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A New Paradigm for Simulating and Forecasting China's Economic Growth in the Medium and Long Term

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Abstract: Taking the system philosophy of human-earth relationship as the theoretical axis, and under the three-dimensional goals of economic growth, social development, and protection of the ecological environment, this paper constructs the supporting system of China's economic development. On this basis, guided by the basic principles of system theory and system dynamics, and combined with the theories of other related disciplines, we constructed an economic geography-system dynamics (EG-SD) integrated forecasting model to simulate and quantitatively forecast China's economic growth in the medium and long term. China's economic growth will be affected by quantifiable and unquantifiable factors. If the main unquantifiable factors are not taken into account in the simulation and prediction of China's economic growth in the medium and long term, the accuracy and objectivity of the prediction results will be diminished. Therefore, based on situation analysis (Strengths, Weaknesses, Opportunities, and Threats, SWOT), we combined scenario analysis with the Delphi method, and established a qualitative prediction simulation model (referred to as the S-D compound prediction model) to make up for the shortcomings associated with quantitative simulation predictions. EG-SD and S-D are organically combined to construct a simulation and prediction paradigm of China's economic growth in the medium and long term. This paradigm not only realizes the integration of various forecasting methods and the combination of qualitative and quantitative measures, but also realizes the organic combination of unquantifiable and quantifiable elements by innovatively introducing fuzzy simulation of system dynamics, which renders the simulation and prediction results more objective and accurate.

Keywords: economic growth; simulation and prediction; prediction model; fuzzy simulation; paradigm

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1 Introduction

The continuous and long-term high-speed growth of China's economy has created a world miracle, but at the same time, there have been serious contradictions in the relationship between humans and the natural environment, as well as between humans and the social environment. These contradictions have caused China to pay a huge price, which has restricted its economic and social development (Chen, 2010). Therefore, the government and academia are thinking about what the trend in China's economic growth will be in the future. In this regard, how to accurately predict China's economic growth in the medium and long term has become an extremely important issue.

Economic forecasting, especially medium- and long-term economic forecasting, has always been a research topic of economists all over the world. Its proponents claim that it is advantageous in terms of its relative accuracy and rigor. Looking at domestic and foreign eco-

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nomic forecasting, there are more than a dozen qualitative forecasting methods, including Delphi methods, brainstorming methods, subjective probability methods, scenario analysis methods, situation analysis methods, judgment prediction methods, nominal group methods, cross probability methods, and electronic conference methods (Elliott and Timmermann, 2013). There are also dozens of quantitative forecasting methods, which are summarized as follows: input-output analysis (Leontief, 1987), econometric methods (e.g., time series methods and causal analysis methods)) (Freeman and Smith, 2011; Ghysels and Marcellino, 2018), system dynamics methods (Li et al., 2015; Leon et al., 2018), artificial neural network methods (Khashei and Bijari, 2010; Emamgholizadeh et al., 2017), gray system model (GM) methods (Chu and Liu, 2007; Zeng and Luo, 2017), and world economic model methods (Kaneko and Yasuhara, 1986).

Economists, especially econometricians, regularly make economic growth predictions spanning the medium and long term. Even if there are experts in other related disciplines, they cannot really break free from the shackles of pure quantitative prediction 'in economic terms'. In the past, quantitative forecasting mostly used general equilibrium models (Lou, 2015). Factors affecting economic growth in forecasting mainly considered the so-called 'troika', namely the investment-led rate, consumption-led rate, net export-led rate, and total factor productivity (Yu, 2014), which are all quantitative factors. Non-quantitative factors were not considered. In fact, econometric models cannot describe unknown or unobservable variables (Hong, 2007; Feng, 2015). Further, when the economic structure changes, time series data cannot be simply 'summed' for statistical analysis. The characteristics of economic systems and economic data indicate the methodological limitations of econometrics. Indeed, econometric models are more suitable for short-term forecasting (Li and Qi, 2010) and inadequate for medium- and long-term economic forecasting (Hong, 2007).

In addition to economic factors, consideration of the ecological environment, ecological footprint, geopolitical economic environment, and government work efficiency is also required. However, these elements have scarcely been considered in extant medium- and long-term economic forecasts (Phillips, 2005; Pinto, 2009, 2011). They are all components of the complex and open regional system of the human-earth relationship, which is interlaced by the geographic environment system and human activities system (Wu, 1991; Liu, 2018). Thus, the theory of human-earth relationship is expected to guide the selection of factors in medium- and long-term economic forecasts.

Given the current economic forecasts of China mainly lack consideration of non-quantitative elements and spatial thinking, taking the theory of human-earth relationship system as the axis, guided by economic geography theory and system dynamics theory, we adhered to the principles of combining quantitative and qualitative, time and space, past and present, present and future, vertical and horizontal, domestic and foreign, and constructed the modules of China's economic development supporting system. On this basis, we established an 'integrated forecasting model of economic geography-system dynamics (EG-SD)' for quantitative forecasting simulation, and a 'scenario-Delphi compound forecasting model (S-D)' for qualitative forecasting simulation. Combining quantitative and qualitative forecasting simulation organically, a new paradigm of simulation and prediction was established, hoping to improve the accuracy of forecasts of China's economic growth in the medium and long run, and provide a theoretical framework for explaining the supporting elements of China's economic growth.

