

Study on the coupling and coordination relationship between ecological environment and economic development in Heyuan City

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Abstract. Quantitative research on the coordination between ecological environment and economic development is of great significance to the realization of the goal of sustainable development. Taking Heyuan City as the research object, this paper constructs the indicator system of ecological environment and economic development, selects the relevant indicator data of ecological environment and economic development of Heyuan City from 2005 to 2021, establishes the coupling coordination degree model, and conducts an empirical analysis of the relationship between the ecological environment and economic development of Heyuan City. The research shows that the coupling degree between the ecological environment and economic development of Heyuan City has been at a high level during the period from 2005 to 2021, and the overall coupling coordination degree has been steadily rising, and has gone through various stages from barely coordinated to high-quality coordinated development; The economic development of Heyuan City has also developed from lagging behind the ecological environment to the synchronous development of both.

1 INTRODUCTION

The report of the 19th National Congress of the Communist Party of China pointed out that we must establish and implement the concept that green waters and green mountains are golden mountains and silver mountains, firmly follow the path of civilized development of production development, rich life and good ecology, and build a modernization of harmonious coexistence between man and nature. Heyuan City is located in the backward mountainous area of northern Guangdong, and is also the northern ecological development area. How to realize the mutual promotion and coordinated development of ecological environment and economy has become an important issue that needs to be studied and solved urgently.

At present, the research on the coordinated development of ecological environment and economy mainly focuses on the following aspects: First, the research model mainly uses the environmental Kuznets model¹, the gray correlation model², the coupling coordination degree model³, the VAR model⁴ and other models to analyze the coordinated development of ecological environment and economy. Second, in terms of research content, it mainly focuses on the relationship between the ecological environment and economic development. Some scholars will also join the political structure, finance, tourism, social and other factors to discuss⁵, reflecting the relationship between several systems. Third, in terms of research objects, it mainly

studies the relationship between the ecological environment and economic development of the whole country, province or river basin, while the research on a certain city is relatively small.

This paper takes Heyuan City as the research object, constructs the indicator system of ecological environment and economic development, selects the relevant indicator data of ecological environment and economic development of Heyuan City from 2005 to 2021, establishes the coupling coordination degree model, analyzes the relationship between the ecological environment and economic development of Heyuan City, and provides certain reference value for promoting the coordinated development of ecological environment and economy.

2 METHODOLOGY

2.1 Entropy method

As an objective weighting method, entropy method can effectively avoid the subjectivity of weight setting. First, the range method is used to standardize the original data⁶ to eliminate the dimensional impact. Then use entropy method to calculate the weights of various indicators for standardized indicators, and calculate the weights of economic development indicators a_i and ecological environment indicators b_i . From this, we can calculate the economic development index U_1 and

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ecological environment index U_2 . The calculation formula is:

$$U_1 = \sum_{i=1}^m a_i x_i ; U_2 = \sum_{i=1}^m b_i y_i \quad (1)$$

2.2 Coupling coordination model

2.2.1 Coupling degree

Coupling originates from the concept of physics and refers to the phenomenon of interaction between two or more systems⁷. The coupling degree is used to measure the interaction between the environmental system and the economic system⁸. The formula is as follows:

$$C = \frac{2\sqrt{U_1 \times U_2}}{U_1 + U_2} \quad (2)$$

In the formula(2), C is the coupling degree, $0 \leq C \leq 1$, the greater the value of C, the higher the coupling degree between and; The smaller the value of C, the lower the coupling between and. Referring to relevant literature, the coupling degree is divided into the following types (Table 1):

Table 1. Classification of coupling types of ecological environment and economic development

Coupling level	Coupling stage	Coupling degree
$0.000 < C \leq 0.399$	Low level coupling stage	Very low coupling
$0.399 < C \leq 0.449$		Low coupling
$0.449 < C \leq 0.499$	Antagonistic stage	Moderate coupling
$0.499 < C \leq 0.549$	Running-in stage	High coupling
$0.549 < C \leq 0.599$	High level coupling stage	Highly coupled
$0.599 < C \leq 1.000$		Very high coupling

2.2.2 Coupling coordination degree

C can only explain the strength of the coupling between the two systems, but can not determine whether it is benign coupling or malignant coupling, and can not accurately reflect the level of coordinated development between the two systems. Therefore, the coupling coordination degree model is introduced to comprehensively reflect the coupling advantages and disadvantages between ecological environment and economic development. The calculation formula is as follows:

$$D = \sqrt{C \times T} ; T = \alpha U_1 + \beta U_2 \quad (3)$$

In the formula(3), D is the Coupling coordination degree. The greater the value of D, the higher the coupling coordination degree, and the better the coordinated development of the system; The smaller the D value, the lower the coupling coordination degree and the more uncoordinated the system; T is the coordination index; α, β Is the relationship weight. The relationship between the two is equally important, and the value is 0.5. Based on the existing research results, the coupling coordination degree is divided, as shown in Table 2.

