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Study on the coupling and coordinated development of population, economy, technology and environment —Take Zhongyuan urban agglomeration as an example

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Abstract: *In order to explore the internal relationship of the population - economy - science and technology - environment complex system, by constructing the evaluation index system of the population - economy - science and technology - environment complex system of the Central Plains urban agglomeration, using the combination weighting method of game theory to weight the indicators, and establishing an improved coupling coordination model, the development level of the population - economy - science and technology - environment of Zhongyuan urban agglomeration in 2010-2019 was analyzed, At the same time, the PSO optimized fractional grey prediction model is used to predict the period from 2020 to 2024.*

Keywords: *Population - economy - science and technology - environment system; Combination weight of game theory; Improve the coupling coordination model; Fractional order FGM (1,1) model*

1. Introduction

With the proposal of the national strategy of Zhongyuan Urban Agglomeration, the central region has gradually shown its important strategic position. As the location of most cities in Zhongyuan Urban Agglomeration, Henan Province should receive more attention. Under the concept of sustainable development, people are increasingly thinking about the relationship and coordination between the development of population, economy, science and technology and the environment. Population can provide sufficient human resources, knowledge resources, etc. for the development of urban agglomeration, and economy can provide sufficient funds, resources, supporting facilities, etc. for the development of core cities of urban agglomeration. Science and technology can provide technology for the development of urban agglomeration, and attract talent gathering, the environment can provide a good natural and social environment for the development of urban agglomeration. Therefore, the coordinated development of population, economy, science and technology, and environment can provide inexhaustible impetus for the development of Zhongyuan urban agglomeration. Therefore, it is necessary to study the coordinated development of the population - economy - science and technology - environment complex system of Zhongyuan urban agglomeration.

2. Literature review

With the proposal of the "two mountains theory", the issue of the coordinated development of population, economy and environment has gradually attracted the attention of scholars at home and abroad. Wang Yiming et al. (1989) studied the eco-economic system in the mountainous areas of southern Ningxia by establishing the method of system dynamics simulation, and predicted and analyzed the coordinated development of economy, population, resources and environment [1]. Zeng Zhenxiang et al. (2003) used the method of combining principal component analysis and regression analysis to evaluate the coordinated development of the economy-environment system [2]. In recent years, the introduction of the concept of coupling degree in physics has injected new soul into the study of coordinated development. Wang Hongwei et al. elaborated the population-economy-environment of the Kuqa River oasis of the Weigan River in Xinjiang by introducing the coupling coordination model and the development of each subsystem [3]. Yang Zheng, et al., used the coupling coordination model to measure the correlation between the sustainable development of counties and ecosystem services in

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Shanxi Province from 2000 to 2015 [4]. Wang Zhiheng et al. analyzed the "rail transit - social economy" coupling and coordinated development pattern and characteristics of the Yangtze River Delta urban agglomeration from 2002 to 2020 [5]. Song Jie established a coupling model and introduced a spatial econometric model to analyze the coupling coordination index within the system [6].

According to the existing research, there are many studies on the development status of the population-economic-environment system in China, but few on the degree and trend of the coordinated development of the system. However, with the development of 5G technology, Internet of Things and other technologies, there is an increasingly complex relationship between science and technology and population, economy and environment. Based on this, this paper takes the Central Plains urban agglomeration as an example and selects the data from 2010 to 2019 to establish an improved coupling coordination model of the population-economy-technology-environment (P-E-T-E) system, taking the population subsystem, economic subsystem, science and technology subsystem and environment subsystem as the primary indicators respectively, and then establishes a scientific and reasonable indicator system to explore the development status of the system in the Central Plains urban agglomeration, At the same time, the fractional FGM (1,1) grey prediction model is used to predict the development trend of the coupling coordination degree of the composite system, providing a theoretical basis for the development of the Central Plains urban agglomeration.

3. Research model design

3.1. Construction of composite system evaluation index system

On the basis of previous studies [3] [4] [5], the population - economy - science and technology - environment assessment model is established. The evaluation index system is shown in Table 1.

