{y} &= -b_1 x-b_2 y-b_3 z \\ \dot{z} &= -c_1 x+c_2 y\left(1-\frac{y}{H}\right)+c_3 z\left(\frac{x}{P}-1\right) \end{aligned} \tag{1}$$

where $x(t)$, $y(t)$, $z(t)$, respectively, are the level of pollution emission, the level of economic growth (GDP), and the level of environmental quality in period t, a_i, b_i, c_i $(i = 1,2,3,4)$, F, E, H, P are normal numbers, $t \in I$, and I is an economic cycle. a_1 represents the development rate elasticity coefficient of pollution emission $x(t)$, a_2 represents the influence coefficient of economic growth $y(t)$ on pollution emission $x(t)$, a_3 denotes the inhibition coefficient of environmental quality $z(t)$ on pollution emission $x(t)$, F represents the peak value of pollution emission $x(t)$ in an economic cycle, E represents the peak value of economic growth $y(t)$ in an economic cycle; b_1 represents the influence coefficient of pollution emission $x(t)$ on economic growth $y(t)$, b_2 represents the restraint factor of investment in reduction pollution emission $x(t)$ on economic growth $y(t)$, b_3 represents the restraint factor of investment in improving environmental quality $z(t)$ on economic growth $y(t)$; c_1 represents the inhibition coefficient of pollution emission $x(t)$ on environmental quality $z(t)$, c_2 represents the influence coefficient of economic growth $y(t)$'s investment on improving environmental quality $z(t)$, c_3 represents the speed coefficient of ecological environment self-repair without external intervention, H represents the peak value of the impact of economic growth $y(t)$ on environmental quality $z(t)$ in an economic cycle, and P represents the maximum amount of pollution that can be contained by the ecological environment.

In system (1), $\dot{x}$ represents the level of change in pollution emissions in t period; $\dot{y}$ represents the growth level of economic growth in the t period; $\dot{z}$ represents the change level of environmental quality in t period. When the impact of pollution exceeds the maximum capacity of the ecological environment (that $\dot{z} > 0$), it means that the ecological environment is deteriorating. In this case, the ecosystem cannot rely on self-regulation to repair. Therefore, when this situation continues, the ecological environment will eventually be sold out; when $\dot{z} \le 0$, it means that the environmental quality has reached a dynamic balance or gradually improved, and only under this condition can the ecological environment be the basis of human social development [15–17].

Energy mildness is the ratio of energy utilization to economic or material output. The energy intensity of a country or region is usually expressed in terms of energy consumption per unit of gross domestic product as follows:

$$\text{Energy intensity} = \frac{\text{Energy consumption over an economic period}}{\text{GDP over an economic period}} \tag{2}$$

In other words, $x^*(t) = \varphi_1(t, kx, y, z)$ and $y(t) = \varphi_2(t, x, y, z)$ can be deduced from system (1), where $x^*(t)$ represents energy consumption over time in an economic period; $k = 1/k_0$, k_0 represents the pollutant discharge coefficient of standard coal. Therefore, the energy intensity in an economic period can be expressed as follows:

$$U(t) = \frac{\varphi_1(t, kx, y, z)}{\varphi_2(t, x, y, z)}, \quad t \in I. \tag{3}$$

Lemma 1 (see [18]). *This is the n dimensional discrete dynamical system and all the eigenvalues of Jacobian matrix $J(x^*)$ of the right function in this system must satisfy the condition that $|\lambda_n| < 1$ in order to stabilize the equilibrium point x^*.*

$$\begin{aligned} \dot{x}_1 &= f_1(x_1(t), x_2(t), \dots, x_n(t)) \\ \dot{x}_2 &= f_2(x_1(t), x_2(t), \dots, x_n(t)) \\ &\cdots \\ \dot{x}_n &= f_n(x_1(t), x_2(t), \dots, x_n(t)). \end{aligned} \tag{A1}$$

2.2. Dynamic Analysis of the Model. Then we will analyze the dynamics of environmental quality system. System (1) is determined by the eigenvalues of the Jacobian matrix as follows:

$$J = \begin{bmatrix} \dfrac{(F-2x)a_1}{F} & \dfrac{(E-2y)a_2}{E} & -a_3 \\ -b_1 & -b_2 & -b_3 \\ -c_1+\dfrac{zc_3}{P} & \dfrac{(H-2y)c_2}{H} & \left(\dfrac{x}{P}-1\right)c_3 \end{bmatrix}. \tag{4}$$

System (1) is a very complex dynamic system, when a_i, b_i, c_i, F, E, H, P values are different, system (1) also shows different dynamic behavior. Therefore, in order to facilitate the study of system (1), the coefficients in system (1) will be set as follows: $a_1 = 0.055$, $a_2 = 0.896$, $a_3 = 0.114$, $b_1 = 0.759$, $b_2 = 0.075$, $b_3 = 0.003$, $c_1 = 0.355$, $c_2 = 0.674$, $c_3 = 0.8127$, $F = 1.6$, $E = 2.55$, $H = 0.25$, $P = 2.4$.

