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Analysis of China's Carbon Emission influencing Factors and Its Peak Prediction

Shaohui Zou [1, a], Zhili Ding [1, b] and Xiaogang Wang [2, c]

[1]School of Management, Xi`an University of Science and Technology, Shaanxi 710054, China;

[2]School of Statistical, Dongbei University of Finance and Economics, Liaoning 116025, China.

[a]978156521@qq.com, [b]995644639@qq.com, [c]2865244948@qq.com

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Abstract: Carbon emissions are a hot topic in the society today. Developing a low-carbon economy has become an important strategy for many countries. Analysis of the factors that affect carbon emissions and accurately predict future carbon emissions have significant positive implications for the government to formulate environmental protection policies. First, based on the three end-uses of fossil fuels, this paper estimates China's carbon emissions from 1981 to 2015. Then we choose four factors that affect the carbon emissions, including energy consumption, economic growth, urbanization and population growth, and conduct path analysis and Granger causality test to analyze the impact of the four factors on carbon emissions. Finally, we use the carbon emissions history data from 1981 to 2015 to establish the $ARIMA$ model for predicting future carbon emissions and predict carbon emissions for the next 20 years. he results show that: (1) energy consumption, economic growth, urbanization and population growth are the causes of carbon emissions growth; (2) energy consumption is the direct cause of carbon emissions changes; (3) China's carbon emissions will reach at peak whichis emissions of 3,247.1 million tons in 2030.

Keywords: Carbon emissions; energy consumption; path analysis; Granger causality testing; $ARIMA$ model.

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1. INTRODUCTION

At present and for some time in the future, China will be in the later stages of urbanization and the later stages of industrialization. The continuous economic growth and urbanization have brought about increasingly serious environmental problems. It is estimated that since the beginning of the 21st century, China's economy has enjoyed an average annual growth rate of 13.6% since the beginning of the 21st century, while the average annual growth rate of carbon emissions is 6.83%. From this we can see that along with the rapid economic growth, carbon emissions are also rapidly rise. In nature, carbon is often in the form of carbon dioxide, a large amount of carbon dioxide has caused an increasingly serious greenhouse effect. In order to cope with the increasingly serious environmental problems, the Chinese government promised in 2009 that compared with 2005, China's carbon emission intensity will be reduced by 40% to 45% by 2020. and that energy-saving and emission reduction and developing a low- A commitment are taken by government to achieve this. Therefore, analyzing the factors that affect carbon emissions and predicting the future carbon emissions have significant positive implications for the government in formulating environmental protection policies.

2. LITERATURE REVIEW

Many domestic scholars and research institutions on the impact of carbon emissions were analyzed, at the same time, to predict the carbon emissions. Wu Hong and Gu Shuzhong[1] used the measurement method to study the causal relationship between fossil energy, carbon emissions and economic growth. The results show that high carbon emissions have promoted economic growth. Teng Xin and Li Jian [2] used discrete second-order difference equations to predict future carbon emissions and used clustering methods to find five factors that affect carbon emissions. The results show that before 2020 China's carbon emissions will still be growing rapidly. Jiang Jinhe [3] carried out a toilet on carbon emissions and made use of the complete exponential decomposition of carbon emissions - the logarithmic average Divisia index to quantitatively analyze the influencing factors and contribution rates of China's carbon emissions from 1995 to 2007, including: economic scale Effect, structure effect, energy intensity effect and carbon intensity effect. Zhao Aiwen, Li Dong et al [4] established a gray $GM(1,1)$ model using carbon emission data from 2002 to 2009 and made a short-term forecast of China's carbon emissions. The forecast shows that by 2015, China's carbon emissions will exceed 32 tons. Du Qiang and Chen Qiao [5] predicted China's future carbon emissions using a modified IPAT model. The forecast shows that by 2050, China's carbon emissions will reach 2366.4522Gg. Li Nan and Shao Kai [6] discussed the issue of carbon emissions from the perspective of population structure and analyzed the impact of population structure and population aging on carbon emissions. A large number of scholars also have studied the regional carbon emissions. Feng Zongxian and Wang Anjing[7] and others used the input-output method to divide the industry and studied the influencing factors of carbon emissions in Shaanxi Province from the overall situation in different time segments, and separately separated the contribution of each factor to the carbon emissions. Finally, Monte Carlo simulation of the carbon peak in Shaanxi Province was predicted, the results show that in 2030 Shaanxi Province will reach the peak carbon emissions. Cheng Haisen and Ma Jing [8] calculated carbon emission data from 1997 to 2015 in Beijing, Tianjin and Hebei provinces on the basis of 27 energy end-use consumption figures and then used the decoupling theory to analyze each of the two aspects of energy consumption, economic growth and carbon emissions. The relationship between the final establishment of a systematic model to quantitatively analyze the relationship between the three. Wang Yan Peng [9] used the theory and method of environmental Kuznets curve to analyze the relationship between carbon emissions per capita and carbon emissions per capita in Henan Province, and then set up a regression model for $ARMA$. The $STIRPTA$ model analyzes the relationship between " Henan Province energy consumption carbon emissions and carbon intensity during the 12th Five-Year Plan period. Taking Jilin Province as an example, Wang Hsien-nien and Wang Yongxuan[10], for example, conducted a set of scenarios of low-carbon scenarios, energy-saving-low-carbon scenarios, energy-saving scenarios and benchmark scenarios according to different stages of low-carbon social development prediction.

