Advances in Social Science, Education and Humanities Research, volume 194
4th International Conference on Education Technology, Management and Humanities Science (ETMHS 2018)

Estimation of Ecological Compensation Rates for Transboundary Watershed Based on Emissions Trading

——A Case of Songhua River Basin

Li Wanhong[1, a], Wang Fuyao[1, b, *]

[1]School of Economics and Management, Harbin Engineering University, Harbin 150001, China

[a]liwanhong@hrbeu.edu.cn, [b]wangfuyao9328@163.com

Keywords: Songhua River basin, emission rights, ecological compensation standard

Abstract: Based on the theory of emissions trading, this paper constructs a panel data model based on Kuznets curve (EKC) and ecological compensation standard calculation model. Taking data of seven cities from Songhua River basin such as Jilin, Changchun, Songyuan, Qiqihar, Harbin, Qitaihe, Jiamusi, the paper also calculates their ecological compensation rates in 2004 and 2015 based on the trading of emission rights, and does longitudinal analysis of the ecological compensation standards of Changchun and Harbin. The results show that cities with transboundary basins should follow the principle of "who pollutes who pays", and cities that overuse the right to emit pollutants should pay more ecological compensation, while the economically viable cities will receive corresponding ecological compensation, which will help clear cross-border river basin water pollution control responsibilities, and improve pollution control efficiency.

1. Literature Review

Due to the fluidity of water resources and the characteristics of public resources, watershed management involves the vertical affiliation between the upper and lower levels of government and the horizontal parallel relationship between governments at the same level. This complex multi-tiered relationship leads to controversy over water quality issues in the upper and lower reaches of the basin. Some scholars think that ecological compensation in watersheds actually means paying for ecosystem services, more like a transaction or payment behavior between upstream and downstream areas that is mostly used to compensate and encourage resource owners to improve their management practices and thereby ensure long-term maintenance and provision of ecosystem services. Existing literature in the study of watershed eco-compensation mode mainly bases on the principle of "who compensates and compensates who", and is divided into government compensation, market compensation, quasi-market compensation, social compensation and self-compensation. From the perspective of measures and diversification of models, the operability of ecological compensation measures in transboundary watersheds needs to be further studied [1].

2. Basic Thinking and Model

According to the theory of environmental economics, this paper assumes that there is an "Environmental Kuznets Curve" between the level of economic development in China and the amount of industrial waste water discharged [2] (Wu Zhaopu, Wang Qian, 2010). This paper takes seven cities (Jilin City, Changchun City, Songyuan City, Qiqihar City, Harbin City, Qitaihe City, Jiamusi City (hereinafter abbreviated as "city" for short)) in Songhua River Basin as observation samples. By building a functional relationship between regional economic development level and industrial waste water discharge, and based on this model, we estimate the overused or abandoned emission rights in sample (Changchun and Harbin), and the ecological compensation rates that need to be paid or obtained by cities due to their emission rights.

2.1 Emission measurement model

2.1.1 Basic model

This paper assumes that there is a certain functional relationship between per capita GDP in a certain region and per capita industrial waste water discharge:

$$rWarter = f(rGDP) \tag{1}$$

$rWater$ stands for actual per capita industrial waste water discharge (Ton / person), $rGDP$ for GDP per capita of the region (Yuan / person). We can use equation (1) to calculate the theoretical per capita industrial waste water discharge, or

$$rWater_i^* = f(rGDP_i) \tag{2}$$

In the equation, $rWater_i^*$ represents the theoretical per capita industrial waste water discharge of region i (Ton / person).

Since $rWater_i$ can be obtained by referring to the statistical data, emission rights of region i can be obtained by the difference from $rWater_i^*$ and $rWater_i$, or

$$\Delta rWater_i = rWater_i^* - rWater_i \tag{3}$$

In that, $\Delta rWater_i$ stands for the overused or loss of emission rights (Ton / person) of region i. When $rWater_i > rWater_i^*$, emission rights is overused, the corresponding pollution fee should be paid. When $rWater_i < rWater_i^*$, emission rights is saved, and should be compensated accordingly.

2.1.2 EKC based regression model

Du Jiang and Luo Jun (2013) argue that there is a similar Environmental Kuznets Curve(EKC) between economic growth and the environment [3], and verified its existence by using the following simple equation,

$$rWater_{it} = \alpha_{it} + \beta_1 rGDP_{it} + \beta_2 rGDP_{it}^2 + \beta_3 z_{it} + \varepsilon_{it} \tag{4}$$

In this equation, z is for other variables that affect the quality of the environment, β_n (n=1, 2, 3) for estimated coefficient, a for fixed intercept item, t for year, and ε for error term.

