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# *Research on Inclusive Green Growth Based on SD-based Industrial Intelligence*

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***Abstract:*** Since the reform and opening up, along with the policy dividend, China's economy has developed rapidly. However, in recent years, with the change of international environment and the adjustment of domestic economic structure, economic development has entered a stage of low-speed growth, mainly manifested in the decline of population, the decline of marginal return on capital and the severe situation of energy and environment, the pressure of energy conservation and emission reduction has been increasing, and the urban-rural income gap has aroused social concern. It shows that the factor-driven economic growth model can no longer meet the requirements of high-quality economic development, and the inclusive green growth model that takes into account green, inclusive and growth provides an opportunity to solve these problems. In this paper, the causal loop diagram and system dynamics flow diagram of dynamic evolution are constructed, and the system dynamics method is used to sort out the dynamic complexity of inclusive green growth and the multi-order nonlinear multi-factor system, and the systematic dynamic model is simulated by different scenario schemes.

## 1. Introduction

Industrial intelligence has a great impact on inclusive green growth. First of all, the penetration characteristics of industrial intelligence have a far-reaching impact, even if artificial intelligence is currently only applied locally, but its huge penetration will gradually form a global influence.

Secondly, the realization of industrial intelligent technology replacement will fully reflect the important role of "intelligent capital", and also reflect the interaction process between this element and land, labor, energy and other factors, thus affecting the factor allocation structure, and then affecting income level, energy saving and emission reduction. At the same time, when the total amount of artificial intelligence capital continues to increase, Its support and influence in economic development will continue to increase. Third, the input-output efficiency formed by the collaborative characteristics of artificial intelligence continues to rise, the total factor productivity increases simultaneously, and the overall profit surplus of enterprises continues to rise. Finally, knowledge production is the greatest manifestation of the creativity of artificial intelligence, and the development of technology inevitably requires the adjustment of the factor structure, which will eventually be reflected in the change of the bias of technological progress, thus affecting inclusive green growth.

There are many literature studies on this topic, such as Mao et al.,[1] based on panel data from 282 cities in China from 2006 to 2019. They first examined the effectiveness of the natural resource carbon curse phenomenon and also explored its heterogeneity. Furthermore, this article uses a threshold effect model to investigate the nonlinear impact of natural resource dependence on carbon emission intensity in various stages of industrial intelligence development (i.e. low, medium, and high stages). Xu et al.[2] used the database of Chinese A-share listed companies from 2012 to 2019 to focus on 813 highly polluting enterprises, and examined the impact of industrial intelligence on green transformation through a bidirectional fixed effect model. Wu et al. [3]constructed an industrial intelligence system from three aspects to explore the relationship between industrial intelligence and energy intensity in China from 2006 to 2018. Yuan et al.[4] used a fixed effects model and data from the International Federation of Robotics (IFR) and Chinese A-share listed companies from 2011 to 2019 to empirically analyze the impact of industrial intelligence on enterprise capacity utilization. Wang et al.[5] used the super efficiency SBM model of unexpected output to measure the efficiency of high-quality industrial development in China, analyzed the spatiotemporal evolution and heterogeneity of industrial high-quality development efficiency, and constructed a panel multiple regression model to analyze the driving effect of its influencing factors on the high-quality industrial development in China.

## 2 Overview of System Dynamics Model

System dynamics takes feedback information and feedback system as the core, and constructs a multilevel feedback loop through the causal relationship between different elements of the system, so as to clarify the relationship structure of complex systems, and analyze the change mode and form of system behavior under the interaction of elements. Its advantages are embodied in the following aspects: First, the information feedback function, system information feedback is the key to the smooth operation of the whole system, and all system behaviors come from the internal structure of the system, on this basis, a closed system is formed, so that the system operation is no longer limited to high-precision and multi-data input; The second is to focus on the dynamic trend of the research object, and the system variable of the study is no longer the specific value of a certain year; The third is the flexible applicability of the research method and the expansion of the research object. In the process of processing, it is found that the problems with low accuracy and few data can be solved flexibly and quickly, and it can play a certain role in predicting and simulating the periodic and long-term matters. The fourth is the simulation function. As an important method for system dynamics to solve complex problems, simulation technology optimizes the selection of problem solving strategies by setting various policy scenarios. Because economic, social, and environmental systems are complex, the impact of industrial intelligence on

