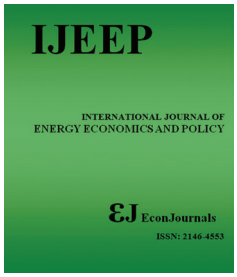

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China's Economic Growth and Energy Consumption

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ABSTRACT

Economic growth needs to consume large amounts of fossil energy, which will result in greenhouse gas emissions and global climate warming. Therefore, how to save energy and protect environment has become a worldwide problem. This paper establishes an econometric model including labor, fixed capital stock, energy inputs and other explanatory variables based on the Cobb-Douglas production function to empirically analyze the relation between China's economic growth and energy consumption. Meanwhile, this paper illustrates the relation of China's carbon dioxide emissions to export trade, too. The study results show that China still promotes economic growth at the costs of high energy consumption and heavily environment pollution. Therefore, how to achieve the transition of a high carbon economy to a low carbon economy will be a fundamental problem that has to solve in China's future development. To this end, China should participate in international environmental cooperation, promote energy saving and environment conservation.

Keywords: Economic Growth, Energy Consumption, The Cobb-Douglas Production Function
JEL Classifications: C32, O13, O24

1. INTRODUCTION

Global climate warming has become increasingly serious. How to deal with environmental protection, energy security and economic growth has become a worldwide problem. Due to interrelation between economic growth, social development and environmental protection, developing countries have firstly to combat poverty. On the other hand, developing countries must still strive to improve environment and to save energy and resources to realize sustainable economic growth (Saidi and Hammami, 2015a, 2015b). China is the largest country of energy consumption and carbon dioxide emissions, how to fairly handle the relationship of energy consumption, carbon dioxide and economic growth is a huge challenge (Śmiech and Papież, 2014).

The issue of energy, environment and economic growth has attracted much attention, which has become a hot topic around the world in a long time (Mercan and Karakaya, 2015; Sebri, 2015) and has been studied by many scholars (Yang et al., 2015; Elliott et al., 2015; Brockway et al., 2015; Kivyiro and Arminen, 2014; Govindaraju and Tang, 2013; Bouoiyour et al., 2014; Tiwari et al., 2013). Using dynamic panel date model and generalized matrix, Saidi and Hammami (2015b) proved that economic growth and carbon dioxide emissions can promote energy consumption. Azam et al. (2015) indicated that energy consumption had a significant impact on economic growth, and growth of per capita carbon dioxide emissions would lead to a decline of economic growth with dynamic simultaneous equations. Using autoregressive distributed lag bounds testing approach, Shahbaz et al. (2015) confirmed the evidence of environmental Kuznets curve hypothesis in Portugal. Using asymmetric causality tests, Ocal et al. (2013) concluded that coal consumption did not affect growth, which showed energy conservation policies may not have effect on economic growth.

Lin and Moubarak (2014) concluded that there is a two-way causal relationship between economic growth and renewable energy consumption through exploring the relationship between China's economic growth and renewable energy consumption from 1977 to 2011. Al-Mulali and Sheau-Ting (2014) illustrated that there was much interaction between energy consumption, carbon dioxide emissions and international trade from a long-term perspective. While promoting economic growth, trade led to increased energy consumption and carbon dioxide emissions, too.

Ying et al. (2011) made an empirical analysis of dynamic relationship between China's energy consumption and economic

growth by the use of state space model, and drew a conclusion that China's economic growth still depended on energy consumption. The study of Enchuang et al. (2012) has shown that non-sustainable resource use and environment deterioration will become an important factor in economic development. Therefore, China has to look for coordinated, operational sustainable development mechanism. The study of Bhattacharya et al. (2015) showed that China should increase investment in coal-fired power industry to reduce carbon dioxide emissions, and transform industrial structure to low energy intensity industry or less export-dependent industry.

