Research on the Influence Mechanism of Green GDP, Green Network Security, and Digital Economy Based on Gray Correlation Model

Chenyang Chen[1, *], Siyan Lin[2]

[1]College of Economics and Management, Northeast Agricultural University, Harbin, China, 150030

[2]School of Public Administration and Law, Northeast Agricultural University, Harbin, China, 150030

* Corresponding Author Email: c2367178421@163.com

Abstract. This paper explores the impact that using GGDP (Green GDP) as an important indicator of a country's economic health will have on global climate mitigation. The GGDP values of 24 EU countries are calculated based on Eurostat data, and greenhouse gas emissions, precipitation, etc. are selected as variables, global data are collected for five years from 2015 to 2019, and the expected impact is estimated using gray correlation model and ridge regression model, which concludes that GGDP is negatively correlated with the climate indicators, and has a significant impact on climate mitigation. The resultant research is applied to the impact of green network security on network ecology and digital economy, selecting network ecological cleanliness, network energy utilization efficiency, and network security inputs as variables to be applied to the model, and the study concludes that green network security has a positive positive impact on the digital economy, and can promote the sustainable development of the digital economy.

Keywords: Economic Health, Green Network Security, Digital Economy, Gray Correlation, Ridge Regression.

1. Introduction

Gross domestic product (GDP) is one of the most commonly used and recognized indicators of a country's economic health. Citing this indicator facilitates the promotion of products but ignores the sustainability of resources. A country can increase its GDP with impunity and at the expense of the environment; therefore, the choice of GDP to measure whether a country's economy is truly healthy is not a good one. Green GDP is the core indicator accounting system for integrated environmental-economic accounting, integrating resource and environmental factors on top of current GDP. This indicator essentially represents the net positive impact of national economic growth. Liu Qihang et al. Found [1] that among the many comprehensive assessment systems reflecting economic development, environmental pollution, resource consumption, and ecological depletion, green GDP performance assessment has significant advantages; Gao Xirong's [2] proposal of green GDP accounting based on the compensation of resource and environmental value highlights the connotation of high-quality development and helps to fundamentally reverse the wrong orientation of destructive development.

Based on information technology, the digital economy has profoundly affected industrial structure, business models, and employment patterns through digitization, networking, and intelligence. There is a strong link between network security and economic sustainability, and it is also critical to a country or region's digital economy. However, similar to traditional GDP measurements that do not take into account environmental and resource sustainability, traditional network security metrics may also ignore environmental risks, leading to incalculable environmental and social risks in the pursuit of digital economic growth. Based on CiteSpac analysis, Wei Baojing [3] et al. found that ecological networks, landscape patterns, ecological corridors, and ecological security patterns are hot research areas; Wang Lei [4] et al. concluded that there exists a single threshold value for green technological innovation and that a high level of green technological innovation drive significantly enhances the role of the digital economy in promoting green total factor productivity. Green network security, which includes reducing the impact of network threats on ecosystems, e-waste, and carbon footprints, among other things, is conducive to promoting the sustainability of global network security and assisting countries to better protect digital ecosystems while fostering the growth of the digital economy.

Based on the selected GGDP model, this paper uses a gray correlation model with a ridge regression model to estimate the expected impact of using GGDP as the main indicator of a country's economic health on climate change mitigation and extends the conclusions to green network security to empower the sustainability of the digital economy.

2. Research On GGDP Modeling

2.1. Model Building

There are many ways to calculate GGDP [5], after comparison and analysis, the following model is chosen in this paper:

$$GreenGDP = GDP - (KtCO_2 * PCDM) - (Twaste * 74kWh * Pelect) - \frac{GNI}{100} * \%NRD) \tag{1}$$

GDP is the total value added of all resident producers in an economy plus any product taxes, minus any subsidies that are not included in the value of the product. The calculation does not deduct depreciation of man-made assets or depletion and degradation of natural resources. Therefore, the model requires deductions from GDP to obtain GGDP.

As can be seen from the model, there is a negative correlation between GGDP and the cost of CO_2 pollution, the opportunity cost of a ton of waste that can be used to produce electricity, and the consumption of natural resources as a percentage of each country's gross national income, varying in the opposite direction. Therefore, if a country wants to increase its GGDP, it has to reduce its costs of CO_2 pollution, waste emissions, and natural resource consumption. To reduce these costs, they must conserve resources, emit less waste and greenhouse gases, contribute to the increase of biodiversity, promote environmental protection, and ultimately be able to have a measurable impact on climate change mitigation based on a calculated comparison of the indicators.