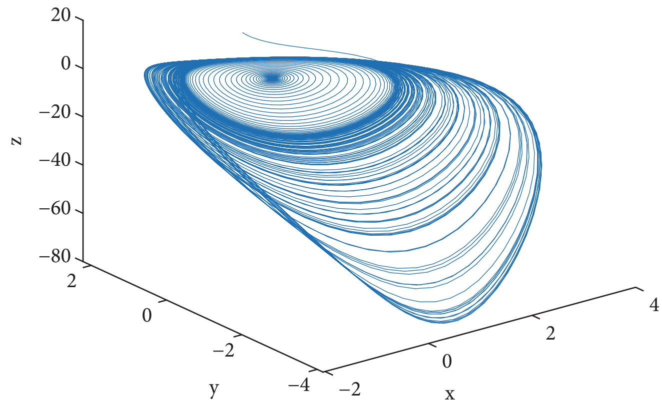

Figure 1: Three-dimensional attractor diagram of system (1): 3D $(x - y - z)$.

Setting parameters are brought into system (1). By calculation, we get the two real equilibrium points of system (1) respectively: $O(0,0,0)$ and $S(0.7118, -3.9918, -80.2967)$.

For equilibrium $O(0,0,0)$, system (1) matrix of linear approximation system is as follows:

$$J_0 = \begin{bmatrix} a_1 & a_2 & -a_3 \\ -b_1 & -b_2 & -b_3 \\ -c_1 & c_2 & -c_3 \end{bmatrix}, \quad (5)$$

If $f(\lambda)$ denotes the characteristic polynomial of the Jacobian matrix $J(O)$, then

$$f(\lambda) = \lambda^3 + A\lambda^2 + B\lambda + C = 0, \quad (6)$$

where $A = b_2 + c_3 - a_1$, $B = a_2 b_1 + a_3 c_1 + b_3 c_2 + b_2 c_3 - a_1(b_2 + c_3)$, $C = a_3 b_2 c_1 - a_2 b_3 c_1 + a_3 b_1 c_2 - a_1 b_3 c_2 + a_2 b_1 c_3 - a_1 b_2 c_3$.

By simple calculation, we get three eigenvalues of the matrix $J(O)$: $\lambda_1 = -0.7876$, $\lambda_{2,3} = -0.0225 \pm 0.78595i$. According to Lemma 1, $\lambda_i < 1 (i = 1,2,3)$, that equilibrium point $O(0,0,0)$ is unstable.

Let b_1 be any value, the corresponding characteristic equation is as follows:

$$\begin{aligned} f(\lambda) = \lambda^3 + 0.8327\lambda^2 + b_1(0.6513 + 0.896\lambda) \\ - 0.0263\lambda - 0.0075 = 0. \end{aligned} \quad (7)$$

Let $p_1 = 0.8327$, $p_2 = 0.896b_1 - 0.026319$, $p_3 = -0.0075 + 0.6513b_1$; according to Routh-Hurwitz criterion, the necessary and sufficient conditions for the real part of all characteristic roots of the equation to be negative are as follows: $p_1 = 0.8327 > 0$, $p_1 p_2 - p_3 > 0$, $p_1 p_2 p_3 - p_3^2 > 0$. By calculation, we know when $0 < b_1 < 0.0114$ that equilibrium point $O(0,0,0)$ is unstable. By calculating, the Jacobian matrix of system (1) at the equilibrium point S, we get the eigenvalue $\lambda_1 = 0.8405$, $\lambda_{2,3} = -0.7405 \pm 0.6863i$.

$$\begin{aligned} \nabla V &= \frac{\partial \dot{x}}{\partial x} + \frac{\partial \dot{y}}{\partial y} + \frac{\partial \dot{z}}{\partial z} = \frac{(F - 2x)a_1}{F} - b_2 + \left(\frac{x}{P} - 1\right)c_3 \\ &= a_1 - b_2 - c_3 + x\left(\frac{c_3}{P} - \frac{a_1}{F}\right) \end{aligned} \quad (8)$$

When $c_3/P - a_1/F = 0$, $a_1 - b_2 - c_3 < 0$, system (1) is dissipative.

Next, the dynamic simulation of system (1) is carried out, setting the parameter values of the system is substituted with initial values [0.758, 1.83, 1.5]. Three-dimensional attractor diagrams of system (1) are given in Figure 1; two-dimensional attractor diagrams of system (1) are given in Figure 2; Figure 3 shows the time series diagram of system (1) $(x(t), y(t), z(t))$; Figure 4 shows bifurcation diagram and corresponding Lyapunov exponential diagram of the variable $b_1 \in [0.7, 1.3]$ change of system (1); sensitive dependence of the dynamical system (1) on initial conditions is given in Figure 5.

When time tends to be infinite, all orbits of unsteady flow on any bounded set tend to a bounded set called attractor, and such a set also has very complex geometric structure. Figure 1 shows that the trajectory of system (1) moves irregularly into the set of shapes with the increase of time. Figure 2 shows the different prints of the phase of system (1) on the two-dimensional plane, which also fully reflects that the trajectory of system (1) is irregular. Because the attractors are closely related to chaos, it is necessary to explore the properties of attractor sets to better reveal the law and structure of chaos in system (1). Figure 4 shows the bifurcation diagram and the corresponding Lyapunov exponential diagram of system (1) with the change of parameter $b_1 \in [0.7, 1.3]$; we found the very complex dynamic behavior of system (1) from Figure 4. The Lyapunov exponential diagram is a quantitative quantity of system stability. The maximum Lyapunov exponent is greater than 0, which indicates that the system has chaotic behavior. For a four-dimensional system, if the maximum Lyapunov exponent at one point is equal to 0 and the rest is less than 0, it can indicate that the system has bifurcation. Impact of initial state on the system (1), Figure 5 gives the sensitive dependence on initial values. The sensitivity of system (when losing stability) with $(x, y, z) = (0.758, 1.83.1.5)$ and $(x_1, y, z) = (0.757, 1.83.1.5)$ and small changes of the initial conditions may cause the observed large changes of the system, which is sensitive to initial states. The butterfly effect is also an important symbol of chaotic motions. Figure 5 shows the difference among the different orbits with slightly deviated initial values which builds up rapidly after many iterations, although their initial states are indistinguishable.