inclusive green growth includes not only economic growth, but also multidimensional, multi-variable, multi-directional feedback loops and nonlinear complex system issues such as energy, society, and the environment. A system dynamic model can be established according to the dynamic trend of industrial intelligent development, identify the causal dynamic relationship between industrial intelligent development and inclusive green growth, and make predictions. Through the system dynamics modeling based on the development trend of industrial intelligence, it reflects the internal causal dynamic relationship between industrial intelligence and comprehensive green growth, predicts the future development path of comprehensive green growth, and uses simulation technology to select the most appropriate strategy to provide realistic solutions to the problems arising in the complex system of industrial intelligence and inclusive green growth.

In this study, firstly, the simulation purpose of the system structure is to identify the impact path of industrial intelligence on inclusive green growth; Secondly, by defining the category of the system, the causal path between economy, society, energy and environment is fed back to form a system affecting environmental quality. Then, on the basis of clarifying the impact of industrial intelligence on inclusive green growth path, the causal relationship feedback chart is constructed. Thirdly, according to the systematic dynamic flow diagram model, the subsystems of economic growth, energy environment and social development are taken as key elements to simulate the development situation of the system. Finally, in-depth analysis of the impact of industrial intelligence on inclusive green growth.

## 3. System Dynamics Model Construction

(1) Causality analysis

The establishment of a scientific and logical causal loop diagram is the guarantee of the stable operation of the system dynamics model. In order to describe the relationship between various elements in more detail and concretely, the causal loop diagram, as a kind of spectrum that qualitatively describes the system structure, plays an important role in analyzing the system dynamics and system behavior. The causal loop diagram can reveal the feedback relationship between various elements through the causal chain, so as to study the internal causal relationship of the dynamic changes of the system. This chapter determines the structure of the system through the in-depth analysis of the research content and objects, and grasms the causal chain between the constituent elements of the system and the system boundary of each subsystem in the systemic dynamic evolution process of industrial intelligence affecting inclusive green growth. Explore the causal relationship between various elements, and deeply analyze the positive and negative feedback and constraints between various elements. Finally, Vensim Dss, a system dynamics software, was used to construct a causal loop diagram based on the impact of industrial intelligence on inclusive green growth.

As the material basis of other systems, the economic growth subsystem can promote population agglomeration and social development, and promote the increase of urbanization rate, which increases energy consumption and puts pressure on the ecological environment. The feedback loop of economic urbanization subsystem is mainly positive feedback relationship. The main feedback relationship is as follows: From the perspective of GDP and its influencing factors, the growth of tertiary industry, high-tech enterprises and private economy drives the growth of GDP. From the perspective of urbanization and its influencing factors, the increase of urban population will promote the increase of urbanization rate, and the increase of fixed asset investment will drive the improvement of urban infrastructure and promote the increase of urbanization rate. From the perspective of private economy and its influencing factors, the increase of urban population promotes the improvement of higher education and increases the output value of high-tech

enterprises. At the same time, the growth of GDP brings the increase of fiscal revenue, and the increase of government investment in research and development will also promote the increase of output value of high-tech enterprises.

At the same time of economic growth, improving the regional innovation level can promote high-quality economic development and reduce the pressure on the ecological environment. The most important manifestation of the increase of urbanization rate is the rapid increase of population in cities and towns, which leads to the rapid increase of consumption, resulting in the increase of energy consumption and pollution emission, which brings great pressure to the limited urban environmental capacity. The feedback relationship of the socialization subsystem is also positive. From the perspective of urban population, the growth of GDP will increase fiscal revenue, bring about the improvement of road infrastructure, educational facilities and medical facilities, and promote the increase of urban population. At the same time, the increase in financial investment will improve the conditions of industrial intelligence, promote the development of high-tech industries, and further drive the increase of GDP.

There is an interaction between the environmental subsystem and urbanization. The rapid development of urbanization will cause damage to the ecological environment, and the increasing pressure on the ecological environment will compress the capacity of urbanization development. The feedback relation of eco-environmental pressure subsystem is negative. The growth of urban population will put pressure on the urban ecological environment, such as the increase of wastewater, sulfur dioxide, nitrogen oxides and other emissions.

