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Convergence of Regional Economic Growth and Carbon Emission Intensity in China

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ABSTRACT

Following rapid economic growth, the environmental pollution is getting worse in most regions in China. Meanwhile, the urbanization and industrialization of China has not completed yet, with energy consumption continuing to grow, environmental carrying capacity is becoming smaller and smaller, which leads to emission reduction cost continues to grow. This paper analysed convergence of economic growth and carbon emission intensity of the east, central and west regions in China by using panel date, and the results show that economic growth is β conditional convergence while carbon emissions intensity is β absolute convergence. By building relation model between carbon emission intensity gap and economic gap, introducing in elastic coefficient η, it was found that when the central and west regions narrow their economic gap with the east region by 1 percent, it leads to their carbon emission intensity gap with the east region narrow by 0.5712 and 0.5900 percent respectively, which shows that when the central and west regions are narrowing their economic gap with the east region, 'the narrowing' is based on energy-saving and emission-reduction. At the same time it can also be found that convergent rating of economy is quicker than that of carbon emission intensity, which suggests that energy-saving and emission-reduction is still what China need to follow when promoting balanced development of regional economy. Based on the above results, some useful suggestions to promote collaborative development of regional economy and synchronous collaborative development between regional carbon emission intensity and economic development were given.

INTRODUCTION

As people pay more attention to the problem of environment, issue of carbon emissions has become a worldwide study object, and this issue is more serious in China. The economic growth of China has often been achieved at the cost of environment. It is due to the extensive pattern of economic growth, the unreasonable industrial structures and energy inefficiency, actually, in the future, the economic growth will be subject to the environmental carrying capacity, especially to the competition of carbon emission space.

After decades of rapid economic growth, carbon emission in China has become a huge problem. In 2007, total amount of carbon emissions in China exceeded America, and China became the largest carbon emissions country in the world. This phenomenon is opposite to energy-saving and emission-reduction policy that Chinese government has always advocated. A lot of scholars began to study issue of carbon emissions in China. But because chosen indexes, regions, time series, analysis methods are different, and there has not been some typical and unified conclusions. In general, methods that used to study the problem of carbon emissions can be divided into three categories. The first category is to study relation between carbon emissions and economic growth (Hu et al. 2008, Lin & Jiang 2009, 2010, McCollum & Yang 2009, Qi et al. 2009, Xu 2010, Zhang 2010). The second category is to study factors that affect carbon emissions and their influence degree (Douglas & Thomas 1995, Friedl & Getzner 2003, Lin & Sun 2010, Sun et al. 2013, Wang et al. 2012, Zhang et al. 2010). The third category is to study convergent mechanism of carbon emissions (Wei et al. 2009, Qi & Li 2007, Yang & Liu 2013, Xu & Song 2010, Yang et al. 2009, Zhou & Zhu 2009). In the meantime, after decades of rapid economic growth in China, economic growth is another important study object along with carbon emissions, especially unbalanced regional economic growth. Lots of scholars have studied convergent traits among provinces, regions and areas, tried to find out whether there was economic convergence in China (Chen et al. 2012, Hu et al. 2008, Shi & Zhao 2011). Just like the problem of carbon emissions, because of different sample methods that scholars chose, there has not been a unified conclusion yet.

Though existing researches have made contribution to solve the above two problems, it is not hard to find that there are studies about regional carbon emissions and about

regional economic growth, there is few researches, which combine the two problems together, namely, there is lack of study of relation between regional carbon emissions and regional economic growth. Chinese government promotes balanced economic growth among regions, and promotion of balanced economic growth is based on energy-saving and emission-reduction, so, when the central and west regions are narrowing their economic gap with the east region, whether "the narrowing" is based on energy-saving and emission-reduction or based on extensive energy consumption and sacrificing the environment is an issue that worth study, which became the main study object of this paper. The paper mainly focuses on solving the three problems, first, does there exist convergence of economic growth among regions? Second, does there exist convergence of carbon emission intensity among regions? Third, if economic growth and carbon emission intensity both exist regional convergence, "the narrowing" of economic gap among regions can lead to what change of carbon emission intensity gap among regions? Along with the narrowing of economic gap among regions, whether the carbon emission intensity gap among regions will narrow or expand; if it narrows, it means regional economic growth convergence is based on energy-saving and emission-reduction as well as low carbon reality, otherwise, it means, regional economic growth convergence is based on extensive energy consumption and sacrificing the environment, which is contrary to the energy-saving and emission-reduction policy that Chinese government has always promoted. By applying the improved convergent model and building theoretical model between carbon emission intensity gap and economic gap, this paper analysed the above three questions and got conclusions.

