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Research on GDP forecast and its relationship with energy consumption

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Abstract –The first part of the paper use the method of the stationary time series to build the 1978-2006 GDP time series model of China. Then carried out an estimate to the regression parameters of the time-series model, and the white noise test of the estimated model, and analyze the test of the regression results. The second part selects China 1990-2009 energy consumption and GDP annual data as the research sample, Using Eviews to do the GDP energy consumption of the time series for unit root test and co-integration test, Engle - Grange causality test, then we found that when GDP and energy consumption are in 5% significance level, there is a co-integration relationship between them; Engle - Grange causality test results show that in 5% of significance level, the energy consumption and GDP exist unidirectional causal relationship.

Keywords –GDP, Forecast, Energy consumption, Industrial upgrading

1. Introduction

GDP is defined as the total value of the products and goods of a country within a specific period of time (usually a year). Because GDP can measure not only national output and income scale in general, but also the economic fluctuation and economic cycle state on the whole, therefore which becomes the biggest concern for economic statistics data in macro-economic, and it's considered to be the most important indicator to measure the development of the national economy, as well as the macro-economic performance. So establish China's GDP time sequence model and carries on the analysis have the extremely vital significance. This paper attempts to take our country's 1978-2006 GDP time data as the basis, and establish ARIMA model to reveal the regularity of the changes in GDP growth, according to which we make further analysis.

2. The basic theory of the time-series model

2.1 The characteristics of the time-series

Time series forecasting is to study the variation trend of the target by processing the time series. That is, according to the historical data of the time series reveal the law what the phenomenon changed with time, extends the law to the future, as a result we can make a forecast for the future of the phenomenon.

The modeling approaches of model identification, parameter estimation and diagnostic test of the random time series are proposed by the famous statistician Box from US and Jenkins from UK in 1968, this time series modeling method called Box --- Jenkins methods, referred BJ methods; it is widely used in economic, business forecasting and economic analysis. This is a Sequential short-term prediction method and it focuses on the analysis of economic time series itself probability or random properties.

The basic characteristic of the time series is its value is changed with time, undulating alternately, some have some sort of trend. Time sequence is the important feature of the time-series, this sequence is not arbitrary arrangement, but has the inherent meaning economically or logically. In the traditional econometric study of economic time-series, which assumed that economic data and the stochastic processes of producing these data is a zero-mean stationary process, that is to say the random nature of process has the time invariance, in graphics it performs that all the sample point fluctuate around a horizontal line, and based on which we carried out parameter estimation and hypothesis testing. Most of the time-series is non-stationary in reality, the changes are influenced by many factors, some plays a long-term, decisive role, making the time-series variations in a certain trend and certain regularity, others play a short-term, the decisive role, make the change of time series presents some irregularity [2], if this time establish economic model to use non-stationary economic time series, we can find spurious regression problem [3]. Therefore, analyzing the non-stationary time series, we should convert it to a smooth process time-series. we usually use the method of differential transform logarithmic transformation, or both, to make the non-stationary time series data become smooth.

2.2 Identification and estimates of the time-series model

When we use the B-J method to carry on the modeling, we make the initial judgment on the time-series model, using the shape of the autocorrelation function and the partial autocorrelation function of sample. Exponential decay of the autocorrelation function and truncation of partial autocorrelation function with P step shows that this time series model is p order autoregressive model. If the autocorrelation function diagram truncates with q step, the partial autocorrelation function has exponential decay, then this time series model for q order moving average model. If the sequence of the autocorrelation function and partial autocorrelation function are trailing, we can judge that the sequence is ARMA sequence, the order of p, q should be fixed adopted the best criterion function method. Here we can choose minimum AIC criterion as a fixed order criterion. carrying on models respectively according to the different value of p and q from low order to high order, estimating the parameter, then comparing the value of AIC and SC of every model, enabling which to achieve minimal model as a result we get the best model.

2.3 Inspection of the time-series model

Inspecting whether the time-series model reasonable or not, we need to test the residual series of estimated model is white noise sequence or not (white noise model accurately depicts the time series process, shows that the identified model is reasonable. Otherwise, the model should be reidentificated and new model should be estimated).