The existing research shows that differences in research objects and methods can lead to different relationship between economic growth, energy consumption and carbon dioxide emissions (Omri, 2013). This paper builds a regression model and error correction model, and analyzes short-term quantitative relationships between China's economic growth and energy consumption based on the existing research, the Cobb-Douglas production function and the data of China's economic growth and energy consumption. Due to the linear relation between energy consumption and carbon dioxide emissions, this paper indirectly finds the relationship between economic growth and carbon dioxide emissions. Meanwhile, paper explores the relationship between China's economic growth and carbon dioxide emissions with the latest data.

2. MODEL AND METHOD

A country's economic growth can be determined by human capital, fixed investment, energy inputs and other factors. Therefore, we set up the following econometric models through extending the Cobb-Douglas production function.

$$\ln G_t=\ln A(t)+\alpha \ln L_t+\beta \ln K_t+\gamma \ln N_t+\varepsilon_t \quad (1)$$

Where, G_t, L_t, K_t and N_t represent gross domestic product (GDP), labor capital, fixed capital stock and energy inputs in the year t respectively. A (t) is a residual term. The α, β and γ is output elasticity of labor, fixed capital stock and energy output respectively. ε_t is white noise series.

The data comes from the China Statistical Yearbook, China statistics network and business intelligence network from the 1991 to 2014. The selection of the relevant variables and calculations in the model is as follows.

a. GDP comes from directly official statistics and the unit is 100 million RMB Yuan
b. Labor capital inputs are total employment measured in 10 thousand people
c. Fixed capital stock takes "perpetual inventory method."

$$K_t = K_{t-1}(1-\delta_t) + S_t \quad (2)$$

Where, K_t represents China's total capital in the year t. K_{t-1} represents China's total capital in the t-1 years. δ_t represents depreciation rate with 9.6% (Wang, 2012). S_t represents fixed capital investment in the year t and the calculation of the stock of fixed capitals is based on the fixed capital inputs in 1989.

d. Direct energy inputs are directly subject to official statistics and the unit is 10 thousand Tons;
e. The total value of exports comes from official statistics directly and the unit is 100 million RMB Yuan.

3. RESULTS AND DISCUSSION

3.1. Stationarity and Cointegration Test

The results of the unit root test of variables are shown in Table 1. It can be seen from Table 1 that, GDP, fixed capital stock and energy inputs are all the first-order integration series, and labor and capital inputs are the second-order integration series. The Johansen cointegration test is shown in Table 2. The results in Table 2 show that there is the cointegration relationship of economic growth, labor inputs, fixed capital stock and energy inputs.

3.2. Granger Causality Test

To investigate whether there is a long-term causality relationship between the variables, this paper takes Granger causality test between GDP, energy consumption (N), fixed capital (K) and labor inputs (L). Test results are shown in Table 3.

As is shows in Table 3. There is a two-way Granger causality relationship between energy consumption and economic growth, which shows that China's economic growth and energy consumption are interrelated. Economic growth and energy consumption mutually promote. Labor inputs are one-way Granger

Table 1: ADF test results

Variable	Type	T statistic	Results
GDP	(c, t, 3)	–1.489158	Non-stationary
L	(c, t, 3)	–1.756666	Non-stationary
K	(c, t, 2)	11.59205	Non-stationary
N	(c, t, 0)	–0.008702	Non-stationary
D(GDP)	(c, t, 1)	–12.05584*	Stationary
D(L)	(c, t, 5)	–1.630995	Non-stationary
D(K)	(c, t, 1)	–20.95489*	Stationary
D(N)	(c, t, 5)	–3.753806**	Stationary
D(L,2)	(c, 0, 5)	–3.32538**	Stationary

Note: (c, t, l) represents the intercept, time trends and lag, respectively. *.**Represent 1%, 5% level of significance, respectively, ADF: Augmented Dickey-Fuller, GDP: Gross domestic product

Table 2: Johansen cointegration test results

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	Critical value at 0.05 level
$\rho \leq 0$	0.997944	307.9713 (0.00000)	54.07904
$\rho \leq 1$	0.994598	165.6684 (0.0000)	35.19275
$\rho \leq 2$	0.666295	45.58432 (0.00000)	20.26184
$\rho \leq 3$	0.58705	20.34188 (0.0003)	9.164546