2 Work Procedure for Simulating and Forecasting China's Economic Growth

To objectively and accurately simulate and forecast China's economic growth in the medium and long term, the work procedure can be summarized in the following aspects (Fig. 1): 1) Build a comprehensive, complete, systematic and scientific economic growth supporting system, which is the basis of economic growth and its prediction. 2) Scientifically define the boundary of the economic growth supporting system. 3) Select various related variables and elements of the economic growth supporting system to create a forecasting model. 4) Distinguish the quantifiable and non-quantifiable variables and elements in the economic growth supporting system to analyze and forecast quantitatively and qualitatively. 5) Collect literature and data for qualitative and quantitative prediction problems and related system variables. 6) Analyze, sieve, process, and apply the col-

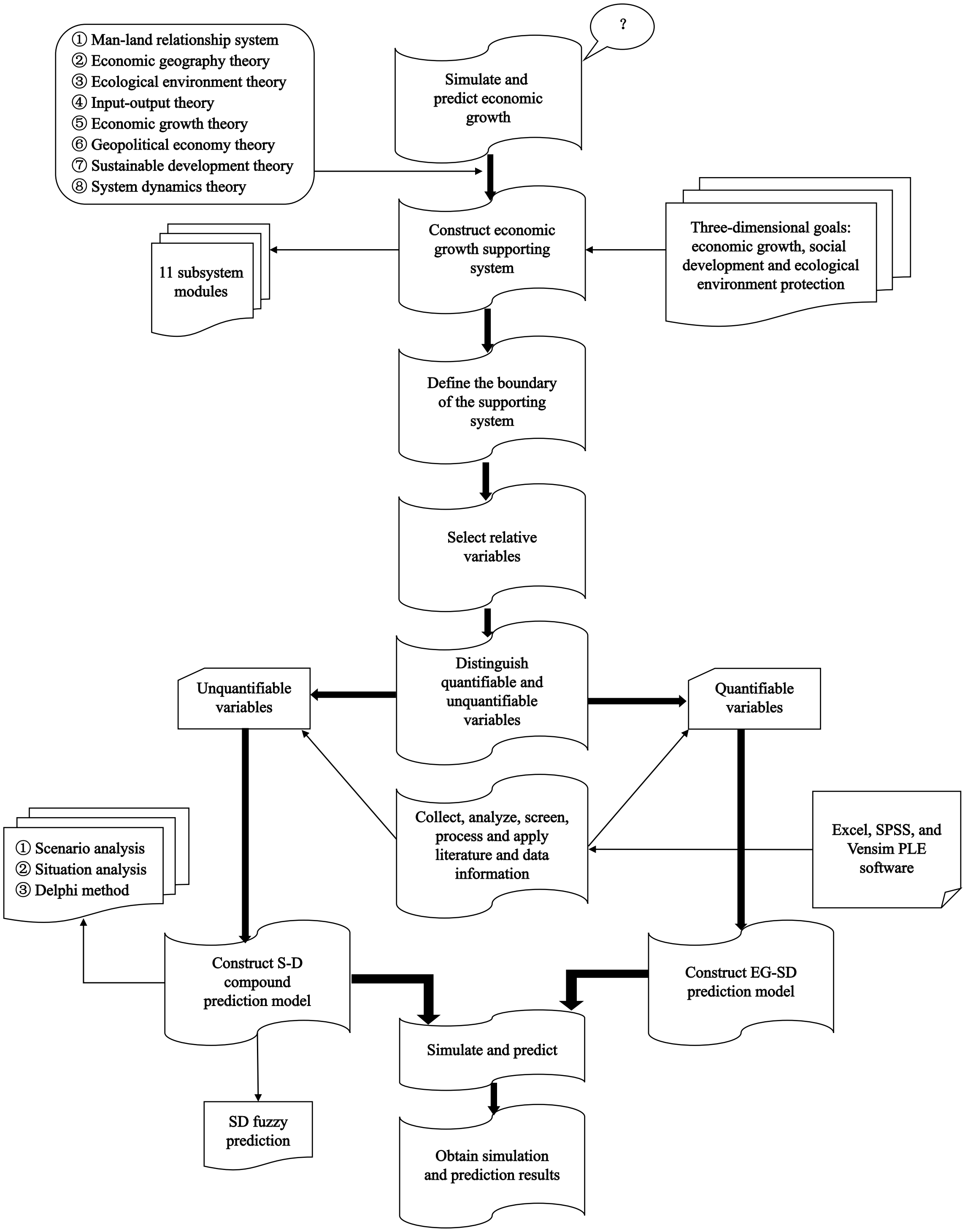

Fig. 1 Paradigm of simulating and forecasting China's economic growth in the medium and long term. 'S-D compound prediction model' means prediction model combining scenario analysis with the Delphi method; 'SD fuzzy prediction' means fuzzy simulation based on system dynamics modelling; 'EG-SD prediction model' represents economic geography-system dynamics integrated prediction model

lected literature and data. 7) Construct the EG-SD integrated prediction model. 8) Construct the S-D compound prediction model. 9) Simulate and forecast. 10) Obtain simulate the prediction results. According to the foregoing, a new paradigm for simulating and predicting China's medium- and long-term economic growth was constructed which is more objective and accurate compared to extant alternatives which have tended to rely on quantitative methodologies rather than adopting mixed-method research designs.

3 China's Economic Growth Supporting System

3.1 Objectives and principles

Before accurately predicting the trend in China's economic growth, it is vital to study the future development and changes in China's economic growth supporting system (CEGSS) and its elements, which are the foundation of paradigm construction. This is because the development of, and changes in, the system functions determine the growth rate of China's economy in the medium and long term (Markusen, 2011; Tan et al., 2016). If a scientific, complete, systematic, and operable economic development supporting system cannot be established, it is impossible to accurately forecast China's economic development in the medium and long term.

China's economic growth supporting system is an extremely complex multi-level and multi-factor system. It involves diverse aspects of the development and changes in human socio-economic activities and natural environmental elements. Therefore, when establishing China's economic development supporting system, it is unrealistic to comprehensively decompose every element in the system. It is necessary to simplify the complexity and grasp the main contradictions. The integration of the elements of the supporting system not only simplifies it, but also maintains the normal operation of the system, thus providing possibilities for simulating China's economic growth in the medium and long term.