Table 1: Evaluation index system of coupling coordination degree of p-e-t-e system

Subsystem	evaluation index	type
population Subsystem	population size	-
	natural population growth rate	+
	Aging coefficient	-
	Urbanization rate	+
	Proportion of population with junior college or above	+
	Total R&D personnel	+
Economics Subsystem	Total GDP	+
	Growth rate of fixed asset investment	+
	Output value of primary industry	+
	Output value of secondary industry	+
	Total retail sales of social consumption	+
	Extent of foreign trade	+
Technology subsystem	R&D expenditure	-
	Technical market turnover	+
	R&D personnel full-time equivalent	+
	Number of scientific and technological papers effectively published	+
	Number of science and technology patents effectively published	+
	Number of R&D items	+
environment Subsystem	forest coverage	+
	Water resources	+
	Sulfur dioxide emissions	-
	Industrial wastewater discharge	-
	Comprehensive utilization of industrial solid	+
	Total amount of smoke (powder) dust area	-

Note: "+" indicates positive indicator, and "-" indicates negative indicator

ISSN 2616-7433 Vol. 5, Issue 4: 78-88, DOI: 10.25236/FSST.2023.050414

3.2. Game Theory Combination Weighting

With regard to the determination of weights, in order to solve the impact of a single weight on the final weight and improve the accuracy of the final weight, this paper introduces the combination weight based on game theory as the final weight determination [6]. That is, the subjective weight and objective weight of the P-E-T-E evaluation system can be calculated respectively according to the AHP and entropy weight method, and the subjective and objective weight can be combined according to the idea of game theory, so as to obtain the combined weight of the evaluation index [7].

The weight of indicators is determined by the analytic hierarchy process: see literature [8] for details, and the weight of indicators obtained is shown in Table 1.

Entropy weight method is an objective assignment method to determine the weight of indicators. Entropy first appeared in the concept of thermodynamics. In information theory, entropy is a measure of several information uncertainties. The smaller the entropy, the lower the uncertainty of information, the greater the utility of information, and the greater the weight. On the contrary, the larger the entropy, the higher the uncertainty of information, the smaller the utility of information, and the smaller the weight [9-11]. The specific steps are as follows:

(1) Raw data standardization

Since population - economy - science and technology - environment has four subsystems, and each subsystem contains several indicators. First of all, the processing of raw data adopts conventional range standardization, that is, let Xij represent the raw data of the jth index of the ith index. In order to avoid the occurrence of the logarithm of 0 in the entropy calculation process making the calculation meaningless, the standardization data is translated by 0.001.

$$x'_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} + 0.001(+) \quad (1)$$

$$x'_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} + 0.001(-) \quad (2)$$

(2) The weight of the jth evaluation index in the ith evaluation index value P_{ij}

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (3)$$

(3) Entropy value ej of index j

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (4)$$

(4) Objective weight Wj

$$w_j = \frac{1 - e_j}{\sum_{i=1}^{n} \left(1 - e_j\right)} \quad (5)$$

The specific steps of the game theory combination weight method are as follows:

(1) Determine the combination of indicator weight vectors. If there are L methods to weight indicators $u_k = \left[u_{k1}, u_{k2}, \cdots, u_{kn}\right](k = 1, 2, \cdots, L)$, the set of indicator weight vectors obtained is, and any group of L vectors is:

$$u = \sum_{k=1}^{L} \alpha_k u_k^{\ T} \ \left(\alpha_k > 0\right) \quad (6)$$

(2) The game model is introduced. According to the idea of game, optimize the solution of game

ISSN 2616-7433 Vol. 5, Issue 4: 78-88, DOI: 10.25236/FSST.2023.050414

model α_k .

$$\alpha_k = \min\left\|\sum_{k=1}^{L}\alpha_k u_k^{\mathrm{T}} - u_L^{\mathrm{T}}\right\|(L=1,2,\cdots,n) \tag{7}$$