Table 3: Granger causality test results

Null hypothesis	F statistic	P	Results
N does not Granger cause GDP	4.22247	0.0314	Reject
GDP does not Granger cause N	3.32427	0.0591	Reject
L does not Granger cause GDP	106.036	1.E-10	Reject
GDP does not Granger cause L	1.23864	0.3133	Accept
K does not Granger cause GDP	157.087	4.00E-12	Reject
GDP does not Granger cause K	2446.63	1.00E-22	Reject

GDP: Gross domestic product

causality of economic growth and increase in labor inputs can promote economic growth. There exists a two-way Granger causality relationship between fixed capital stock and economic growth, which indicates that China's economic growth will lead to increase investment in fixed capitals, while increase in fixed capital investment will promote China's economic growth.

According to the calculating formula of carbon dioxide emissions that "carbon dioxide = carbon energy consumption × carbon equivalent coefficient × coefficient of carbon gasification" (carbon energy including coal, natural gas and oil. Carbon equivalent coefficient set by the National Development and Reform Commission is 0.67 and the coefficient of carbon gasification is 3.67) (Wang, 2012). There is a linear relationship between carbon dioxide and energy consumption, that is, increases in energy consumption directly lead to linearly increasing of carbon dioxide emissions (Figure 1).

Increase in carbon dioxide emissions is proportional to increase in energy consumption. Due to the bidirectional Granger causality between energy consumption and economic growth, energy consumption and economic growth have interaction effects. China's economic growth requires a lot of energy, which indirectly leads to an increase in carbon dioxide emissions. To control carbon dioxide emissions, China has to consider the impact of energy consumption on real economy and improve energy structure.

3.3. REGRESSION RESULTS

The estimated results of the equation (1) are shown in Table 4. According to the Table 4, the following equation is obtained:

$$\ln G_t = \underset{(2.517615)}{0.836449} + \underset{(7.539854)}{1.734665} \ln L_t + \underset{(30.95173)}{0.559403} \ln K_t + \underset{(6.539506)}{0.230009} \ln N_t \quad (3)$$

R^2=0.99994, D.W.=1.078807, F=79460.99

Obviously, labor's output elasticity is 1.734665 and fixed capital's output elasticity is 0.559403, while energy's output elasticity is 0.230009. Therefore, 1% increase in labor will result in 1.734665% increase in GDP and 1% increase in fixed capital will cause 0.559403% increase in GDP, while 1% increase in energy inputs will lead to 0.230009% increase in GDP. The sum of output elasticity is 2.524077, showing there are the effects of increasing economies of scale in China.

Average annual growth rate of GDP is 16.07%, and that of labor, capital stock and energy per year is 0.739%, 26.35% and 6.358% respectively. The contribution rate of labor, the stock of fixed capitals and total energy inputs on economic growth is 1.28%, 14.74% and 1.46% respectively. Therefore, it can be concluded that energy inputs have a significant impact on economic growth, which shows that China's economic growth needs energy.

Carbon dioxide emissions will increase proportionally with the growing of energy consumption. The regression analysis indicates that, besides fixed capital stock, energy consumption takes a huge contribution to economic growth. There exists a long-term

Figure 1: Carbon dioxide emissions and total energy consumption

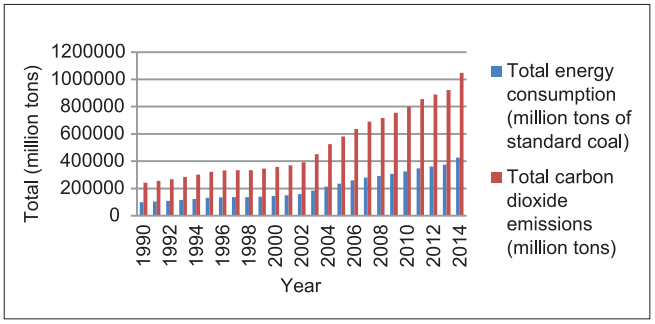


Table 4: OLS estimation results

Variable	Coefficient	Standard error	T statistic	P
C	0.836449	0.332239	2.517615	0.0209
lnL	1.734665	0.230066	7.539854	0.0000
lnK	0.559403	0.018073	30.95173	0.0000
lnN	0.230009	0.035172	6.539506	0.0000
AR(1)	0.164895	0.01489	11.07412	0.0000