Grossman and Krueger (2000) incorporate industrial scale effects, industrial structure effects and technological innovation effects into the traditional EKC model as control variables and constructs the following extended logarithmic EKC model [4]:

$$\ln rWater_{it} = \alpha_{it} + \beta_1 \ln rGDP_{it} + \beta_2 \ln(rGDP_{it})^2 + \beta_3 \ln sEffect_{it} + \beta_4 \ln iEffect_{it} + \beta_5 \ln tEffect_{i(t-1)} + \varepsilon_{it} \tag{5}$$

$sEffect$ represents industrial scale effects measured by regional industrial output value and adjusted according to the gross industrial output index; $iEffect$ is for industrial structure effect measured by GDP proportion of secondary industry, while $tEffect$ for technological innovation effect, selects a lagged number of regional patents to measure[5] (Sun Zhenjia, Zhang Xiangxian, 2015).

2.2 Ecological compensation standard calculation model

The following formula can be used to further determine the ecological compensation standards.

$$E_{compensation} = P_{water} \times T_{population} \times \Delta rWater_i \tag{6}$$

$E_{compensation}$ means ecological compensation standard (Yuan), P_{water} for emission right price (Yuan / ton), and $T_{population}$ for total population (Person). This paper uses the calculation results of emission price (6.44 Yuan/ton) of Jin Shuai (2011) [6].

3. Demonstration Calculation of Ecological Compensation Standard in Songhua River Basin

3.1 Data source analysis

This paper collects the data of the above seven sample cities from 2004 to 2015 and calculates the ecological compensation standard of Songhua River Basin. Among which, GDP per capita, total industrial waste water discharge, total industrial output value and the total population at the end of each city come from the "China City Statistical Yearbook". We first eliminate the impact of each city's price level (replaced by the GDP deflator (the year of 2000 = 100)) and then calculate the annual real GDP of each city. Description of the original data is shown in Table 1.

Table 1 Original data description

Variables	Observation	Median	Standard deviation	Maximum value	Minimum value
rWater (Ton / person)	84	13.196	10.23828	43.530	2.590
rGDP (Person / yuan)	84	18999.610	9561.978	46317.530	5437.121
sEffect (100 million yuan)	84	843.740	867.8793	3477.427	27.957
iEffect (%)	84	0.423	0.112845	0.662	0.199
tEffect (Piece)	84	2586.393	4742.223	24787.000	43.000

Fig.1 shows the per capita industrial waste water discharge trends of Jilin, Changchun, Songyuan, Qiqihar, Harbin, Qitaihe, Jiamusi from 2004-2015.

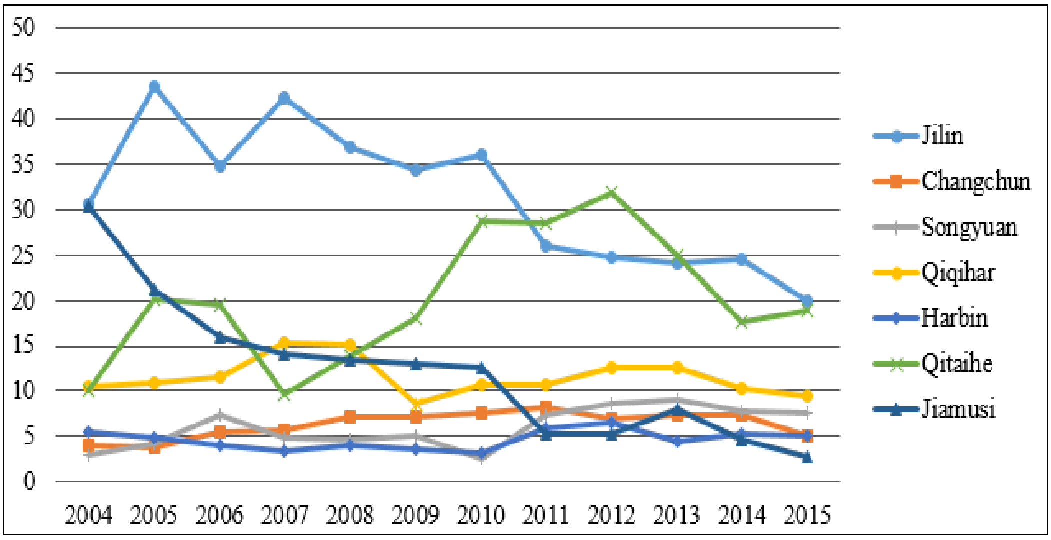

Fig.1 Per Capita Industrial Waste Water Emissions Trends

As can be seen from Fig.1, the numbers of Jilin City, Jiamusi City and Qitaihe City fluctuate greatly. The figure of Jilin City and Jiamusi City drops while that of Qitaihe comes up. The rest four cities show more flat curve.

