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Coordination Between Economic Development and Environmental Protection in Free Trade Zone: A Case Study of Hubei, China

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ABSTRACT

The rapid economic development in China is accompanied by severe environmental pollution. Particularly, realizing the harmonious development of economy and environment is an urgent problem in the construction of free trade zone in China. In order to explore the coordination state between economic development and environmental protection in the free trade zone, evolution law of the coordination and type of coordination degree, this study constructed an evaluation index system of coordination to investigate the coordination state between economic development and environmental protection in the free trade zone. Time, degree and mechanism of such coordination were analysed based on the free trade zone in Hubei Province by using the coordinated development degree model. Research demonstrates a weak interaction between economic development and environmental protection. Economy and environment basically synchronously develop. The environment can meet the demands of the economy, thereby showing a harmonious development. Development is in the basic, harmonious, and quasi-sustainable stage. In Wuhan, economic development and environmental protection are relatively coordinated. Environment mainly drives economic development, thereby showing strong coordination between environmental protection and economic development. The economy of Yichang develops ahead, and environmental protection begins to improve. The driving effect of the environment on economic development is enhanced, thus showing strong coordination. The economy of Xiangyang develops ahead, and pressure on environmental protection is heavy. The environment mainly inhibits economic development with moderate coordination. Conclusions can provide a few references for local government in formulating relevant policies according to actual conditions, thus facilitating the harmonious development between environmental management and investment trade and realizing the win-win goal of environmental protection and economic development.

INTRODUCTION

The increasing environmental problem has recently become the main barrier that influences sustainable economic development. Solving environmental pollution problems and effectively relieving environmental degradation, has attracted considerable attention worldwide. The amount of required production scale necessary for economic development when economic growth could not continuously improve human welfare is investigated. The rapid economic development in China has been accompanied with a series of environmental pollution problems. In 2014, China ranked last in the world evaluation of PM2.5 index. In the EPI ranking issued by Yale University in 2014, China ranked 118th among 178 countries (Jason et al. 2014). According to estimation results of the Ministry of Environmental Protection in 2016, only 84 cities, which only accounted for 24.9% of the total number of cities, had satisfactory environmental air quality among 338 prefectures or higher cities in China. The Government of China proposed the concept of "free trade zone" in 2013 to facilitate industrial restructuring, accelerate innovative reform development and further increase the liberalization of trade and investment. However, although liberalization of trade and investment can result in tremendous dividends for social economic development, the relevant environmental problem in the trade-exporting country cannot be overlooked.

To solve this problem, a few scholars in the 1990s discovered that Mexico, as the largest developing country in the North American Free Trade Agreement, experienced a sharp downturn of environmental quality in the promotion of free trade (Gene et al. 1992). Thus, research on the relationship between free trade and environmental quality has become the focus of theoretical studies, and a few theoretical opinions, such as Kuznets curve of environmental quality (Brock et al. 2010) and polluter's paradise effect and hypothesis (Walter et al. 1979) have been developed. The intensifying internal environmental problems in developing countries might have effects on international trade. Subsequently, the effect of promoting liberalization of trade and investment in free trade zone to the environmental qual-

ity of China was also investigated. In this study, the evaluation index system for coordination degree between economic development and environmental protection was constructed. State, evolution law, and type of coordination between economic development and environmental protection in free trade zone in China were analysed by using the coordinated development degree model. This study aims to facilitate the harmonious development of environmental management and investment trade and realize the win-win goal of environmental protection and economic development.

STATE OF THE ART

The most famous theory regarding environmental pollution problems brought by economic development is the Environment Kuznets Curve (EKC) theory. Many studies have proved or disproved this theory since its proposition. For example, Dipankor et al. (2002) and Abdul et al. (2009) carried out empirical studies on the relationship among different environmental pollution indexes and economic growth and proved the existence of EKC theory. On the contrary, the empirical studies of Perman et al. (1999), Stern (2004) and Nektarios et al. (2009) based on the panel data model state, that an inverted U-shaped relationship between environmental pollution and economic growth did not exist as implied by EKC theory. Environmental problems in China are complicated. Based on the panel data analysis of the provinces in China, Wang et al. (2014) found that the influences of economic growth on environmental pollution conform to the EKC theory, and their relationship is the declining section of the inverted U-shaped curve at present. Yu et al. (2012) discovered that the research conclusions of inverted-shaped curve account for approximately 35% of empirical studies in industrial "wastewater, waste gases and residues," but these conclusions accounted for the largest proportion in empirical studies of three wastes and other environmental indexes.