China's economic growth supporting system is configured to fulfill two goals: 1) A comprehensive, systematic, open, scientific, rigorous, targeted, and predictable supporting system of economic development, which is the basis for determining whether the established supporting system can solve the given problems. 2) A supporting system which ensures the development of China's economic growth, social development, and ecological environment protection (Tan et al., 2016).

3.2 General framework

As previously demonstrated, when establishing China's economic growth supporting system, it is vital to take the human-earth relationship theory as the guidance. According to the theory of human-earth relationship system, the most active factor in China's economic development is the socialized people distributed in various industries. They promote the development of various industries, and industrial development in turn promotes economic development (Harden, 2012). Besides the industrial system, the supporting system of China's economic development also includes the resources and environment system, and the population and society system. The former provides space, material, and energy for the development of the industrial system, while the latter provides investment, production, consumption, science and technology, infrastructure, and development mode for the industrial system. The population and society system is superimposed on the resources and environment system. The two systems are interdependent and form a complex system with the industrial system, supporting economic development. Therefore, only the coordinated development of the industrial system, resources and environment system, and population and society system can promote the sustainable growth and development of China's economy (Lu and Guo, 1998).

The above relationships among the industrial system, population and society system, and resources and environment system reveal the interactions among economic growth, social development, and ecological environment protection (three-dimensional goals). Accordingly, we designed and constructed the general framework of China's economic growth supporting system under the three-dimensional goals (Fig. 2).

3.3 Subsystems and modules

According to the principle of system dynamics (Guan et al., 2011; Hwang et al., 2013; He et al., 2017), within the general framework of China's economic development supporting system, the comprehensive factors affecting and supporting China's economic development were considered. The system was designed to contain 11 modules. The population and society subsystem includes 1) economic growth-population system module; 2) economic growth-urbanization system module; 3) economic growth-market system module; 4) economic growth-science and technology innovation drive system module; 5) economic growth-government system module; 6) economic growth-international geopolitical economic system module. Resources and environment subsystem includes 7) economic growth-natural re-

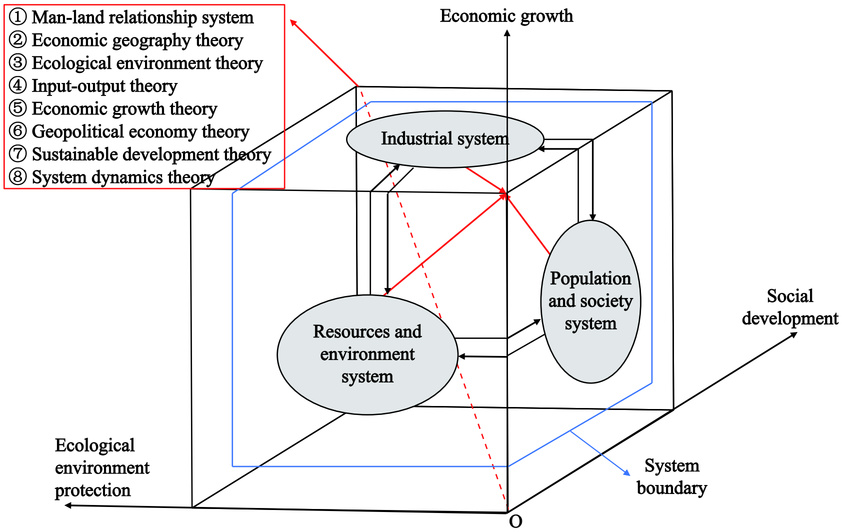

Fig. 2 General framework of China's economic development supporting system

sources system module; 8) economic growth-energy system module; 9) economic growth-ecological environment system module; 10) economic growth-ecological footprint system module. Industrial subsystem includes 11) economic growth-industrial system module. The systematic relationship between China's economic development supporting system and its subsystem modules is shown in Fig. 3.

4 Simulation and Prediction Paradigm

The simulation and prediction of China's economic growth in the medium and long term involves quantitative and qualitative methodologies pursuant of achieving the objective of accurate prediction results.

4.1 Construction of quantitative prediction model: EG-SD integrated prediction model

4.1.1 The EG-SD integrated prediction model

Based on human-earth relationship system theory, system dynamics, and other related theories (Wu, 1991; Li et al., 2015; Liu, 2018), the supporting system of China's economic development is composed of population, resources, energy, ecological environment, industry, urbanization, market, scientific and technological innovation, government, geopolitical economy, and ecological footprint. Each subsystem module is composed of its own subsystem, forming a network system with the characteristics of economic geography, such as aggregation, hierarchy, correlation, purpose, openness, dynamics, and environmental adaptability. The system

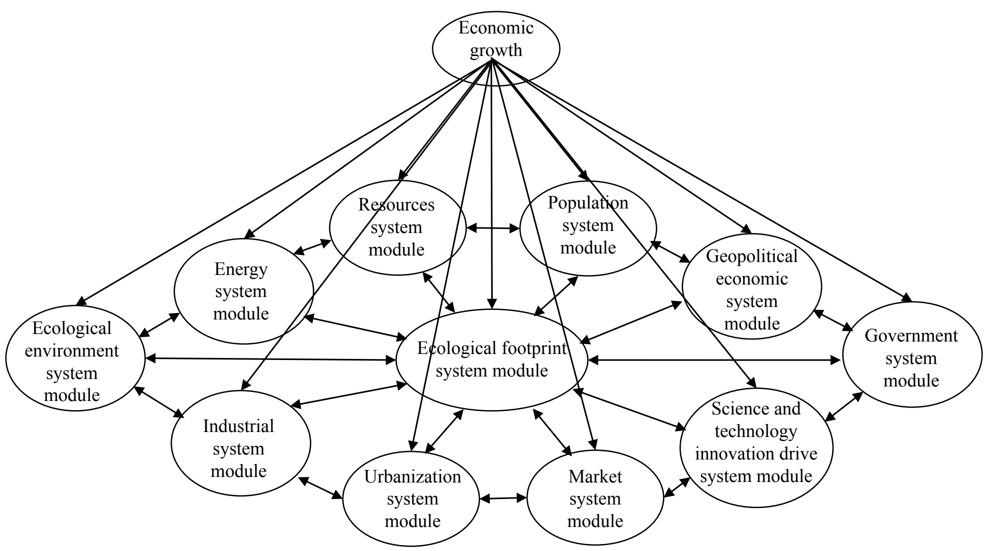

Fig. 3 The systematic relationship between China's economic development supporting system and its subsystem modules