2.2. Model Applications

To make the model more rigorous, this paper collects data from Eurostat and Eps databases for a sample of 24 countries (both developing and developed) for the application and analysis of the model. The analysis covers 24 countries in the world for the period 2015-2019. The six main search indicators are as follows: CO2 emissions, GHG prices, waste volumes, electricity prices, natural resource consumption, and GNI. According to the GGDP model formula established above, these indicators were substituted, and after data processing in Python, GGDP data for the selected sample countries were obtained. The results are shown in Fig 1.

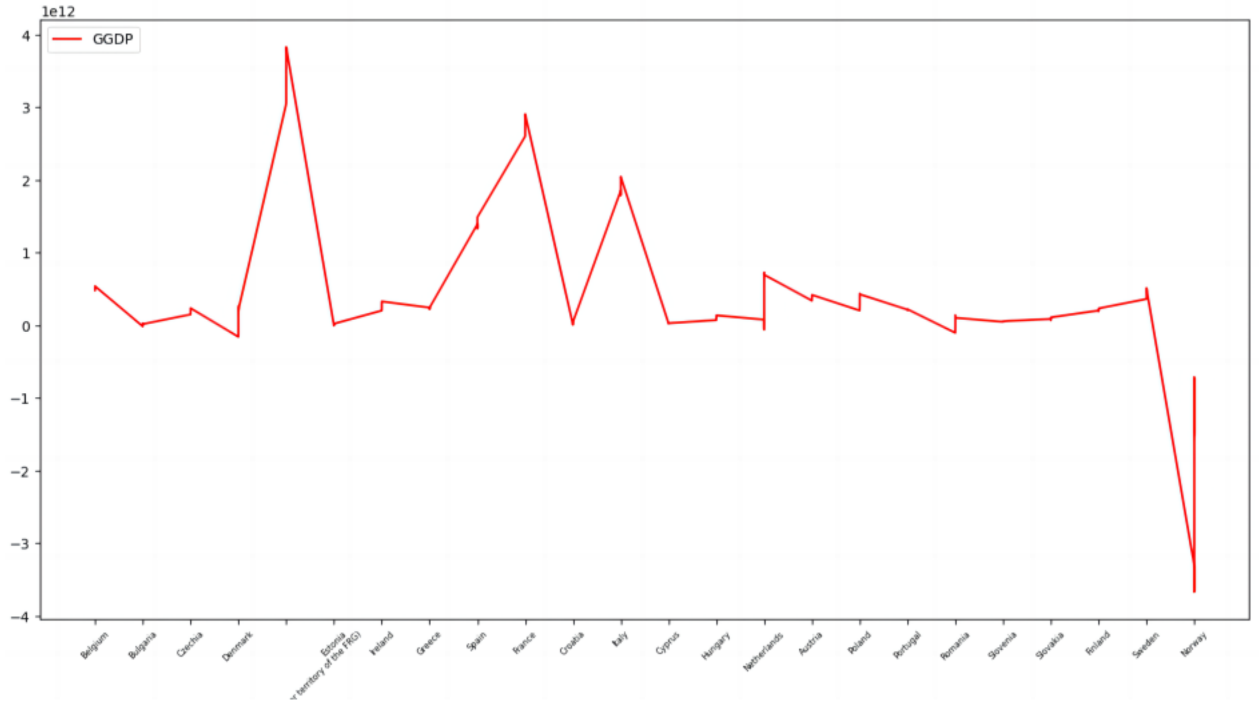

Fig. 1 GGDP line graph by country

3. Expected impact study

Suppose the above GGDP is used as the main indicator of a country's economic health, to estimate the expected global impact on climate change mitigation, the enhancement effect of green network security and the robust development of the digital economy. In that case, this paper examines it using a gray correlation model with a ridge regression model.