(3) In order to find the optimal combination coefficient, the optimal differential condition according to formula (7) is:

$$\sum_{k=1}^{n}\alpha_k u_L u_k^{\mathrm{T}} = u_L u_k^{\mathrm{T}}(L=1,2,\cdots,n) \tag{8}$$

(4) Normalize according to the calculated results.

$$\alpha_k' = \frac{\alpha_k}{\sum_{k=1}^{n}\alpha_k} \tag{9}$$

(5) The combination weight of game theory is:

$$u' = \sum_{k=1}^{n}\alpha_k' u_k^{\mathrm{T}} \tag{10}$$

3.3. Improved coupling coordination model construction

By constructing the coupling and coordination model of P-E-T-E composite system and analyzing the interdependent relationship between systems, it has guiding significance for real production and life. Therefore, on the basis of previous studies, the coupling coordination degree model of four systems is established, as follows:

$$C = 4\left[\frac{v_1 \times v_2 \times v_3 \times v_4}{\left(v_1+v_2+v_3+v_4\right)^4}\right]^{\frac{1}{4}} \tag{11}$$

$$v_1 = \sum_{i=1}^{m} a_i x_i \; ; v_2 = \sum_{j=1}^{n} b_j y_j \; ; v_3 = \sum_{k=1}^{o} c_k z_k \; ; v_4 = \sum_{s=1}^{p} d_s v_s \tag{12}$$

$$T = \alpha v_1 + \beta v_2 + \gamma v_3 + \delta v_4 \tag{13}$$

$$D = \sqrt{C \times T} \tag{14}$$

In formula (11)，(12)，(13) and (14), C represents P-E-T-E coupling degree, $0 \leq C \leq 1$. When C is closer to 1, it means that the higher the coupling degree of the system, the closer the system relationship, and vice versa. V1, V2, V3 and V4 respectively represent the development level of population, economy, technology and environment. α, β, γ is the undetermined coefficient. In such studies, it is generally considered that the values of undetermined coefficients are equal, α=β=γ = 0.25. T is the comprehensive index of population - economy - science and technology - environment system. D represents coupling co-scheduling. The classification of coupling degree C is shown in Table 2.

Table 2: Evaluation criteria of coupling degree C

Evaluation condition	development stage
C=0	Uncoupled
0＜C≤0.3	Low level coupling stage
0.3＜C≤0.5	Coupling and antagonism stage
0.5＜C≤0.8	Coupling running-in stage
0.8＜C＜1	High level coupling stage
C=1	Full coupling stage

ISSN 2616-7433 Vol. 5, Issue 4: 78-88, DOI: 10.25236/FSST.2023.050414

In this paper, the evaluation standard of P-E-T-E coupling and coordination dispatch of the Central Plains urban agglomeration is established with reference to Jiang Weibin's evaluation standard of coupling and coordination degree [12], as shown in Table 3.

Table 3: Evaluation criteria for P-E-T-E coupling and co-dispatch of Zhongyuan urban agglomeration

SN	coupling coordination degree	coordination level
1	0.90-1.00	Quality coordination
2	0.80-0.89	Good coordination
3	0.70-0.79	Intermediate coordination
4	0.60-0.69	Primary coordination
5	0.50-0.59	Grudging coordination
6	0.40-0.49	Borderline disorder
7	0.30-0.39	Mild disorder
8	0.20-0.29	Moderate disorder
9	0.10-0.19	Serious disorder
10	0-0.09	Extreme maladjustment

In view of the original coupling coordination model, experts and scholars only consider the comparison between the research objects in the research process, without considering the comparison of the status of various indicators in the time dimension. According to Wang Jiaming's [13] improvement of the coupling coordination model, the following formulas (15), (16), (17), (18) and (19) can be obtained.

