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A Convergent Analysis on Economic Growth of Industrial Sector and Strength of Environmental Regulation

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ABSTRACT

With the increasingly urgency of the environmental problems, researches on this field have become hot spot. However, there are a few scholar studies on the convergence in intensity of environmental regulation and the relationship between the differences of GDP per worker and those of intensity of environmental regulation. Based on this reason, this paper studied above issues by the panel data of industrial sectors of each province in China during 2000-2011, and got conclusions as follows: (1) Among the national group and four individual groups, only some groups existed absolute convergence in the two indexes of GDP per worker and the intensity of environmental regulation, but conditional convergence of the two indexes was existed in all groups. Specific to the convergence speed, the high-yield low-emission group per worker (group I) was slower than the high-yield high-emission group per worker (group II), the low-yield low-emission group per worker (group III) and the low-yield high-emission group per worker (group IV). (2) While the chasing group narrowed the gap in GDP per worker with group I, it was also narrowing the gap in the intensity of environmental regulation, but the convergence speed of the latter is slower than the former. However, the specific situations of the chasing group in 19 provinces are all different; there are four tendencies that are strong convergence, weak convergence, strong divergence and weak divergence.

INTRODUCTION

From 18 to 19th century, the resources and environmental problems caused by Western Europe industrialization began to receive extensive attention and criticism. Later in the 20th century, all the world has stepped into the stage of development of industrialization, which led to an outstanding issue - environmental pollution, which increasingly broke up the tolerance limit of people. Eventually, in the 1970s many countries started the movement of protecting and regulating environment.

Scholars of domestic and foreign once thought that economic growth and environmental regulation would present a "dilemma" pattern, because of the reason that from static state angle, strengthening environmental regulation will enhance the production cost of enterprises, then reduce the labour productivity and weaken their market competitiveness (Gollop & Roberts 1983, Gray 1987). But this view was questioned by the scholars like Porter (1991) and Porter & Van Der Linde (1995). From the dynamic angle, people thought reasonable environmental regulation could stimulate the "compensation with innovating" effect of the enterprises, thus it could not only compensate to offset the "following cost" of enterprises ,but also improve its labour productivity and international competitiveness.

"Potter hypothesis" proposes that let people know that the "economic growth" and "environmental regulation" are not certain to show conflicting dilemma pattern, and they have the foothold and possibilities to achieve a "win-win" pattern. This important practical significance got the attention of the scholars from both at home and aboard. Around the theme "economic growth and environment", scholars at domestic and overseas have got quite unanimous conclusions by using distinctive researching angles, different analysis methods and different researching samples.

The investigation by the sample of China's economic growth and environmental pollution shows that our country is facing with the situation of ecological environment congenital deficiency and acquired disorders, especially the multiple pressures by accelerating the industrialization and the urbanization, which inevitably caused a lot of pollutant emissions before we have not yet reached the historical stage of theoretical inflection point of the environmental Kuznets curve theory. Whether the pollution emissions, which caused average annual GDP reduced up to 10%, or the low ranking of the 121-seat in the world's environment performance in 2010, both of them means the country is carrying the "threshold" of environment. For our country is concerned, to further strengthen environmental protection and regulation is imminent.

In fact, in the process of pursuing economic growth, China is becoming increasingly enhancing the attention of environment and the protection. Back in the early 1990s, China put environmental protection as a basic national policy and implement it. After entering the new century, CPC National congress proposed the people-centered scientific concept of development, not only explore a new road for the industrialization and the innovation of the socialist new countryside construction, and also actively explore to build a resource-saving and environment-friendly society, and to create man and nature and coordinated development between people of a harmonious society. The Party's seventeenth congress put "the construction of ecological civilization" as one of the new requirements to achieve the goal of building a moderately prosperous society.

It is generally believed that faster the growth of the industrial economy the more the produced pollution is, and the higher the intensity of environmental regulation is needed; but will the improvement of the intensity of environmental regulation have the same convergence trend as economic growth? With the gap of economic growth among provinces is getting narrow, would the gap in the intensity of environmental regulation of them also converge? This paper has tried to answer these questions.