model can be simply described as per Equation (1):

$$CEGSS = \{[Q_{CEGSS}, (\delta_{CEGSS})], [\beta_Q]\} \tag{1}$$

where $CEGSS$ is the supporting system of China's economic development, Q_{CEGSS} represents the subsystems of $CEGSS$, δ_{CEGSS} is the intra-relationship of the subsystems, and β_Q is the inter-relationship of the subsystems.

According to the principle of system dynamics, the mathematical expression of the overall structure of the system dynamics prediction model of China's economic development supporting system is as per Equation (2):

$$CEGSS = \cup_{i=1} S_i [S_i = (L, R, A.\lambda, t)] \tag{2}$$

where L is the state variable, R is the rate variable, A is the auxiliary variable, λ is the parameter, and t is the time variable. According to the principle of positive and negative feedback loop, the model equation is designed. When determining the reference behavior pattern and parameters, a variety of curve models are used to assist simulation. Therefore, this model can be referred to as the Integrated Prediction Model of Economic Geography-System Dynamics (EG-SD).

4.1.2 The system dynamics of the EG-SD integrated prediction model

(1) Causality in the EG-SD integrated prediction model

The EG-SD integrated prediction model constructed under the 'three-dimensional target' includes three subsystems and 11 subsystem modules. The operation of each system module depends not only on its internal structure, but also on its connection with external environment elements. Changes in one system module will be fed back to others, and each module will influence, restrict, and promote each other to realize the overall function of the system. Eleven subsystem modules and their causal feedback are described below.

1) Population system: original power of CEGSS. GDP growth cannot be separated from population, which is both the producer and the consumer. From the perspective of production, economic growth needs a labor force, and sufficient labor resources are conducive to economic development, otherwise they hinder economic development. The interaction forms a positive feedback loop: GDP → + total population → + labor resources → + per capita output → + GDP. From the perspective of consumption, the larger the population, the larger the final consumption expenditure, driving the growth of GDP and forming a positive feedback loop: GDP → + total population → + final consumption expenditure → + proportional contribution of final consumption to GDP → + GDP.

2) Urbanization system: driving engine of CEGSS. Increases in GDP promote the development of urbanization, which in turn promotes economic growth and improves the proportional contribution to economic growth (when the urbanization level < 70%, according to Northam (1979) 's 'S-curve of urbanization process' model). It promotes GDP growth and forms a positive feedback loop: GDP → + urbanization level → + economic growth rate → + proportional contribution of urbanization level to economic growth → + GDP.

3) Market system: configuration platform of CEGSS. Economic growth is inseparable from domestic and international markets. The growth of GDP promotes the development of domestic wholesale and retail industries, which in turn promotes the growth of GDP, forming a positive feedback loop: GDP → + domestic wholesale and retail industries→ + GDP. GDP growth promotes the development of foreign trade in the international market, expands the scale of imports and exports, and promotes net exports. The larger the scale of net exports, the greater the proportional contribution to economic growth, and the greater the amount of economic growth, forming a positive feedback loop: GDP → + foreign trade → + GDP.

In fact, large net export trade surpluses (total exports > total imports) over a significant time period can easily cause friction with relevant trading partners, while a trade deficit (total exports < total imports) will affect the normal and effective operation of the national economy. A small trade surplus is conducive to the sustainable development of the national economy.

4) Driving system of science and technology innovation: endogenous power of CEGSS. GDP growth needs the support of science and technology. With the growth in GDP, R & D expenditure increases, and thus the scale and scope of scientific and technological innovation is enhanced. The greater the proportional contribution of scientific and technological innovation to economic growth, the higher the economic growth rate, forming a positive feedback loop: GDP → + R & D expenditure → + proportional contribution of scientific and technological innovation to economic growth → + GDP.

5) Government system: control center of CEGSS. The so-called 'troika,' namely investment, consumption, and exports, plays an important role in promoting economic growth. To optimize the structure of the 'troika,' the government's scientific macro-control plays a leading role. GDP growth promotes the development of the 'troika,' which in turn promotes GDP growth, forming a positive feedback loop: GDP → + the 'troika' of economic development → + GDP.

6) Geopolitical economic system: international environment of CEGSS. With the growth in GDP, China's international geopolitical and economic status has improved. The use of foreign capital is the catalyst which accelerates China's economic development, improving the proportional contribution of economic growth, stimulating the economic growth rate, and promoting GDP growth, which forms a positive feedback loop: GDP → + use of foreign capital → + contribution rate of foreign capital to economic growth → + economic growth rate driven by actual use of foreign capital → + GDP. In addition, China's international geopolitical and economic status has improved, the international market scale has been enlarged, and the import and export trade has expanded, which has promoted the growth of GDP and formed a positive feedback loop. This causal relationship is also reflected in the market system-configuration platform of CEGSS: GDP → + foreign trade → + GDP.

7) Natural resource system: material basis of CEGSS. Economic growth consumes mineral and water resources. Excessive consumption of these resources will cause supply shortages, which becomes a bottleneck restricting economic development and forming a negative feedback loop: GDP → + mineral and water resources consumption → − mineral and water resources supply → − GDP. Economic growth also needs land resources. The effect of land resources on economic growth will be discussed below in the context of the ecological footprint system.