3.1. Gray correlation

Gray correlation analysis is [6] based on the sample data of each factor, and gray correlation is used to describe the strength, magnitude, and order of the relationship between the factors. In order to estimate the expected global impact on climate mitigation after GGDP is used as the main indicator of a country's economic health, total greenhouse gas emissions, precipitation, and a few extreme weather events are chosen as proxies for climate in this paper.

The series were first standardized using the mean value method and then the number of links was calculated based on the following formula.

$$\xi_{i1}(j) = \frac{\Delta(\min) + \rho\Delta(\max)}{\Delta_{i1}(j) + \rho\Delta(\max)} \tag{2}$$

Δdenotes the absolute difference between each comparison series and the reference series in the same period, denoted as

$$\Delta_{i1}(j) = \left| X_{i1}(j) - Y_{i2}(j) \right| \tag{3}$$

X is the comparison sequence and Y is the reference sequence, and ρ is the resolution coefficient, which takes values in the range (0,1), and here we take its usual value of 0.5. After dimensionless processing of the data, this paper solves the gray correlation coefficient between GGDP and the feature series by taking a resolution factor of 0.5. According to the correlation coefficient in Fig 2. It shows the value of correlation between the selected climate proxies and the corresponding latitude of GGDP, which is larger in a certain latitude range, showing a strong correlation.

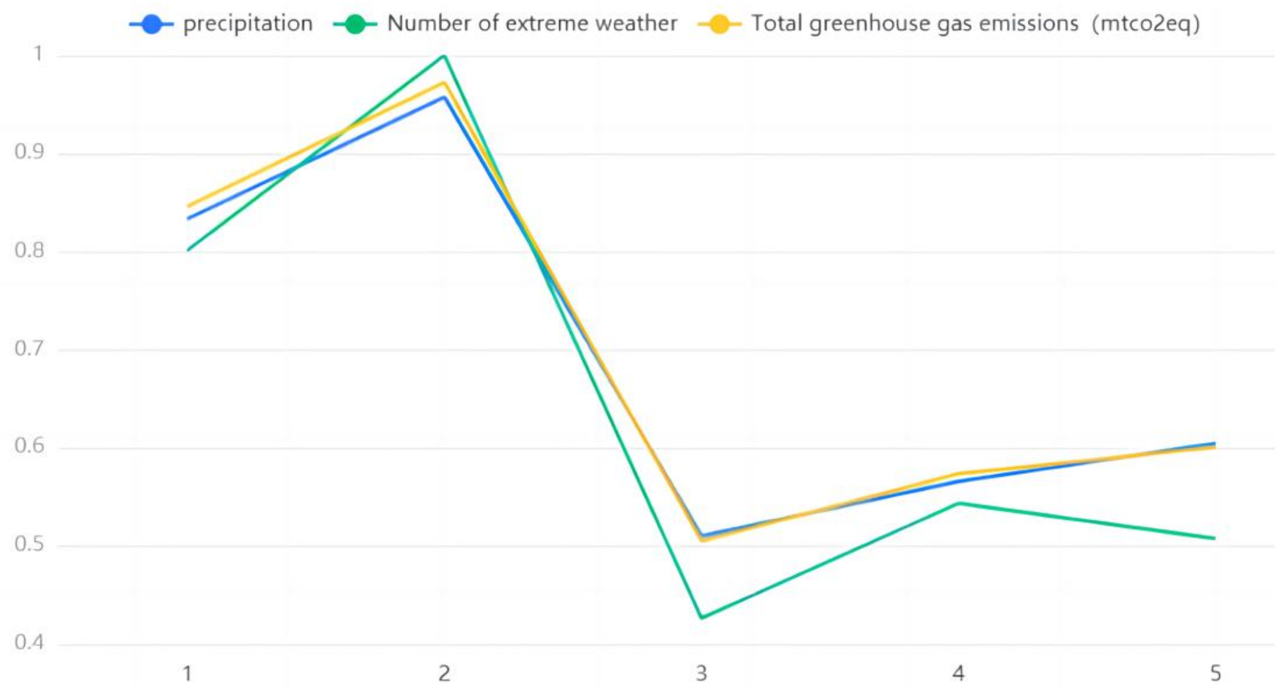

Fig. 2 Correlation coefficient graph

The correlation value is obtained by weighting the correlation coefficients. As shown in Table 1, it can be seen that there is a high degree of similar correlation with GGDP, all exceeding 0.5. Among them, total GHG emissions are rated the highest (correlation of 0.699), and precipitation and the number of extreme weather also have a more significant correlation with GGDP. Thus, it can be concluded that GGDP has a global impact on climate mitigation.