THE BRIEF LITERATURE ON CONVERGENCE

Tracing the convergence issues, it generally began from the Solow (1956) neoclassical growth model. The model is based on some hypothesizes such as perfect competition, technological externalities, returns of marginal capital diminishing, etc, and it believed that the backward regions could have a higher rate of economic growth than developed regions. As the time went on, the gap of economic between backward regions and developed regions will gradually shrink, so as to converge to a steady-state level. However, Solow pointed out that the difference of savings and population growth in the real world led to different steady-state level. The theory has aroused widespread concern of scholars at home and abroad. First they focused on the verification of the existence of convergence of economic growth and the type of convergence. Because of the methods of analysis and measurement models are different, plus the different sample selection, scholars got not so consistent conclusions. In the research with the sample of the countries all over the world, Baumol (1986), Mankiw et al. (1992), Caselli et al. (1996) and other scholars believed that there was convergence of economic growth. And the studies of Delong (1988) and other scholars showed economic growth mostly existed divergence trend. In the researches based on the samples of Chinese regions or sectors, whether on the convergence of economic growth or the form of the convergence has not reached a consensus; relevant literature could be seen from Demurger (2001) and Lin & Liu (2003).

With the environment and energy issues have become increasingly prominent, gradually there are scholars to begin to combine the environment or energy variable to analysis corresponding convergence problems, but the volume of research is still relatively small. The specific research angles are as follows: First one is to use data envelopment analysis by considering both "good" output (GDP) and "bad" output (pollution) to estimate the total factor productivity, and then analyse its convergence (Yang & Hu 2010). The second is to set the energy into the framework of total factor productivity to calculate the energy efficiency and analyse its convergence trend (Li & Huo 2009). The third is to structure the variable of the energy consumption intensity based on national, provincial, industry sector or enterprise data, then analyse the convergence of energy intensity variable (Mielnik & Goldemberg 2000). The fourth is to study how degree of convergence or divergence influence the differences of economic growth in bringing to the changes of the differences of energy intensity by analysing the relationship of the differences of energy intensity and those of economic growth (Markandya et al. 2004).

From the existed literature, the empirical analysis of convergence combined environment or energy issues have become a hot spot of research. However, if economic growth existed convergence trend, is there convergence trend of environmental regulation which is caused by the pollution because of controlling economic growth? What influence will the convergence of regional economic growth gap give to the gap of intensity of regional environmental regulation? These problems in the existed literature are rarely involved. We believe that if economic growth in different economies exists convergence trend in theory, environmental regulation, which is highly related with income levels should exist convergence's convergence trend, too. And the gap of intensity of environmental regulation between two economies will be narrowed as the gap of economic level shrink. Based on this theoretical assumption, this paper will use China's industrial sector data to do a variety of convergence tests to provide a theoretical basis for China's environmental regulatory policy-making.

THE AUTHENTICATION METHOD

1. b **convergence:** In the domestic and foreign literature there are three analysis of convergence, which are often used: σ convergence, absolute β convergence and conditional β convergence (Sala-I-Martin 1996). Convergence mostly focuses on that the coefficient of variation of per capita income in the cross-section decline with the time went on. Absolute

convergence shows that under the effect of the law of diminishing marginal returns on capital, backward regions have a faster growth rate than developed regions, making the backward regions' income per worker converge to the developed regions. However, in reality there are many differences in technology preferences of each economy and institutional arrangements, making the steady-state of the different economies are not the same, which is the meaning of conditional β convergence. Drawing on existed literature set in the analysis of economic growth, we will apply it to the analysis of the intensity of environmental regulation.

According to the methods used by Barro & Sala-I-Martin (1992) and Miller &Upadhyay (2002), we set the regression model of absolute β convergence and conditional β convergence as follows:

$$(LnY_{i,t+T} - LnY_{it}) / T = a_1 + b_1 LnY_{it} + j_{i,t+T} \quad ...(1)$$

$$(LnR_{i,t+T} - LnR_{it}) / T = a_2 + b_2 LnR_{it} + f_{i,t+T} \quad ...(2)$$

Equations (1) and (2) are the regression models to verify whether GDP per worker and the intensity of environmental regulation of the industrial sector in China's provinces exist absolute β convergence. LnY_{it} and $LnY_{i,t+T}$ are the logarithms of GDP per worker of the industrial sector in the I[th] province in year *t* and year *t+T*. LnR_{it} and $LnR_{i,t+T}$ are the logarithms of the intensity of environmental regulation of the industrial sector in the I[th] province in year *t* and year *t+T*. a_1 and a_2 are the constant term, b_1 and b_2 are the fitting coefficients, and $j_{i,t+T}$ and $f_{i,t+T}$ are the error terms. If the two values of β are less than 0, then there is absolute β convergence.

