The Environmental Kuznets Curve Effects of Energy Intensity and Emission Intensity on Optimizing Chinese Emission-reduction under the Constraint of Energy-saving Policy

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Abstract: - Using Environmental Kuznets Curve theory, this article examines the EKC effect of economic growth, energy intensity and carbon emission intensity on total quantity of carbon emission under the constraint of energy-saving policy. Optimizing energy-consuming structure and decreasing energy-consuming intensity can incline carbon emissions intensity and slow down the increasing speed of carbon emissions quantity. GDP per population and carbon emission intensity have significantly inverted U-shape EKC effect on carbon emission quantity at the confidence of 95% level from 2006 to 2015, accordingly optimizing energy-consuming structure and reducing energy intensity are helpful to incline carbon emission intensity and total quantity growth of carbon emission in eleventh-five and twelfth-five periods under the constraint of energy-saving and emission-reduction policy. However planning target of carbon emission intensity faces greater challenges and risks in the future, Chinese government should introduce a serial of energy-saving and emission-reduction advices and policies in the future.

Key-Words: - Environmental Kuznets Curve; energy-consuming structure; energy intensity; carbon emission intensity; energy-saving; emission-reduction;

1 Introduction

Based on BP world energy statistical yearbook in 2013, total quantity of Chinese energy consumption account for 20% of global energy consumption in 2012, China had been become the largest energy-consuming country and second carbon emission country. Coal-consuming quantity account for 68.4% of total quantity of Chinese energy consumption in 2012, energy-consuming structure is unreasonable, energy efficiency is relatively lower, energy-consuming structure with over-dependent coal resources cannot turn around in the short term. Accordingly a larger number fossil energy utilization cause serious damage of ecological environment, resource-environment pressure is ever-increasingly growing. Since 2006, Chinese government had carried out mandatory energy-saving and emission-reduction responsibility system using energy development planning and comprehensive programs of energy-saving and emission-reduction in the eleventh-five and twelfth-five period, strengthen government and corporate responsibility using the constraint of energy-saving and emission-reduction policy.

Since an inverted U-type relationship between economic development and environmental degradation by Grossman and Krueger [1], this relationship means that the lower degree of economic development causes less environmental pollutions, environmental degradation is serious with an quick increase of initial economic growth, and then environmental problems will be gradually improve with higher developed degree of economic growth. Environmental Kuznets Curve (EKC) suggests the relationship between economic growth and environmental degradation taking the forms of an inverted U-type, and then sufficient economic development will solve environmental degradation and natural resource exhaustion problems in both developed and underdeveloped nations. Bruyn (1997) find evidence for structural changes of economic growth as an important determinant of the impressive reductions in SO2 emissions of developed economies during the 1980s [2]. Unruh and Moomaw (1998) imply that national income levels determine pollution levels using the EKC hypothesis, and historical economic growth can forecast pollution trajectories of individual country

[3]. Dijkgraaf and Vollebrgh (2005) cast an inverted-U relationship between per capita GDP and environmental pollution, CO_2 emission-reduction is difficult due to the overall Environmental Kuzents Curve [4]. Verbeke and Clercq (2006) posits an inverse U-shaped relation between environmental pollution and national income with a Monte Carlo investigation of an transited Environmental Kuznets type [5]. He (2008) discusses the validity of the Environmental Kuznets Curve (EKC) hypothesis for the case of Chinese industrial SO2 emissions, his result show the decreasing trend in per capital emissions may well not be enough to bring about an immediate reduction in terms of total quantity of industrial SO_2 emissions and SO_2 emissions density [6]. Brajer, Mead and Xiao (2008) find some support for the typical inverted-U-shaped relationship and an N-shaped cubic configuration between economic growth and environmental degradation [7]. Diao et al (2009) develop regression modes for investigating the inverted-U relationship between economic growth and environmental quality in China using Environmental Kuznets Curve (EKC) theory [8]. Miah et al. (2010) examine the effect of economic development processes on environmental changes using Environmental Kuznets Curve (EKC) hypothesis [9].