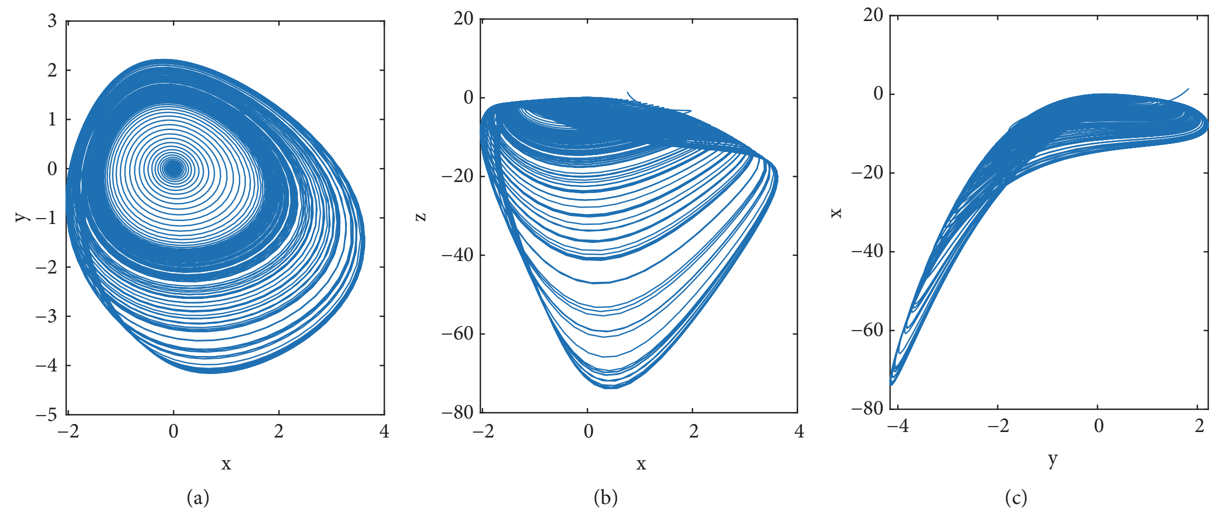

Figure 2: Two-dimensional attractor diagram of system (1): (a) 2D $(x - y)$, (b) 2D $(x - z)$, (c) 2D $(y - z)$.

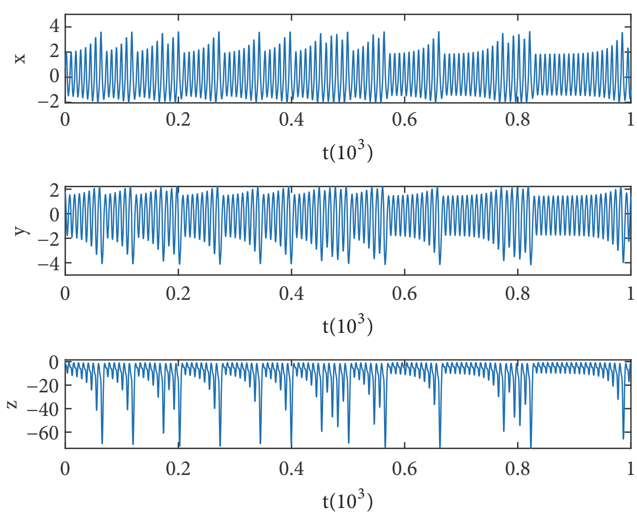

Figure 3: Time series diagram of system (1) $(x(t), y(t), z(t))$.

3. Parameter Identification of the System Based on GA Optimization LM-BP Neural Network Method

3.1. Data Acquisition. The system is based on the complex relationship between pollution emission reduction, economic growth, and environmental quality. The determination of parameters in the system is of great significance to practical research. Based on the statistical data of China, the parameters of the actual system are obtained by GA optimizing LM-BP neural network method. The evolutionary relationship between actual pollution emission, economic growth, and environmental quality is analyzed. The environmental quality, energy intensity, and economic growth are affected with those variables.