Existed studies have generally adopted Panel Date fixed effect model to test the condition b convergence, and often include some control variables to reflect the characteristics of different areas. To modify the equation (1) and (2), we got (3) and (4) to verify the conditions b convergence. However, the fixed effects can already reflect the steady-state form of the different economies on their own, so adding an additional controlling variables is unnecessary (Miller & Upadhyay 2002).

$$(LnY_{i,t+T} - LnY_{it}) / T = a_3 + b_3 LnY_{it} + \sum_{j=1}^{m} k_j c_{it}^j + n_i + t_t + j_{i,t+T} \quad ...(3)$$

$$(LnR_{i,t+T} - LnR_{it}) / T = a_4 + b_4 LnR_{it} + \sum_{j=1}^{m} L_j w_{it}^L + y_i + u_t + f_{i,t+T} \quad ...(4)$$

So, when we verified the conditional β analysis, we did not add control variables possible, but took the double-fixed regression form of individual and time. n_i and y_i are the individual effects of the equations, and t_t and u_t are the corresponding time effect. The representative meanings of the remaining variables are basically the same as the (1) and (2) , because of the limited space, we don't repeat them again.

2. The convergence model of the relationship of differences in environmental regulation and those in GDP per worker: If GDP per worker in the backward areas has trend of convergence to the developed areas, GDP per worker in the two regions will continue to narrow the gap. However, whatever the enhancing of economic growth process in the backward areas is based on the basis of protecting the environment, or taking the road of sacrificing the environment for growth, are two different models of economic development. The former means that the backward areas is gradually narrowing the gap of GDP per worker with developed regions, and also gradually reducing its gap on the strength of environmental regulation with developed regions, which is a sustainable development model. The latter means that although the backward areas narrowed the gap of GDP per worker between it and developed areas, but they did not put much emphasis on protecting the environment, and can not effectively achieve a win-win pattern of both economic growth and environmental protection. Therefore, we assume that the differences of the strength of environmental regulation in the backward areas and developed areas are the function of the gap of GDP per worker in the two areas. In reference of Markandya et al. (2004) and other scholars' model-based analysis of differences of the intensity of energy and those of economic growth, we built the following model:

$$R_{it}^* = A(\frac{Y_{ht}}{Y_{it}})^h R_{ht} \quad ...(5)$$

$$R_{it} = R_{i,t-1}(\frac{R_{it}^*}{R_{i,t-1}})^m \quad ...(6)$$

Y_{ht} is an average of the GDP per worker of industrial department of the developed areas in year *t*; Y_{it} is the GDP per worker of industrial department of I[th] province in the backward areas in year *t*; R_{it} is an average of the intensity of environmental regulation in the developed areas in year *t*; R_{it}^* is the intensity of environmental regulation of I[th] province in the backward areas in year *t*; R_{it}^* is the index which included time-delay. In addition, *A* is a constant, η is the coefficient of elasticity of the variation of the intensity of environmental regulation vs. the variation of the GDP per worker, μ is an adjustable factor of time-lag. d_{it} is a random error. Taking the natural logarithm and organizing the equations (5) and (6), we can get the following formula (7):

$$Ln(\frac{R_{it}}{R_{i,t-1}}) = mLnA + mLn(\frac{R_{ht}}{R_{i,t-1}}) + mhLn(\frac{Y_{ht}}{Y_{it}}) + d_{it} \quad \textbf{...(7)}$$

Formula (7) described the convergence relationship of differences of the strength of environmental regulation and those of GDP per worker of industrial sector in different areas. When h is more than 0, it means that whenever GDP per worker between the backward areas and developed areas in the province's industrial sector reduced 1%, it will cause the gap of the intensity of environmental regulatory between the two to convergent, the specific reduction in the range of *h %*.

DESCRIPTION OF THE DATA

In this paper, we take the industrial sector for the 2000-2011 panel data of China's 30 provinces for empirical research samples, the data used are organized and calculated based on "China Statistical Yearbook", "China Industrial Economy Statistical Yearbook" and "China Environment Yearbook" in 2000-2012.