F=79460.99, R^2=0.999928, D.W.=1.078807, OLS: Ordinary least squares

and two-way Granger causality relationship between energy consumption and economic growth through Granger causality test, resulting in mutual promotion between economic growth and energy consumption. Therefore, China needs a lot of energy to develop economy.

The relationship of China's economic growth, energy consumption and carbon dioxide emissions from 1990 to 2014 is shown in Figure 2. Obviously, China's rapid economic growth is one of the important reasons that lead to increase in carbon dioxide emissions in recent years.

Due to linear relation between energy consumption and carbon dioxide emissions, increase in energy consumption will inevitably lead to increase in carbon dioxide emissions. Therefore, China's economic growth will indirectly lead to increase in carbon dioxide emissions. China's current economic growth heavily depends on energy. Substantial emissions reduction will affect economic growth. It requires the government to make emissions reduction policy to match the capacity of economy development.

China's foreign trade has a significant impact on carbon dioxide emissions, too. As is shown in Figure 3, there is a high linear relationship between trade exports and carbon dioxide emissions in China, which indicates that international trade has also led to increase in carbon dioxide emissions. The existing research show that international trade can lead to increase in carbon dioxide emissions for the newly industrialized countries (Al-Mulali and Sheau-Ting, 2014), and there is a interdependent relation between trade openness and energy consumption (Kyophilavong et al., 2015). While government makes international trade policy to promote economic growth, energy consumption and carbon dioxide emissions should be fully taken into account.

Renewable energy should be fully taken into account, for it may reduce environmental impacts in international trade. Research indicated that international trade can promote the consumption

Figure 2: Relationship between economic growth, energy consumption and carbon dioxide emissions from 1990 to 2014

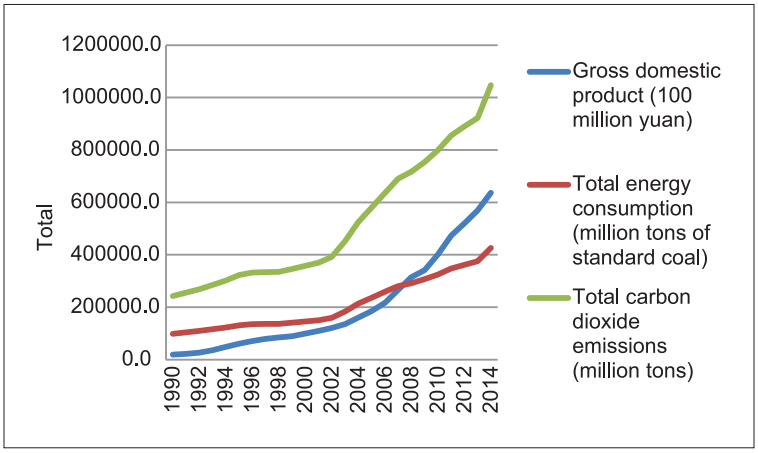
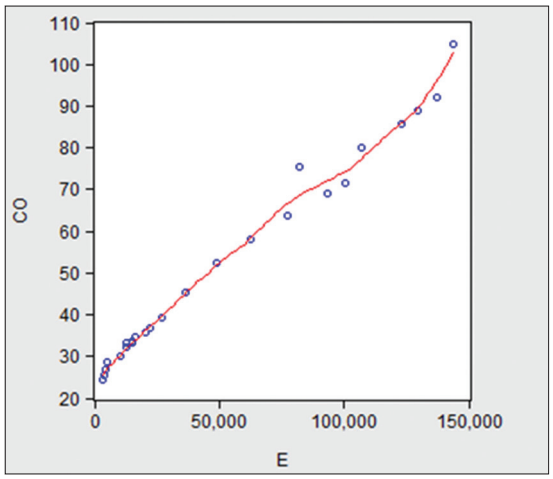