Quantitative studies on coordinated environmental and economic development mainly combine mathematical model and system simulation. For example, Ammar (2003) studied Mzab and reported the important role of environmental protection in economic development. Barry (2007) improved ISAT, an evaluation tool of harmonious environmental development capacity. Hanley et al. (1999) carried out a time series analysis on the coordinated development capability between economy and environment in Scotland during 1980-1993. Huang et al. (2014) believed that economic development is not the pre-condition of coordinated development, and imbalanced economic-environmental development is attributed to environmental inefficiency, which is mainly caused by the output inefficiency of smoke dust and solid wastes. Hong et al. (2013) constructed the evaluation index system for resource-environment-economy-society coordinated development in middle China and quantitatively estimated the coordinated development degree.

Studies on free trade zone mainly focus on the role and feature evaluation of free trade zone. Inland free trade zone not only relieves pressure on commodity storage at coastal ports (Boring 2005) and drives regional economic development and infrastructure construction (Hampe et al. 2007), but also attracts foreign investment and develops off-shore finance (Yang 2009). Meng et al. (2011) constructed the feature evaluation model of free trade zone by using relevant theories of economic geology and tested such model based on the New Binhai District in Tianjin. Liu et al. (2016) established a set of comprehensive performance evaluation system that conforms to the development orientation of free trade zone in China through systematic analysis.

In summary, scholars are highly concerned on environmental problems brought by economic development. Many studies have been reported, and studies on their relationship mainly focus on provincial or higher level of economic layer. Most studies on free trade zone emphasize the role or feature structural evaluation of free trade zone. The combination of economic, environmental, and resource problems in the free trade zone is mainly observed in studies of management mode. Thus, the evaluation index system for coordination between economic development and environmental protection in the free trade zone was constructed. The inhibition and driving effects of economic development and environmental protection were combined to discuss their coordination state and evaluation law in the free trade zone in China by using the coordinated development degree model. In addition, the coordination type in free trade zones in China was classified by using the calculated coordination degree as the standard.

RESEARCH METHODS

Index system: Testing free trade zone in Hubei Province, China (hereinafter referred as the Hubei free trade zone) was set. Promoting reform and opening-up policy is an important strategic measure of the government of China to accelerate the development of the Yangtze River Economic Zone and facilitate the rise of Central China. The evaluation index system for coordination between economic development and environmental protection was constructed based on the Hubei free trade zone.

Coordinated development is the overall deepening process based on coordination from low to high level, simple to complex, and disordered to order. Quantitative index is the coordinated development degree. Based on the regional economic-environmental coordinated development capacity evaluation model of Barry (2007) and the feature

Table 1: Evaluation index system for coordination between economic development and environmental protection in Hubei free trade zone.

Index layer	System layer	Subsystem layer	Index layer	unit
Economic-environmental coordinated development index (A1)	Economic development index (B1)	Economic level (C1)	Urbanization level (D1)	%
			Per capita GDP (D2)	RMB
			GDP growth rate (D3)	%
			Fixed investments (D4)	10,000 RMB
			Retail sales of per capita consumer goods (D5)	RMB
			Local fiscal revenues (D6)	10,000 RMB
		Economic structure (C2)	Proportion of secondary industry in GDP (D7)	%
			Proportion of tertiary industry in GDP (D8)	%
	Environmental development index (B2)	Environmental pollution (C3)	Emission of industrial waste water (D9)	tons
			Utilization of industrial solid wastes (D10)	%
		Environmental governance (C4)	Standard rate of industrial waste water discharge (D11)	%
			Per capita Greenland area (D12)	m^2/ per capita
			Harmless processing rate of domestic wastes (D13)	%
			Investment in environmental protection (D14)	RMB 10,000

evaluation system and data availability of free trade zone of Tian et al. (2015), the evaluation index system of economic-environmental coordinated development in the free trade zone was constructed from two layers, namely, economic and environmental development, and four dimensions, namely, C1-C4. Table 1 lists the specific indexes.