We selected GDP per worker in each province's industrial sectors as the indicator to measure economic growth, which is obtained by the industrial added value of industrial enterprises above the general in each province, divided the average of all employees. Among them, the industrial added value of industrial enterprises was deflated according to the producer price index and the constant prices of each provinces in 1996, but this indicator of the average of all employees does not directly provided in the yearbook before 2003, so based on the equation of full labour productivity: Labour productivity = added value in industry/the average of total number of employed persons, we got the annual average number of employees of industrial sector in each province. For the variable intensity of environmental regulation, domestic and foreign scholars mainly measured from the following points:

1. Study the level of the intensity of environmental regulation by inspecting the environmental regulatory policy.
2. To use the ratio of pollution control investments taking for the total cost or value to measure.
3. To use costs of operating pollution control facilities to measure.
4. To take the per capita income as an indicator to measure endogenous environmental regulation strength.
5. To use the sewage number of inspection and supervision environmental regulatory agencies by enterprises to measure.
6. To measure the changes of pollution emissions under the environmental regulation, etc.

There are some deficiencies of the six indicators, based on the indicators' relative improvement and the data availability; we selected the investment per worker on dealing with industrial pollution in each province as the measure of the intensity of environmental regulation.

For the vast territory of China, how to divide rationally the provinces was the basic premise for whether the convergence analysis can more accurately reflect the reality. Currently, there are two basic methods of classification: one is to divide on geographical location, such as three points method, four points method, or the more detailed method like six points or eight ones. The other is to divide by establishing some indicators on their own, such as by income level and the degree of industrialization. Based on the second method, we construct the level of output per worker and environmental pollution to group China's 30 provinces, and they were divided into high-yield low-emission per worker group, high-yield high-emission per worker group, low-output and low-emissions per worker group and low-yield high-emissions per worker group. The criteria for the classification level of output is the industrial sector divided by GDP per worker, while the integrated pollution index is to be divided by constructing the entropy law model with SO_2 per worker, dust per worker, waste water per worker and solid waste per worker in the industrial sector. The composition of the corresponding groups of provinces is given in Table 1.

EMPIRICAL ANALYSIS

1. Absolute b **convergence analysis**: Table 2 is the estimated results of the formulas (1) and (2). On the specific estimates, we defined the annual averages of GDP per worker and the average annual pollution control expenditure per worker of each provinces in 2000-2002 as Y_{it} and R_{it} and the annual averages of GDP per worker and the average annual pollution control expenditures per worker of each provinces in 2009-2011 as $Y_{i,t+T}$ and $R_{i,t+T}$. The two time periods separated by 9 years, so take the T 9. Fitting to the corresponding model, we found the absolute β convergence of both GDP per worker and the intensity of environmental regulation of the industrial sector in national group and four subgroups.

By first look at the absolute β convergence on the GDP per worker of the national group and the groups, it can be seen that, except group III, the coefficient of the initial conditions variable LnY_{it} of the national group, group I, group II and group IV is negative, indicating that if the province's initial GDP per worker is higher, its economic growth would be relatively slow, which mean there is a negative correlation relationship between them. But is this relationship significant in the statistical sense? We found that the national group and group II could pass the *t*-test at 1% significance level, but group I and group IV could not. The symbol of group III before the variable coefficient of the initial conditions is positive, indicating that the group's initial economy level and growth rate have a positive correlation relationship, but this result did not pass *t*-test and F-test.

Table 1: The grouping results based on GDP per worker and pollution emissions of each provinces' industrial sector.

Group	Number	Province composed
High-yield low-emission group	11	Shanghai, Tianjin, Beiing, Hainan, Jiangsu, Guangdong, Zhejiang, Shandong, Jilin, Fujian, Hubei
High-yield high emission group	4	Hebei, Inner Mongolia, Liaoning, Yunnan
Low- yield low-emissions group	4	Hei longjiang, Anhui, Jiangxi, Henan
Low-yield high-emissions group	11	Shanxi, Guangxi, Hunan, Chongqing, Sichuan, Guizhou, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang

Table 2: Absolute β convergence test of GDP per worker and the intensity of environmental regulation of industrial sector.