(2) Stock flow diagram

The establishment of a systematic dynamic model of the impact of industrial intelligence on inclusive green growth requires comprehensive consideration of the operating state of each element of the system, and the causality loop diagram only reveals the causality and feedback mechanism between each element of the system. Therefore, it is important to construct a system dynamic flow diagram to describe the cooperative operation state between different elements. Based on the system dynamics causal loop diagram of the impact of industrial intelligence on inclusive green growth, the system dynamics flow diagram further analyzes the nature of variables and adds the description of the nature of variables, so as to explain the law of system operation, reflect the running path of information flow and material flow among system elements, and show the logical relationship between system elements.

(3) Validity test

To some extent, the historical test can truly describe the real system. By using the real gap between the simulation results and the actual system, the fit degree between the two is judged, and the gap between the two is continuously corrected to make it constantly fit the real system. The main purpose of historical testing is to compare the gap between simulation results and historical data to determine whether the simulation model is valid. As shown in Table 1.

*Table 1. Historical test results*

| | Value added of the tertiary industry (RMB 100 million) | | | Per capita output value (Yuan) | | |
|---|---|---|---|---|---|---|
| year | Historical value | Artificial value | error | Historical value | Artificial value | error |
| 2008 | 136827.50 | 135489.33 | -0.98% | 24100.00 | 24875.35 | 3.22% |
| 2009 | 154765.10 | 148741.33 | -3.89% | 26180.00 | 26313.05 | 0.51% |
| 2010 | 182061.90 | 183180.49 | 0.61% | 30808.00 | 30823.34 | 0.05% |
| 2011 | 216123.60 | 213602.73 | -1.17% | 36277.00 | 36102.22 | -0.48% |
| 2012 | 244856.20 | 233831.79 | -4.50% | 39771.00 | 38484.09 | -3.24% |
| 2013 | 277983.50 | 270279.47 | -2.77% | 43497.00 | 41954.34 | -3.55% |
| 2014 | 310654.00 | 304391.22 | -2.02% | 46912.00 | 44595.20 | -4.94% |
| 2015 | 349744.70 | 343346.47 | -1.83% | 49922.00 | 46719.10 | -6.42% |
| 2016 | 390828.10 | 387882.82 | -0.75% | 53783.00 | 50794.17 | -5.56% |
| 2017 | 438355.90 | 444781.32 | 1.47% | 59592.00 | 58449.26 | -1.92% |
| 2018 | 489700.80 | 498062.93 | 1.71% | 65534.00 | 66806.41 | 1.94% |
| 2019 | 535371.00 | 539958.06 | 0.86% | 70078.00 | 73073.83 | 4.28% |
| 2020 | 551973.70 | 560726.90 | 1.59% | 71828.00 | 76619.93 | 6.67% |

## 4. Simulation

(1) Scenario setting

It should be made clear in this section that research focuses on the impact of industrial intelligence on inclusive green growth. Under normal circumstances, the composition of the system has many uncertainties, and the system itself is a complex and changeable whole. The main system is composed of various subsystems, which interact and restrict each other. The factors affecting the system are multifaceted and complex. Due to the excessive influence factors, it is impossible to list all the factors, so it is necessary to select the main factors to carry out the problem discussion, and use the method of combining qualitative and quantitative analysis to clarify the research direction. This section takes industrial intelligence as the basic basis for determining parameters, and obtains representative parameters such as labor employment, fixed asset investment, energy consumption, GDP, environmental pollution and income gap, and then calculates the level of inclusive green growth. Since the existing status cannot be changed, this section adjusts the parameters of key factors to 2022 as the initial point.

① Base scenario

The characteristic of the benchmark scenario is that it does not adopt any artificial means to make it evolve in accordance with the characteristics of the law of natural development, which is embodied in that all things develop according to the existing trend of change, not only does it not emphasize the speed of economic development, but also does not adjust parameters according to the environment and income gap. The development of each subsystem is consistent with the current speed of change. Therefore, the future trend of intelligent and inclusive green growth in China's industry is speculated. In terms of the selection of model parameters, the setting of relevant parameters was mainly carried out based on the linear regression model established by the historical data of variables (2008-2019). The scenario setting was developed according to the existing trend without manual intervention, and this scenario behavior setting mode was taken as the basic standard for parameter adjustment under other scenarios.