Evaluation model: The coordination level between economic development and environmental protection in the pilot cities of free trade zone was objectively evaluated by using principal component analysis. Dimensions of evaluation indexes were eliminated through data normalization, dimension reduction, and weight processing. Indexes were used to reflect repeatability of information.

The evaluation model of coordination between economic development and environmental protection generally covers "coordination degree model" and "coordinated development degree model." The "coordinated development degree model" was used to establish the evaluation model of coordination between economic development and environmental protection based on the coordination degree model of Yang (2003). The comprehensive coordination level between economic development and environmental protection is reflected as in Equation (1):

$$D = \sqrt{C \times T} \quad ...(1)$$

Where, D is the relative coordination degree of system, and C is the coordination degree.

$$C = \left[\frac{f(x) \cdot g(y)}{\left(\frac{f(x) + g(y)}{2} \right)^2} \right]^k \quad ...(2)$$

Table 2: Comprehensive scores of economic development in pilot cities from 2010 to 2016.

	2010	2011	2012	2013	2014	2015	2016
Wuhan	1.327	1.251	1.347	1.402	1.384	1.948	1.781
Yichang	1.072	1.063	1.106	1.103	1.065	0.187	0.561
Xiangyang	-0.858	-0.583	-0.618	-0.524	-0.350	-0.479	-0.234

Table 3: Comprehensive score of environmental protection in pilot cities from 2010 to 2016.

	2010	2011	2012	2013	2014	2015	2016
Wuhan	0.838	-0.173	0.639	1.126	1.307	0.467	0.662
Yichang	1.692	-1.703	-1.504	0.562	1.979	1.427	0.736
Xiangyang	-1.577	0.982	1.005	-0.774	-2.126	-0.497	-1.478

Table 4: Comprehensive scores of economic development and environmental protection in pilot cities from 2010-2016.

Time	Wuhan		Yichang		Xiangyang	
	f(x)	*g(y)*	*f(x)*	*g(y)*	*f(x)*	*g(y)*
2010	0.644	0.873	0.985	0.974	0.600	0.670
2011	0.600	0.600	0.981	0.671	0.756	0.997
2012	0.655	0.655	1.000	0.600	0.737	1.000
2013	0.686	0.686	0.999	0.874	0.784	0.773
2014	0.676	0.676	0.982	1.000	0.889	0.600
2015	1.000	1.000	0.600	0.951	0.815	0.808
2016	0.904	0.904	0.763	0.889	0.955	0.683

Table 5: Evaluation results on economic development and environmental protection in pilot cities.

Year	Wuhan			Yichang			Xiangyang		
	T	C	D	T	C	D	T	C	D
2010	0.758	0.962	0.851	0.980	0.912	0.990	0.635	0.994	0.794
2011	0.600	0.975	0.775	0.826	0.931	0.877	0.877	0.963	0.919
2012	0.737	0.948	0.848	0.800	0.879	0.839	0.868	0.955	0.910
2013	0.819	0.927	0.881	0.936	0.991	0.963	0.779	0.904	0.882
2014	0.838	0.967	0.881	0.991	0.923	0.995	0.744	0.926	0.830
2015	0.886	0.996	0.926	0.900	0.900	0.836	0.812	0.921	0.901
2016	0.865	0.998	0.928	0.988	0.988	0.903	0.819	0.946	0.880

Table 6: Mean scores of pilot cities.

	Wuhan	Yichang	Xiangyang	Mean
g(y)	0.821	0.852	0.777	0.817
f(x)	0.741	0.905	0.817	0.821
Coordination degree (C)	0.609	0.772	0.635	0.672
Comprehensive coordinated development coefficient (T)	0.781	0.879	0.797	0.819
Mean of coordinated development degree (D)	0.882	0.937	0.892	0.904

Where, k is the accommodation coefficient (let k=2). The value range of C is [0, 1] and C=1, which is the best coordination state. A small C leads to high non-coordination. T is the comprehensive coefficient of coordination between economic development and environmental protection. Therefore,

$$T = \alpha f(x) + \beta g(y) \quad ...(3)$$

Where, α and β are undetermined coefficients set as 1/2. *f(x)* is the coefficient of comprehensive economic development, and *g(y)* is the coefficient of comprehensive environmental protection. $f(x) > g(y)$ reflects lagged environmental protec-

tion, and $f(x) < g(y)$ indicates lagged economic development. $f(x) = g(y)$ indicates synchronous economic development and environmental protection.