3. The establishment of the China's GDP time-series model

3.1 Inspection of the data stationary

Total GDP has the obvious characteristics of increasing with time; past research of economics attribute this to continuous technology improvement, the sustained growth of labor and quality and some other persistent factors. as a sustained economic growth economy, our GDP has the trend of increasing with time obviously, if use non-stationary sequence to establish model, which will lead to the spurious regression problem, namely, even though there is no relationship between the basic sequence, we will also get regression model [4]. When the random variable is not smooth, the statistic rejection region is far more than the normal value of the test; the accepted assumptions which are derived in accordance with the general test methods are likely to be wrong. Therefore, before building time-series model and carrying out empirical analysis of China's GDP, the first of all things is checking China's GDP data smoothness.

We check the time data's stability of our national GDP during 1978-2004. From the entire time series to see (as shown in figure 1), we can see our country's GDP sequence obviously increasing with time, containing index trend, we can preliminary identified which for a non-stationary process.

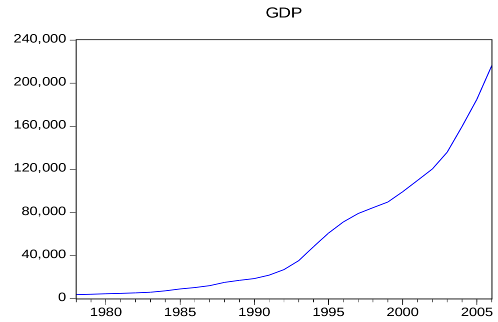

Figure 1.
Source: China Statistical Yearbook 2010

Then we carry out accurate unit root test to verify whether the time series steady or not. The time series of GDP has the significant trend of growing in time, so the model can be used as a test equation to carry out unit root test about GDP timing, if H0 accepted, it means that GDP is non-stationary process containing unit root, and the conclusion of the unit root test has strong inspection force. ADF test results are as follows (Table 1):

Table 1. ADF test results of the sequence of GDP

Augmented Dickey-Fuller test statistic		**1.373967**
Test critical values	1% level	-3.808546
Test critical values	5% level	-3.020686
Test critical values	10% level	-2.650413

As presented in Table 1, the test statistic of the ADF is 1.374, significantly greater than threshold value of three different levels, indicating that the sequence is non-stationary.

3.2 Data tranquilization

We can take the logarithm of the Time series with exponential trend into linear, and then eliminating the linear trend by difference. When given an increasing population and a technological progress, we can assume that the generated data has the trend of growth with time. As can be seen from Figure 2, it does not eliminate the non-stationarity. Therefore, after the logarithm we still need take the first-order difference. As can be seen from the autocorrelation FIG got by the method of difference, the autocorrelation coefficients of the sequence tends to 0 soon, namely falling into the random interval, indicating that the timing is stationary. Its unit root test, ADF test results (Table2) are as follows:

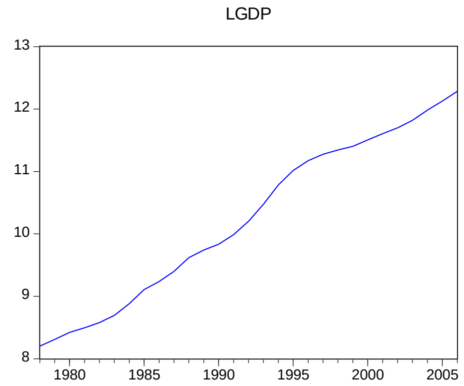

Figure 2

Table 2. sequence of ADF test results

Augmented Dickey-Fuller test statistic		1.373967
Test critical values	1% level	-3.808546
Test critical values	5% level	-3.020686
Test critical values	10% level	-2.650413

According to SC and AIC criterion which are widely used in practice, make sure the lag interval is 5, and when the model take lag 5 order time, the test works best. Seen from Table 2, the ADF statistic is -3.21, less than the critical value 5% and 10%, indicating that we can reject the null hypothesis at least at the 95% confidence level. So, after the differential, we can judge that the sequence does not exist the unit root, as a result GDP timing-series can be seen as a smooth sequence. So China's GDP time series data is a smooth process and first order (1).

3.3Building model

The identification and fixed order of ARMA model can be acquired by observing the sample autocorrelation and partial autocorrelation function, take a logarithm, the sequence of AC and PAC are shown in figure 3.