Figure 3: Relationship between foreign trade and carbon dioxide emissions



of renewable energy and reduce carbon dioxide emissions (Ben Jebli and Ben Youssef, 2015). According to the research of Lin and Moubarak (2014), the development and utility of renewable energy is an effective method for sustainable economic development. The exploitation of renewable energy in China grew 17% from 1977 to 2011, but it is only 8.8% of total energy in 2011. Visibly, the potentials of renewable energy are huge. To promote economy development, China should develop new energy sources to promote exports. Meanwhile, international trade can foster the development of renewable energy and lay the foundation for future low carbon economic development in China.

3.4. Error Correction Model

Equation (3) describes a long-term relationship between the variables. It is necessary to explore the relationship of short term again. An error correction model is built as follows on the basis of equation (3).

$$\Delta \ln G_t = \underset{(9.325933)}{4.819385} + \underset{(3.264075)}{0.56345}\,\Delta \ln L_t + \underset{(8.348971)}{0.621809}\,\Delta \ln K_t + \underset{(5.107620)}{0.491987}\,\Delta \ln N_t - \underset{(2.714882)}{0.612655}\,ECM_{t-1} \quad (4)$$

R^2=0.999986, D.W.=1.409543, F=184012.3

R^2=0.999986 indicates that the goodness of fit of the model is good and dependent variable can be better explained by independent variables. D.W.=1.409543 shows that there is not autoregression in the equation (4). All explanatory variables pass the t test and they are all statistically significant.

It can be seen from equation (4), in the short term, labor's output elasticity is 0.56345 and fixed capitals' output elasticity is 0.621809, while energy's output elasticity is 0.491987. Residual term coefficient is –0.612655, indicating that negative adjustment will reduce the possibility of errors. In the short term, increase in 1% labor will result in 0.56345% GDP's increase. The 1% increase in fixed capitals will cause 0.621809% increase in GDP. The 1% increase in energy input will result in 0.491987% increase in GDP.

Average annual growth rate of GDP, labor, capital stock and energy inputs is 16.07%, 0.739%, 26.35% and 6.358% respectively. The contribution rate of labor, capitals and energy on economic growth is 0.416%, 16.38% and 3.13% respectively. Therefore, it can be concluded that, in the short term, energy inputs have significant impact on economic growth, while China's economic growth heavily depends on energy consumption.

There is direct Granger causality between China's long-term economic growth and energy consumption from the perspective of empirical analysis. Regression analysis and error correction model show that the contribution rate of energy inputs on economic growth is large. Because of linear relationship between energy consumption and carbon dioxide emissions, economic growth will indirectly lead to increase in carbon dioxide emissions. Increase in export trade and carbon dioxide emissions at the same time suggests that international trade exports will cause significant increase in carbon dioxide emissions in China.

China still needs to consume a lot of energy and emit large amounts of carbon dioxide with economic growth. Therefore, economic growth and environmental protection will be a huge challenge for China in the coming decades. Because of the restraints of national resources on China's energy consumption structure, energy consumption structure cannot be changed within a short time. Meanwhile, the improvement of energy consumption efficiency will face technical and financial problems. Therefore, it will be

a serious problem for China to manipulate economy growth and environmental protection.

4. STRATEGIES AND COUNTERMEASURES

Economic growth and environmental protection interact with each other. However, environmental protection is based on economic development. China should adhere to the position of developing countries to seek to maximize the interests of developing countries on the issue of coordination between economic development and environmental protection during international negotiations (Wang, 2007).