3.2 Model estimation and calculation

Through unit root test and co-integration test function of Eviews 8.0 software on panel data, we can determine that the panel data model passes the smoothness test, that is, there is no spurious regression and the long-term stable co-integration relationship among the five variables. For small samples, we select individual fixed-effect model to estimate the variables. As can be seen from Table 2, except that the intercept item P value is not significant, other coefficients and index estimation results are more ideal. Therefore, it is feasible to use the individual fixed effect model to deal with the relationship between per capita GDP and per capita industrial waste water discharge.

Table 2 Processing results of individual fixed effects model

Variable	Coefficient	Standard error	T value	P value
c	-0.4512	1.8412	-0.2451	0.8071
$rGDP$	0.9961	0.4146	2.4028	0.0188
$\ln sEffect$	-1.4446	0.3946	-3.6614	0.0005
$\ln iEffect$	0.8685	0.4387	1.9791	0.0516
$\ln tEffect$	0.4018	0.1332	3.0166	0.0035
fixed effect				
Jilin	2.1260			
Changchun	0.2995			
Songyuan	-0.7472			
Qiqihar	0.7712			
Harbin	-0.3970			
Qitaihe	-1.6668			
Jiamusi	-0.3859			
R^2:0.9023 D.W.:1.0594	Adj R^2:0.8889		F:67.3822	P:0.0000

Based on the results of formula (5) and Table 2, the overused or saved emission rights can be obtained. Taking the capital cities of Changchun and Harbin for example, the $rWater^*$ and $rWater$ in 2004-2015 are shown in Fig.2 and Fig.3. Among them, Changchun in 2004-2007, and 2015, $rWater < rWater^*$, the corresponding ecological compensation can be obtained, in 2008-2014 $rWater > rWater^*$, then need to pay ecological compensation. Likewise, there is also a discrepancy between $rWater^*$ and $rWater$ in Harbin in 2004-2015, so payment or acquisition of ecological compensation should be made accordingly.

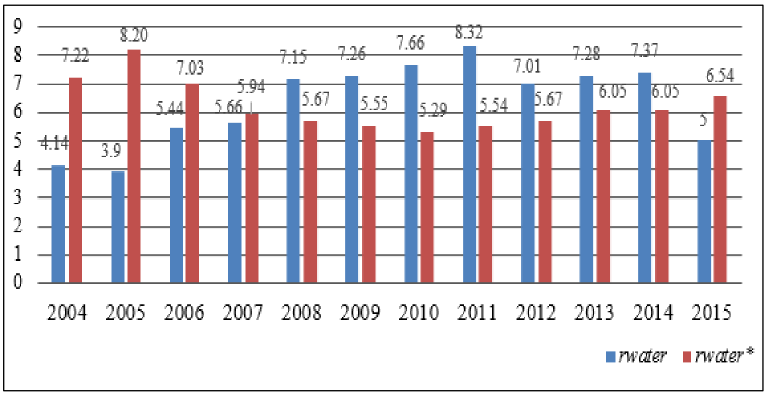

Fig.2 Per Capita Industrial Waste Water Discharge of Changchun (tons / person)

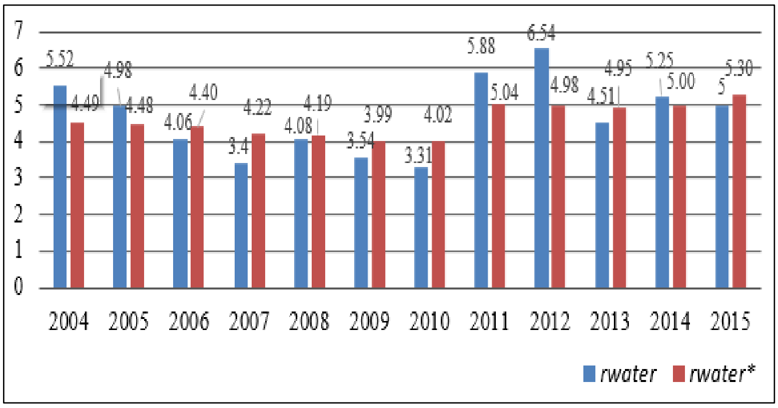

Fig.3 Per Capita Industrial Waste Water Discharge of Harbin (tons / person)