3. CARBON EMISSIONS ESTIMATES

In today's relevant statistics, there is no direct statistics on carbon emissions, so initial estimates of carbon emissions can only be based on other available statistics. Numerous studies show that the main source of carbon emissions is fossil fuels, so the initial calculation of carbon emissions can be based on the use of fossil fuels. In estimating emissions, there are usually two indicators that are used to measure emissions: CO_2 emissions and C emissions, and the conversion factor between CO_2 emissions and C emissions, calculated by relative molecular mass and atomic mass, is 12/44, that is, C emissions equivalent to 12/44 (about 0.273) per unit of mass of CO_2 emissions. Due to the different carbon emission factors of fossil fuels that make up primary energy,

$$CO_2 = \sum_{i=1}^{n} w_i \times m_i \tag{1}$$

$$C = \sum_{i}^{n} w_i m_i \times \frac{12}{44} \tag{2}$$

In the above formula, i represents the i kind of fossil energy; n represents a total of n kinds of fossil fuels; w_i represents the i kind of energy CO_2 emission factor; and m_i represents the i kind of energy consumption. The carbon emission factors used by different researchers are different, and the commonly used carbon emission factors in the world are shown in Table 1. By consulting relevant literature, this paper uses the average to determine the carbon emission factors of various energy sources.

Table 1. Various fossil energy emission factors

Data Sources	Coal	Oil	Natural gas	Other
DOE/EIA	0.702	0.478	0.389	0
Japan Institute of Energy Economics	0.756	0.586	0.449	0
National Development and Reform Commission Energy	0.7476	0.5825	0.4435	0
National Science and Technology Commission climate change project	0.726	0.583	0.409	0
Average value	0.7329	0.5574	0.4226	0

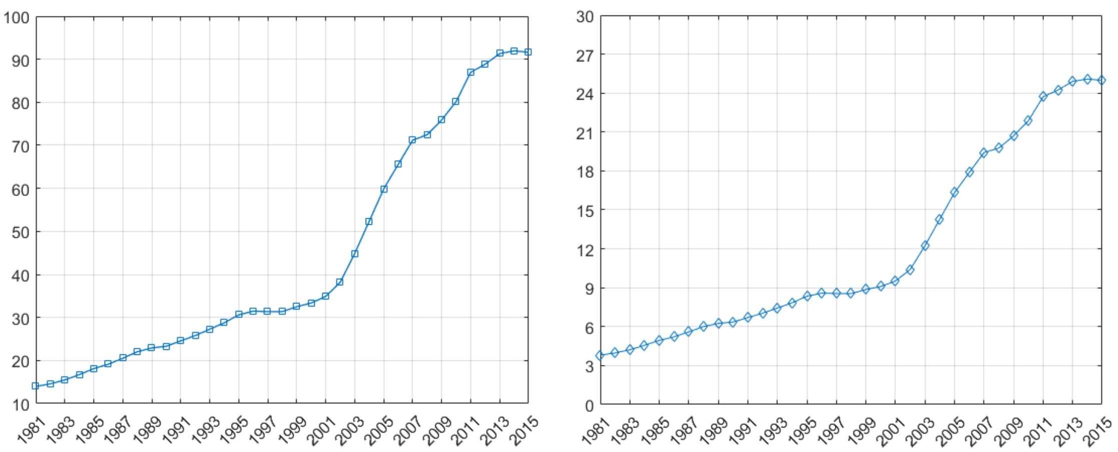


Fig 1. Change of CO_2 emissions (left) and C (right) in China from 1981 to 2015 (Unit: 100 million tons)

China's consumption of coal, oil and natural gas from 1981 to 2015 was obtained by referring to "2016 China Energy Statistical Yearbook” and calculating CO_2 and C emissions of China from 1981 to 2015 according to formulas (1) and (2). The result is shown in Figure 1.