Additionally, *x1, x2,....,xm* are m indexes to evaluate comprehensive economic development, and *y1, y2,....,yn* are *n* indexes to evaluate comprehensive environmental bearing capacity. Subsequently, the evaluation functions of comprehensive economic development and environmental bearing capacity are as follows:

$$f(x) = \sum_{i=1}^{m} a_i \hat{x}_{ij} \quad ...(4)$$

$$g(y) = \sum_{i=1}^{n} b_j \hat{y}_{ij} \quad ...(5)$$

Where, $\hat{x}_{ij}$ and $\hat{y}_{ij}$ are the index values after normalization. a_i and b_j are weights that must be determined.

Equations (2), (3), (4), and (5) were incorporated into Equation (1). Therefore, the calculation formula for coordinated development degree is:

$$D = \left[\alpha \sum_{i=1}^{m} a_i \hat{x}_{ij} + \beta \sum_{i=1}^{n} b_j \hat{y}_{ij} \right]^{\frac{1}{2}} \times \left[\frac{\alpha \sum_{i=1}^{m} a_i \hat{x}_{ij} + \beta \sum_{i=1}^{n} b_j \hat{y}_{ij}}{\left[\frac{\alpha \sum_{i=1}^{m} a_i \hat{x}_{ij} + \beta \sum_{i=1}^{n} b_j \hat{y}_{ij}}{2} \right]^2} \right]^{\frac{k}{2}} \quad ...(6)$$

Data source: Data were mainly collected from China City Statistical Yearbook (2010-2016) and Statistical Yearbook of Hubei Province (2010-2016). Among these data, data of Wuhan, Yichang, and Xiangyang were selected, as shown in the index layer of the "Index System".

RESULT ANALYSIS AND DISCUSSION

Comprehensive Scores of Economic Development and Environmental Protection

Comprehensive scores of economic development: The original data were analysed and evaluated by using the SPSS 21.0 software. After data normalization, the corresponding principal components were extracted according to the principle of large accumulating contribution rate. The comprehensive scores of different principal components, that is, the comprehensive scores of economic development, were calculated. The comprehensive scoring model of principal components is as follows:

$$F = F_1 \times \frac{f_1}{f_1 + f_2} + F_2 \times \frac{f_2}{f_1 + f_2} \quad ...(7)$$

Where, F is the score of comprehensive factor, F_1 and F_2 are the scores of the first and second common factors, respectively, and f_1 and f_2 are the contribution rates that correspond to the extracted common factors. On this basis, the comprehensive scores of economic development in pilot cities from 2010 to 2016 could be calculated (Table 2).

Comprehensive scores of environmental protection: Similarly, the comprehensive scores of environmental protection in pilot cities from 2010 to 2016 could be calculated (Table 3).

Coordination Scores Between Economic Development and Environmental Protection

Reconstruction of economic development *(f(x))* and environmental protection *(g(y))*: Tables 2 and 3 show that the comprehensive scores of economic development and environmental protection have negative values. These values cannot meet the calculation requirements of coordination degree and coordinated development. Hence, the comprehensive scores of environmental protection and economic development are transformed into the interval of [0.6, 1]. The transformation formula is as follows:

$$f_{ij} = \frac{F_{ij} - \min\{F_j\}}{\max\{F_j\} - \min\{F_j\}} \times 0.4 + 0.6 \quad ...(8)$$

Where, f_{ij} is the score after transformation, F_{ij} is the value of index *j* in system *i*, $\min\{F_j\}$ is the minimum value under index *j*, and $\max\{F_j\}$ is the maximum value under index *j*. The comprehensive scores of economic development and the comprehensive scores of economic development and environmental protection after transformation can be calculated (Table 4).