② Core scenario

Improving the level of industrial intelligence is conducive to promoting inclusive green growth. The core scenario takes the development of industrial intelligence as the main adjustment approach, studies the impact of expanding the scale of industrial intelligence on the future change trend of the system, and other parameters are consistent with the benchmark scenario. The Ministry of Industry and Information Technology, the National Development and Reform Commission, the Ministry of Science and Technology and other units issued at the end of 2021 in the "14th Five-Year Plan" robot industry development Plan proposed that during the "14th Five-Year Plan" period, the average growth rate of the overall scale of China's industrial intelligence will be 15%. In the "Robot +" application Action Implementation Plan released by the Ministry of Industry and Information Technology in January 2023, it was pointed out that the compound annual growth rate during 2021-2025 was 20%. Therefore, based on the above policy background, 15% is set as the medium scenario and 20% as the high scenario.

③ auxiliary situation

China's technological progress is mainly manifested in the use of capital and labor and energy conservation, so improving labor and energy efficiency is an important way to promote inclusive green growth. ① Green innovation-oriented scenario. Green innovation is one of the main means to improve energy intensity, reduce total energy consumption and pollution emissions. According to the "14th Five-Year Plan", the growth target of research and development funds is set at 7%, according to the "14th Five-Year Plan" research and development funds growth target, the average is 11%, so the medium scenario is set as 7% growth of research and development funds. The high scenario assumes an 11% increase in R&D spending. Human capital improvement scenario. Improving the level of human capital is not only an important way to improve inclusive green growth, but also a major means to narrow the income gap between urban and rural residents. According to the Report on the Development of Rural Education in China 2020-2022, the investment in rural compulsory education in 2012-2020 has continued to grow, and the conditions for running schools have been significantly improved, but the growth rate is lower than the national average level, and the gap between urban and rural areas is still large in general. The average growth rate of education funding in 2012-2020 is 5.85%, so the medium scenario is set at 6%. The higher scenario is 10%.

④ Comprehensive scenario

To improve the level of inclusive green growth requires the joint implementation of multiple regulatory measures. The comprehensive scenario emphasizes the coordination and common development of multi-factor inputs, and focuses on the effect of the policy combination model. That is, the promotion of industrial intelligence as the core, assisted by green innovation and human capital, specifically: in the case of other parameters unchanged, the medium scenario is set as the industrial intelligence growth rate of 15%, research and development investment growth of 7%, rural compulsory education investment growth of 6%. In the higher scenario, the growth rate of industrial intelligence is set at 20%, the investment in research and development is increased by 11%, and the investment in rural compulsory education is increased by 10%.

(2) Simulation

① Base scenario

If the approach of baseline evolution does not implement industrial intelligtion-related policies, inclusive green growth will grow slowly, inclusive green growth will suddenly exceed 0.02 in 2024, and it will still not break through the level of 0.03 in 2030. In terms of market performance, energy saving and emission reduction performance and social equity performance, it also shows a slow increasing trend. As is shown in figure1.