	GDP per worker				Intensity of environmental regulation			
	α	Intercept	R^2	F value	α	Intercept	R^2	F value
NationalGroup	-0.034**	0.558***	0.134	4.315**	-0.044	0.338	0.046	1.345
	(-2.077)	(2.911)			-1.160	1.500		
Group I	-0.056	0.837	0.152	1.609	-0.092	0.595	0.116	1.179
	(-1.269)	(1.547)			-1.086	1.180		
Group II	-0.175***	2.233***	0.996	442.435***	-0.024	0.270	0.022	0.046
	(-21.034)	(22.925)			-0.214	0.408		
Group III	0.119	-1.209	0.193	0.477	-0.219*	1.252*	0.814	8.750*
	(0.691)	(-0.610)			-2.958	3.055		
Group IV	-0.065	0.905*	0.221	2.550	-0.015	0.186	0.013	0.116
	(-1.597)	(1.939)			-0.341	0.739		

Note: *, ** and *** denote that the level of 10%, 5% and 1% are significant.

From the absolute β convergence of the intensity of environmental regulation of industrial sector, the national group and four groups' initial condition variable coefficient had a negative symbol , indicating that higher the initial intensity of environmental regulation of the provinces was, the slower the rate of regulation level will be relatively, which reflects the initial level of regulation and growing speed had a negative correlation, but only group III passed *t*-test and F test under the level of significance 10%, the fitting results of the other groups were not significant statistically.

2. Condition b **convergence analysis**: We also used the panel date fixed-effects model to test GDP per worker and the intensity of environmental regulation of the industrial sector in the various provinces if they existed condition β the convergence. In data preparation, in order to eliminate cyclical influence caused by the economic cycle or some other factors, we divided the sample year into six time periods, which is 2000-2001, 2002-2003, 2004-2005, 2006-2007, 2008-2009, 2010-2011, and then averaged each time period, thus got the formation of type (3) and (4), and since the time period is 2 years apart, so we chose T for 2. In the fitting, we selected which effect to take through redundant fixed effects test results, the results showed that the use of both individual fixed effects and time fixed effects is superior, and got the condition β convergence test results of GDP per worker and the intensity of environmental regulation of industrial sector (Table 3).

What can be seen from the fitting results in Table 3, was that the final regression results of condition β convergence of GDP per worker and the intensity of environmental regulation of the industrial sector in national group and four subgroups are significantly negative, indicating that the country as a whole and the four groups existed the characteristics of conditional convergence, which meant that the GDP per worker and the intensity of environmental regulation of the industrial sector in national group and four subgroups are moving closer to their own steady state. On the condition β convergence speed of the index GDP per worker, the fastest is group III, then group II, group IV with the group I as slowest. On the condition β convergence speed of the intensity of environmental regulation, the four groups from fast to slow are as follows: group II, group III, group IV, and group I. With the results of absolute β convergence in national groups and four groups, we found that the national group and group II existed both absolute β convergence and condition β convergence on the index of GDP per worker, while on the intensity of environmental regulation, only group III existed both absolute β convergence and condition β convergence. In addition to the other groups, there are only condition β convergence but no absolute β convergence, indicating that these groups did not convergent to a common value of GDP per worker and the intensity of environmental regulation, but tend to their own steady-state level because of the following reason such as production technology, industrial structure preferences, etc.

Table 3: The condition β convergence test of GDP per worker and the intensity of environmental regulation of industrial sector.

		α	Intercept	R^2	F value	Fixed effects	
						Individual	Time
GDP Per worker	National group	-0.598***	7.132***	0.575	3.532***	Including	Including
		(-9.628)	(9.604)				
	Group I	-0.529***	6.726***	0.587	2.942***	Including	Including
		(-5.729)	(5.735)				
	Group II	-0.629***	7.806***	0.774	3.903**	Including	Including
		(-4.649)	(4.673)				
	Group III	-0.755***	9.142***	0.773	3.883**	Including	Including
		(-4.865)	(4.887)				
	Group IV	-0.599***	7.249***	0.621	3.399***	Including	Including
		(-6.202)	(6.207)				
Investment of pollution Control GDP per worker	National group	-0.657***	4.006***	0.728	6.977***	Including	Including
		(-14.127)	(14.159)				
	Group I	-0.434***	2.641***	0.531	2.347**	Including	Including
		(-4.634)	(4.625)				
	Group II	-0.869***	5.534***	0.874	7.938***	Including	Including
		(-7.217)	(7.256)				
	Group III	-0.759***	4.284***	0.869	7.555***	Including	Including
		(-4.923)	(4.961)				
	Group IV	-0.757***	4.693***	0.848	11.551***	Including	Including
		(-12.136)	(12.151)				

Note: *, ** and *** denote on the level of 10%, 5% and 1% significance.