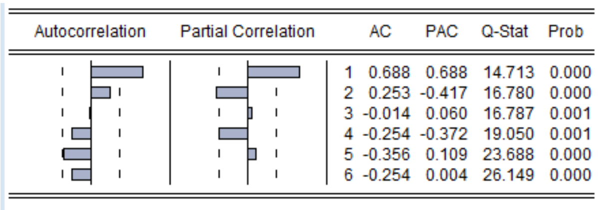

Figure 3 sequence of AC and PAC diagram

It can be seen from Figure 3, the autocorrelation coefficients is significantly different from zero when the lag order is 1:00 ,and when the lags is greater than 1 the autocorrelation coefficients are basically at a confidence band, so we can take q=1. Partial autocorrelation coefficient is significantly different from zero when the lag order is 1:00. It seems that the Partial autocorrelation coefficient is also different from zero when the lag order is 2, so 1 or 2 can be considered. However, this kind of judgment is rough; there is a lot of subjective. We should establish several models for accuracy, and use the AIC criterion and SC to compare model (see table 3).

$$\Delta \ln(GDP_t) = c + \sum_{i=1}^{p} \phi_i \Delta \ln(GDP_{t-1}) + \varepsilon_t + \sum_{i=1}^{q} \varepsilon_{t-i}$$

Figure 2

Table 2. AIC and SC criteria for comparison of multiple ARIMA model

	ARIMA(1,1,1)	ARIMA(2,1,1)	ARIMA(1,1,2)
AIC	-3.479909	-3.308054	-3.616364
SC	-3.335928	-3.114500	-3.424388

As can be seen from Table 3, when p = 1, q = 2, the model of the AIC and SC have achieved minimum, we selected ARIMA (1, 1, 2) Model. Using Eviews6.0 software ARIMA (1, 1, 2) model to estimate and the result is:

$$\Delta \ln(GDP_t) = 0.150983 - 0.340837\, \Delta \ln(GDP_{t-1}) + \varepsilon_t + 1.763477\, \varepsilon_{t-1} + 0.930648\, \varepsilon_{t-2}$$

$$GDP_t = 59199.56 + 0.998290 GDP_{t-1} + \varepsilon_t + 1.774456 \varepsilon_{t-1} + 1.250738 \varepsilon_{t-2}$$

After parameter estimation, we inspect the ARMA model fitness, as a result we carry out white noise testing for model Q statistic [5], by analyzing the residual sequence correlation diagram and partial correlation diagram (figure 4), we can find that if the residual sequences is dependent mutually So the probability of white noise is very great, and we can't refuse the null hypothesis that the sequences are mutually independent; the test through pass) .

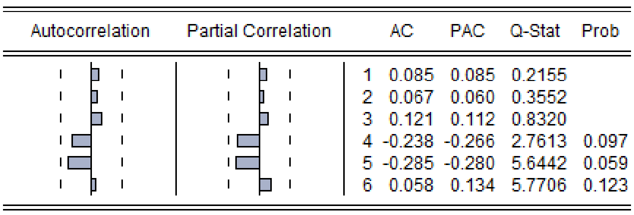

Figure 4 ARIMA (1, 1, 2) a correlation diagram of the model residuals

3.4 Model predictions

(Table 4) It has given the measured and the predicted results of 2007-2009 gross national economy. It can be seen that the results of prediction relative error is not big and the result is satisfactory, which indicates that the model has a good effect on forecasting.

Table 4.

Years	2007	2008	2009
The actual value	265810.3	314045.4	340506.9
The predictive value	256401.8	310048.3	339423.7
Error%	-3.53	-1.27	-0.32

As can be seen in the comparison chart of predictive value and observed value of GDP (Figure 5) we can see a small difference, the red line is the predicted value; the blue line is the actual value. This shows that the ARMA models predict more accurately. From the figure we can see predictive value is a little smaller than the actual value, Maybe because the sample data is not big enough, but the change of the overall growth trend is not particularly great, so the GDP value per year predicted by ARMA model is quite valuable.

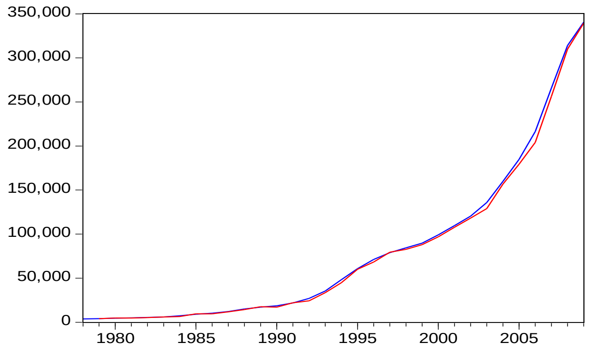

Figure 5.