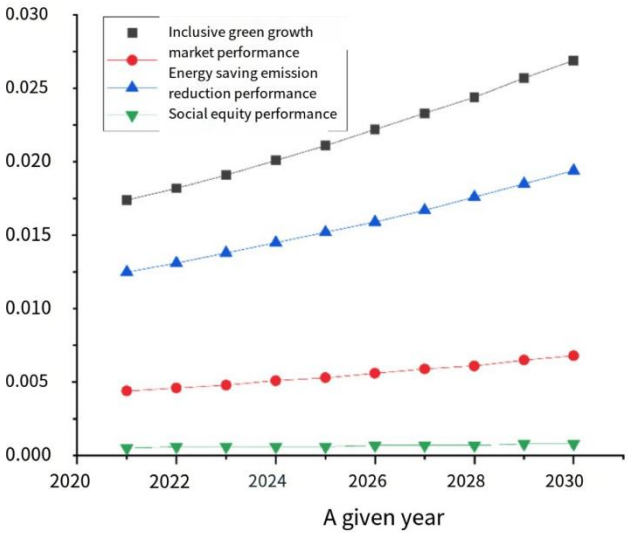


*Figure 1. Results of inclusive Green growth scenarios in the baseline scenario*

② Core scenario

Artificial intelligence, the Internet of Things, blockchain and other technologies have been deeply integrated into agriculture, industry and service industries, improving production efficiency through full automation of production processes and promoting the modernization of industrial structure. Therefore, under the implementation of the enhanced industrial intelligence policy scenario, the level of inclusive green growth increases rapidly, breaking through 0.03 in 2029 under the medium scenario, breaking through 0.03 in 2027 under the higher scenario, and breaking through 0.5 in 2030.As is shown in figure2.

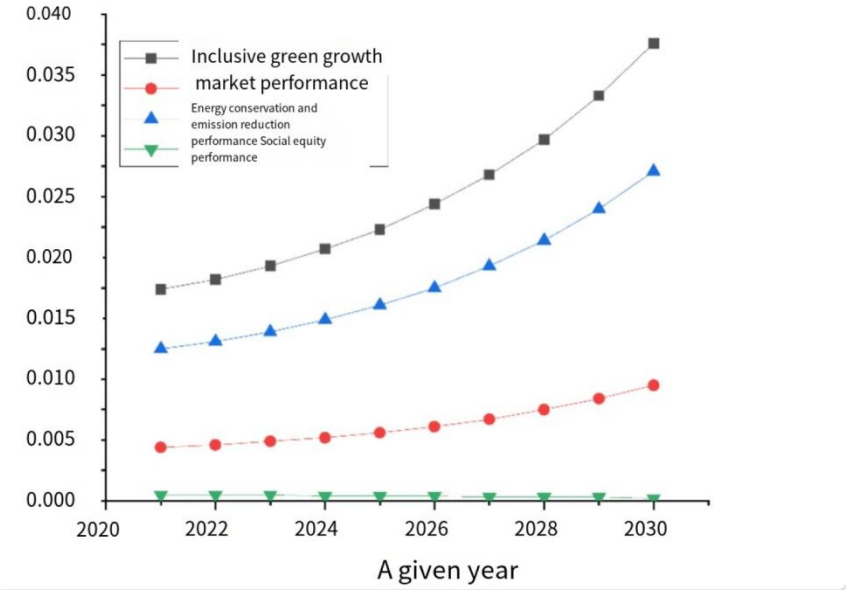


*Figure 2. Results of Inclusive Green Growth Medium scenario*

By improving labor productivity, promoting capital accumulation and stimulating total economic

output, industrial intelligence promotes continuous research and development of enterprises and creates new products to promote economic growth, and significantly improves market performance. For enterprises, the development of intelligence helps them to use intelligent technology to improve pollution control efficiency, overcome the resource curse of high dependence on resources, and develop scientific and technological innovation economy. For the country, industrial intelligence can strengthen the supervision of the national environmental protection department on the emission of carbon dioxide and other pollutants, and achieve energy conservation and emission reduction goals through the implementation of good ecological technology. However, industrial intellectualization has significantly increased the wage level of urban residents, and made the wage gap between urban and rural residents increasingly large. As is shown in gigure3.

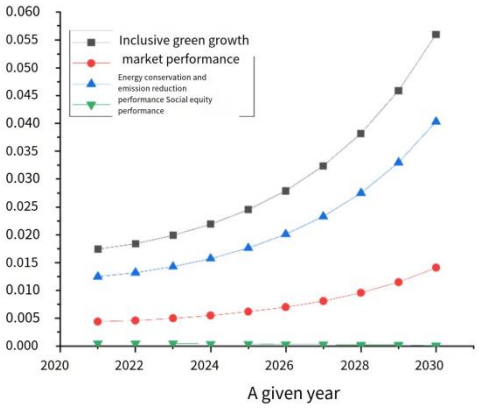


*Figure 3. Results of the Inclusive Green Growth Advanced Program under the core scenario*

③ auxiliary situation

Improving the level of scientific and technological innovation and human capital can effectively promote inclusive green growth. And it is worth noting that at the same program level, scientific and technological innovation plays a greater role in promoting inclusive green growth. This is because the current pollution emission intensity is still at a relatively high level, and scientific and technological innovation can promote the rapid reduction of pollution emission intensity, and increase the contribution of scientific and technological innovation to inclusive green growth. Under the higher scenario, green innovation could bring inclusive green growth to a level of 0.4 by 2030.As is shown in figure4.