3. The convergence analysis of the relationship between the differences of the intensity of environmental regulation and the differences of GDP per worker: Above the length we have verified absolute β convergence and condition β convergence of GDP per worker and the intensity of environmental regulation in China's industrial sector, and got the conclusions such as convergence and divergence are not so significant. But for sure, in the national group, the GDP per worker showed absolute β convergence and condition β convergence trend, but the intensity of environmental regulation showed only condition β convergence trend. We knew that, as GDP per worker continued to improve, government and enterprises' awareness for environmental protection will be corresponding to increase gradually, such as Antweiler et al. (2001) and CIESIN (2008) had confirmed that the intensity of environmental regulatory and income levels correlated highly. However, the problem is that there are many models of GDP growth, intensive and extensive economic growth mode will obviously lead to different intensity of environmental regulation. Then, when provinces in group II, group III and group IV kept shrinking the gap of the GDP per worker with group I through their growth patterns, would the value strength of environmental regulation convergent with a same ratio?

To answer this question, we analysed the convergence of the differences of the intensity of environmental regulation and those of GDP per worker based on equation (7). **T**he data are the same as condition β convergence above, the sample was divided into six year time period, and T is 2 too. As the group one in GDP per worker and the environmental performance are generally ahead of other groups, we set the corresponding variables' average values of the 11 provinces in group I in year *t* as the average Y_{ht} and R_{ht}. In the fitting, we selected the effect through redundant fixed effects test results; the results show only the use of individual fixed effects is superior. At the same time, taking the large differences between the various provinces into account, we want to the intercept to reflect some certain individual characteristics, so we use variable intercept model. The corresponding regression results are given in Table 4.

It can be seen, μ η and μLnA all passed the t test, and the explanatory power of the model is strong. With μ η divided μ, got the overall η value (0.3976), which is greater than 0, indicating whenever the gap of GDP per worker of the industrial sector in the 19 provinces of the whole nation except group I reduced 1% each, it will cause the intensity of environmental regulation of both of them convergent 0.3976%, far slower than the convergence rate of the catch-up group in GDP per worker. This shows that although the catch-up group continued to narrow the gap of GDP per worker between group I with time went on, but the corresponding intensity of environmental regulation is not the same percentage increased, or that the chasing group had lack of consciousness with economic growth in the management of industrial pollution and protect the environment on the growth.

Table 4: The relationship convergence test of the intensity of environmental regulation and GDP per worker of industrial sector.

	μ	μη	μLnA	R^2	F value	Fixed effects	
						Individual	Time
The convergence model of the relationship	1.3012*** (13.8744)	0.5173*** (2.9332)	-0.3966*** (-3.6125)	0.6819	5.8951***	including	No including
Individual effects of each province				η value of each province			
Heibei	-0.0540	Hunan	-0.1869	Heibei	0.3499	Hunan	0.2702
Inner Mongolia	-0.5334	Chongqing	0.5283	InnerMongolia	0.1695	Chongqing	-1.1974
Liao ning	-0.5107	Sichuan	-0.7747	Liao ning	0.1738	Sichuan	0.1346
Yunnan	-0.1305	Guizhou	0.1623	Yunnan	0.2991	Guizhou	0.6729
Heilongjiang	0.4942	Shanxi	-0.0566	Heilongjiang	-1.6150	Shanxi	0.3479
Anhui	-0.2314	Gansu	0.6935	Anhui	0.2511	Gansu	-0.5310
Jiangxi	-0.1503	Qinghai	-0.2605	Jiangxi	0.2883	Qinghai	0.2399
Henan	0.5495	Ningxia	0.2814	Henan	-1.0313	Ningxia	1.3691
Shanxi	0.0205	Xinjiang	0.3707	Shanxi	0.4193	Xinjiang	6.0884
Guangxi	-0.2114			Guangxi	0.2593	Overall	0.3976

Note: *, ** and *** denote on the level of 10%, 5% and 1% significance.