Through all about these, we can get the following basic conclusions:

1. China's GDP render integrated of order nature.

From our country GDP time series model and China's GDP unit root test, it is known that the GDP sequence is a one order single sharp when we eliminate the exponential growth trend, which shows that our country GDP sequential data to have a lasting impact of characteristic, a fixed growth trend, and will not return to a specific value. Therefore, we should keep the macroeconomic controls and control of steady and persistent in order to prevent the economic ups and downs.

2. Persistence of our GDP.

The process of economic development can be considered as a time series of the total GDP from a quantitative point of view. With total GDP time-series data from 1978 to 2006 we can make Chinese line graph of the growth rate of GDP in 1978-2006. As can be seen, since the reform and opening up in 1978, China's economic growth rate was significantly enhanced and economic become much more strengthened. According to the National Bureau of Statistics of China, in 1978 ~ 1998 the economic developed with an annual GDP growth rate of 9.7%. In 1998 ~ 2002, our country has experienced deflation for the first time since the foundation of New China, the average annual GDP growth rate dropped to 8 percent, while in 2003 and 2004, China's economy entered the fast lane, the rate reaches 9.1% and 9.5%, fully demonstrated that China's GDP growth has long-term sustainability [6]. China's GDP time series data verify the above analysis that the shock is persistent. It can be seen that the long-term growth of our GDP is sustainable.

4. The relationship between GDP and energy consumption

Since the reform and opening up, China's economy has enjoyed rapid and sustained growth, and maintains a speed of more than 9% of the average annual GDP growth. Along with rapid economic growth, China's energy demand and consumption are also rapidly increase, increased from 570 million tons of standard coal in 1978 to 3.1 billion tons of standard coal in 2009, increased nearly 5.4 times. At present, China is in the middle stage of industrialization, especially the rapidly development of heavy chemical industry and traffic transportation, energy demand and consumption rising sharply. For a long time economic structure being not reasonable, GDP growing at the cost of a large number of resource consumption, shorting of energy and resources, environment pollution, ecological imbalance and so on, all of which have become the bottleneck of restricts the economic development. Therefore, the study of the relationship between GDP and energy consumption is of great theoretical and practical significance, which helps to change the mode of the economic growth fundamentally, improve the quality of economic growth, and make a scientific energy policy.

Obviously, conclusion only from the econometric research or get to know the relation between energy consumption and GDP only from one aspect of technological innovation, industrial structure and industrialization process is not comprehensive enough. This paper try to explore the relationship between energy consumption and GDP according to the econometric research conclusions and combined with China's industrial structure, technological innovation, energy policy, industrialization mode, and the industrialization periods .

Selecting GDP as the explained variable as well as total energy consumption (EC) as an explanatory variable, GDP, EC represents the nominal GDP (Unit: 100 million) and total energy consumption (unit: WT SCE). The data comes from the National Bureau of Statistics Network 1985-2009 every period GDP and energy consumption data; total energy consumption including coal, crude oil and its products, natural gas, hydropower, nuclear power, wind power. Taking the price factor into account, this paper takes 1985 as the base year (1985 = 100), and converts the 1990-2009 GDP to 1985 levels.

4.1 Date unit root tests

Carrying out unit root test to GDP and EC sequence in case two variables of non-stationary time series present causality fallacy or unnecessary regression in subsequent co-integration and causality test, we know that these two variables are unrelated. According to analysis above we have know that the GDP original sequence is not smooth. Making the first-order differential to real GDP series, the results show: first-order differential sequence of real GDP is non-stationary. Further making second-order difference to real GDP series, we can refuse the hypothesis having a unit root at 5% significant level. That is to say the second-order differential of GDP is steady at 5% significant level, and the mean and variance do not change with the time (Table 5).Carrying out unit root tests to the total energy consumption sequence (Table 6), we find that it's non-stationary sequence at the 5% significance level. Further carrying out second-order differential sequence to actual EC sequence, we can reject the hypothesis having unit root at 5% significant level, that is to say the EC second-order differential sequence is steady at the 5% significant level and the mean and variance are not changing with time.