$$U'_{gy} = U_{gy} \times \left(1 - R_g\right)^{y_{\max} - y} \quad (15)$$

$$r_{iy} = \frac{\left(\overline{X_{iy}} - \overline{X_{i(y-1)}}\right)}{\overline{X_{i(y-1)}}}, R_1 = \frac{\sum_{y=y_{\min}}^{y_{\max}} \sum_{i=1}^{m} a_i \times r_{iy}}{y} \quad (16)$$

$$r_{jy} = \frac{\left(\overline{X_{jy}} - \overline{X_{j(y-1)}}\right)}{\overline{X_{j(y-1)}}}, R_2 = \frac{\sum_{y=y_{\min}}^{y_{\max}} \sum_{j=1}^{m} b_j \times r_{jy}}{y} \quad (17)$$

$$r_{ky} = \frac{\left(\overline{X_{ky}} - \overline{X_{k(y-1)}}\right)}{\overline{X_{k(y-1)}}}, R_3 = \frac{\sum_{y=y_{\min}}^{y_{\max}} \sum_{j=1}^{m} c_k \times r_{ky}}{y} \quad (18)$$

$$r_{sy} = \frac{\left(\overline{X_{sy}} - \overline{X_{s(y-1)}}\right)}{\overline{X_{s(y-1)}}}, R_4 = \frac{\sum_{y=y_{\min}}^{y_{\max}} \sum_{j=1}^{m} d_s \times r_{sy}}{y} \quad (19)$$

Where, y is the year, with the value range from 2010 to 2019. $\overline{X_{iy}}$, $\overline{X_{jy}}$, $\overline{X_{ky}}$, $\overline{X_{sy}}$ and respectively represent the mean value of the four subsystems' indicators in the 17 cities and r_{iy}, r_{jy}, r_{ky}, r_{sy} regions they contain Represents the growth rate of population, economy, science and technology, and environment indicators relative to the previous year in year y. R_1, R_2, R_3, R_4 It is the development adjustment coefficient of the scores of population, economy, science and technology and environment system respectively; U_{gy} Is the score of the g th system in year y, g=1,2,3,4; U'_{gy} is the score of the new system adjusted by the development adjustment coefficient, as shown in Table 4.

ISSN 2616-7433 Vol. 5, Issue 4: 78-88, DOI: 10.25236/FSST.2023.050414

Table 4: P-E-T-E system development adjustment coefficient of Zhongyuan urban agglomeration

System category	Population system	Economic system	technology system	Environment system
Adjustment factor	0.0209	0.0289	0.096	0.0128

3.4. Grey prediction of coupling coordination degree of composite system

The grey system theory was founded by Professor Deng Julong, a Chinese scholar, to solve the problem of "small sample, poor information", and has been applied in many fields [14]. Grey GM (1,1) model and fractional FGM (1,1) model are commonly used prediction methods [15] [16] [17] [18]. Based on the coupling coordination degree of the P-E-T-E composite system in 2010-2019, this paper uses the fractional order FGM (1,1) model to predict the coupling coordination degree of the system in the next few years.

The basic process of fractional order FGM (1,1) model is as follows:

(1) Set the original non-negative sequence: $X^{(0)}=\{x^{(0)}(1),x^{(0)}(2),\cdots x^{(0)}(n)\}$, Accumulate the original non-negative number column to obtain the r-order accumulation sequence: $X^{(r)}=\{x^{(r)}(1),x^{(r)}(2),\cdots x^{(r)}(n)\}$

Among

$$X^{(r)}(k)=\sum_{i=1}^{k}C_{k-i+r-1}^{k-i}x^{(0)}(i),C_{k-i+r-1}^{k-i}=\frac{(k-i+r-1)(k-i+r-2)\cdots(r+1)r}{(k-i)!},$$

$$C_K^{K+1}=0,C_{r-1}^{0}=1$$

(2) Establish albinism differential equation:

$$\frac{dx^{(r)}(t)}{dt}+ax^{(r)}(t)=b \tag{20}$$

The formal solution of the equation is:

$$x^{(r)}(t+1)=\left[x^{(0)}(1)-\frac{b}{a}\right]e^{-at}+\frac{b}{a} \tag{21}$$

Use the least square method to solve:

$$\begin{pmatrix}\hat{a}\\ \hat{b}\end{pmatrix}=\left(B^TB\right)^{-1}B^TY \tag{22}$$