The EKC literatures shift the main issue from natural resource exhaustion and environmental degradation and economic growth to overcome necessarily environmental deterioration and pollution. Appropriate economic growth and environmental regulation policies have played an important role in the developed and underdeveloped countries.

However a large parts of empirical evidence attempt to examine the significance of other factors than economic growth that may lead to an EKC-pattern. Lindmark (2002) examines the inverted-U trajectory of Swedish CO_2 emissions associated with technology, industrial structural changes, economic growth and fuel price, and suggests higher sustained-growth rates was associated with less technological and industrial structural changes relating to CO_2 emissions quantity than those periods with lower growth rates [10]. Lantz and Feng (2006) investigate that gross domestic product per capita (GDP/capita), population and technological change have the important impact on CO_2 emissions, their results show that GDP per capital is not an inverted U-shaped relationship with population, a U-shaped relationship with technology progress [11]. Harris et al. (2009) test the validity of the EKC effect using the ecological footprint, which is a more comprehensive measure of environmental degradation [12]. Kijima et al.(2011) find that expected level of overall pollutions exhibit a inverted V-shaped or an N-shaped pattern with an increase of economic growth [13]. Park and Lee (2011) investigate a relationship between economic development and air pollution at the regional level, their results show potential existence of U-shaped and N-shaped curves, and the region-specific coefficients are enormously heterogeneous across regions [14]. Thompson (2012) determines the effect of water abundance on an EKC for water pollution using Environmental Kuznets Curve theory, and water abundance greatly affects the turning point of an EKC [15]. Lin et al. (2013) verify that the initial goals of the government on energy conservation and emission reduction could not be achieved through improving energy efficiency alone, but need to be supplemented with relevant energy pricing reforms [16]. The above studies examine the other underlying factors that may drive such an EKC relationship, such as the distribution of income, international trade, structure changes, technical progress, energy efficiency improvement, governance and consumer preferences [17-18]. Chang and Wang (2012) propose a new N-factor affine term structure model for CO2 futures price and estimate parameters in the new affine model by using the Kalman filter technique, their results CO2 futures price follow significant mean-reversion process, and the estimated coefficients of mean-reversion speed, market risk premium, volatility and their correlation among state variables are almost significant [19]. Chang, et al.(2012) develop the general model of the futures options valuation under the term structure of stochastic multi-factors, suggest the futures options function carry information about the volatility and adjustment speed of arbitrary multi factors, the correlation among multi-factors, and the time to maturity of futures and options contract [20]. Chang (2013) propose the market behavior of convenience yields and examine the options feature of convenience yields for emission allowances, his empirical evidences show that when the convenience yields are call or put options, market participants can flexibly adjust portfolio policies of emission allowances assets, and then achieve extra market arbitrage revenues through exchanging emission allowances assets between spot and futures [21]. Chang (2013) proposes the empirical evidence of the effects of ownership and capital structure on environmental information disclosure, his empirical results show that state legal-person ownership, non-state ownership, ownership concentration, financial

leverage, long-term debts and short-term debts have significantly positive impacts on environmental information disclosure [22]. Neri (2010) describes how the software agent paradigm can be a powerful and versatile simulation tool to model and study complex systems, and software agents allow to approximate the behavior of complex systems under several scenario conditions [23]. Neri (2012) discusses a computational simulation technique based on agent based modeling and learning to closely approximate the SP500 and DJIA indexes over many periods and under several experimental set ups [24]. Neri (2012) presents an introduction to the special issue on computational techniques for trading systems, time series forecasting, stock market modeling, and financial assets modeling [25]. Yu and Zhou (2010) adopts stochastic frontier analysis to measure R&D efficiency and its impacts on Chinese high- tech industry in 2001- 2007 with provincial panel data, Institutional environment, the size of firms, and the expense on digestion and adoption of technology have a positive impact on R&D efficiency of high- tech industries [26]. Zhang and Wang (2010) use provincial panel data to examine the relationship between economic growth and air pollutants, the inverted- U relation results from government regulations rather than the endogenous mechanism [27]. Yao (2012) finds that the environmental performance appraisal system towards local governments is implemented to resolve the soft constraints of environmental regulation in the long run In order to break political connection buffer effect between the local government and some regulated firms [28]. Cheng and Wang (2014) present a vector auto regression model of energy consumption , technological progress and economic growth is established and the dynamic relationships between them are empirically analyzed with the econometric method of the cointegration test , Granger causality test , impulse response function and variance decomposition [29].
Hájek and Neri (2013), Azzouzi and Neri (2013), Bojkovic and Neri(2013), Pekař and Neri(2013), Guarnaccia and Neri(2013) propose an introduction to the special issue on computational techniques for trading systems, time series forecasting, stock market modeling, financial assets modeling, advanced control of energy systems, interactive multimedia systems, and advanced control methods: Theory and application [30-34].Energy consumption structure, energy intensity, energy efficiency and energy-saving policy have important role in economic growth and emission target control.