In this paper, according to China Statistical Yearbook 2018, the main indicators of pollution emissions are energy and carbon emissions caused by energy consumption in a cycle, and GDP is the main choice for economic growth. Environmental quality is the key variable in this paper, but how to measure it accurately is one of the difficulties faced by relevant research. This paper mainly refers to the research on the quality of economic growth of Chao Xiaojing and Ren Baoping and calculates the environmental quality index using the principal component analysis method (PCA) based on covariance matrix [19]. In order to ensure the consistency of statistical caliber (in 2017, the Ministry of Ecology and Environment revised the standard system, survey methods, and related technical regulations of the statistical system. For this reason, the data selected in this paper are up to 2017.), we selected the per capita urban green space area (hectare/urban population), forest coverage (%), and the area occupied by nature reserves (%) from 2000 to 2017 as the positive indicators of environmental status. The per capita water resources (cubic meters/person), per capita industrial wastewater discharge (ton/person), and per capita industrial solid waste production (ton/person) were taken as the positive indicators of environmental status. Average industrial exhaust emissions (cubic meters per person) are regarded as the inverse indicators of potential environmental pressure, and all the inverse indicators are treated by reciprocal positive treatment, so that the effect of all indicators on environmental quality is similar. In view of the difference of dimension and magnitude, the results of main components will be biased to the indexes with larger variance or magnitude, so this paper treats all the indexes by means of dimensionless processing. By observing the cumulative contribution rate of the main components, the weight of each index is determined by the standard orthogonal eigenvector of the first main component. In addition, in order to make the environmental quality index positive, the logarithmic logistic model is adopted to standardize the data, and all the data are processed based on 1999. The final number is shown in Table 1.

3.2. System Parameter Identification and Model Validation. GA optimized LM-BP neural network method has better

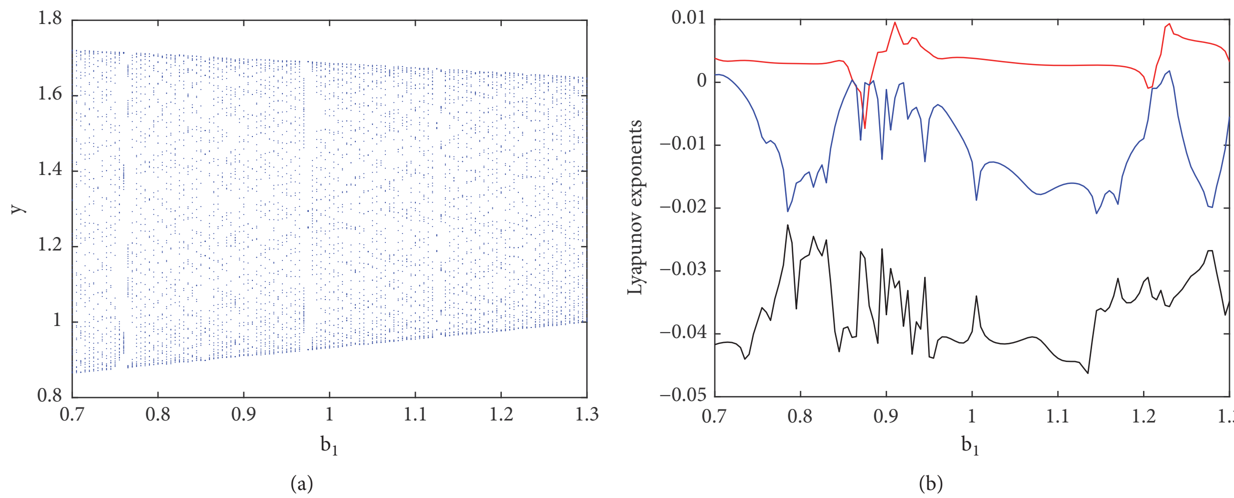

FIGURE 4: Bifurcation diagram and corresponding Lyapunov exponential diagram of the variable $b_1 \in [0.7, 1.3]$ change of system (1): (a) bifurcation diagram and (b) Lyapunov exponential diagram of corresponding (a).

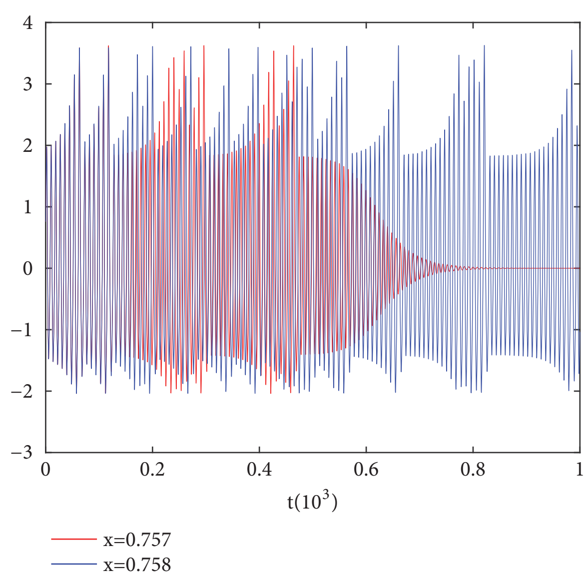

FIGURE 5: Sensitive dependence of the dynamical system (1) on initial conditions.

TABLE 1: Statistics on energy consumption, economic growth, and environmental quality in China.