Among: $B=\begin{pmatrix}-0.5\left(x^{(r)}(1)+x^{(r)}(2)\right) & 1\\ -0.5\left(x^{(r)}(2)+x^{(r)}(3)\right) & 1\\ \vdots & \vdots\\ -0.5\left(x^{(r)}(n-1)+x^{(r)}(n)\right) & 1\end{pmatrix}$, $Y=\begin{pmatrix}x^{(r)}(2)-x^{(r)}(1)\\ x^{(r)}(3)-x^{(r)}(2)\\ \vdots\\ x^{(r)}(n)-x^{(r)}(n-1)\end{pmatrix}$

The response formula of time series is:

$$\hat{x}^{(r)}(r+1)=\left[x^{(0)}(1)-\frac{\hat{b}}{\hat{a}}\right]e^{-\hat{a}k}+\frac{\hat{b}}{\hat{a}} \tag{23}$$

Sequence based $\hat{X}^{(r)}=\left\{\hat{x}^{(r)}(1),\hat{x}^{(r)}(2),\cdots,\hat{x}^{(r)}(m+n)\right\}$, Its restore sequence is:

ISSN 2616-7433 Vol. 5, Issue 4: 78-88, DOI: 10.25236/FSST.2023.050414

$$\hat{X}^{(r)} = \left\{ \hat{x}^{(r)(1-r)}(1), \hat{x}^{(r)(1-r)}(2), \cdots, \hat{x}^{(r)(1-r)}(m+n) \right\} \tag{24}$$

(3) Accumulate the reduction sequence to obtain the prediction sequence:

$$\left\{ \hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \cdots, \hat{x}^{(0)}(n) \right\}.$$

The average absolute percentage error (MAPE) is used to evaluate the model:

$$MAPE = \frac{1}{n} \times \sum_{k=1}^{n} \left| \frac{x^{(0)}(k) - \hat{x}^{(0)}(k-1)}{x^{(0)}(k)} \right| \times 100\% \tag{25}$$

4. Empirical analysis

According to the analytic hierarchy process (AHP) and entropy weight method, the subjective and objective weights of the population-economy-science and technology-environment evaluation system can be calculated respectively, and the subjective and objective weights can be combined according to the idea of game theory. The data comes from expert scoring and the 2010-2019 Henan Statistical Yearbook, China Statistical Yearbook, Henan Environmental Statistical Yearbook and China Science and Technology Statistical Yearbook, Thus, the combination weight of the evaluated indicators can be obtained, as shown in Table 5.

Table 5: Evaluation index weight of coupling coordination degree of composite system of Zhongyuan urban agglomeration

Subsystem	evaluating indicator	AHP	Entropy method	Portfolio Weights
population Subsystem	population size	9.223%	0.03846	0.05282
	natural population growth rate	12.274%	0.02389	0.05029
	Aging coefficient	4.808%	0.02678	0.03250
	Urbanization rate	16.335%	0.03906	0.07226
	Proportion of population with junior college or above	23.903%	0.03837	0.09197
	Total R&D personnel	33.458%	0.02918	0.11075
Economics Subsystem	Total GDP	33.830%	0.03819	0.11835
	Growth rate of fixed asset investment	17.315%	0.04727	0.08089
	Output value of primary industry	7.909%	0.02839	0.04193
	Output value of secondary industry	6.152%	0.02973	0.03822
	Total retail sales of social consumption	30.597%	0.03904	0.11034
	Extent of foreign trade	4.198%	0.02542	0.02894
Technology subsystem	R&D expenditure	8.62%	0.04511	0.05609
	Technical market turnover	33.46%	0.09472	0.15879
	R&D personnel full-time equivalent	9.80%	0.02653	0.04562
	Number of scientific and technological papers effectively published	12.85%	0.03028	0.05651
	Number of science and technology patents effectively published	14.30%	0.06658	0.08699
	Number of R&D items	20.97%	0.04324	0.08770
environment Subsystem	forest coverage	25.89%	0.01843	0.08266
	Water resources	29.61%	0.03449	0.10437
	Sulfur dioxide emissions	7.49%	0.07529	0.07518
	Industrial wastewater discharge	4.98%	0.09485	0.08282
	Comprehensive utilization of industrial solid	18.28%	0.02132	0.06445
	Total amount of smoke (powder) dust area	13.76%	0.04538	0.07001