The above literatures pay much attention on crucial factors such as economic growth, population, technology progress, industrial structure changes etc using an inverted-U and N-type EKC theory. Especially this article has two major contribution: firstly those literatures have not take full account for the inverted-U type EKC effect of energy intensity, energy- consuming structure and carbon emission intensity on environmental degradation. Secondly the constraint of energy-saving regulation policy has a significant impact on energy efficience and energy intensity and emission intensity. Since 2006, Chinese government proposes specific constricted targets in energy consumption structure, energy intensity, energy efficiency and carbon emission intensity. This paper presents energy efficiency, energy-consuming quantity and carbon emission intensity have significant effects on emission-reduction target on the constraint of energy-saving policy, and then propose reasonable advices on energy planning and environmental regulation policies for further energy-saving policy.

The remainder of our paper is organized as follows. Section 2 presents Environmental Kuznets Curve theory. Section 3 describes the source of data samples and constraint energy-saving and emission-reduction indicators. Section 4 proposes co-integration and Granger causality tests. Section 5 presents the statistical results of EKC effect of economic growth, energy intensity and carbon emission intensity on carbon emission quantity under the constraint of energy-saving policy. Section 6 provides a brief conclusion and a serial of resonable advices.

2 Environmental Kuznets Curve (EKC) estimation

According to the EKC-hypothesis, further economic growth can improve environmental degradation after an economy has reached an adequate level of economic growth [17]. In the early stages of economic growth, there is an abundance of natural resource stock and a limited generation of wastes and greenhouse emissions due to limited economic growth. There occurs a significant depletion of natural resource and wastes accumulate with an quick increase of economic growth and industrialization. During this stage, there is a positive relationship between economic growth and environmental degradation. Industrial structure optimization, technology improvement, energy efficiency and information diffusion can reduce environmental degradation with further economic growth. The early studies test the EKC-hypothesis using the following general model.

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 x_t^2 + \beta_3 z_{it} + \beta_4 z_{it}^2 + \varepsilon_t \quad (1)$$

In equation (1), y is the dependent variable of environmental degradation, which denotes the logarithm of total quantity of carbon emission, the lower carbon emissions mean the better environmental quality. x is the independent variable of economic growth which denotes the logarithm of GDP per population. z_i reflects other variables that may affect y. β_0 is the constant term, β_i is the estimated coefficients, ε is the error term. Based on equation (1), we can examine multi-shapes relationship between economic growth and carbon emission quantity. When $\beta_1 = \beta_2 = 0$, x and y has no relationship. When $\beta_1 > 0, \beta_2 = 0$, x and y exist increasing linear relationship, while $\beta_1 < 0, \beta_2 = 0$, x and y exist inclining linear relationship. When $\beta_1 \le 0, \beta_2 > 0$, x and y exist U-shape curve relationship, while $\beta_1 \ge 0, \beta_2 < 0$, x and y exist inverted U-shape curve relationship.