Year	x	y	z
2000	1.0455	1.1085	0.9837
2001	1.1066	1.2228	0.9595
2002	1.2064	1.3482	0.9347
2003	1.4020	1.5283	0.8747
2004	1.6382	1.8062	0.7741
2005	1.8594	2.0813	0.7242
2006	2.0380	2.4509	0.6403
2007	2.2156	3.0307	0.5455
2008	2.2808	3.5976	0.4752
2009	2.3912	3.8997	0.4061
2010	2.5656	4.6020	0.3693
2011	2.7534	5.4243	0.3565
2012	2.8608	6.0326	0.3210
2013	2.9659	6.6068	0.2817
2014	3.0292	7.2151	0.2575
2015	3.0583	7.6813	0.2322
2016	3.1004	8.2872	0.2159
2017	3.1942	9.2297	0.2147

identification accuracy for the parameter identification of the nonlinear system. Firstly, system (1) is discretized and the following difference equations are obtained:

$$\begin{aligned}
x(k+1) &= x(k) \\
&\quad + T\left[a_1 x\left(1-\frac{x}{F}\right) + a_2 y\left(1-\frac{y}{E}\right) - a_3 z\right] \\
y(k+1) &= y(k) + T\left[-b_1 x - b_2 y - b_3 z\right] \\
z(k+1) &= z(k) \\
&\quad + T\left[-c_1 x + c_2 y\left(1-\frac{y}{H}\right) + c_3 z\left(\frac{x}{P}-1\right)\right]
\end{aligned} \tag{9}$$

The front $n-1$ sets of actual statistical data are used as input data of GA optimized LM-BP neural network after $n-1$ sets as output data of GA optimized LM-BP neural network, and the data are normalized in $\overline{x_i} = (x_i - x_{\min})/(x_{\max} - x_{\min})$ form. All other parameters are random numbers. The appropriate feedforward neural network is selected, and its output results are brought into the system (9). The results are compared with the target output. By comparing and controlling the error at 10^{-6}, the identified system parameters are obtained as shown in Table 2.

In order to verify the feasibility of obtaining identification parameters, this paper chooses the data of 1980 as the initial

Table 2: Identifying the actual parameters of system (1) by identifying the actual data.

a_1	a_2	a_3	b_1	b_2	b_3	c_1
0.0945	0.0348	0.0161	0.0262	0.0834	0.0734	0.0321
c_2	c_3	F	E	H	P	
0.0151	0.1401	1.5616	2.7837	1.1943	2.3121	

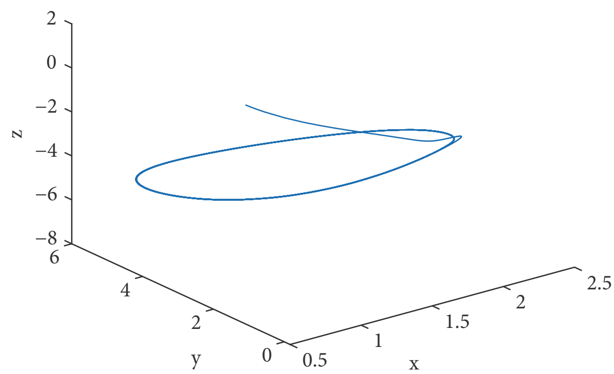

Figure 6: Three-dimensional phase diagram of system (1) with identified parameters: 3D ($x-y-z$).

value of the system $[0.658, 1.73, 1.1211]$ and obtains the actual system diagram as shown in Figures 6 and 7. From the phase diagram of the actual system, we can find that the system is developing steadily, which is consistent with the actual situation.

4. Analysis of the Influencing Factors of the System

In order to better study the stability of system (1) and how to reduce energy intensity and improve environmental quality more effectively, it is necessary to do in-depth analysis and research on some key parameters of system (1).

Figure 8 shows under different values the influence of the system parameter c_2 on the evolution path of energy intensity and environmental quality based on the parameters of system (1) as shown in Table 2 and the initial conditions are unchanged. When $c_2 = 0.0151$, system (1) evolves as shown in the red curve in Figure 8; when $c_2 = 0.0159$, system (1) evolves as shown in the blue curve in Figure 8. By comparing Figure 8, we can find that the effect of increasing investment in environmental protection on energy intensity and environmental quality is not obvious, and it also aggravates the economic instability; the fluctuation around a central value is not conducive to the control of environmental pollution with the course of time. Therefore, simply increasing investment in environmental protection with the stability of effectively reducing energy intensity and improving environmental quality is not obvious.

Figure 9 shows the effect of different values of the system parameter F on energy intensity and environmental quality based on the parameters of system (1) as shown in Table 2 and the initial conditions are unchanged. When $F = 1.5616$, system (1) evolves as shown in the red curve in Figure 9; when $F = 1.2616$, system (1) evolves as shown in the blue curve in Figure 9. By comparing Figures 9(a) and 9(b), it can be found that when $F = 1.5616$, energy intensity and environmental quality fluctuate around a central value in the course of time. This phenomenon is not conducive to controlling pollution emissions (that is, it cannot effectively reflect the effect of energy saving and emission reduction) and improving environmental quality; when $F = 1.2616$, the evolution of energy intensity and environmental quality tends to be stable at a faster speed and eventually stabilizes with a certain value, which indicates that the development of a good control system or effective control of pollution can be achieved. In addition, it is found that the peak value of pollution emissions arrives too early, but it poses a certain threat to the environment from Figure 9(b). The reason for this phenomenon is that the peak value of pollution emissions exceeds the speed of natural environment itself and environmental remediation from the outside, and the pollutants in the environment rapidly accumulate to the maximum capacity of the environment. Therefore, it is very important to control the peak value of pollution emission reasonably for the stability of control system and the improvement of environmental quality.