China's 70% or more of carbon dioxide emissions come from the production, while 70% come from international consumption in United States. Obviously, China's development is far behind the United States. China should change its industrial structure and develop new industries to avoid the heavy industries of high energy consumption and high pollution. If China's economic structure takes a significant transformation, not only can it solve climate problem, but also can help to promote the development of national economy. Therefore, China should always maintain its national interests and take some measures while China conducts international negotiations. Meanwhile, countermeasures have to be taken to achieve the win-win goals of specified economic growth and carbon dioxide emissions reduction with commitment to the international community.

4.1. Active Participation in International Environmental Cooperation

4.1.1. To enhance the power of international environmental negotiations

Because China is a big country of carbon emissions, China should actively participate in international environment cooperation to improve its status and enhance negotiation power in international environmental cooperation to maximize its national interests. During international environmental cooperation, China must adhere to pragmatic attitude and adhere to the "common but differentiated responsibilities" obligation to negotiate on carbon emissions.

On the one hand, China should strengthen exchanges with developing countries to make an alliance with developing countries to deal with international environment cooperation negotiations and uphold the fundamental interests of developing countries. On the other hand, China should strengthen cooperation with developed countries to actively introduce advanced technology and participate in the research and development of clean technology (Zhu, 2014).

4.1.2. Insisting on the fairness of climate negotiations

With the improvement of China's international status and the enhancement of national discourse power, China should cooperate with developing countries to insist on the "fairness" principle in international environmental cooperation. The developed countries should take full account of China's development conditions and set a reasonable emissions reduction task, while China shares carbon emissions reduction responsibility.

The "international" characteristics of climate change show that it has more or less influence on any country. Therefore, it is the responsibility of every country, too. At the same time, in the signing of a number of agreements, it is necessary to uphold the interests of developing countries. Because warming temperatures were initially caused by non-sustainable development of developed countries during the industrial revolution, the developed countries have the obligation to undertake more emissions reduction task (Dou, 2015).

In a word, China should always follow "common but different responsibilities" principle in the negotiations on environmental cooperation. Developed countries should bear primary responsibility about the history of carbon dioxide emissions and reduce carbon dioxide emissions initiatively. Because the economic development and technology level of developing countries are behind of developed countries, developing countries should bear secondary responsibility (Tian, 2014).

4.1.3. Strengthening international cooperation of environmental technology and economy

China should show an open attitude in international environmental cooperation. China has to strengthen technical cooperation with developed countries and international trade partners to introduce advanced science and technology from them. Some studies have shown that, if developing countries adopt an inward-looking trade, their manufacturing sector will rapidly increase the accumulation of toxic substances. Their productivity is low and they will not have any competition. If developing countries adopt a more export-oriented trade, the concentration of toxic substance will be low (Hettige et al., 1992). Therefore, China should be more opened to join international community and strengthen international cooperation, when China deals with global issues. China should actively participate in international researches on energy-saving and clean technologies and conduct exchanges with developed countries. Meanwhile, China can advance international standards through international environmental cooperation, too.

At this stage, China's international trading exports are mainly high energy consuming products, while developed countries depend on the import of these products. Therefore, China can use this advantage to cooperate with the developed countries. China exports some high energy consumption products to the developed countries, while the developed countries should transport some of the advanced energy-saving or high-tech technology to China.

4.2. Effective Measures to Promote Domestic Energy Conservation and Emissions Reduction

4.2.1. More efficient utility of fossil fuels

The key to energy saving and emissions reduction is effective control of total energy consumption and more efficient use of fossil fuels. Fossil fuel is broadly used. However, the efficiency of fossil fuel utilization to produce different products is different. Therefore, China can examine the utilization of different fuels for different products and make a thorough assessment to maximize energy efficiency of different fossils. It could effectively improve the efficiency of energy (Cao, 2010).

Foreign practice has proved that the construction of a reasonable index system and evaluation model has a great help for low carbon development and energy conservation (Lin and Moubarak, 2014). For example, when fossil fuels are used in power generation, producer can optimize his power generation technology to improve efficiency of energy use effectively to avoid large waste of energy resources. Research and application of processing technology of fossil energy may increase the efficiency of fossil energy and optimize fossil energy consumption, too.