Table 2. Coupling coordination degree of ecological environment and economic development

D	Coupling coordination level	D	Coupling coordination level
$0 < D \leq 0.1$	Extreme maladjustment	$0.5 < D \leq 0.6$	Barely coordination
$0.1 < D \leq 0.2$	Serious disorder	$0.6 < D \leq 0.7$	Primary coordination
$0.2 < D \leq 0.3$	Moderate disorder	$0.7 < D \leq 0.8$	Intermediate coordination
$0.3 < D \leq 0.4$	Mild disorder	$0.8 < D \leq 0.9$	Good coordination
$0.4 < D \leq 0.5$	Borderline disorder	$0.9 < D \leq 1.0$	Quality coordination

2.2.3 Relative development degree

In order to reflect the development gap between ecological environment and economic growth, the relative development degree model is introduced to analyze the relative lag between ecological environment and economic development. The calculation formula is as follows:

$$P = U_1 / U_2 \quad (4)$$

In the formula(4), P is the relative development degree, U_1 is the economic development level and U_2 is the ecological environment development level. When $P > 1.2$, it indicates that the development of ecological environment is relatively backward; When $0.8 \leq P \leq 1.2$, it indicates that the ecological environment and economic development are developing simultaneously; When $P \leq 0.8$, it indicates that the economic development is relatively lagging behind.

3 INDICATOR SYSTEM AND DATA SOURCE

3.1 Overview of economic development and ecological environment in Heyuan City

Heyuan City, located in the northeast of Guangdong Province, belongs to the mountainous area of northern Guangdong, and is located in the middle and upper reaches of the Dongjiang River. It has a subtropical monsoon climate with mild climate and abundant rainfall. The city has 1 district and 5 counties under its jurisdiction, with a total area of 15654 square kilometers. In 2021, the city's GDP and per capita GDP will be 127.399 billion yuan and 44886 yuan respectively, with an average annual growth rate of 8.42% and 7.85% in the past decade. At the same time of the economic development of Heyuan City, attention has also been paid to the protection of the ecological environment. The discharge of major pollutants has decreased significantly. The average annual decline of the discharge of industrial wastewater and industrial sulfur dioxide in the past ten years has been 14.29% and 20.96% respectively.

3.2 Indicator system

Following the principles of systematicness, comprehensiveness, scientificity and feasibility, and referring to the existing relevant research results^{9&10}, an evaluation index system for the coupling and

coordination of ecological environment and economic development is built. The whole indicator system is composed of environmental system and economic system, among which the environmental system is composed of 9 indicators in total, including three subsystems of ecological environment level, ecological environment pressure and ecological environment protection; The economic development system is composed of 9 indicators in total in three subsystems: economic development level, economic development structure and economic development vitality (Table 3).

Table 3. Coupling coordination evaluation indicator system of ecological environment and economic development in Heyuan City

System layer	Subsystem	Indicator	Indicator attribute
Ecological environment system	Ecological environment level	Air quality excellent days ratio (%)	forward
		Green coverage rate of completed area (%)	forward
		Per capita park green area (m ²)	forward
	Ecological environment pressure	Industrial sulfur dioxide emissions (10000 tons)	Negative
		Industrial wastewater discharge (10000 tons)	Negative
		Industrial solid waste output (10000 tons)	Negative
	Ecological environment protection	Urban sewage treatment rate (%)	forward
		Comprehensive utilization rate of solid industrial waste (%)	forward
		Domestic garbage harmless treatment capacity (ton/day)	forward
Economic development system	Economic development level	GDP per capita (yuan)	forward
		Per capita local general public budget income (yuan)	forward
		Total fixed assets investment per capita (10000 yuan)	forward
	Economic development structure	Proportion of added value of primary industry in GDP (%)	forward
		The added value of the secondary industry accounts for% of GDP	forward
		The added value of the tertiary industry accounts for% of GDP	forward
	Economic development vitality	Per capita retail sales of social consumer goods (yuan)	forward
		Per capita disposable income of urban residents (yuan)	forward
		Per capita disposable income of rural residents (yuan)	forward

3.3 Data source

Taking 2005-2021 as the research period, the research data are mainly from the Statistical Yearbook of Guangdong Province, the Statistical Yearbook of Heyuan City and the Statistical Bulletin of National Economic and Social Development of Heyuan City. Due to the limitation of data availability, individual missing data shall be supplemented and improved by interpolation or extrapolation.