Figure 10 shows the environmental quality under the influence of different system parameters c_3, based on the parameters of system (1) as shown in Table 2 and the initial conditions are unchanged. Figure 10 shows the parameter $c_3 = 0.1401$, and the evolution of system (1) is shown in the red curve; when parameter $c_3 = 0.2401$, the evolution form of system (1) is shown in the blue curve. By comparing Figure 10, when the speed of ecological environment self-repair is $c_3 = 0.1401$, energy intensity and environmental quality fluctuate around a central value in the course of time, which is not conducive to controlling pollution emissions and improving environmental quality; when $c_3 = 0.2401$, energy intensity, environmental quality, and economy eventually evolve into stable values. Although it cannot effectively reduce energy intensity, improve environmental quality, and maintain economic growth, it can control the stability of the control system or effectively control pollution.

Figure 11 shows the parameter $P = 2.3121$, and the evolution form of system (1) is shown in the red curve; when parameter $P = 2.0121$, the evolution form of system (1) is shown in the blue curve; when parameter $P = 2.8121$, the evolution form of system (1) is shown by green curve. By comparing Figure 11, it can be found that, in the short term, the environmental capacity has no obvious impact on the system, but when the environmental capacity decreases, the environmental quality fluctuates around a central value in the course of time and the vibration amplitude increases when the environmental capacity decreases to a certain extent (that is, when the pollution impact exceeds the ecological environment). When the amount of environmental pollution reaches the maximum capacity of the ecological environment system, the environmental system will collapse: that is, the ecological environment will deteriorate and the ecosystem cannot rely on self-regulation to repair in this situation. As a result, the situation continues, and the ecological environment is eventually sold out.

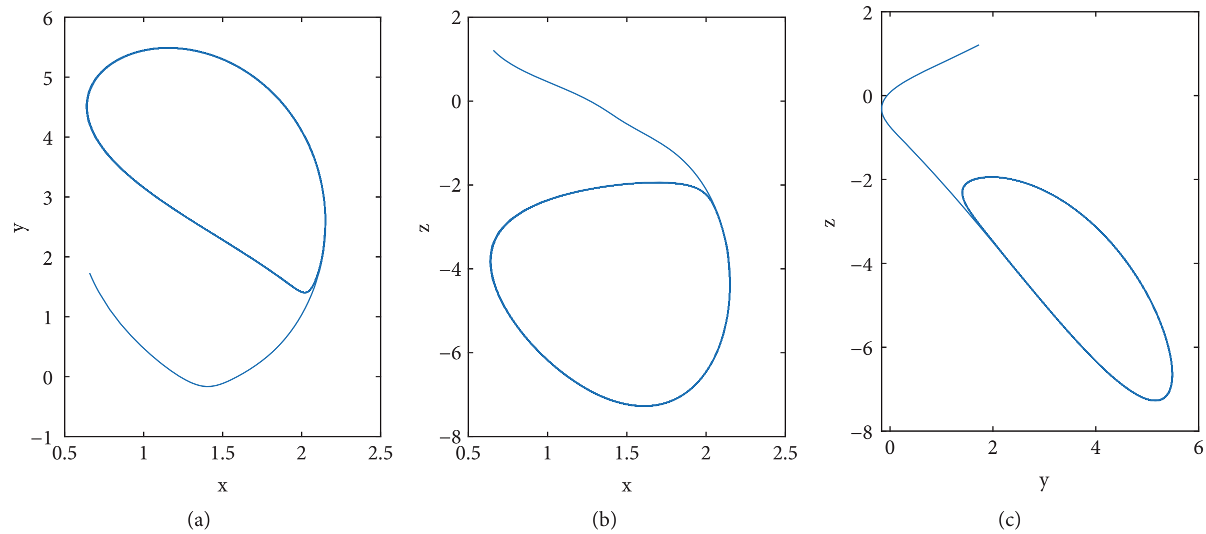

FIGURE 7: Two-dimensional phase diagram of system (1) with identified parameters: (a) 2D $(x-y)$, (b) 2D$(x-z)$, (c) 2D $(y-z)$.