4.2.2. Less dependence on fossil fuels

Since China's economic development is still extensive at the current stage, China must upgrade industrial structure, reduce high energy-consuming industries and eliminate backward production facilities to decrease dependence on fossil fuels. Governments may encourage companies to develop energy-saving technology and eliminate extensive production facilities. At the same time, enterprises should change the ideas of technology research to develop energy-saving technology. The Government should increase support for the development of green industries, high-tech industries and service industry vigorously. China can transform its economic growth mode to promote comparative advantage industries and economic transition to intensive mode, too (Dou, 2013).

A large proportion of China's exports are primary products and high carbon emissions products. Therefore, although China obtains huge economic profits and stimulates domestic economic growth, it brings pollution, too. The empirical analysis shows that, China's trade exports are positively related to carbon dioxide emissions. The production of high carbon products increases the consumption of fossil fuels and the generation of a large amount of greenhouse gases. This pattern of growth severely raises the costs of national environmental governance. Therefore, China has to significantly cut the exports of primary products to reduce the consumption of fossil fuels (Geng and Zhang, 2012).

4.2.3. Development and application of green renewable energy

China should pay more attention to the development and popularization of clean energy, and vigorously develop green renewable energy to promote China's energy consumption from fossil energy to clean green energy. China may learn the experience of encouraging the development of green and renewable energy industries from India. Government may guide and encourage the green industry development through price protection and tax policy to make these industries profitable. Through some incentives, more companies can be encouraged to invest in green renewable energy industries (Leng, 2012).

4.2.4. Regulation construction for carbon taxes and emissions trading

Reduction in energy consumption and carbon emissions in the short term is very difficult for China. However, China may adjust energy policy to solve this problem (Luukkanen et al., 2015). Key policies and measures are to impose a carbon tax and set up carbon emissions trading markets.

China can learn successful experience from the Nordic countries in terms of carbon emissions tax. They formulate different taxes policies according to different energy types and uses. Generally, carbon emissions taxes of energy consumption for production and life are lower, while higher carbon emissions taxes of energy consumption for non-production may be levied. China may practice different carbon taxes on different products to achieve "who pollution, who governance" principle (Geng and Zhang, 2012).

The establishment of carbon emissions trading markets is conducive to carbon emissions reduction to achieve the principle of "efficiency." Carbon emissions trading markets can promote the reform of high energy consumption industries and the transformation of production structure to improve energy efficiency and promote environmental protection technology innovation. At the same time, it may play a role in promoting economic development and technological progress, too.

4.2.5. Green consumption promotion

It is essential to enhance people's awareness of environmental protection and change people's consumption habits. The government can invest heavily to carry out publicity and education in the promotion of green consumption and energy conservation through some economic incentives. People can reduce their energy consumption and carbon dioxide emissions through increasing society's awareness of low carbon and green consumption. At the same time, China should accelerate the construction of low carbon city, low carbon country and low carbon transportation to build a full range of green consumption environment and consumption patterns.

5. CONCLUSIONS

Global warming caused by energy consumption and carbon dioxide emissions is increasingly prominent, which is restricting economic development. As a developing country, China faces enormous challenges for economic development, energy security and environment protection.

This paper illustrates the relationship between economic growth and energy consumption. The study indicates that there is a linear relationship between economic growth, energy consumption and carbon dioxide emissions. China is currently extensive mode of economic growth at the expense of the increase in carbon dioxide emissions. Meanwhile, international trade has a significant impact on carbon dioxide emissions, that is, China's carbon dioxide emissions and export trade have a high correlation.

To achieve emissions reduction targets, to strengthen the market's ability to adjust energy is effective in the short term. However, China should develop new energy, adjust industrial structure and reduce economic growth rate in the long term. As pure administrative intervention can lead to cyclical fluctuations of energy markets, so it should be regulated by market mechanism. In the future, China should change the strategy of international

environmental cooperation to realize the cooperation with other countries in environmental technology, economy and other aspects.

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