8) Energy system: energy power of CEGSS. Economic growth consumes energy. Excessive energy consumption will cause energy shortages and insufficient energy supply, which becomes a bottleneck restricting economic development and forming a negative feedback loop. GDP→+energy consumption→−energy supply→−GDP.

9) Ecological environment system: space platform of CEGSS. GDP growth promotes investment in environmental governance, improving environmental quality, and promoting sustainable development, which forms a positive feedback loop: GDP → + environmental governance investment → + GDP.

10) Ecological footprint system: barometer of CEGSS. GDP growth promotes per capita GDP growth, the per capita ecological footprint increases correspondingly, the per capita biological carrying capacity decreases, and the per capita ecological deficit increases, which constrains economic development to a certain extent, forming a negative feedback loop: GDP → + per capita GDP → + per capita ecological footprint → − per capita biological carrying capacity → + per capita ecological deficit → − GDP. Ecological footprint is the barometer of the quality of economic development. It reveals the relationship between economic development and the ecological environment.

11) Industrial system: the symbol of development of CEGSS. From the perspective of production, the symbol of GDP growth is industry, and the industrial system is the development foundation of the GDP growth supporting system. GDP growth promotes industrial development, which in turn promotes GDP growth, forming a positive feedback loop: GDP → + industrial development → + GDP.

It should be noted that: 1) As per the use of foreign capital and foreign investment, import and export trade can reflect the systematic effect of international environment-geopolitical economy. It is more appropriate to consider import and export trade in the configuration platform-market system, and consider the use of foreign capital and foreign investment in the international environment-geopolitical economic system. 2) There is an impact of the non-quantitative international environment-geopolitical economic system (e.g., international political and economic deterioration, trade wars, and civil conflicts) and control center-government system on economic growth. We will use relevant modeling methods to conduct qualitative analysis and scientific diagnosis, to make the prediction closer to reality.

Through the description of the subsystem modules and their causal feedbacks, we used Vensim PLE® software, developed by Ventana Systems, Inc. in the U.S.A., to draw the causality diagram of the EG-SD integrated prediction model of China's medium- and long-term economic growth system (Fig. 4).

(2) Flow chart of the EG-SD integrated prediction

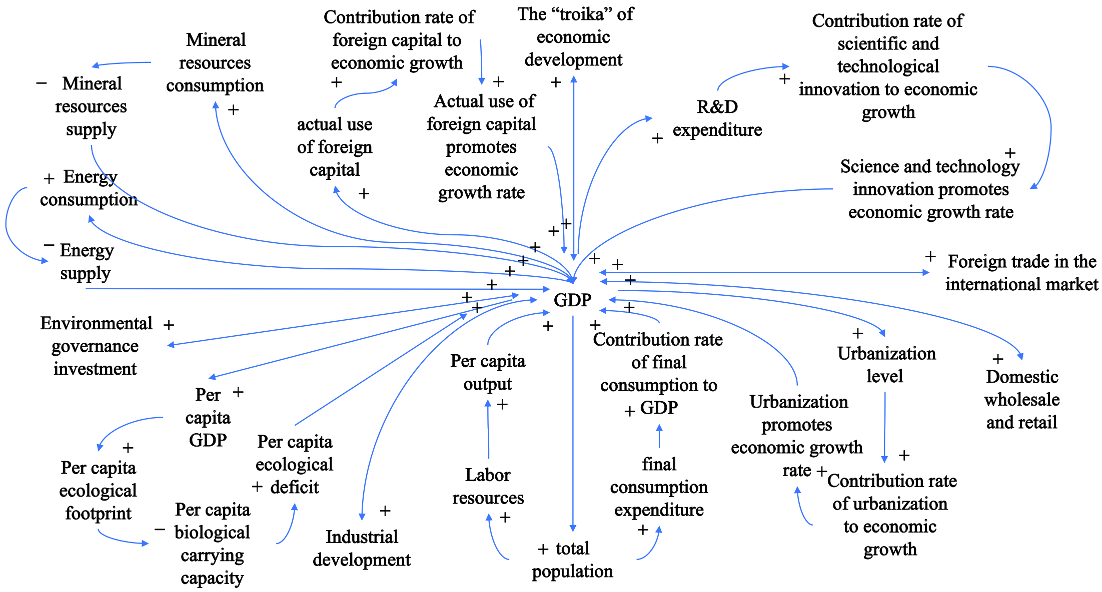

Fig. 4 Causality diagram of the economic geography-system dynamics integrated prediction model. 'GDP' means 'gross domestic product'; 'R & D' means 'research and development'

model

Based on the causality analysis and subsystem design of the above main variables, a flow chart of the EG-SD integrated prediction model of China's medium- and long-term economic growth system was drawn using Vensim PLE (Fig. 5). The number of variables involved in this model was large (nearly 400 variable indexes including the initial value). Excel, SPSS, and Vensim PLE were used to simulate and predict some variables, which not only reduced the number of variables in the flow diagram of the prediction model, but also simplified the simulation and prediction process, and at the same time ensured prediction accuracy. The simplified model involves 232 variables, which can be divided into six categories: state (level) variable (L), rate variable (R), auxiliary variable (R), constant (C), initial value (N), and time variable (T).

Due to the long time-span of collecting relevant data, some variable indicators were not consistent in statistics. The relevant data were unified. Year data of some variable indicators were missing and the missing value analysis function in SPSS was used for interpolation.

The collected data were processed and fitted to determine the relationship between related variables, and SD formula variables in the model were assigned. The main assignment methods are as follows: 1) use SPSS and Excel to determine the relationship between different variables through curve fitting; 2) use the entropy method to determine the relationship between the two related variables; 3) use the Vensim PLE to directly assign values to related variables with the table function method; 4) for some auxiliary variables or parameters that are difficult to determine, use the empirical estimation method or average value method to take their approximate values.