As there is a big difference in the chase group among the provinces, it is necessary to study the changing intercept effect to analyze the corresponding individual effects, and then find the η value of the catch-up group of the provinces. In the chase group of 19 provinces, the value of the four provinces Heilongjiang, Henan, Chongqing and Gansu are negative, indicating that η on GDP per worker of the four provinces reduced 1% each with group I, the gap in the environmental regulation strength will expand 1.6150%, 1.0313%, 1.1974% and 0.5310%, the first three provinces' η value is less than 0, which are belonging to strong divergence, ϖαλυε of Gansu is between -1 and 0, which is weak divergence. The η value of the remaining 15 provinces like Hebei, Inner Mongolia, is positive, indicating that GDP per worker in these provinces reduced 1% each, their gap on the strength of environmental regulation with group I will continue to narrow. The provinces Ningxia and Xinjiang's η values are greater than 1, showing a strong convergence trend. That is, their reducing speed in the difference of the intensity of environmental regulation is faster than the speed of GDP per worker. The remaining 13 provinces' η values are between 0 and 1, belonging to the weak convergence. The reducing speed in the difference of the intensity of environmental regulation is slower than the speed of GDP per worker. From fast to slow in the order is Guizhou, Shanxi, Hebei, Shaanxi, Yunnan, Jiangxi, Hunan, Guangxi, Anhui, Qinghai, Liaoning, Inner Mongolia and Sichuan.

CONCLUSIONS

This paper studied above issues with panel data of industrial sectors of each province of China in 2000-2011, and divided the 30 provinces into 4 groups by the indexes of output and environmental pollution: high-yield low-emission group per worker (group I), high-yield high emission group per worker (group II), low-output low emissions group per worker (group III) and low-output high-emission group per worker (group IV). Then, based on the data of national group and four groups we examined their σ convergence and absolute β convergence and condition β convergence in GDP per worker and the intensity of environmental regulation, and finally examines the relationship of the convergence in GDP per worker and the intensity of environmental regulation, the following conclusions were drawn: First, by absolute β convergence and condition β convergence analysis, we believed that on the indicators of GDP per worker, the national group and group II both existed absolute β convergence and condition β convergence; group I, group III and group IV only existed condition β convergence. On the indicators of the intensity of environmental regulation, only group III existed both absolute β convergence and condition β convergence, the national group, group I, group II and group IV only existed condition β convergence. On each indicator, if the group existed both absolute β convergent and condition β convergence, it indicated that there are certain characteristics of club-convergence on them, but the group which merely existed condition β convergence did not exist the same club convergence trend, and tended to their respective steady-state level.

Second, the test of the relationship between differences in the intensity of environmental regulation and differences in convergence test results showed that when the catch-up group as a whole shrinked the gap of GDP per worker, it also continued to narrow the gap of the intensity of environmental regulation with group I, but the latter's rate of convergence was slower than the former's. The specific

situations of the chase group of 19 provinces were of various shapes, including, when the four provinces of Heilongjiang, Henan, Chongqing and Gansu shrinked the gap of GDP per worker with group I, the gap in the intensity of environmental regulation between them was expanding; Ningxia and Xinjiang's convergence rate in the intensity of environmental regulation with group I is faster than the rate in GDP per worker, while the rest 13 provinces like Guizhou, Shanxi are opposite.

Through the above analysis, we know that there is a big difference of the national group and the four subgroups in the GDP per worker and the intensity of environmental regulation, especially when the catch-up group narrowed its gap in the GDP per worker with group I. The speed of improvement for environmental regulation and protection is not so consistent. Based on sustainable development perspective, group I set a good example on "win-win" situation of economic growth and environmental protection for the country, and it also contains different policy recommendations for different provinces in the catch-up group. For the provinces in group II, the industry they should increase the protection of the environment and regulatory efforts when pursuing high economic growth to reverse adverse pattern of the high industrial growth and low environmental performance. For the provinces in group III, further improving the economic level is still the focus of future work, but maintaining and improving the existing environmental performance should be taken into account, especially guard against the intensity of environmental regulation of the two provinces of Heilongjiang and Henan on gradual weakening trend. Group IV is the one whose position is the most difficult of four, so it should be developing not only economic growth but also improving the environment in the future, this "win-win" situation should be established on achieving a reasonable environmental regulation policy, stimulating enterprises to innovate pollution control technology and production of technology, so let the theoretical possibility of Porter's "innovative compensation" effect could be an existence of a reality.

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