4. INFLUENCING FACTORS ANALYSIS

According to (1) and (2), the consumption of primary energy will have a direct impact on carbon emissions. Today, primary energy is still China's major energy source. The annual consumption of coal, oil and natural gas accounts for more than 85% of the total energy consumption, while the total energy consumption also increases rapidly with an average annual growth rate of more than 7% The reasons for this trend of change are roughly the economic growth, population growth and urbanization process, so this article makes the following assumptions:

(1) Energy consumption is the direct reason for the increase of carbon emissions;

(2) Economic growth is the indirect reason for the increase of carbon emissions;

(3) Population growth is the indirect reason for the increase of carbon emissions;

(4) The process of urbanization is the indirect reason for the increase of carbon emissions;

In order to verify these four hypotheses, this paper conducts a path analysis of each Granger causality test on carbon emissions, energy consumption, economic growth, population growth and urbanization.

4.1 Path analysis

In order to study the impact of the four selected factors on carbon emissions, this paper conducts a path analysis of these factors. Pathway analysis is proposed by quantitative geneticist Sewall Wright in 1921. This method not only eliminates the traditional multi-regression analysis method which cannot eliminate the problem of multiple collinearity, but also this method enables the analysis of the direct and indirect effects of each independent variable on the dependent variable as well as the combined effects through the direct path, indirect path and comprehensive path of the independent variables and Decomposition of the correlation between the dependent variables.

Before carrying on the path analysis, we first need to test the normality of the dependent variable. Since the sample size of the sample selected in this paper is 35, which belongs to the small sample, the Shapiro-Wilk method is adopted for the test. The test results are shown in Table 1, with a statistic of 0.848 and a skewness of 0, indicating that the carbon emissions are subject to normal distribution and can be used for path analysis. The results of the path analysis are shown in Table 2.

Table 2. Normality of carbon emissions test results

	Shapiro—Wilk		
	Statistics	Degree of freedom	Sig.
C_t	0.848	35	0.000

As can be seen from Table 2, the correlation coefficients between the selected energy consumption (x_1), economic growth (x_2), population growth (x_3) and urbanization (x_4) and carbon emissions (C_t) are all above 0.9, indicating that these four macroeconomic indicators Highly correlated with carbon emissions.

Table 3. Path analysis results

Argument	Correlation with C_t	Direct path coefficient	Indirect path coefficient				
			x_1	x_2	x_3	x_4	Total
x_1	0.995	0.654	—	0.204	0.641	-0.086	0.341
x_2	0.992	0.227	0.205	—	0.641	-0.081	0.765
x_3	0.997	0.207	0.225	0.646	—	-0.081	0.790
x_4	0.904	-0.092	0.184	0.198	0.614	—	0.996

Among them, the direct impact of energy consumption on carbon emissions is the greatest, and the other three factors have an indirect impact on carbon emissions more than the indirect impact of energy consumption on carbon emissions. The coefficient of determination R^2 = 0.9998, which shows that the selected four influencing factors can explain the explanatory variables to 99.98%, which proves that the four selected influencing factors are effective.

4.2 Granger causality test

In order to further determine the exact causal relationship between carbon emissions and the above four factors, this paper uses the Granger causality test to analyze the relationship between variables. This test can be used to investigate the causal relationship between economic variables. Granger causality test has two preconditions. First, the time series must be stable. Second, non-fixed variables have long-term equilibrium relationships. Granger causality tests can be performed in a time series that satisfies one of the above preconditions or a false regression problem can occur. Therefore, the original data is verified by using the ADF test method. The test results are shown in Table 4. From Table 4, the original data of the selected variables are not stable, but in the second-order differential state, the ADF test values are less than 0.05 under the t level of significance level, indicating that the data is stable and the next step can be carried out the test.