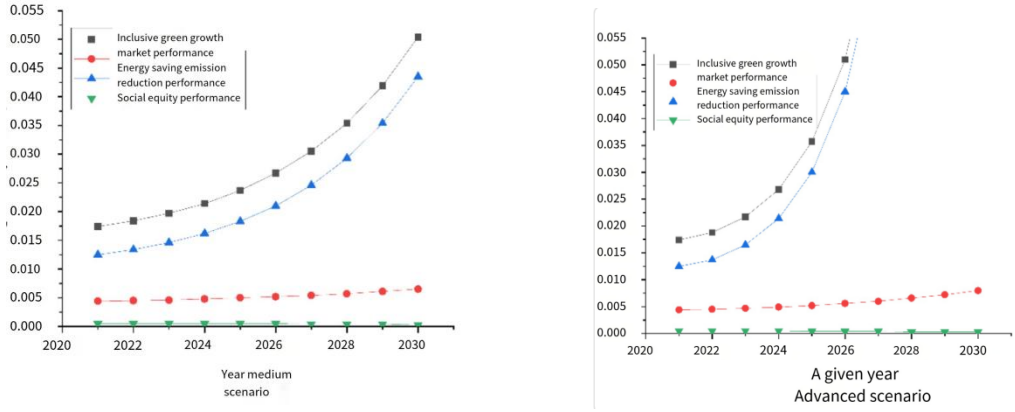


*Figure 4. Results of the inclusive green growth technology innovation scheme under the auxiliary scenario*

The trend of artificial intelligence's replacement of labor force is irreversible, and the resulting problems such as short-term unemployment, excessive income gap, and declining labor income share need to play the role of government public services, increase the education expenditure of the whole society, especially invest in those skills and professions that are difficult to be replaced by artificial intelligence in the foreseeable future, and accelerate the accumulation of human capital. Improve the level of labor and human capital. It can be seen that by raising the level of human capital, the contribution of social equity to inclusive green growth is enhanced. By 2030, social equity will contribute more to inclusive green growth than market performance. As is shown in figure 5.

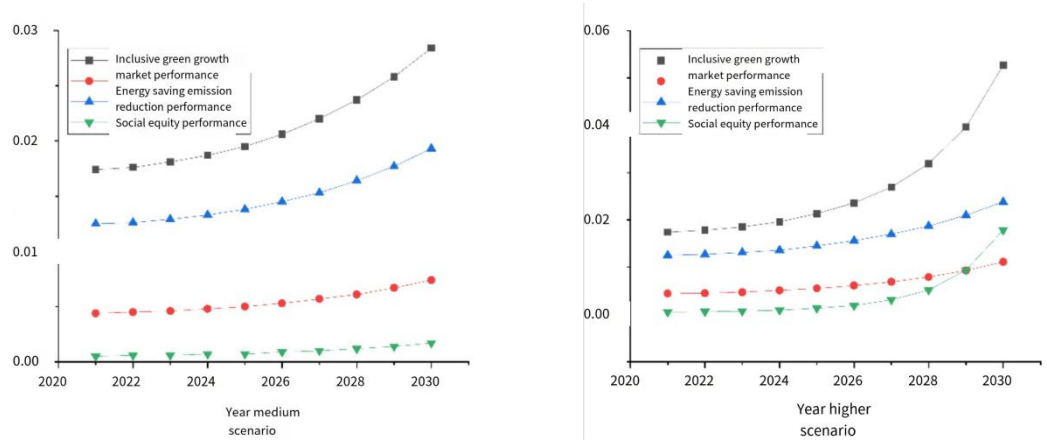


*Figure 5. Results of inclusive Green Growth human capital program under the auxiliary scenario*