3 Data Source and Constraint Indicators

3.1 Data Source

In order to examine the EKC effects of energy efficiency, energy consumption structure and carbon emission intensity on carbon emission quantity, we choose that data samples on GDP, population, energy-consuming quantity and their consumption structure are sourced from China Statistical Yearbook. Actual GDP per population is estimated by retailed price index in 2005. Estimated methodology and data samples are sourced from Inter-government Panel on Climate Change, CO_2 emission coefficient of coal is 2.7942 tons per ton of standard coal energy (TCE), CO_2 emission coefficient of oil is 2.1494 tons per TCE, CO_2 emission coefficient of natural gas is 1.6443 tons per TCE, CO_2 emission quantity per year is estimated in the equation (2)

$$C_t = \sum_{i=1}^{3} E_{it} \times \eta_i \quad (2)$$

Where i=1,2,3 denote coal, oil and natural gas, C denote total quantity of CO_2 emission, E_i denote consuming quantity of fossil energy i, η_i denote CO_2 emission coefficients of energy i. Based on equation (2), total quantity of CO_2 emission is 14.38 one hundred million tons in 1978, and total quantity of CO_2 emission is 85.03 one hundred million tons in 2012. In the figure 1, total quantity of CO_2 emission exhibit an increasing trend from 1978 to 2012.

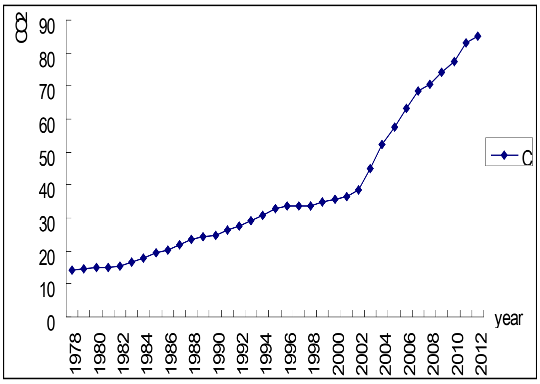

Figure 1. Total quantity of CO_2 emission (100 million tons)

3.2 Constraint Indicators of Energy-saving and Emission-reduction Planning

Based on twelfth-five energy planning in China and comprehensive program of energy-saving and emission-reduction policy, Chinese state council proposes some constraint target of energy-saving and emission-reduction in twelfth-five period. Compared with 0.9350 tons TCE per ten thousand Yuan in 2010, energy intensity will attain 0.7854 tons TCE per ten thousand Yuan in 2015, reduce 16% than energy intensity in 2010, and incline 32% than energy intensity1.2761 tons TCE per ten thousand Yuan in 2005. Chinese economic growth will reduce 6700 million tons TCE in twelfth-five period. Energy consumption structure will optimize, the ratio of non-fossil energy counted underlying energy consumption quantity will increase 2.8% than its ratio 8.6% in 2010, the consumption ratio of natural gas counted underlying energy consumption will enhance 3.1% than its ratio 4.4% in 2010, coal consumption ratio will incline 3.0% than its ratio 68.0% in 2010, oil consumption ratio will incline 2.9% than its ratio 19.0% in 2010. Carbon emission intensity will attain 1.8477 tons per ten thousand Yuan, and will reduce 17% than emission intensity 2.2261 tons per ten thousand Yuan in 2010.

Table 1 constraint index of energy-saving and emission-reduction in China

variable	*2010*	*2015*	*target*	*attribute*
CI	2.2261	1.8477	-17%	constraint

EI	0.9350	0.7854	-16%	constraint
ECQ	32.5	40	23.1%	forecast
RNFE	8.6%	11.4%	2.8%	constraint
RC	68.0%	65.0%	-3.0%	forecast
RO	19.0%	16.1%	-2.9%	forecast
RG	4.4%	7.5%	3.1%	forecast

Note: 1. CI denotes carbon emission intensity, EI denotes energy consumption intensity, ECQ denotes energy-consuming quantity, RNFE denotes consuming ratio of non-fossil energy,RC denotes consuming ratio of coal, RO denotes consuming ratio of oil, RG denotes consuming ratio of natural gas.
2.Measured unit of emission intensity is denoted by tons per ten thousand Yuan, measured unit of energy intensity is denoted by tons TCE per ten thousand Yuan, measured unit of energy-consuming quantity is denoted by 100 million tons.
3. Data source are from twelfth-five energy planning in China and comprehensive program of twelfth-five energy-saving and emission-reduction policy, GDP is adjusted according to constant price index in 2005.