4 Results and analysis

The coupling degree, coordination degree and relative development degree of the ecological environment and economic development of Heyuan City from 2005 to 2021 were analyzed by using entropy method and coupling coordination degree model (Table 4).

Table 4. Coupling coordination degree of ecological environment and economic development in Heyuan City from 2005 to 2021

year	Economic development index (U ₁)	Ecological environment index (U ₂)	Coupling degree (C)	Degree of coordination (D)	Coupling stage	Coordination level	Relative development degree (P)	Development stage
2005	0.1816	0.4487	0.9058	0.5343	High level	barely coordination	0.4049	Economic development lags behind
2006	0.2122	0.4679	0.9266	0.5614	High level	barely coordination	0.4536	Economic development lags behind
2007	0.2385	0.4258	0.9594	0.5645	High level	barely coordination	0.5000	Economic development lags behind
2008	0.2590	0.3828	0.9797	0.5589	High level	barely coordination	0.6662	Economic development lags behind
2009	0.2705	0.4045	0.9801	0.5751	High level	barely coordination	0.6687	Economic development lags behind
2010	0.3079	0.4335	0.9855	0.6045	High level	Primary coordination	0.7103	Economic development lags behind
2011	0.3581	0.4847	0.9886	0.6455	High level	Primary coordination	0.7388	Economic development lags behind
2012	0.4102	0.4986	0.9953	0.6725	High level	Primary coordination	0.8227	Synchronous development
2013	0.4706	0.5780	0.9947	0.7222	High level	Intermediate coordination	0.8143	Synchronous development
2014	0.5464	0.4829	0.9981	0.7167	High level	Intermediate coordination	1.1316	Synchronous development
2015	0.6452	0.5673	0.9979	0.7778	High level	Intermediate coordination	1.1373	Synchronous development
2016	0.6911	0.7002	1.0000	0.8341	High level	Good coordination	0.9870	Synchronous development
2017	0.7660	0.7662	1.0000	0.8753	High level	Good coordination	0.9997	Synchronous development
2018	0.8224	0.7857	0.9997	0.8966	High level	Good coordination	1.0467	Synchronous development
2019	0.8747	0.8344	0.9997	0.9243	High level	High-quality coordination	1.0482	Synchronous development
2020	0.8543	0.8517	1.0000	0.9236	High level	High-quality coordination	1.0031	Synchronous development
2021	0.9243	0.8016	0.9975	0.9278	High level	High-quality coordination	1.1530	Synchronous development

It can be seen from Table 4 that the coupling degree of the ecological environment and economic development in Heyuan City fluctuated steadily between 0.9 and 1.0 during the period from 2005 to 2021, which is at a high level of coupling, indicating that the interaction between the ecological environment system and the economic development system is very strong, and the two systems are closely dependent. From the perspective of coupling coordination degree, the coupling coordination degree of ecological environment and economic development in Heyuan City has been on the rise from 2005 to 2021. From a barely coordinated state to a high-quality coordinated state, there have been five stages of changes: from 2005 to 2009, it was in a barely coordination state; From 2010 to 2012, it was in primary coordination; From 2013 to 2015, it was in an intermediate coordination state; In 2016-2018, it was in good coordination; From 2019 to 2021, it is in a high-quality coordination state. From the perspective of relative development degree, the economic development in 2005-2011 lagged behind the development of ecological environment. During this period, the economic development of Heyuan City started late, and the environmental pollution and resource consumption were relatively low. The government also took some ecological protection measures, making the ecological environment of Heyuan City better than the economic development; From 2012 to 2021, the ecological environment and the economy will develop simultaneously. At this stage, the economy of Heyuan City will grow gradually. The Heyuan Municipal Government has also been practicing the concept of "green water and green mountains are golden mountains and silver mountains", paying attention to the protection of the ecological environment and the scientific development of resources while developing the economy, so as to promote the synchronous development of the ecological environment and the economy.

5 Conclusions and suggestions

5.1 Conclusion

From 2005 to 2021, the coupling degree of ecological environment and economic development in Heyuan City has been in a high level coupling stage, and the overall coupling coordination degree has shown a steady upward trend, and has gone through various stages from barely coordinated to high-quality coordinated development; The economic development of Heyuan City has also developed from lagging behind the ecological environment to the synchronous development of both.

5.2 Suggestions

In order to promote the further sustainable development of the ecological environment and economy in Heyuan City, we should combine the positioning of Heyuan City's "Northern Ecological Development Zone", strengthen the protection of the ecological environment

and pollution control, promote the transformation and upgrading of industrial structure, promote industrial upgrading, vigorously develop high-tech information industry, promote high-quality and efficient economic growth, and take the win-win road of ecological environment protection and economic development.

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