Table 4. Unit root test results

Sequentially	Value of ADF	0.05 Critical Value	Conclusion
CE	1.274	-2.981	Non-stationary
x_1	-0.703	-2.954	Non-stationary
x_2	2.357	-2.976	Non-stationary
x_3	-1.995	-2.954	Non-stationary
x_4	1.554	-2.954	Non-stationary
D(CE,2)	-3.074	-2.971	Stationary
D(x_1,2)	-4.495	-2.957	Stationary
D(x_2,2)	-7.088	-2.960	Stationary
D(x_3,2)	-3.977	-2.957	Stationary
D(x_4,2)	-8.647	-2.957	Stationary

Cointegration is a statistical description of the long-term equilibrium relationship between unstable economic variables. The long-term stable equilibrium relationship among unstable economic variables can be called the cointegration relationship. Since this paper involves many variables, we use the Johansen cointegration test to test the cointegration relationship of the selected variables. The test results are shown in Table 5. As can be seen from Table 5, "None" represents the null hypothesis that there is no cointegration relationship. The trace statistics for this hypothesis is 82.53191, but the threshold for 0.05 is 69.81889. In other words, the tracking statistics are greater than the critical value. Therefore, the results do not support the null hypothesis, indicating that there is at least one cointegration relationship. Then "at most 1" represents a null hypothesis that in most co-integration relationships, the tracking statistic for this assumption is 54.93757, but the key value for 0.05 is 47.85613, so this finding does not support the null hypothesis that at least There is a total integration. Similarly, you can see that there are four cointegration relationships. The results show that carbon emissions and the four influencing factors, respectively, maintained a long-term equilibrium relationship, which met the Granger causality test one of the prerequisites.

Table 5. Cointegration test results

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.863605	82.53191	69.81889	0.0035
At most 1*	0.690228	54.93757	47.85613	0.0013
At most 2*	0.579134	32.70245	29.79707	0.0047
At most 3*	0.490885	16.188385	15.49471	0.0033
At most 4	0.000131	0.004309	3.841466	0.64

Table 6. Granger causality test results

Null hypothesis	Lag1	Lag2	Lag3	Lag4
C does not Granger Cause x_1	0.0553	0.5195	0.6125	0.1712
x_1 does not Granger Cause C	0.0358	0.0106	0.0214	0.0118
C does not Granger Cause x_2	0.1682	0.4466	0.9229	0.5200
x_2 does not Granger Cause C	0.0473	0.0171	0.0325	0.0110
C does not Granger Cause x_3	0.0582	0.1663	0.2276	0.0650
x_3 does not Granger Cause C	0.0003	0.0005	0.0003	0.0002
C does not Granger Cause x_4	0.2006	0.3275	0.4705	0.2745
x_4 does not Granger Cause C	0.0473	0.0417	0.0092	0.0478

Note: The significance level is 0.05

Based on the results of the above common test, Granger causality test can be implemented and the results of non-fixed variables from 1 to 4 are indicated in Table 6. From Table 6, based on the relevant probabilities, it can be seen that "Granger causes of energy consumption not carbon emissions" can be rejected at 0.05 confidence level, indicating that energy consumption is the cause of carbon emissions. However, the Granger reason that carbon emissions are not the cause of energy consumption is accepted, suggesting that carbon emissions are not the cause of energy consumption. Therefore, it can be concluded that there is a one-way causal relationship between carbon emissions and energy consumption. Similarly, there is a one-way causal relationship between carbon emissions and the other three factors. Therefore, the use of Granger causality test can further confirm the impact of energy consumption, economic growth, population growth and urbanization on carbon emissions.

5. FORECAST OF FUTURE CARBON EMISSIONS

5.1 The construction of ARIMA model

The ARIMA(p,d,q) model, ie, the auto-regressive differential sliding average model, was proposed by Box and Jenkins in the early 1970s as a well-known time series prediction method; where p represents the partial correlation coefficient at the end of the truncation and d represents the original The data is processed by step differential and q indicates that the autocorrelation coefficient is truncated at the level.

To build the model, first the original data is required to be stationary. The ADF test is performed on C_t. The t (-1.0155) statistic is greater than 1% (-3.6891), 5% (-2.9718) and 10% (-2.6251), indicating that the sequence is non-stationary. The sequence, obtained after the first-order differential processing, was tested against the ADF. The statistic was -3.4083, which was less than 10% and 5%, indicating that the sequence trend was basically eliminated. Therefore $d=1$, the $ARIMA(p,1,q)$ model can be used. p and q depend on the autocorrelation function (ACF) and partial correlation function ($PACF$) of $D(G_t)$. The ACF and $PACF$ diagrams for $D(G_t)$ are shown in Figure 2. It can be seen from Fig. 2 that the autocorrelation function is truncated after the fifth order, and the partial correlation function is truncated after the third order, so $p=3$ and $q=5$ can be obtained. Therefore, the $ARIMA(3,1,5)$ model was established to predict future carbon emissions.