4.2 Construction of qualitative prediction model: S-D compound prediction model

China's economic growth in the medium and long term will be affected not only by quantifiable factors but also by non-quantifiable factors, which will promote, delay, and even block China's economic development. China's GDP growth rate was 6.6% in 2018 and 6.1% in 2019, which was 0.5% lower than that in 2018 (National Bureau of Statistics, 2020). Further, the trade war launched by the United States has generated profound negative impacts on China's economic growth (Li and Liu, 2019). On the basis of SWOT (Strengths, Weaknesses, Opportunities, and Threats, Lou, 2012), combining scenario analysis with the Delphi method, a qualitative prediction simulation model (the S-D compound prediction model) was established to make up for the deficiency of quantitative simulation and prediction.

4.2.1 Trend analysis of China's economic growth in the medium and long term

Based on the 11 subsystem modules of China's economic growth supporting system, and referring to Zeng and Wang (2007), Habermann and Padrutt (2011), Banister

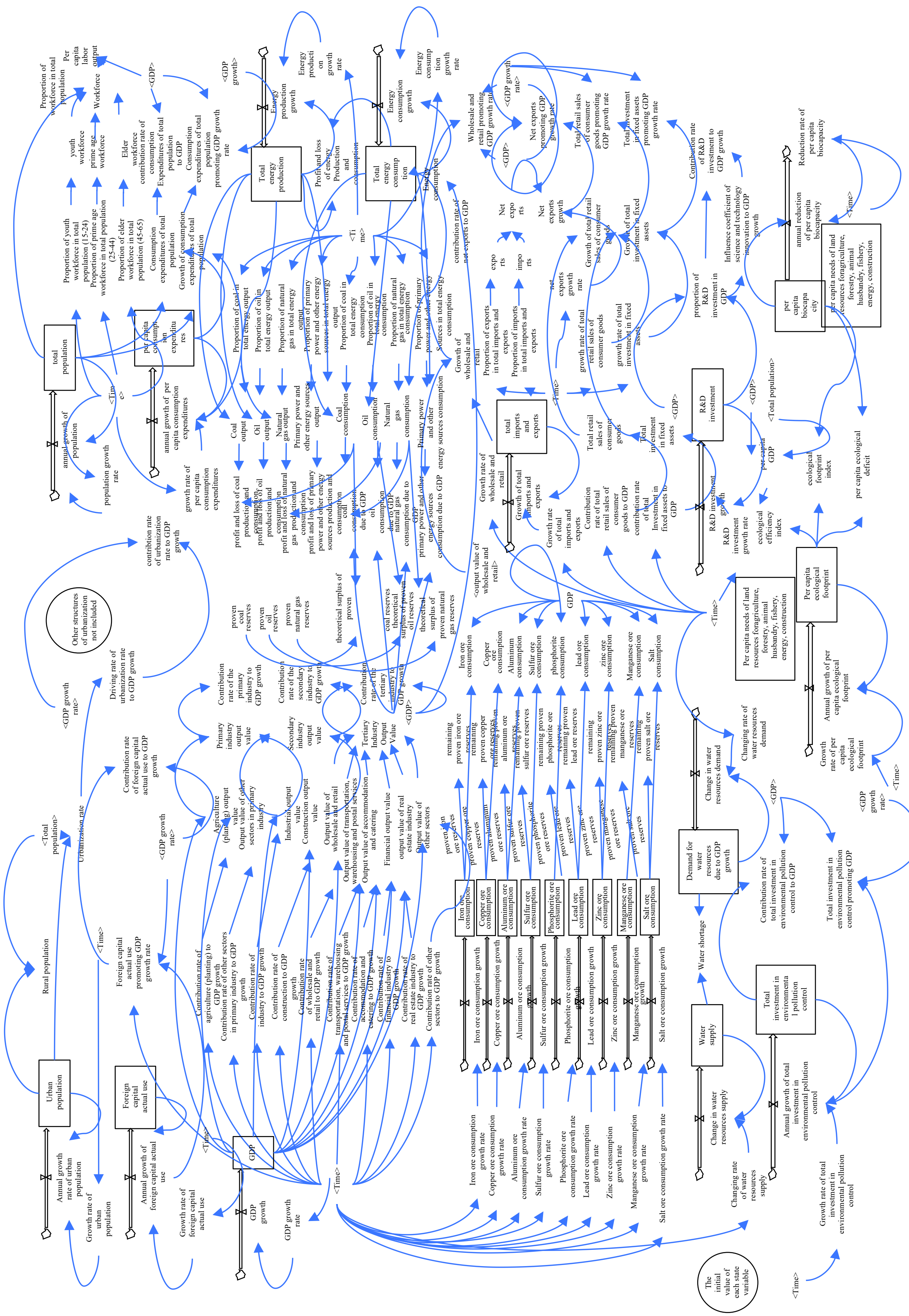

Fig. 5 Flow chart of economic geography-system dynamics integrated prediction model

et al., (2012) and Ke (2015), *etc*., we comprehensively considered the main factors affecting economic growth, and used the SWOT matrix to evaluate and analyze China's economic growth in the future, so as to lay the foundation for the situation scenario design of China's economic growth in the medium and long term (Table 1).