THEORETICAL MODELS

This paper chose 30 provinces which do not contain Taiwan, Hong Kong, Macao and Tibet, and divided the 30 provinces into the east, central and west regions according to the traditional three regions' division method and studied the three regions' economic growth, carbon emission intensity and relation between economic growth and carbon emission intensity.

β convergent model of economic growth among the three regions: Per capita GDP was used to represent economic growth. β convergence of economic growth means growth rate of per capita GDP in less developed area is quicker than that of developed area, and per capita GDP of the two regions will converge in the end. β convergent model is shown as the following formula.

$$LN\left(Y_{i,t+T}/Y_{i,t}\right)=\alpha-\beta\times LN(Y_{i,t})+\varepsilon_{i,t} \quad ...(1)$$

$LN(Y_{i,i+t}/Y_{i,t})/T$ means average economic growth of economy i from time t to $t+T$, $LN(Y_{i,t})$ means logarithm of the per capita GDP of economy i in time t. In order to observe the annual change of per capita GDP of the three regions better, the paper improved the traditional convergent model to the following formula:

$$LN(Y_{i,t}/Y_{i,t-1})=\alpha+\beta\times LN(Y_{i,t-1})+\varepsilon_{i,t} \quad ...(2)$$

$\beta>0$, there is no convergence of per capita GDP; $\beta<0$, there is convergence of per capita GDP, per capita GDP of the three regions will converge.

β convergent model of carbon emission intensity among the three regions: Model of β convergence of carbon emission intensity adopted that of average GDP, CEI is short for carbon emission intensity. So the model can be shown as:

$$LN(CEI_{i,t}/CEI_{i,t-1})=\alpha+\beta\times LN(CEI_{i,t-1})+\varepsilon_{i,t} \quad ...(3)$$

$CEI_{i,t,}$ $CEI_{i,t-1}$ means carbon emission intensity of economy i in time t and time t-1. $\beta>0$, there is no convergence of CEI. $\beta<0$, there is convergence of CEI among regions. i contains the east, central and west regions, using e,c,w to stand for the three regions respectively.

Model constructing between regional carbon emission intensity gap and economic gap: Plenty of researches have proved that there is causality between carbon emissions and GDP, so, when the central and west regions are narrowing their economic gap with the east region, whether "the narrowing" is based on energy-saving and emission-reduction or on extensive energy consumption and sacrificing the environment has totally different influence to regional carbon emission intensity. If "the narrowing" is based on energy saving, energy efficiency will improve and their gap of carbon emission intensity with the east region will narrow, otherwise, energy efficiency will decrease and gap of carbon emission intensity with the east region will expand. To solve the above problem, it is supposed that carbon emission intensity gap of the central and west regions with the east region is function of economic gap (represented by average GDP) of the central and west regions with the east region, introducing coefficient η to represent the influence degree of change in economic gap to carbon emission intensity gap. The model is expressed as:

$$CEI_{j,t}*=A\left\{Y_{e,t}/Y_{j,t}\right\}^{\eta}CEI_{e,t} \quad ...(4)$$

$CEI_{j,t}*$ and $Y_{j,t}$ stand for carbon emission intensity and per capita GDP of economy j (the central and west regions) in time t, $CEI_{e,t}$ and $Y_{e,t}$ stand for carbon emission intensity and per capita GDP of the east region in time t, η stands for elastic coefficient of gap of carbon emission intensity to

gap of per capita GDP, which means when the economic gap between the central and west regions with the east region narrows by 1 percent, can lead to their carbon emission intensity gap with the east region change η percent. Working out coefficient η is the most important task of this paper.