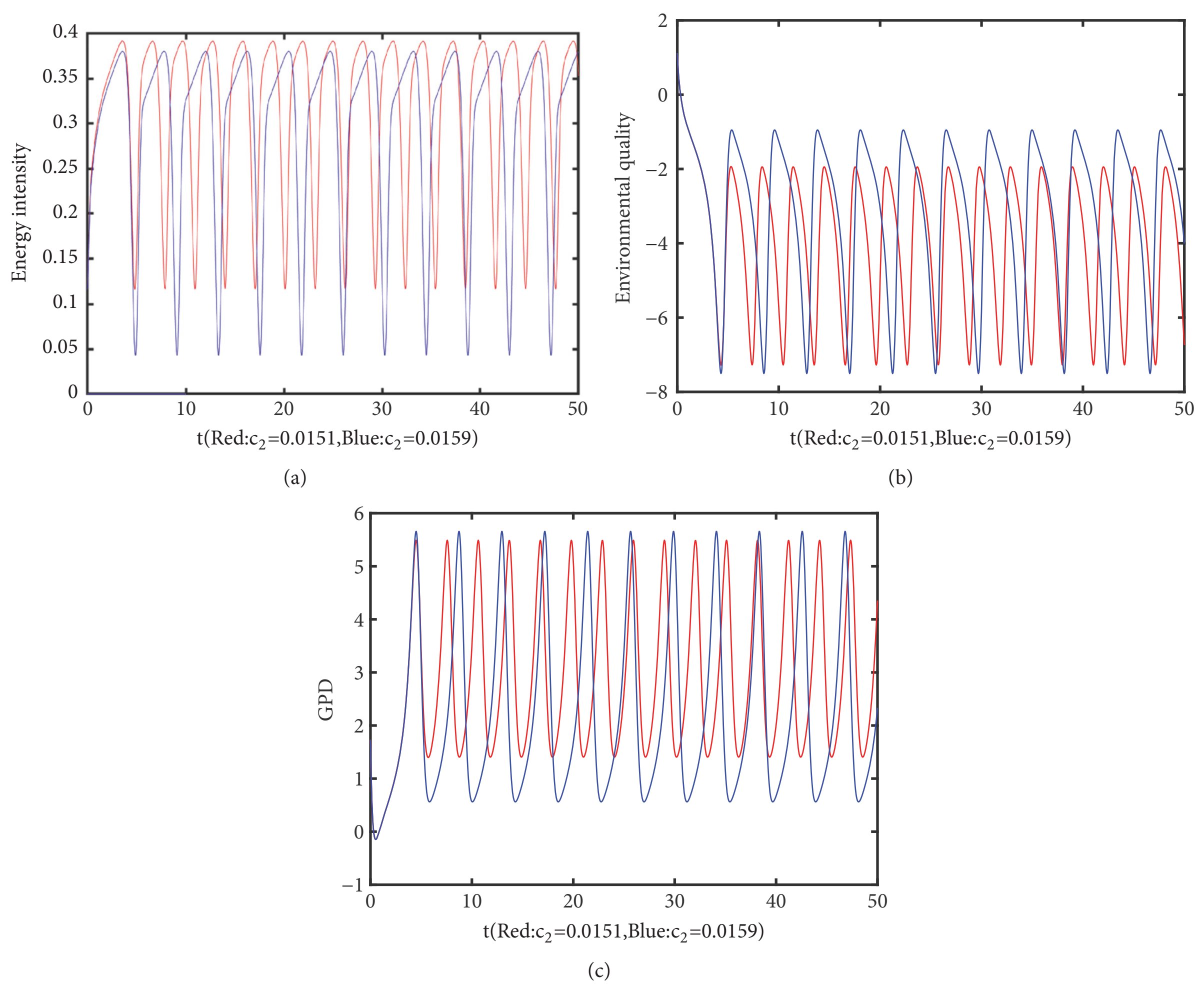

FIGURE 8: The influence of system (1) parameters c_2 on energy intensity and environmental quality: (a) energy intensity, (b) environmental quality, and (c) GDP.

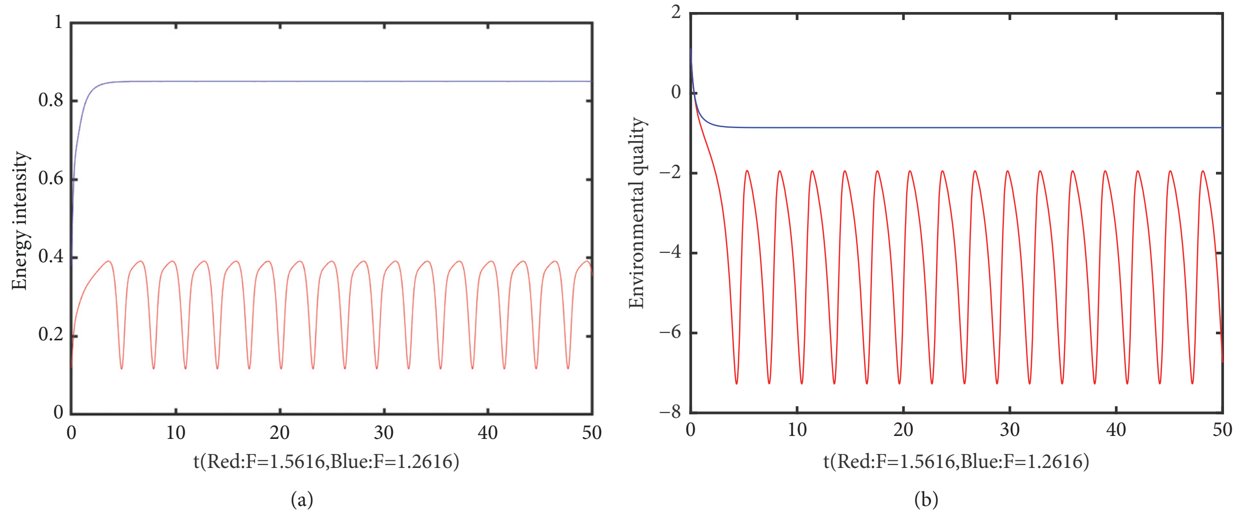

FIGURE 9: The influence of system (1) parameters F on energy intensity and environmental quality: (a) energy intensity and (b) environmental quality.