4.2.2 Scenario analysis of China's economic growth in the medium and long term

After China's economic growth reaches a certain scale in the future, it is inevitable that the economic growth will continue to slow down. The reasons are complex and diverse. Considering the 11 subsystem modules of China's economic growth supporting system, there are 12 main factors that will affect China's economic growth in the future: 1) economic and institutional reform; 2) technological innovation and efficiency; 3) conversion of the new and old kinetic energy; 4) economic structure; 5) urbanization quality; 6) total factor productivity; 7) economic growth potential; 8) comprehensive resource utilization; 9) ecological environment protection; 10) Taiwan issue; 11) China-US relations; 12) international geopolitical and economic environment (Yu, 2014; Zhang et al., 2015; Ma, 2018; Randers, 2018; Fan et al., 2019; Lee and Xuan, 2019; Liang and Yang, 2019; Zhang and Wang, 2019; Zhou et al., 2020) (Table 2).The development and changes of each factor are uncertain, and there are three scenarios (optimistic, normal, and conservative) of China's economic growth in the medium and long term. The reality could be among the three.

4.2.3 Determination of China's economic growth rate

Based on the situation and scenario analysis of China's medium- and long-term economic development, combined with other countries' economic development history and lessons (Kuznets, 1988; Pike and Tomaney, 2009; Aoki, 2012), as well as the cycle law of China's economic development evolution, an expert questionnaire was designed on China's economic growth rate in the medium and long term. The growth rate of China's economy in different historical stages and scenarios in the future was finally determined after several rounds of solicitation and feedback by way of the Delphi method.

We conducted qualitative evaluation and prediction on the relative and main non-quantifiable factors of quantitative simulation and prediction from theory and practice, to achieve the combination of qualitative and quantitative prediction, and improve accuracy. The S-D compound prediction model is shown in Fig. 6. It can be seen that the simulation process of the S-D compound prediction model is actually a process of logical thinking, reasoning, and judgment. In addition, for the impact of some non-quantifiable factors on China's economic growth in the future, such as the effect of international geopolitical and economic environment and government work efficiency, we can also use the S-D model to make fuzzy simulation and prediction to improve the accuracy of qualitative analysis.

5 Discussion

Quantitative methods of economic forecasting have their own advantages, but they also have shortcomings. In regression analysis, time series methods, and macro econometric modeling, the main variables considered are the 'troika' (investment-led rate, consumption-led rate, net export-led rate) and total factor productivity, which are all quantitative forecasts, without considering the influence of non-quantitative factors. The total factor productivity growth rate is not the productivity of all factors, and can only be used to measure the productivity growth of pure technological progress except all tangible production factors, and therefore is not suitable for predicting medium- and long-term economic growth. GE models put forward a lot of assumptions, which are contrary to the facts. CGE models are initially applied to satisfy in mathematical conditions, not in economic ones, and the assumptions put forward in the construction of the models are not realistic. For DSGE models, some key phenomena, especially non-quantitative phenomena, are not included in the model, and the calibration method and parameter estimation method used are also not perfect.

Against this backdrop, this research first constructed the modules of China's economic development supporting system. Then, an economic geography-system dynamics (EG-SD) integrated forecasting model was created and applied to quantitatively forecast China's economic growth. In addition, scenario analysis and Delphi method was combined to form a qualitative prediction simulation model (S-D). The quantitative and qualitative forecasting model were integrated to make simulation and prediction results more objective and accurate. The research has revealed that:

(1) The supporting system of China's economic de-

Table 1 'Strengths, Weaknesses, Opportunities, and Threats' analysis of China's economic growth in the medium and long term

Aspects	Factors affecting China's economic growth in the medium and long term
Strengths	1) Superior geographical location
	2) Complete range of natural resources
	3) Rich Human resources
	4) Strong leadership of the party and government
	5) Rapid urbanization
	6) Large economy
	7) Complete categories in manufacturing system
	8) Broad market resources
	9) Great potential for domestic investment
	10) Large number of researchers
	11) Large R & D investment
	12) Increasing geopolitical and economic status
Weaknesses	1) Relatively low per capita resources
	2) Increasingly scarce resources and energy
	3) Serious environmental pollution
	4) Large gap between urban and rural areas
	5) Employment shortage due to rapid urbanization
	6) Not-in-place supply-side structural reform
	7) Relatively unreasonable industrial structure
	8) Relatively blind, lagging and volatile market regulation
	9) Weak ability to transform scientific achievements
	10) Relatively slow development of 'Internet+'
	11) Trade protectionism hindering economic development
	12) Increasingly complex international geopolitics
Opportunities	1) Great reform and adjustment
	2) Great consumption and market and 'economic effects of great powers' construction
	3) 'Great depth' and multiple growth pole construction
	4) 'Great talent' and second demographic dividend construction
	5) 'Great innovation' and technology dividend construction
	6) 'Great upgrade' and upgraded china's economy construction
	7) 'Great open' and global layout of china's economy
	8) 'Great scale' and new urbanization
	9) 5G era and the fourth industrial revolution (big data)
	10) Environmental protection and green economic development
	11) World geopolitical and economic relations reconstruction
	12) Opportunities presented by the trade war between china and us
Threats	1) Aging population
	2) Vanishing demographic dividend and labor advantage
	3) Resource shortage
	4) Arduous task of improving the ecological environment
	5) Long-standing gap between urban and rural areas
	6) Enormous employment pressure
	7) Supply-side structural reform
	8) Goals set at the 19th national congress of the Communist Party of China
	9) Increasingly fierce international innovation competition
	10) Reconstruction of the international industrial division of labor pattern
	11) China-us relations and taiwan issue
	12) Increasingly complex international geopolitical and economic environment
SO (Strengths-opportunities) Strategy	Make use of advantages, seize all kinds of opportunities, and achieve efficient economic development with low cost of input
WO (Weaknesses-opportunities) Strategy	Transform development mode, turn weaknesses into strengths, and promote economic development
ST (Strengths-threats) Strategy	Give full play to advantages and stem challenges, use our strengths to overcome others' weaknesses, and achieve economic development through competition
WT (Weaknesses-threats) Strategy	Overcome disadvantages, avoid challenges, promote self-innovation and self-improvement, and boost economic development