4 Granger Causality Test

In the table 2, the statistical value of ADF test of emission quantity, GDP per population, energy intensity and carbon emission intensity is greater than -2.6210 at the confidence of 90% level, those variables are non-stationary. The statistical values of first-difference ADF test of each variable are less than -2.9640 at the confidence 95% level, those variables are stationary at the condition of first-difference ADF test. Empirical evidence of ADF test show that GDP, energy intensity, carbon emission intensity and carbon emission quantity can not exhibit long-run co-integration relationship, as a result, Chinese government carry out appropriate energy-saving and emission-reduction policy which has obvious impact on economic growth.

Table 2. The test results of Augmented Dickey-Fuller unit root

variables	*level*	*1st difference*
y	-0.5326	-2.9722**
x	-0.1147	-302112**
EI	-0.6930	-4.0850***
CI	-0.4365	-4.2260***

Note: ***,**,* denote the significance of 99%, 95%, 90% level, unit root test is estimated by ADF model with intercept term and lag=2, the critical statistical results of ADF test are -3.6701 , -2.9640 and -2.6210 at the significance of 99%, 95%, 90% level.

Table 3 Empirical evidence of Granger causality test of each vairiables

variables	*Lag*	*t-statistical value*	*p-value*
$x \to y$	2	3.9414	0.035
$y \to x$	2	0.2434	0.786
$EI \to y$	2	4.1924	0.029
$y \to EI$	2	2.5842	0.099
$CI \to y$	2	4.2888	0.027
$y \to CI$	2	2.4661	0.109

Note: $x \to y$ denotes x does not Granger cause y, $y \to x$ denotes y does not Granger cause x, the following variables are similarly defined.

In the table 3, the t-statistical value of Granger $x \to y$, $EI \to y$ and $CI \to y$ are 3.9414, 4.1924 and 4.2888, their p-values are 0.035, 0.029 and 0.027, those Granger causality test significantly refuse initial hypothesis at the significance of 95% level, those empirical results show that GDP per population, energy intensity and carbon emission intensity have causal impacts with carbon emission quantity, historical data of GDP per population, energy intensity and carbon emission intensity can predict short-term trend of carbon emission quantity. the p-value of Granger $y \to x$, $y \to EI$ and $y \to CI$ are 0.786, 0.099 and 0.109, those Granger causality test accept initial hypothesis at the confidence of 95% level, those empirical results can not support their Granger causality relationship. Accordingly GDP per population, energy intensity and carbon emission intensity have single-directionally causal relationship with carbon emission quantity. Since 2005, carbon emission quantity in China have structural change, carbon emission quantity and GDP per population do not have long-term co-integration relationship, however sample data before 2006 pay little role to predict further carbon emission quantity.

5 EKC Effects Estimation under the Constraint of Energy-saving Policy

5.1 Discrete EKC Model

Assumed GDP per population at intial period is GDP_0, growth ratio of GDP at period t is

g_t , GDP_T at period T is equal to $GDP_T = GDP_0 \times \prod_{t=1}^{T}(1+g_t)$. Assumed population quantity at intial period is P_0, natural growth ratio of population at period t T is k_t ,population quantity at period T is equal to $P_T = P_0 \times \prod_{t=1}^{T}(1+k_t)$. Assumed X_0, X_T are GDP per population at intial period and period T, accordingly

$$X_T = X_0 \times \prod_{t=1}^{T}\frac{1+g_t}{1+k_t} \quad (3)$$

Assumed Q_0 is total quantity of energy consumption at intial period, Q_T is total quantity of energy-consuming planning at period T, l_t is increasing ratio of energy consuming quantity at period t.

$$l_t = \sqrt[T]{\frac{Q_T}{Q_0}} - 1 \quad (4)$$

Total quantity of energy consumption at period t is equal to $Q_t = Q_0 \times (1+l_t)^t$. Assumed q_c, q_o, q_g are consuming ratio of fossil fuel coal, oil and natural gas, r_c, r_o, r_g are inclining ratio of fossil fuel coal, oil and natural gas, and their incling ratio is similarly defined as equation (4). Assumed Q_t is total quantity of energy consumption at period t, total quantity of carbon emission at period t is equal to

$$C_t = 2.7942 Q_t q_{ct}(1-r_{ct}) + 2.1494 Q_t q_{ot}(1-r_{ot}) + 1.6443 Q_t q_{gt}(1-r_{gt}) \quad (5)$$