Table 5 GDP second-order differential ADF test results

Augmented Dickey-Fuller test statistic		**-3.834727**
Test critical values:	1% level	-3.769597
	5% level	-3.004861
	10% level	-2.642242

Table 6 EC second-order differential ADF test results

Augmented Dickey-Fuller test statistic		**-3.719802**
Test critical values:	**1% level**	**-2.679735**
	5% level	**-1.958088**
	10% level	**-1.607830**

4.2 Co-integration and causality test

According to the conclusion of ADF test we can know that the second-order difference of energy consumption and real GDP sequence are smooth in 5% significance level, which are also the same order single whole process. By co-integration analysis to energy consumption and original real GDP sequence, we find that, at the 5% significance level, there are co-integration relationship between energy consumption and real GDP (see Table 7).

Table 7 GDP and EC co-integration test in 5% significance level

Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical Value	Prob. **	Max-Eigen Statistic	0.05 Critical Value	Prob. **
None *	23.11008	15.49471	0.0029	14.73721	14.26460	0.0421
At most 1 *	8.372874	3.841466	0.0038	8.372874	3.841466	0.0038

The co-integration test The co-integration conclusion shows, the first-order difference sequence of GDP and energy consumption EC exists co-integration relationship in 5% significance level, so we do the causality test (see table 8). The test results show that the energy consumption (EC) has one - way causal relationship to GDP at the 5% significance level, and GDP exist unidirectional causal relationship to energy consumption in the second-order lag.

Table 8 Economic growth (GDP) and energy consumption (EC) causality test Note: A EC; B GDP

Null Hypothesis:	Obs	F-Statistic	Prob.	Whether to reject the null hypothesis or not
A does not Granger Cause B	24	29.4335	2.E-05	yes
B does not Granger Cause A		1.36949	0.2550	no
A does not Granger Cause B	23	16.2635	9.E-05	yes
B does not Granger Cause A		5.73255	0.0118	yes
A does not Granger Cause B	22	10.8252	0.0005	yes
B does not Granger Cause A		2.71037	0.0821	no
A does not Granger Cause B	21	21.7599	2.E-05	yes
B does not Granger Cause A		3.30770	0.0480	no
A does not Granger Cause B	20	12.2103	0.0009	yes
B does not Granger Cause A		2.80179	0.0852	no
A does not Granger Cause B	19	39.1503	0.0001	yes
B does not Granger Cause A		1.70561	0.2664	no

4.3 Conclusion Analysis

(1)The expansion of the total economy is the most important factor in driving energy demand and the rapid increase in energy consumption. According to statistics, China's GDP increased from 406.2 billion Yuan in 1978 to 30.067 trillion Yuan in 2008, increased nearly 74 times; primary, secondary and tertiary industries, respectively, from 1027billion, 1745billion and 87.2 billion Yuan in 1978, to 34 000 trillion, 146183 trillion and 12.0486 trillion Yuan in 2008, an increase of 33 times,83 times and 138 times, respectively. The theory of economic growth shows that the continuous growth of the total output must be accompanied by the increase of the production factor input. Because energy is a kind of essential factors of production, the energy demand and consumption are increasing with the continuous growth of the total economy. So the expansion of the economies will inevitably boost energy demand and energy consumption, especially in the industrial sector. Energy demand will increase with the expansion of the total economy. That is when the economy scale increases; the energy consumption will increase endogenously.

(2)China being in the intermediate stage of industrialization and the extensive mode of economic growth are the important factor that leads to increased energy consumption. The second industry is the most energy-intensive industry. Our country's gross industrial output value increases from 17.69 billion Yuan in 1978 to 12.9111 trillion Yuan in 2008, up nearly 72 times, the proportion of GDP deceases from 43.56% to 42.9%, still occupy the leading position in the national economy. From 1980 to 2006, the energy that consumed by the industry is close to 70% in the vast majority of the year, which result from the rapid and stable growth of the industry. For a long time, the extensive industrial development mode makes economic structure especially in the industrial structure imbalance seriously, most of the leading industry choose heavy and chemical industries including iron, steel, petroleum, chemical industry, equipment manufacturing. These high - energy-consuming industrial sectors have been giving priority to the development. In recent years, steel, copper, aluminum, lead, zinc, cement, electricity, calcium carbide, coke and high energy-consuming industries have gained rapid development. The industrialization mode, the stage of the industrialization and the economic structure are the important factors that affect energy consumption.