Use EViews to complete the construction of the $ARIMA(3,1,5)$ model. The estimated results of the equation parameters are: $c=0.563$, $AR1=0.574$, $AR2=0.486$, $AR3=0.332$, $MA1=-0.470$, $MA2=-1.076$, $MA3=-0.216$, $MA4=-0.546$, $MA5=0.479$, various coefficients All less than 1, indicating that the established $ARIMA(3,1,5)$ model is stable, while the AIC indicator reaches a minimum, indicating that the selected lag period is appropriate. Autocorrelation and partial autocorrelation analysis of the residuals of the model showed that the residual autocorrelation and partial autocorrelation plots are truncated, indicating that the model's residual sequence is white noise, which further proves that the model is effective.

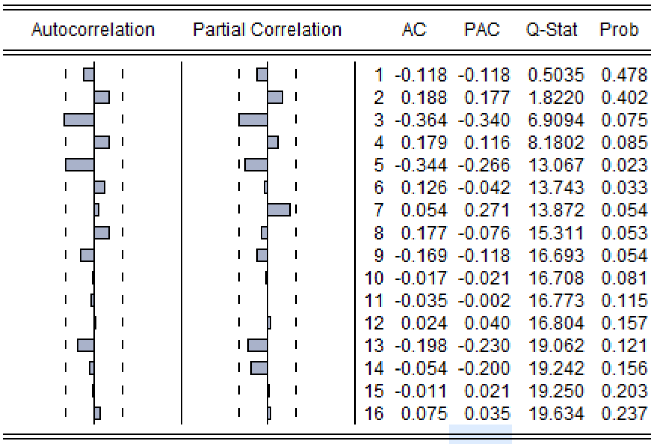
In summary, the resulting time series $D(C_t)$ of the $ARIMA(3,1,5)$ model is:

$$\begin{aligned} D(C_t) &= 0.563 + 0.574DC_{t-1} + 0.486DC_{t-2} + 0.332DC_{t-3} \\ &-0.470\varepsilon_{t-1} - 1.076\varepsilon_{t-2} - 0.216\varepsilon_{t-3} - 0.546\varepsilon_{t-4} + 0.479\varepsilon_{t-5} \end{aligned} \tag{3}$$

The resulting sequence C_t expression is:

$$C_t = C_{t-1} + D(C_t) \tag{4}$$

Using the established model (4) to fit China's carbon emissions from 1981 to 2015, a fitted figure 3 was obtained. As can be seen from Figure 3, the established model has a very high degree of goodness of fit. At the same time, the calculated model goodness of fit $R^2 = 0.998$, and the predicted average absolute percentage error is 1.964%, indicating that the established $ARIMA(3,1,5)$ model can be used to predict future carbon emissions in China.



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.118	-0.118	0.5035	0.478
		2	0.188	0.177	1.8220	0.402
		3	-0.364	-0.340	6.9094	0.075
		4	0.179	0.116	8.1802	0.085
		5	-0.344	-0.266	13.067	0.023
		6	0.126	-0.042	13.743	0.033
		7	0.054	0.271	13.872	0.054
		8	0.177	-0.076	15.311	0.053
		9	-0.169	-0.118	16.693	0.054
		10	-0.017	-0.021	16.708	0.081
		11	-0.035	-0.002	16.773	0.115
		12	0.024	0.040	16.804	0.157
		13	-0.198	-0.230	19.062	0.121
		14	-0.054	-0.200	19.242	0.156
		15	-0.011	0.021	19.250	0.203
		16	0.075	0.035	19.634	0.237