3.3 Ecological compensation standard calculation

Taking Changchun and Harbin, 2004 and 2015 as examples and combining with formula (6), the ecological compensation for the sample cities is shown in Table 3 and Table 4.

Table 3 Ecological compensation rates for Changchun and Harbin from 2004-2015

Year	Changchun			Harbin		
	Overused emission right/10,000 tons	Abandoned right to discharge/10,000 tons	Compensation standard/ 100 million yuan	Overused emission right/10,000 tons	Abandoned right to discharge/10,000 tons	Compensation standard/ 100 million yuan
2004	-	2229.920	1.4361	999.337	-	-0.6436
2005	-	3147.910	-2.0273	489.236	-	0.3151
2006	-	1174.510	-0.7564	-	332.307	-0.2140
2007	-	206.486	-0.1330	-	807.550	-0.5200
2008	1115.089	-	0.7181	-	107.896	-0.0695
2009	1296.695	-	0.8351	-	447.823	-0.2884
2010	1798.310	-	1.1581	-	704.077	-0.4534
2011	2114.324	-	1.3616	836.073	-	0.5384
2012	1017.571	-	0.6553	1552.518	-	0.9998
2013	924.5953	-	0.5954	-	439.453	-0.2830
2014	995.2276	-	0.6409	244.813	-	0.1577
2015	-	1160.898	0.7476	-	288.411	0.1857

As can be seen from Table 3, in the 12-year sample study period, Changchun overused emission rights for more than seven years and saved emission rights for five years, while Harbin overused emission rights for more than five years and saved emission rights for seven years. As a result, the annual emission of industrial waste water may increase or decrease due to the impact of industrial scale, industrial structure, and technological innovation in environmental protection and other factors in various cities. As a result, the emission rights also change accordingly.

Table 4 Ecological compensation rates of cities in Songhua River Basin in 2004 and 2015

City	Year of 2004			Year of 2015		
	Overused emission right/10,000 tons	Abandoned right to discharge/10,000 tons	Compensation standard/100 million yuan	Overused emission right/10,000 tons	Abandoned right to discharge/ 10,000 tons	Compensation standard/100 million yuan
Jilin	-	1394.478	0.8980	-	4228.301	2.7230
Changchun	-	2229.920	1.4361	-	1160.898	0.7476
Songyuan	-	342.552	0.2206	333.684	-	-0.2149
Qiqihar	-	3626.509	2.3355	137.348	-	-0.0885
Harbin	999.337	-	-0.6436	-	288.411	0.1857
Qitaihe	-	675.229	0.4348	-	145.443	0.0937
Jiamusi	3862.980	-	-2.4878	-	1259.015	0.8108

As can be seen from Table 4, Harbin and Jiamusi switched from overusing in 2004 to saving emission rights by 2015, thus obtaining ecological compensation of 18,570,000 yuan and 81,080,000 yuan respectively. On the contrary, Songyuan and Qiqihar should pay ecological compensation of 21,490,000 yuan and 8,850,000 yuan. Jilin, Changchun and Qitaihe saved emission rights, thus obtaining ecological compensation of 272,300,000 yuan, 74,760,000 yuan and 9,370,000 yuan respectively.

4. Conclusion

Based on the theory of emissions trading, the results show that transboundary river basins should follow the principle of "who pollutes who pays", and the more that cities use excessive emission rights, the more ecological compensation they will pay, while the cities that save the emission rights will also receive corresponding ecological compensation. In conclusion, exploring the transboundary ecological compensation in Songhua River Basin plays an important role in improving the efficiency of water pollution control. However, ecological compensation in cross-border watersheds is still in its infancy in China, and there is still room for further improvement in terms of compensation subjects, standards and methods.

Acknowledgments

This research was financially supported by funding from the National Social Science Foundation of China (NO.17BGL204) and the Philosophy & Social Science Project of Heilongjiang Province (NO.16JYB04).

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