Calculation of coordination degree and coordinated development degree: The comprehensive coordinated development coefficient (*T*), coordination degree (*C*), and coordinated development degree (*D*) between economic development and environmental protection in pilot cities in free trade zone could be calculated using Equations (1), (2), and (3), respectively. The results of the calculation are given in Table 5.

Analysis of Coordination Between Economic Development and Environmental Protection

Time course of coordination between economic development and environmental protection: The analysis results in Table 6 show that $g(y)$, $f(x)$, *C*, *T*, and *D* of three pilot cities are 0.817, 0.821, 0.672, 0.819, and 0.904, respectively, and $g(y) < f(x)$. *C*, *T*, and *D* belong to intervals of [0.6, 0.8], [0.7, 1.0], and [0.9, 1.0], respectively. These results reflect that environmental protection in pilot cities meet the needs

Table 7: Type and degree of coordination between economic development and environmental protection.

Year	Wuhan		Yichang		Xiangyang	
	D	Type	D	Type	D	Type
2010	0.851	Relatively high coordination and economic-ahead type	0.990	High coordination and synchronous type	0.794	Relatively high coordination and gradual improving type
2011	0.775	Relatively high coordination and economic-ahead type	0.877	Relatively high coordination and economic-ahead type	0.919	High coordination and gradual improving type
2012	0.848	Relatively high coordination and gradual improving type	0.839	Relatively high coordination and economic-ahead type	0.910	High coordination and environmental-dominated type
2013	0.881	Relatively high coordination and synchronous type	0.963	High coordination and gradual improving type	0.882	Relatively high coordination and gradual improving type
2014	0.881	Relatively high coordination and synchronous type	0.995	High coordination and synchronous type	0.830	Relatively high coordination and economic-ahead type
2015	0.926	High coordination and economic-ahead type	0.836	Relatively high coordination and environmental-dominated type	0.901	High coordination and synchronous type
2016	0.928	High coordination and economic-ahead type	0.903	High coordination and synchronous type	0.880	Relatively high coordination and economic-ahead type

Table 8: Interaction states of economic development and environmental protection in Hubei free trade zone.

Regions	$f(x)$	$g(y)$	$f(x)$ and $g(y)$	Interaction	Coordinate state
Overalls of pilot cities in Hubei free trade zone	0.820	0.814	$f(x)>g(y)$	Economic development and environmental protection are basically synchronous. Interaction between them is relatively weak. Regional economy and environment are coordinated.	Moderate
Wuhan	0.741	0.821	$f(x)<g(y)$	Ecolog.05ical environment is shows relatively harmonious development. The driving force of ecological environment to economic development is enhanced.	Relatively strong
Yichang	0.905	0.852	$f(x)>g(y)$	Economic develops ahead, economic environment gets better, and the inhibition effect of ecological environment to economic development declines.	Strong
Xiangyang	0.817	0.777	$f(x)>g(y)$	Economic develops ahead, ecological environment has heavy pressures, and it mainly inhibits economic development.	Moderate

of economic development. These factors are in the stage of coordination and improvement. Economic development is relatively ahead of environmental protection and environmental damages are serious, thereby indicating that environmental protection inhibits economic development. Although environmental damage rate is relatively high, the environmental conditions can meet the demands of economic development. Economic development and environmental protection show a relatively weak interaction. The dynamic changes of these factors show moderate coordination and quasi-sustainable development mode.

The level and degree of economic-environment coordination reflect that the economic development and environmental protection in Wuhan is in the second level. Environmental protection drives economic development, and environment can meet the needs of economic development. The dynamic changes of economic development and environmental protection show strong coordination and relatively strong sustainability. Economic development and environmental protection in Yichang are in the first level. Environmental protection inhibits economic development and interaction between them is weak. Environmental protection manages to meet the needs of economic development. Dynamic changes of economic development and environmental protection show strong coordination and sustainability. Economic development and environmental

protection in Xiangyang are in the third level. Environmental protection inhibits economic development, thereby showing a high coordination degree. Environment meets the need of economic development. Dynamic changes of economic development and environmental protection show moderate coordination and quasi-sustainability.