Energy-consuming intensity is equal to $EI_t = \frac{Q_t}{GDP_t}$, carbon emission intensity is equal to $CI_t = \frac{C_t}{GDP_t}$. Environmental problems will improve with an increase of economic growth, we believe that Environmental Kuznets Curve can achieve a turning piont.

5.2 Target Analysis of Carbon Emission Intensity and Energy Intensity

Chinese government smoothly attain planning target of carbon emission in twelfth-five period, there are two ways. One way is to enhance energy usage efficiency and incline energy-consuming intensity per GDP, another way is to optimize energy consumption structure, especially reduce coal-energy-consuming ratio in underlying energy consumption, and improve consuming ratio of renewable energy. Based on the constrained planning target of energy-saving policy in twelfth-five period, if planning growth ratio of GDP per year is 7.5%, total quantity and structure of energy consuming can attain according to planning target in twelfth-five period, energy-consuming intensity in 2015 is 0.8606 tons TCE per ten thousand Yuan. Compared with energy intensity 0.9350 tons TCE per ten thousand Yuan in 2010, energy intensity reduces 3.921% and it is much less than inclining ratio of planning target 16% in twelfth-five period. Carbon emission intensity in 2015 is 1.9670 tons per ten thousand Yuan, compared with carbon emission intensity 2.2261 tons per ten thousand Yuan, carbon emission intensity reduces 11.64% and it is less than inclining ratio of carbon intensity 17% in twelfth-five period.

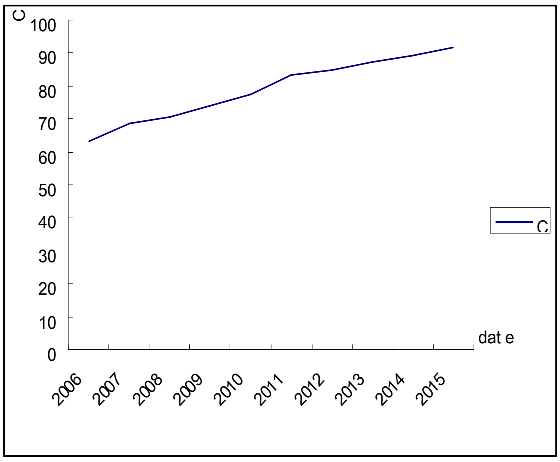

Figure 2. Total quantity of carbon emission (100million tons)

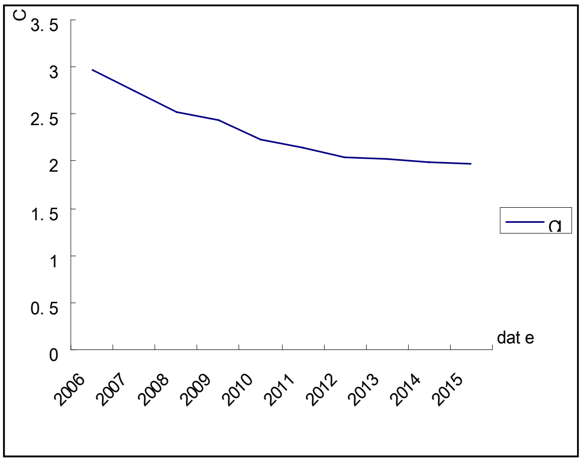

Figure 3. Carbon emission intensity (CI)