Table 1. Relevance results table

Evaluation items	Relevance	Ranking
Total greenhouse gas emissions	0.699	1
precipitation	0.694	2
Number of extreme weather	0.656	3

Similarly, through the analysis of the gray correlation model, it can also be explored that there is a significant correlation between green network security and a clean network ecology and digital economy. First, the clean network ecology is positively correlated with green network security, indicating that strengthening green network security helps create a cleaner and healthier network environment. Second, the development of the digital economy is closely related to green network security, and the correlation coefficient reaches a significant level, indicating that the enhancement of green network security has a positive impact on the robust growth of the digital economy.

In green network security, major variables such as the cleanliness of network ecology [7], network energy utilization efficiency, and network security investment have an important impact on the digital economy. The study shows that the cleanliness of network ecology is positively correlated with the development of the digital economy, indicating that the healthy growth of the digital economy can be promoted by strengthening green Network Security measures. In addition, there is a significant correlation between network energy utilization efficiency and digital economic growth, Due to the booming development of the digital economy, the energy demand is increasing, and the improvement of network energy utilization efficiency can effectively slow down the energy consumption rate. The development speed of the digital economy can be effectively enhanced by improving network energy utilization efficiency. At the same time, the impact of network security inputs on the digital economy should not be ignored, and the investment of appropriate network security resources can help enhance the sustainable development of the digital economy.

Therefore, it can be concluded that green network security has a positive global impact on the clear network ecology and digital economy. Strengthening green network security measures will help promote the clean development of the network ecology, enhance the digital economy's healthy growth, and, inject more sustainable development momentum into the global digitalization process.

3.2. Ridge regression

After concluding that GGDP has an impact on global climate mitigation through gray correlation analysis, this paper establishes a ridge regression model to analyze the expected impact of GGDP on climate mitigation. The three indicators of total GHG emissions (X_1), precipitation (X_2), and several types of extreme weather (X_3) are still chosen as independent variables to analyze the specific impact relationship between climate and GGDP. Since the problem of covariance of independent variables inevitably arises and the removal of independent variables with covariance will directly affect the results of the study, this paper chooses the ridge regression method for regression analysis.

3.2.1 Ridge regression and determination of k values

Ridge regression analysis is a biased [8] estimation method specifically used for covariance data analysis. The basic idea of ridge regression is to add a normal data matrix $KI(K>0)$ to $X'X$ when there is a multicollinearity problem between the independent variables of the regression equation, i.e., When the absolute value of $X'X$ is approximately equal to 0, and the probability of $X'X+KI=0$ is much smaller than that of $X'X=0$ which is much less likely than $X'X=0$, where the value of K is called the ridge parameter. The ridge regression estimation expression is as follows.

$$\hat{\beta}(k)=(X'X+KI)^{-1}X'y \tag{4}$$

In this paper, all values of 0.01 intervals between 0 and 1 are selected as ridge parameters in the regression process to form a ridge trace plot, and the value of K is determined based on the ridge trace plot.

When $K=0$, it is the ordinary least squares estimate, and usually the smaller the K value [9], the better. As shown in Fig 3, regression analysis of the data was carried out in this paper by SPSS to obtain standardized ridge traces, thus determining the K-value from the ridge traces.