Types and degree of coordination between economic development and environmental protection: According to Table 7, the coordination degree between economic development and environmental protection in pilot cities in the Hubei free trade zone mainly has strong or relatively strong coordination. Coordination has four types, namely, economic-ahead, environment-dominated, gradual-improving, and synchronous. Low coordination level and irretrievable coordination have not been observed, thereby indicating the relatively good environmental conditions in pilot cities in Hubei free trade zones. The economic development rate is moderate. Contradiction between economic development and environmental protection is relatively relieved and environmental pressure is always in the environmental accumulative pressure threshold. However, large differences are observed in different regions. Specifically, Wuhan shows high coordination between economic development and environmental protection. The coordination belongs to the economic-ahead type, and economic development takes the dominant role. Economic development and environmental protection run in, thereby increasing the overall coordinated development degree. Yichang, which basically belongs to synchronous type, shows high coordination, and its coordination degree is also relatively high. Xiangyang, which mainly belongs to economic-ahead and environmental-dominated types, show high coordination. Economic development and environmental protection show relatively weak interaction.

Coordination mechanism between economic development and environmental protection: According to Table 8, economic development and environmental protection slightly interact in the entire Hubei free trade zone. They show synchronous development, and environment basically meets the need of economic development. They have high coordination degree, which is identified as basic and moderate coordination and quasi-sustainability. However, a few regional differences are observed. Economic development and environmental protection in Wuhan are relatively coordinated, and environment mainly drives economic development, thereby demonstrating strong coordination. The economy of Xiangyang develops ahead and pressure in environmental protection intensifies. Environment mainly inhibits economic development. Economic development and environmental protection are in moderate coordination.

The unique geographical conditions in the Hubei free trade zone determine the maximum environmental bearing capacity. When "compromising" environment is difficult, economic development must "concede" to relieve contradiction with the environment. In this sense, policy principle, structural optimization, and environmental investment drive and inhibit the coordination between economic development and environmental protection. Policy principle is the most effective way to relieve the contradiction between economy and environment. Structural optimization is an endogenous power to relieve this contradiction. Environmental investment can decelerate the inhibition effect of environment on economic development.

CONCLUSION

Liberalization of trade and investment is conducive to social economic development but will influence environmental quality in trade-exporting countries. The construction of free trade zone can influence the environmental quality of China. The traditional relationship between economy and environment can be changed by constructing free trade zones to realize the coordinated development between economy and environment, thus improving environmental quality. In this study, free trade zones in China are used as the analysis carrier, whereas important data of economic development and environmental protection in pilot cities of Hubei free trade zone (Wuhan, Yichang and Xiangyang) from 2010-2016 are used as analysis objects. Based on the established evaluation index system, coordination problems between economic development and environmental protection in free trade zones in China are systematically investigated using the calculated data of comprehensive score of environmental protection, economic development, coordination degree, coordinated development degree, and comprehensive coordination coefficient between economic development and environmental protection. The following conclusions can be drawn:

1. Economic development and environmental protection in Hubei free trade zone in China interact weakly. Both are basically synchronous, and environment basically meet the needs of economic development, thereby showing high coordination. Economic development and environmental protection are in basic coordination and quasi-sustainability stage. Economic development is significantly influenced by development mode, optimized infrastructure layout, vigorous development of circular economy, and considerable attention on industrial restructuring.
2. The type and degree of coordination has four main types, namely, economic-ahead, environment-dominated,

gradual-improving, and synchronous type. In the Hubei free trade zone, economic development and environmental protection have relatively high coordination degree. A large space for coordination expansion is observed. However, this phenomenon does not indicate that the coordination degree is continuously increasing.

3. Economic development and environment protection for coordination state in Wuhan are relatively coordinated. Environment mainly drives economic development, thereby showing strong coordination. In Yichang, economy develops ahead and environmental protection improves. The driving force of environment on economic development is enhanced. Economic development and environmental protection are in strong coordination stage. In Xiangyang, economy develops ahead and pressure on environmental protection is strong. Environment mainly inhibits economic development. Economic development and environment protection are in moderate coordination.

This study only focuses on time changes of coordination between economic development and environmental protection in free trade zones in China and did not analyse the spatial changes. Further studies on coordination mechanism of different elements are required.

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