(3) Conclusion of this article neither support Wuqiao Sheng, Lee, Mozumber who contain that there is unidirectional causality between energy consumption and GDP nor Yang, Glasure, who believe that there is bi -

directional causality between energy consumption and GDP. Energy as a kind of production factors and the complementarities, the more we input, the greater it output and vice versa. Because of the imperfect market system and unreasonable energy price system, the degree of scarcity of resources is not reflected clearly. According to microeconomics theory, the manufacturer's rational choice is to choose cheap energy elements to substitute labor, capital and other factors of production, based on which, the existence of the above point of view is reasonable. But in the 21st century, with the development of our national economy, the release of the country's energy policy, the adjustment, upgrade, optimization of industrial structure, and the progress of technology, the enhancement of people's environmental awareness, the energy input is declining, but the output is growing. For the past few years, our country's consciousness of self-innovation has been enhanced; as a result, large number of technology that can save Labor, capital, energy appears. Technical progress has played an important role in changing energy consumption structure, improving energy efficiency and reducing energy consumption. By transforming the traditional technology, introducing new technology, developing renewable energy, we have increased the efficiency of the energy production and consumption. So the increase of energy consumption will not necessarily lead to the increase of output, which shows that there is no one-way or two-way causality between energy consumption and GDP.

(4) Yu and Hwang use the American GDP (1947-1997) and energy consumption annual data as a sample, they found that there is no causal relationship between energy consumption and GDP [13], this article does not support the view that there is no causal relationship between energy consumption and GDP. The United States and other developed countries have entered post-industrial and knowledge-intensive industries have become the dominant sector of its economy, there is no relationship between the growth of economic and energy consumption, the expansion of total scale will not cause the increase in energy demand and consumption. According to statistics, the technical contributes 70 % to GDP in U.S, other elements account for only about 30%, However, the situation is completely different in our country.

5. Outlook

(1) We must guarantee to provide the necessary energy for economic growth [14]. Provided that China is bound in the middle stage of industrialization for a very long time, keeping the economy going, which help to solve many problems that are produced in the process of the development such as the economic growth, employment, the single structure of the energy supply and demand. Adequate energy supply is necessary to the continued economic growth. Our country's energy reserves are limited, the production of the coal and oil is difficult, the efficiency of energy utilization is low and the energy consumption exists certain path dependence, and the energy consumption is impacted by numerous factors. First, avoiding the vicious cycle that the energy only consumes in conventional aspects, which will lead to locking situation. We should increase the proportion of new energy consumption, especially increase the renewable energy consumption; second, it is necessary to accelerate technological innovation, develop new energy actively, make up for the deficiencies of conventional energy sources, and solve the negative impact on economic growth due to energy shortages. Third, transform the economic development pattern fundamentally, adjust the industrial structure, increase the proportion of the high-tech industry and the tertiary industry; accelerate the reform of the energy price, adjust energy strategy and energy policy, accelerate the development of circular economy, and implement the various measures of the energy conservation.

(2)Accelerate the development of knowledge-intensive and technology-intensive industries, making economic growth and energy consumption decoupling. The increase or decrease of energy consumption will not impact on output and employment. The contribution of energy to GDP is gradually declining, the high energy-consuming industry is no longer the dominant sector, and knowledge-intensive low-energy industry has become the dominant sector of the economy. Because of the scarcity energy resource, the disequilibrium of regional distribution, we should do: firstly, speed up the adjustment of industrial structure, develop new and high technology industries vigorously and make it become the leading department of the national economy, reduce energy consumption, make economic growth and energy consumption decoupling; Secondly, we need to pay attention to environmental problems caused by energy consumption to make the economic development and human environment coordinate.

Economic growth, technological innovation and industrial restructuring are different sides of the economic system, there is a certain degree of interaction between them, the synergistic mechanisms are relatively complex, and it is difficult to judge the impact of the results simply. From the point of the running mechanism, the impact of economic growth on energy consumption rather ambiguous from the total demand, technological innovation can save energy consumption; the upgrade and optimization of the industrial structure can reduce energy consumption from the view of demand structure.

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