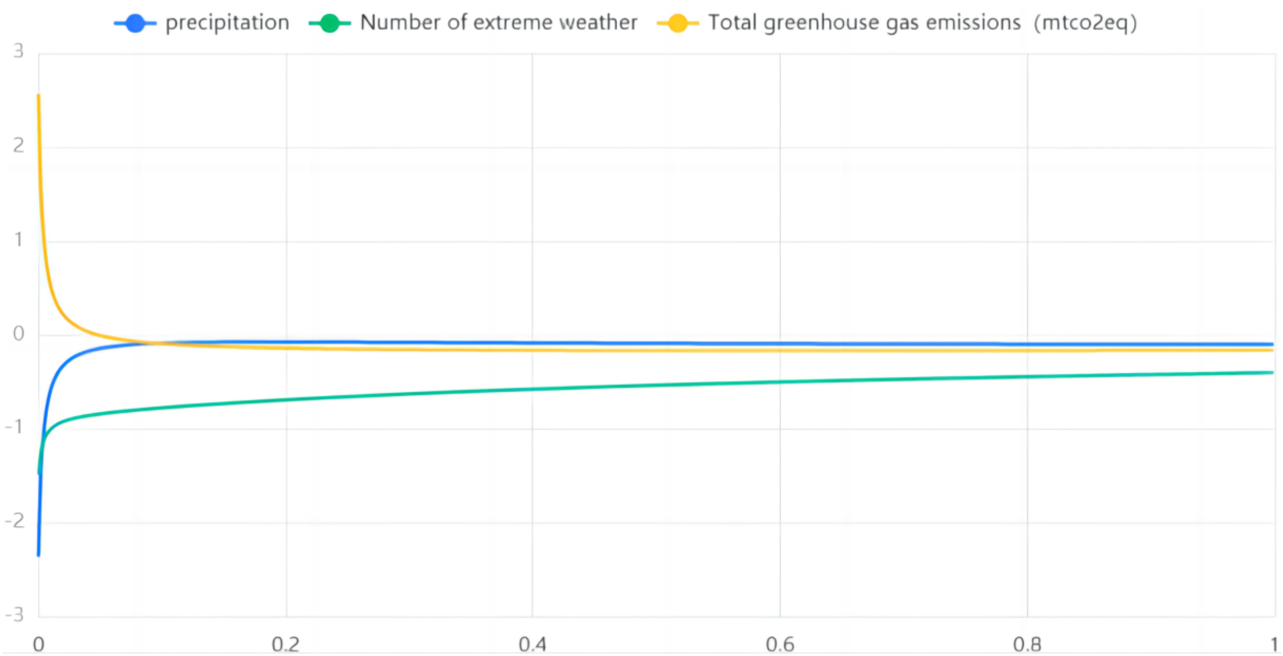

Fig. 3 Ridge Trail Map

After the analysis, it is obtained that the regression coefficient values of some of the variables vary significantly when the value of K varies from 0 to 0.2, indicating the presence of covariance.

3.2.2 Regression analysis

After determining the optimal K value (K=0.168) according to the variance expansion factor method, ridge regression analysis was performed on variables X_1, X_2, and X_3, and a ridge regression model could be obtained. Clustering the model, it was concluded that the total greenhouse gas emissions (X_1), precipitation (X_2), and the number of extreme weather (X_3) were negatively correlated with the dependent variable y (GGDP). When the total amount of greenhouse gas emissions decreases, GGDP will increase; when the number of extreme weather decreases, GGDP will increase.

Based on the conclusion of the above ridge regression analysis, this paper applies it to analyze the impact of green network security on network ecology and the digital economy. The three factors of network ecological cleanliness, network energy utilization efficiency, and Network Security investment are taken as independent variables, and their relationship with the digital economy is examined.

First of all, with the implementation of green network security, network ecological cleanliness will be improved. By reducing carbon emissions and environmental pollution of the network, the improvement of network ecological cleanliness will promote the development of the digital economy. Lower carbon emissions and environmental pollution will not only help improve environmental quality, but also provide a better business environment for enterprises, attract more investment and innovation activities, and promote the growth of the digital economy.

Secondly, green network security plays an important role in improving network energy utilization efficiency. Network energy utilization efficiency is improved by optimizing network equipment, improving data center energy utilization, and promoting energy-saving technologies. This will reduce energy consumption and costs and improve the competitiveness and sustainability of the digital economy. Efficient utilization of energy can also provide enterprises and users with more stable and reliable network services and promote innovation in the digital economy.

Finally, network security investments are critical to the protection of the digital economy. The implementation of green network security will help reduce network security incidents and improve the stability and security of the digital economy. By investing in appropriate network security resources and technologies, risks such as network criminal activities and data leakage can be reduced and users' privacy and digital assets can be protected. This will enhance user trust and facilitate the development of the digital economy and the growth of online transactions.