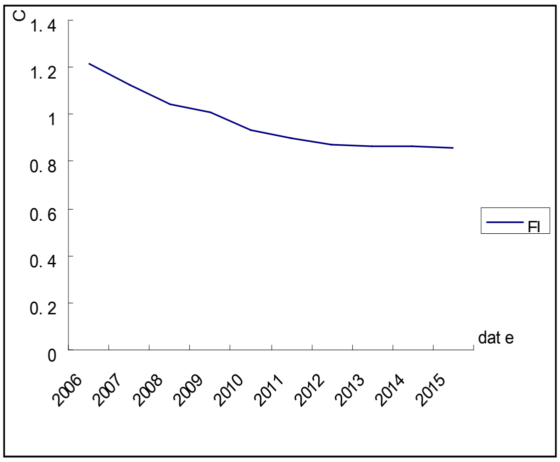

Figure 4. Energy-consuming intensity (EI)

Table 4. Target analysis of carbon emission intensity and energy intensity under the constraint of energy-saving policy

Variable	*2010*	*2015*	*Target achievement*
Carbon intensity	2.2261	1.9670	11.64%
Energy intensity	0.9350	0.8606	3.92%

Note: GDP is estimated according to constant price index in 2005.

5.3 EKC Effect Estimation under the Constraint of Energy-saving Policy

Chinese government has set constrained target responsibility of energy-saving and emission-reduction policy and strengthens government and enterprises responsibility, push government and enterprises improve energy efficiency and reduce energy intensity, optimize energy-consuming structure and than incline carbon emission intensity. In order to examine the EKC effect of energy intensity, GDP per population and carbon emission intensity on total quantity of carbon emission, we propose the following equation (6).

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 x_t^2 + \beta_3 ei_t + \beta_4 ei_t^2 + \beta_5 ci_t + \beta_6 ci_t^2 \quad (6)$$

Where ei denotes energy-consuming intensity, ci denotes carbon emission intensity, β_0 is intercept term, $\beta_1 - \beta_6$ are the coefficients of each variables. Because Chinese government has carried out the constraint of energy-saving policy, we choose data samples from 2006 to 2015, and examine the EKC effect of energy intensity, GDP per population and carbon emission intensity on carbon emission quantity under the constraint of energy-saving policy. The regression results are as following table 5.

Table 5. EKC effect estimation under the constraint of energy-saving policy

variables	*1978-2005*	*2006-2015*
β_0	-15.5985***	-75.1483***
	(-9.9205)	(-6.1691)
β_1	2.8545***	14.9605***
	(11.5950)	(6.0846)
β_2	-0.0953*	-0.6921***
	(-1.9092)	(-5.7157)
β_3	0.6904	1.8803**
	(0.8728)	(3.2385)
β_4	0.7389	3.2658**
	(1.4552)	(2.1502)
β_5	1.4481	5.4811**
	(0.9832)	(3.2168)
β_6	-0.6047	-3.1752**
	(-1.2984)	(-2.7414)
R^2	0.9996	0.9999

Note:1. GDP values are adjusted as the constant price in 2005, energy intensity and carbon emission intensity are estimated as the constant price in 2005.
2. ***,**,* denote the significance of 99%, 95%, 90% level, the number in the parentheses are t statistic values.

In the table 5, the related coefficients among total quantity of carbon emission, GDP per population and squared GDP per population from 1978 to 2005 are 2.8545 and -0.0953 at the confidence of 90% level, t-statistical values are larger than 1, GDP per population have an inverted U-shaped EKC effect on carbon emission quantity at the confidence of 90% level from 1978 to 2005. The related coefficients among carbon emission quantity, carbon intensity and squared carbon intensity are 1.4481 and -0.6047, t-statistical values are less than 1, carbon emission intensities have a non-significantly inverted U-shaped EKC effect on carbon emission quantity from 1978 to 2005. The related coefficients among Carbon emission quantity, GDP per population and squared GDP per population are 14.9605 and -0.6921 at the confidence of 99% level from 2006 to 2015, those results show that GDP per population have a significantly inverted U-shaped EKC effect on carbon emission quantity at the confidence of 99% level from 2006 to 2015. The related coefficients among carbon emission quantity, carbon intensity and squared carbon intensity are 5.4811 and -3.1752 at the confidence of 95% level, and carbon emission intensity has a significantly inverted U-shaped EKC effect on carbon emission quantity at the confidence of 95% level from 2006 to 2015. The related coefficients among carbon emission quantity, energy intensity and squared energy intensity are 1.8803 and 3.2558 at the significance of 95% level from 2006 to 2015. Those empirical evidences show that Chinese government encourage enterprises to enhance investment of energy-saving and emission-reduction projects using the constraint of energy-saving policy, promote energy-saving technology implication, implement energy-saving and emission-reduction management practices, those activities are helpful to reduce carbon emission quantity. Optimizing energy-consuming structure and reducing energy intensity are helpful to incline carbon emission intensity and total quantity growth of carbon emission.