Considering the time series factors that exist in data, we added a one lag coefficient, it is shown as:

$$CEI_{j,t} = CEI_{j,t-1}\left\{CEI_{j,t}^{*} / CEI_{j,t-1}\right\}^{u} \quad ...(5)$$

u is time delay adjust factor, then $CEI_{j,t}^{*}$ is carbon emission intensity that contains time delay influence. Simplify formulas (4), (5), we got formula (6), shown as:

$$LN\left(CEI_{j,t} / CEI_{j,t-1}\right) = \mu \times LNA + \mu \times LN\left(CEI_{e,t} / CEI_{j,t-1}\right) + \mu\eta \times LN\left(Y_{e,t} / Y_{j,t}\right) + \varepsilon_{j,t} \quad ...(6)$$

In order to make the formula more simple, formula (6) is turned into:

$$LN\left(CEI_{j,t} / CEI_{j,t-1}\right) = B + C \times LN\left(CEI_{e,t} / CEI_{j,t-1}\right) + D \times LN\left(Y_{e,t} / Y_{j,t}\right) + \varepsilon_{j,t} \quad ...(7)$$

$B = \mu \ln A$, $C = \mu$, $D = \mu\eta$. By making regression of the central and west regions, coefficient η can be obtained.

As showed in formula (2), (3), if $\beta < 0$, there exists β convergence of per capita GDP and carbon emission intensity, relation between carbon emission intensity gap and per capita GDP gap can be tested and μ,η can be obtained.

If $\eta > 0$, it means when the central and west regions narrow their economic gap with the east region by 1 percent, it leads to their carbon emission intensity gap with the east region narrow by η percent and shows that economic growth of the central and west regions is based on energy-saving and emission-reduction.

If $\eta < 0$, it means when the central and west regions narrow their economic gap with the east region by 1 percent, it leads to their carbon emission intensity gap with the east region expand η percent and shows that economic growth of the central and west regions is based on extensive, high energy consumption and high emissions.

SAMPLES AND DATA

Data of the east, central and west regions from 1995-2010 were chosen as samples to study convergence of regional economic growth and carbon emission intensity, as well as relation between carbon emission intensity gap and economic gap. All the data needed can be obtained directly or indirectly computing from "China Statistic Yearbook", "China Population and Employment Statistic Yearbook", "China Energy Statistic Yearbook", "Local Statistic Yearbook" and Statistical Bulletin. Money included in the data has been adjusted into relative quantity based on the price index of 1990.

Data of per capita GDP: This paper chose per capita GDP as the index to measure the development degree of a region, data of GDP and population can be got from "China Statistical Yearbook", "China Population and Employment Statistical Yearbook". For China National Statistical Bureau adjust price index every ten years, so GDP was adjusted to relative quantity based on the price index of 1990.

Data of carbon emission intensity: At present, carbon emissions is mainly emitted by burning of fossil fuels. According to "IPCC guidelines for national greenhouse gas inventories 2006", carbon emissions can be estimated by aggregating the consumption of different fuels multiply by their carbon emission coefficients. Total fuel consumption (standard coal as unit) of different provinces can be got directly from "China Energy Statistic Yearbook". By multiplying coefficient of standard coal, carbon emissions of different provinces and the three regions can be got. China's National Development and Reform Commission recommends CO_2 emission coefficient of standard coal in China as $2.4567t(C)/tce$, then carbon emission coefficient of standard coal is $0.6700t(C)/tce$. Carbon emission intensity equals carbon emissions divided by GDP. Data of carbon emission intensity are given in Table 1, which shows the data of carbon emission intensity and per capita GDP of the east, central and west regions.

EMPIRICAL ANALYSIS

Eviews 6.0 was used to test convergence of economic growth, carbon emission intensity and relation between carbon emission intensity gap and economic gap.

Convergence test of economic growth: Making convergent regression of per capita GDP among the three regions, regression result is shown in Table 2. It can be seen that when $\beta > 0$, equation and all variables passed significance test with 5% confidence level, so there is no β absolute convergence of per capita GDP. For this, it is necessary to test whether there is β conditional convergence of regional per capita GDP. According to C–D function, when technology stays stable, output is function of capital and labour, and it is shown as: $Y = AK^{m}L^{n}$. Supposing technology stays the same, $A = 1$, then we can know GDP is function of capital and labour. Given this, when testing conditional convergence of per capita GDP, fixed capital investment and labour were added into the equation. Making logarithm of the equation, we get: $LNY = mLNK + nLNL$ then,

Table 1: Carbon emission intensity and per capita GDP of east, central and west regions.