3.2.3 Model testing

(1)ANOVA test

In this paper, the ANOVA [10] test was used to determine the suitability of X_1, X_2 and X_3 for the estimation of GGDP. A significance level of 0.05 was taken and the model was subjected to the test of variance and the result was obtained, $F = 15.164, p(F \le f) = 0.015$, indicating that the level is more significant and the difference in the effect of the three variables, X_1, X_2, and X_3, on y is statistically significant.

(2)Goodness-of-fit test

The R^2 value is used to determine the fit of the model. As shown in Table 2, the goodness-of-fit test of the model yields an R^2 of 0.915, with a small error (the ridge regression still allows some errors to exist in exchange for higher accuracy than the unbiased estimator), and the fit is relatively good, so the model can meet the needs.

Table 2. Model test results

R^2	Adjusting R^2	F
0.915	0.661	3.604(0.365)

The model path diagram Fig 4 shows the results of this simulation and includes the coefficients of the model to be able to better interpret the resulting model formulation.

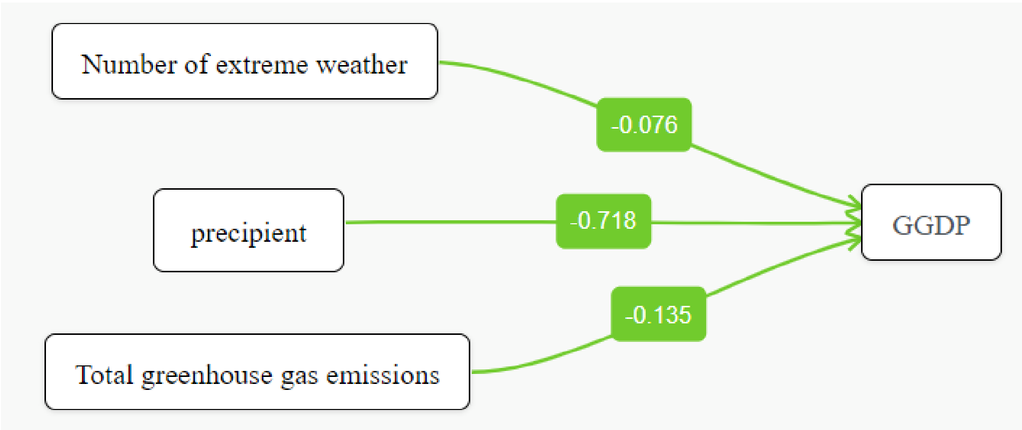

Fig. 4 Model path diagram

The model results graph Fig 5 shows the original data plot of this model's model-fitted values, including the true and predicted values, and can see that GGDP and climate have a significant impact. The blue line in the graph represents the true value and the green line represents the predicted value.