Fig 2. Autocorrelation and partial autocorrelation plots of $D(C_t)$ sequences

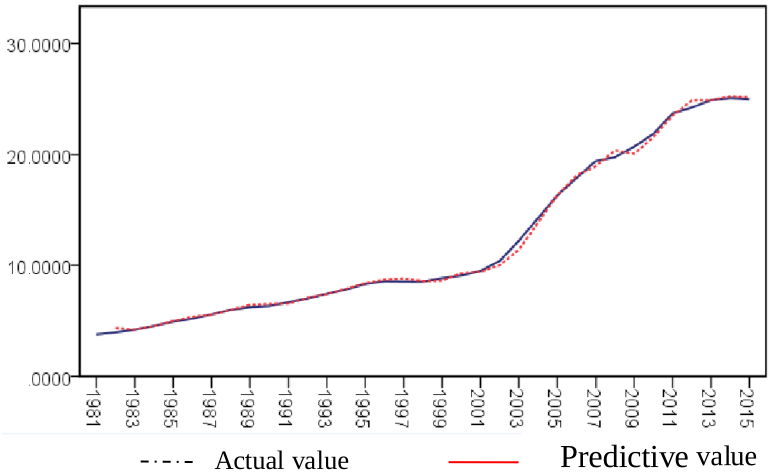


Fig 3. Fitting model prediction and actual value

5.2 Forecast of future carbon emissions and analysis of results

Using the model established above, China's carbon emissions in the next 20 years are predicted. The forecast results are shown in Figure 4.

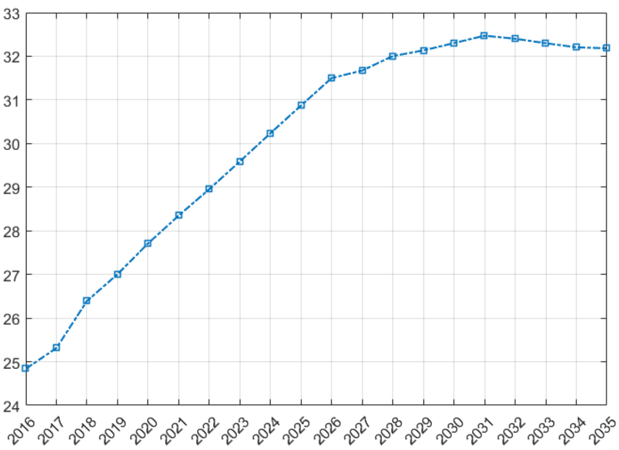


Fig. 4 Forecast of China's Carbon Emissions in the Next 20 Years

From the above forecast results, it can be seen that in the next 20 years, China’s carbon emissions will experience roughly two stages. The first stage will be from 2016 to 2031. Carbon emissions will gradually increase during this period, and carbon emissions will reach its peak value in 2031. This is 3,217.1 million tons, roughly 1.5 times the carbon emissions in 2015; the second phase is from 2032 to 2035. During this four-year period, carbon emissions gradually decreased, but the deceleration was slow, the average annual reduction rate was only 0.22. %.

Based on the above forecast results, it is not difficult to find that the changes in carbon emissions and urbanization, economic development, energy consumption and population growth all have similar changes. According to the State Development Plan for Population Development (2016-2030) published by the State Council, China’s total population will reach 1.42 billion in 2020 and reach 1.45 billion in 2030. The urbanization rate of permanent residents will reach 60% in 2020 and will be 2030. After reaching 70%, this ratio will slow down and eventually reach a level of 85% in the urbanization rate of the developed countries. After China’s economy experienced rapid growth, its growth rate began to gradually slowdown in recent years, according to the 13th Five-Year Plan and other agencies predict that China’s economy will continue to grow at a rate of more than 6% in the next few years; China’s energy consumption will continue to grow, reaching 5 billion tons of standard coal by 2020, subject to economic growth. After the stimulus, energy consumption will continue to increase, but the proportion of fossil energy will gradually decrease, especially the proportion of coal. Among the above four factors, only fossil energy consumption will decline, which will lead to a gradual decline in China's carbon emissions after 2031.

6. CONCLUSION

In order to study the influencing factors and future trends of China's carbon emissions, this paper first results carbon emissions, then uses path analysis and Granger causality analysis to analyze energy consumption, economic growth, population growth, and urbanization processes for carbon impact of emissions. The Path analysis results show that energy consumption has the greatest direct impact on carbon emissions, followed by economic growth and population growth. The urbanization process has the smallest direct impact on carbon emissions while the indirect impact is greatest. Granger causality test results show that energy consumption, economic growth, population growth, and urbanization are indeed Granger causes of carbon emissions. Therefore, this article believes that energy consumption is the direct cause of carbon emissions. Economic growth, population growth, and urbanization are the indirect causes of carbon emissions. Based on this, this paper uses the carbon emissions data from 1981 to 2015 to construct the $ARIMA(3,1,5)$ model to predict the carbon emissions in the next 20 years. The forecast results show that the carbon emissions in the next 20 years will be the first. After the increase, it decreased and peaked in 2031 with a peak of 3.247 billion tons.

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