Year	Carbon emission intensity (10^4t/10^9¥)			Average GDP(¥)		
	East	Central	West	East	Central	West
1995	2.13	3.02	3.16	3785	2089	1878
1996	1.96	2.94	3.18	4423	2341	2030
1997	1.78	2.69	2.99	4792	2580	2201
1998	1.64	2.41	2.81	5243	2791	2368
1999	1.54	2.24	2.55	5703	2989	2507
2000	1.36	2.13	2.45	6003	3282	2737
2001	1.42	2.06	2.37	6708	3514	2910
2002	1.34	1.98	2.32	7596	3960	3240
2003	1.35	1.99	2.44	8520	4377	3571
2004	1.46	2.14	2.50	9609	4932	3980
2005	1.28	2.14	2.45	10742	5744	4553
2006	1.44	2.08	2.39	12132	6515	5118
2007	1.38	2.00	2.30	13764	7466	5816
2008	1.30	1.88	2.18	15217	8410	6464
2009	1.24	1.76	2.06	16790	9423	7252
2010	1.20	1.69	1.98	18322	10698	8415

Table 2: Absolute convergence results of per capita GDP of the three regions in China.

Variables	East	Central	West
$\alpha_{average}$	-0.1620**(-2.6781)		
α	-0.1767**(-2.6781)	-0.1533**(-2.6781)	-0.1560** (-2.6781)
$LN(Y_{i,t-1})$		0.0314***(4.4145)	
Adj.R^2		0.2913	
F		7.0271	
P(F)		0.0006	
DW		1.4523	

Notes: ***,**and * indicate significance at the 1%, 5% and 10% levels, respectively.

conditional convergence model of per capita GDP changed into:

$$LN(Y_{i,t}/Y_{i,t-1}) = \alpha + \beta \times LN(Y_{i,t-1}) + m \times LNK_{i,t} + n \times LNL_{i,t} + \varepsilon_{i,t} \quad ...(8)$$

Regression result is shown in Table 3.

The result shows $\beta < 0$, the equation and all variables passed significance test with 10% confidence level. So there exists conditional convergence of per capita GDP.

Convergence test of carbon emission intensity*:* Making convergent test of carbon emission intensity, the following result was obtained:

It shows that when $\beta < 0$, the equation and variables passed significance test with 10% confidence level. So there exists β absolute convergence of carbon emission intensity in China.

Test of relation between carbon emission intensity gap and economic gap: A model, which contains elastic coefficient of carbon emission intensity gap to per capita GDP gap, was built. It is shown as:

Table 3: Conditional convergence results of per capita GDP of the three regions in China.

Variables	East	Central	West
$\alpha_{average}$		-1.7310*(-2.0151)	
α	-1.8525* (-2.0151)	-1.7810* (-2.0151)	-1.5595* (-2.0151)
$LN(Y_{i,t-1})$		-0.4235*** (-3.9419)	
LNK		0.2968*** (4.5919)	
LNL		0.2757**(2.3409)	
Adj.R^2		0.4800	
F		9.1225	
P(F)		0.0000	
DW		1.5964	

Notes: ***,**and * indicate significance at the 1% , 5% and 10% levels, respectively.

$$LN(CEI_{j,t}/CEI_{j,t-1}) = B + C \times LN(CEI_{e,t}/CEI_{j,t-1}) + D \times LN(Y_{e,t}/Y_{j,t}) + \varepsilon_{j,t} \quad ...(9)$$

Making regression of the central and west regions respectively, following results were got:

It shows that, with 10% confidence level, the equations and variable passed significance test. By computing coefficients, we can get value of η. To distinguish the central from the west, $Cc, Dc, \eta c$ are used to represent values of the central region, $Cw, Dw, \eta w$ are used to represent values of the west region. From former analysis we know that $C = \mu, D = \mu\eta$, and $\eta = D/C$.

Table 4: Absolute convergent result of carbon emission intensity among the three regions in China.

Variables	East	Central	West
$\alpha_{average}$		0.0682* (1.8954)	
α	0.0206* (1.8954)	0.0782* (1.8954)	0.1057* (1.8954)
$CEI_{i,t-1}$		-0.1479*** (-2.9579)	
Adj.R^2		0.1196	
F		2.9924	
P(F)		0.0418	
DW		2.0988	

Notes:***,**and * indicate significance at the 1% , 5% and 10% levels, respectively.

Table 5: Regression results of the central and west regions.

Variables	Central	West
C	0.5147***(3.8741)	0.4088**(2.7029)
D	0.2940***(3.1804)	0.2412*(2.3356)
Adj.R^2	0.4795	0.2883
DW	1.4440	1.5893

Notes:***,**and * indicate significance at the 1% , 5% and 10% levels, respectively.