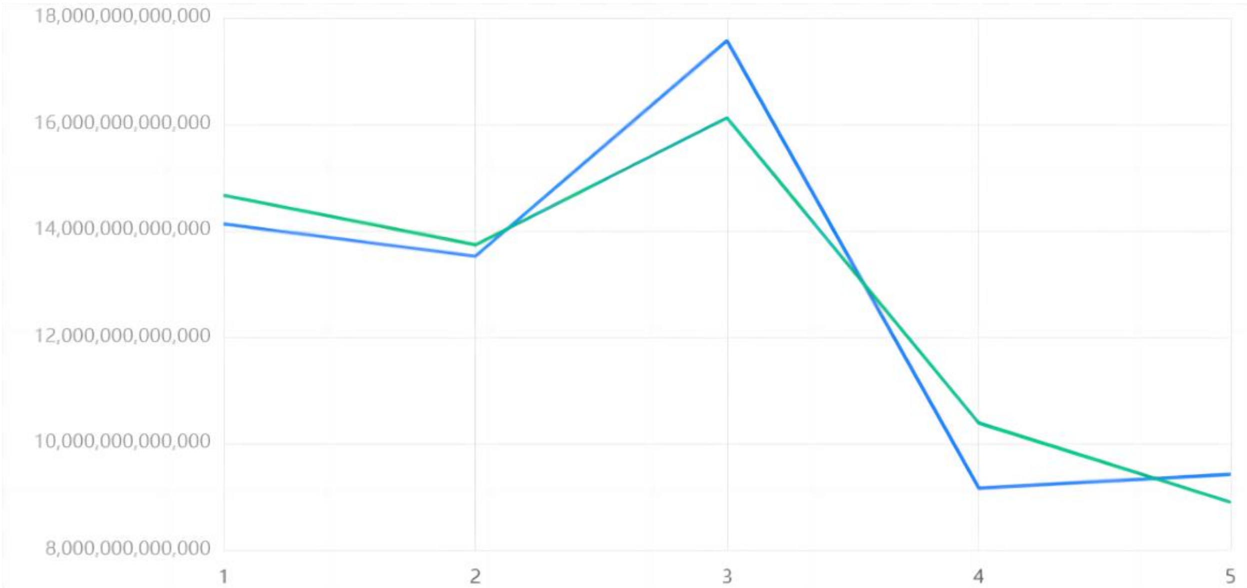

Fig. 5 Model results graph

4. Conclusions

In summary, After an analytical study using gray correlation and ridge regression models to explore the correlation between GGDP and climate change indicators and the way GGDP affects climate change, it can be seen that using GGDP as the main indicator of a country's economic health will be conducive to mitigating climate change. Using GGDP as a primary indicator will increase the importance of climate change in society, and the health of the economy is crucial for policymakers and business decision-makers. By linking GGDP to climate change, more attention can be called to climate change and positive actions can be prompted to mitigate the effects of climate change, increasing society's attention to climate change and promoting action to mitigate it.Green GDP accounting can also reflect the degree of contribution of enterprises and regions to society, and fully understand which enterprises and regions are "high-intensity regions" in resource consumption, and which enterprises and regions are "hard-hit regions" regarding environmental pollution and ecological damage. In this way, each enterprise and region's environmental degradation costs and resource consumption can be measured, and a scientific performance evaluation system can be established to promote a shift from the pursuit of profits to the pursuit of coordinated development of the economy, society, and the natural environment.

Furthermore, the impact of green network security on network ecology and the digital economy is positively positive. Improving network ecological cleanliness, network energy utilization efficiency, and Network Security investment will promote the development of the digital economy. By reducing network carbon emissions and environmental pollution, improving energy utilization efficiency, and protecting network security, a sustainable digital economic ecosystem can be established to promote economic growth and social prosperity. This will not only help to realize the sustainable development of the digital economy but can also contribute to the realization of green and sustainable development goals.

References

[1] Liu Qihang, Ouyang Kang. Rethinking Green GDP Performance Assessment under the Vision of "Dual Carbon"[J]. Theory Monthly, 2023(10):91-97.

[2] Gao Xirong, Zhao Xinyue, Chai Chengxin. Green GDP Accounting Based on Resource and Environmental Value Compensation--Taking Chongqing Municipality as an Example[J]. Ecological Economy,2023,39(05):148-153.

[3] WEI Baojing, HU Xijun, ZHU Manle et al. Research hotspots and trends of green ecological networks in China based on CiteSpace[J]. Economic Geography,2021,41(09):174-183.

[4] WANG Lei, WANG Junyao. Research on the impact of the digital economy on urban green total factor productivity under the perspective of green technology innovation[J/OL]. Xinjiang Agricultural Reclamation Economy:1-15[2023-11-24].

[5] Mungcharoen P V V K K .Thailand Green GDP assessment based on environmentally extended input-output model[J]. Journal of Cleaner Production,2017,167970-977.

[6] Dang Yaoguo, Wang Yibo, Wang Junjie et al. Gray vector mode correlation model based on panel data and its application[J/OL]. Control and Decision Making:1-9[2023-11-28].

[7] Chen Zhenwen, Chang Jun. Application of integrated ridge regression and SARIMA methods in the analysis of bridge health monitoring data[J]. Science, Technology and Engineering, 2023,23(20):8846-8853.

[8] LU Chang, WANG Zhiyu. Carbon metabolism analysis of the Yellow River Delta based on ecological network analysis[J]. China Environmental Science,2023,43(11):6090-6101.

[9] WU Le, CHEN Gang. Shanghai logistics demand forecasting model based on ridge regression and GM(1,1) combination[J]. Logistics Science and Technology,2023,46(15):6-9.

[10] LU Jiaqi, WANG Lingyun, ZHOU Chaomin, et al. A prediction model of Yuyao shoreline of Qiantang River based on SS-ANOVA model[J]. Henan Water Resources and South-North Water Diversion,2023,52(05):110-111+114.