④ Coordination scenario

Under the factor coordination scenario, while promoting the development of industrial intelligence, further improving the level of scientific and technological innovation and human capital can offset the widening of the urban-rural income gap caused by industrial intelligence, promote green development, and improve energy conservation and emission reduction performance. The results of system dynamics simulation show that, from the perspective of inclusive green growth results, the collaborative oriented scenario is the best scenario. The factor collaborative orientation scenario also reflects the current problems and the direction that needs to be improved in the future, that is, the insufficient contribution of scientific and technological innovation and human capital to inclusive green growth, which also makes the improvement of industrial intelligence on inclusive green growth limited, and its energy saving and emission reduction potential has not really highlighted. Therefore, in the future, while continuing to accelerate the promotion of industrial intelligence, we need to pay more attention to the driving role of scientific and technological innovation and human capital, so as to reduce the input of factors in the production process, promote the innovation of clean technology and pollution control technology, reduce the Gini coefficient, realize the shift from high energy consumption and high pollution to low energy consumption and low pollution, and promote social equity. Only in this way can the high-quality development of our country's economy be promoted more effectively. As is shown in figure6.

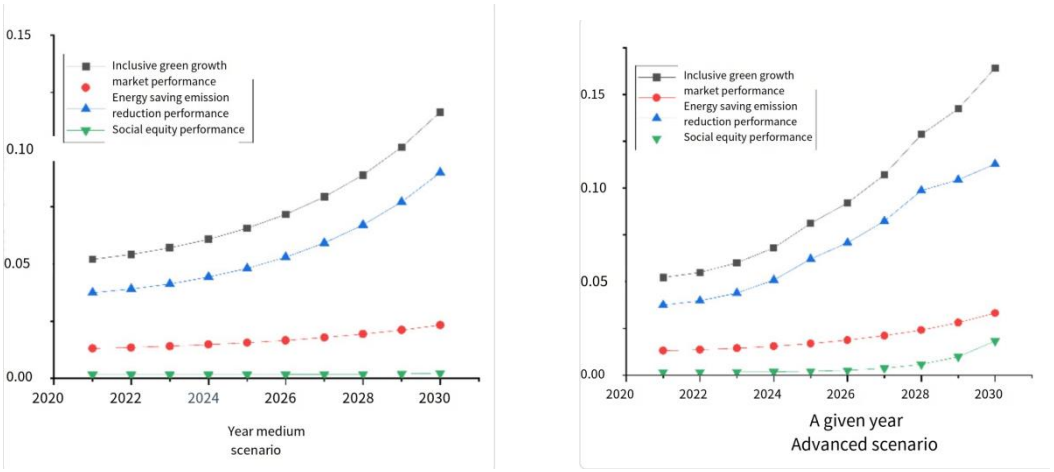


*Figure 6. Results of inclusive green growth under the coordinated scenario*

## 5. Conclusion

By determining the boundary of the systematic dynamic model of the impact of industrial intelligence on inclusive green growth, establishing the feedback structure within the system, constructing the causal loop diagram of dynamic evolution and the system dynamics flow diagram, the system dynamics method is used to sort out the dynamic complexity of inclusive green growth and the multi-order nonlinear multi-factor system. Model-based current situation simulation tests the path of China's industrial intelligence affecting inclusive green growth, and simulates the systemic dynamic model using different scenarios, and draws the following conclusions:

(1) With the deepening of the development of industrial intelligence, inclusive green growth has been greatly improved, energy conservation and emission reduction performance and market performance continue to improve, the improvement of social equity performance is small, on the whole, the coordination of industrial intelligence, economic development and ecological environment has been realized, and the development of industrial intelligence and people's needs for a better life can be effectively connected.

(2) In the auxiliary scenario, the acceleration of scientific and technological innovation promotes the further deepening of industrial intelligent application, greatly improves market performance and energy conservation and emission reduction performance, and greatly accelerates inclusive green growth, but scientific and technological innovation has little impact on social equity performance. Under the scenario of the improvement of human resources, the level of human quality is promoted, the coupling of industrial intelligence and human capital is greatly enhanced, which promotes the improvement of social equity performance, and then promotes inclusive green growth.

(3) In the collaborative scenario, while promoting the development of industrial intelligence, improving the level of scientific and technological innovation and human resources can further promote the level of inclusive green growth, offset the negative impact of industrial intelligence on the widening income gap, and the inclusive green growth in the factor collaboration scenario is also more obvious.

## Funding

If any, should be placed before the references section without numbering.

## Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Conflict of Interest

The author states that this article has no conflict of interest.

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