$Cc = 0.5147Dc = 0.2940$, so $\eta c = 0.5712$

$Cw = 0.4088Dw = 0.2412$, *so* $\eta w = 0.5900$

We can get that, when the central region narrows its economic gap with the east region by 1 percent, it leads to narrowing of its carbon emission intensity gap with the east region by 0.5712 percent. When the west region narrows its economic gap with the east region by 1 percent, it narrows its carbon emission intensity with the east region by 0.5900 percent. Three conclusions can be drawn from this result, first: when the central and west regions are narrowing their economic gap with the east region, their "narrowing" is based on energy-saving and emission-reduction; second: "narrowing" rate of carbon emission intensity of the west region with the east region is quicker than that of the central region; third: values of $\eta < 1$, which means convergent rate of economic growth of the three regions is quicker than that of carbon emission intensity of the three regions, energy-saving and emission-reduction is still the guideline that China should promote in its developing process.

CONCLUSIONS AND SUGGESTIONS

Conclusions: This paper tried to find out when the central and west regions are narrowing their economic gap with the east region, whether their "narrowing" is based on energy-saving and emission-reduction or on extensive energy consumption and sacrificing the environment. Making adjustment to the traditional β absolute convergent model, according to the adjusted absolute convergent model and conditional convergent model, it is revealed that economic growth of the three regions exists β conditional convergence, carbon emission intensity of the three regions exists β absolute convergence. By building relation model between carbon emission intensity gap and economic gap, introduce in elastic coefficient η, find out that when the central region narrows its economic gap with the east region by 1 percent, it leads to its carbon emission intensity with the east region narrows by 0.5712 percent. When the west region narrows its economic gap with the east region by 1 percent, it leads to its carbon emission intensity with the east region narrows by 0.5900 percent. Three conclusion were drawn from this result, first: when the central and west regions are narrowing their economic gap with the east region, their narrowing is based on energy-saving and emission-reduction; second: "narrowing" rate of carbon emission intensity of the west region with the east region is quicker than that of the central region; third: values of $\eta<1$, which shows convergent rate of economic growth among the three regions is quicker than that of carbon emission intensity among the three regions, energy-saving and emission-reduction is still the guideline that China should promote in its developing process.

Suggestions: The above results have important and practical meaning and policy implication, it not only supports the reality of promoting balanced development of regional economy and low carbon economy in China, but also makes implications for regional economic development. Considering the fact of China's regional economic development and the conclusions this paper got, how to promote collaborative development of regional economy, how to realize synchronous collaborative development of carbon emission intensity along with equilibrium of regional economy are two most urgent problems that need to be solved. In order to solve above two problems, some useful suggestions are given.

To achieve collaborative development of regional economy needs to: Firstly, arrange industry undertaking properly, which means equilibrium allocation of the three industries. The central and west regions needs to bring in the east region's high efficiency industry, and change their current status as places for resource intensive and energy consuming industries. Secondly, strengthening economic exchange and cooperation between developed areas and less developed areas, realizing exchange and sharing of resources and technology, lead by the east developed area, promoting development of surrounding areas, making full use of mutual depended and space spillover effect and boosting equilibrium development among regions.

To achieve synchronous collaborative development of carbon emission intensity needs to: Firstly, transform eco-

nomic growth mode, change the traditional mode of only pays attention to "quantity" to "quality and quantity". Secondly, promote upgrading of industry structure. On the one hand, strict market system, cut off high energy consumption, high pollutant and low efficiency enterprises, implement pollution rewards and punishment mechanism, and on the other hand, intensify support for the third industry, encourage development of financial, service industry and give proper preferential policy to them. Thirdly, constructing sustainable energy structure, replace fossil fuels with clean energy and achieve upgrading of energy structure. This asks, on one way, the government to regulate energy market, control the low price of fossil fuels; and on the other way, promote the universal use of clean energy, give subsidies and technology innovation encouragement to enterprises which produce clean energy and reduce production cost from sources. Fourthly, establish tolerate and incentive mechanism between central government and local government, and local government and local enterprises. At present, China's energy-saving and emission-reduction mechanism is mainly rely on administrative measures, which lacks internal incentive mechanism. In order to pursue GDP, local government and enterprises always act oppositely to the environmental constraint that China central government calls on, so balance the benefit conflict of GDP with energy-saving and emission-reduction, change the external, passive energy-saving and emission-reduction mechanism into internal incentive mechanism as a vital way to realize energy-saving and emission-reduction.

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