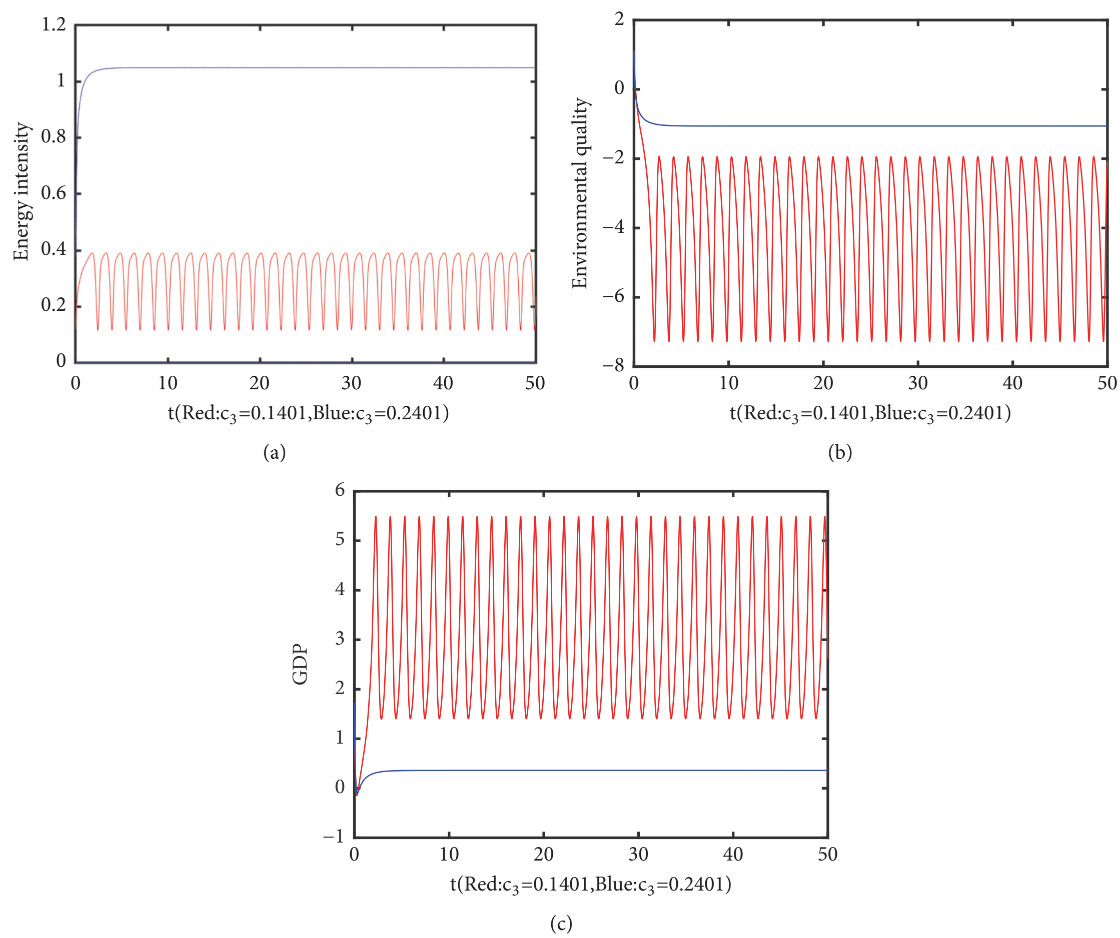

FIGURE 10: The influence of system (1) parameters c_3 on energy intensity and environmental quality: (a) energy intensity, (b) environmental quality, and (c) GDP.

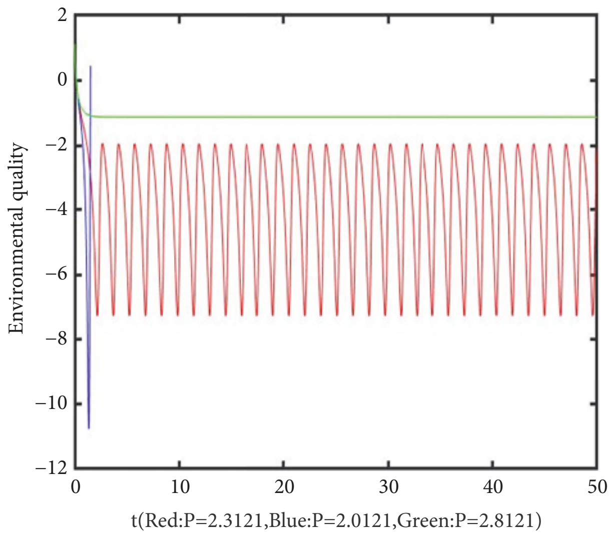

FIGURE 11: The identified system (1): the influence of environmental quality under the different parameters P.

5. Conclusion

In this paper, a model of energy-saving and emission-reduction with environmental constraints is constructed by using dynamic large-scale system modeling method. The stability and complexity of the model are analyzed in depth by applying system science analysis theory, game equilibrium theory, control optimization theory, complex system analysis, and decision-making theory model. Then the environmental quality variables are calibrated by Bayesian estimation, and the system parameters are effectively identified by GA optimized LM-BP neural network method for calibration of variables and official data. Finally, the influence of the change of key parameters on the stability, energy intensity, and environmental quality of the system is analyzed. Therefore, in order to improve the environmental quality, we need to take more measures in parallel, use more means and resources for environmental governance, and ultimately achieve "win-win" between environmental quality and economy.

Data Availability

The numerical simulations data used to support the findings of this study were supplied by LiuWei Zhao under license and so cannot be made freely available. Requests for access to these data should be made to LiuWei Zhao, E-mail address: 136901672@qq.com.

Conflicts of Interest

The authors of this paper have no conflicts of interest.

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