Table 2 Scenario analysis of China's economic development in the medium and long term

Situational supporting system	Optimistic scenario	Normal scenario	Conservative scenario
Economic and institutional reform	Overall success	Basic success	Lack of success
Technological innovation and efficiency	Rapid rise	Medium rise	Slow rise
Conversion of the new and old kinetic energy	Smooth	Basic smooth	Not smooth
Economic structure	Optimized	Relatively optimized	Unreasonable
Urbanization quality	High	Medium	Low
Total factor productivity	High	Medium	Low
Economic growth potential	Full release	Successful release	Slow release
Comprehensive resource utilization	Intensive and efficient	Relatively good	Common
Ecological environment protection	Good	Relatively good	Common
Taiwan issue	Peaceful reunification	Unification by force	No unification
China-US relations	Competition and cooperation	Competition	Vicious competition
International geopolitical and economic environment	Optimization	Normality	Deterioration

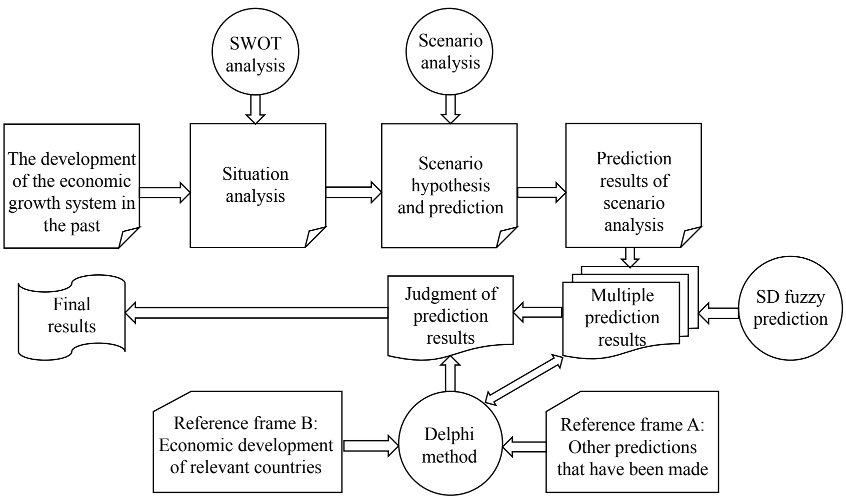

Fig. 6 Workflow of qualitative prediction using scenario-Delphi compound forecasting model. 'SWOT' represents Strengths, Weaknesses, Opportunities, and Threats; 'SD fuzzy prediction' means fuzzy simulation based on system dynamics modelling

velopment is composed of 11 subsystem modules, i.e., population, resources, energy, ecological environment, industry, urbanization, market, scientific and technological innovation, government, geopolitical economy, and ecological footprint. The operation of each subsystem module depends not only on its internal structure, but also on its connection with external environment elements. Their interactions confirm the three-dimensional goals of economic growth, social development, and ecological environment protection.

(2) In accordance with the 11 subsystem modules, the main factors that will affect China's economic growth in the medium and long term include: 1) economic and institutional reform; 2) technological innovation and efficiency; 3) conversion of the new and old kinetic energy; 4) economic structure; 5) urbanization quality; 6) total factor productivity; 7) economic growth potential; 8) comprehensive resource utilization; 9) ecological environment protection; 10) Taiwan issue; 11) China-US relations; 12) international geopolitical and economic environment. The development and changes of each factor are uncertain, and the reality could be among the three scenarios of the optimistic, normal, and conservative.

We conducted qualitative evaluation and prediction on the relative and main non-quantifiable factors of economic simulation and prediction, so as to lay the foundation for the situation scenario design of China's economic growth in the medium and long term, and make up for the deficiencies of merely using quantitative methods in economic forecasting.

6 Conclusions

Guided by the system philosophy of human-earth relationship and the three-dimensional goals of economic growth, social development, and protection of the ecological environment, this research constructed the subsystem modules of China's economic growth supporting system, and comprehensively considered the main factors affecting China's economic growth. Combining scenario analysis and Delphi method, a qualitative prediction simulation model was constructed to improve the accuracy of forecasting China's economic growth in the medium and long run. The research has the following innovations:

(1) Construction of the EG-SD integrated prediction model. The supporting system of China's economic development under the three-dimensional target is built. On this basis, the EG-SD integrated model for quantitative prediction is constructed.

(2) Comprehensive integration of multiple forecasting model and methods. The paradigm fully considers the quantifiable and non-quantifiable variables influencing China's economic growth in the medium and long term, and builds the economic growth prediction model in qualitative and quantitative terms, realizing the comprehensive integration of various forecasting model and methods.

(3) Simulation, forecast, and analysis of the key factors affecting the trend of economic growth. The paradigm fully considers the characteristics of the key factors affecting the trend in economic growth, and carries out simulation, prediction, and analysis on population change, new urbanization development, economic inertia growth, the reference frame of the economic growth forecast, the reference frame of classic cases of foreign economic growth, the law of the economic development cycle, the efficiency of government work, and the international geopolitical and economic environment. It provides a new vision for the simulation and prediction of GDP growth rate.

(4) Application of S-D model fuzzy simulation. The paradigm fully considers the important influence of non-quantifiable variables on China's economic growth in the medium and long term, and uses the S-D model to conduct fuzzy simulation, which provides a new reference and perspective for qualitative prediction and analysis.

(5) Organic combination of multiple levels. The paradigm focuses on the supporting system that will affect China's medium- and long-term economic growth. Under the guidance of the human-earth relationship system theory and other related theories, in the process of designing the economic growth supporting system, variable selection, simulation and prediction, it has realized the organic combination of quantitative and qualitative, time and space, past and present, present and future, vertical and horizontal, domestic and foreign.

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