6 Conclusion

Using Environmental Kuznets Curve theory, this article examines the EKC effect of economic growth, energy intensity and carbon emission intensity on total quantity of carbon emissions under the constraint of energy-saving policy. Economic growth, energy-consuming intensity and carbon emission intensity can not exhibit long-term co-integration relationship and single-directionally causal relationship with total quantity of carbon emission. Energy-saving policy implemented by Chinese government has not significant effect on economic growth, and we can predict future short-run trend of carbon emission quantity. Based on the constrained planning target of energy-saving policy in twelfth-five period, if planning growth ratio of GDP per year is 7.5%, energy-consuming intensity in 2015 forecasts 0.8606 tons TCE per ten thousand Yuan and reduces 3.921% in 2015 using discrete EKC model, as a result energy intensity will not achieve constraint indicators of energy-saving planning in twelfth-five period. Carbon emission intensity in 2015 forecasts 1.9670 tons per ten thousand Yuan and reduces 11.64% in 2015 using discrete EKC model, accordingly carbon emission intensity will not attain constraint indicators of emission-reduction planning in twelfth-five period. GDP per population have an inverted U-shaped EKC effect on carbon emission quantity at the confidence of 90% level from 1978 to 2005, while carbon emission intensities have an non-significantly inverted U-shaped EKC effect on carbon emission quantity from 1978 to 2005. Those empirical evidences exhibit energy-consuming structure, energy intensity and emission intensity have non-significant impact on inclining speed of carbon emission intensity from 1978 to 2005. GDP per population and carbon emission intensity have significantly inverted U-shape EKC effect on carbon emission quantity at the confidence of 95% level from 2006 to 2015, accordingly optimizing energy-consuming structure and reducing energy intensity are helpful to incline carbon emission intensity and total quantity growth of carbon emission in eleventh-five and twelfth-five periods on the constraint of energy-saving and emission-reduction policy. Energy-saving and emission-reduction policy have a significant impact on eerngy efficience and emission reduction. Under the constraint of energy-saving and emission-reduction policy, optimizing energy-consuming structure, especially optimizing coal-consuming structure, inclining energy intensity and total quantity of energy consumption, and then carbon emission intensity reduces and environmental degradation improves with an increase of economic growth.

However planning target of carbon emission intensity faces greater challenges and risks in the future, Chinese government should introduce a serial of energy-saving and emission-reduction advices and policies. Firstly, government should establish government-guided, market-driven, enterprise -led regulation schemes of energy saving and emission-reduction, actively promote those regulation schemes implication and then achieve long-run emission reduction effect using market scheme. Secondly, government should improve constrained-indicators system of energy-saving and emission-reduction, improve market trade scheme and supervising assessment system, establish information communication and punishment mechanism of energy-saving and emission-reduction and then strengthen enterprises environmental responsibility and enhance environmental benefits of energy-saving enterprises.

Thirdly, our government should take an effective ways to optimize energy-consuming structure incline, reduce consuming-ratio of fossil fuels and increase consuming-ratio of renewable energy, control total quantity of energy consumption, drive carbon emission intensity incline and decrease the rising speed of carbon emission quantity. Fourthly, government should promote renewable energy technology implication, encourage enterprises to increase investment of energy-saving and emission-reduction projects using fiscal tax and subsidy instruments and market mechanism, and then effectively promote energy-saving management practices. Fifthly, government should introduce emission trade scheme and interests-oriented incentives, foster energy-saving and emission-reduction finance services markets, establish target responsibility and marketization of energy-saving and emission-reduction and then significantly reduce carbon emission intensity and total quantity of carbon emission.

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