ISSN 2616-7433 Vol. 5, Issue 4: 78-88, DOI: 10.25236/FSST.2023.050414

4.1. Time sequence analysis of overall situation of subsystem

According to the established comprehensive evaluation index system of the P-E-T-E system of the Central Plains urban agglomeration, the game theory combination weighting model, and the improved coupling coordination model, the evolution of the subsystems and coupling coordination degree of the Central Plains urban agglomeration in 2010-2019 is calculated. As shown in Figure 1.

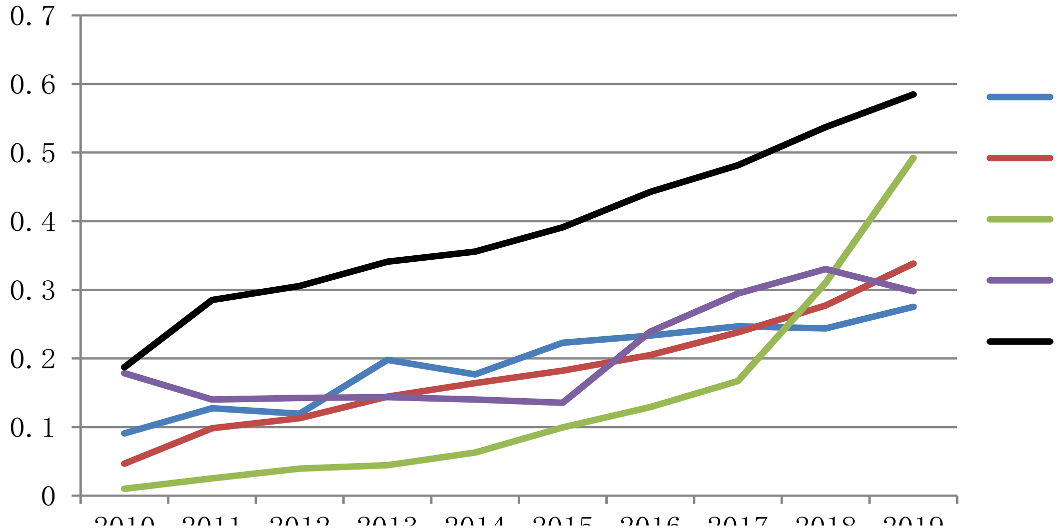

Figure 1: P-E-T-E composite system and coupling evolution of Zhongyuan urban agglomeration

It can be seen from Figure 1 that the P-E-T-E system has made great progress in the coordinated development from 2010 to 2019. Time series analysis of P-E-T-E system: From the figure, it can be seen that the coupling degree is generally in the rising stage from 2010 to 2019. Among them, the evaluation index of the population subsystem increased by 0.1854, or 203.2%, from 2010 to 2019, with an average annual growth rate of 20.32%. Except for the decline of the population evaluation index in 2012 and 2014 compared with the previous year, the evaluation index in other years maintained an upward trend. From 2010 to 2019, the evaluation index of the economic subsystem increased by 0.2915, with an increase of 624.2% and an average annual growth rate of 62.42%. From the economic evaluation index in Figure 1, it has maintained a growth trend. From 2010 to 2019, the evaluation index of the science and technology subsystem increased by 0.4820, or 4725%, with an average annual growth rate of 472.5%. It has maintained a growth trend for ten years. The evaluation index of the environmental subsystem increased by 0.1192 from 2010 to 2019, with an increase of 66.74% and an annual growth rate of 6.674%. Among them, there was a downward trend in 2011, 2014, 2015 and 2019 compared with the previous year, and the overall evaluation index maintained an upward trend.

4.2. Timing analysis of coupling degree and coupling coordination degree

According to the improved coupling and coordination model adopted in this paper, the coupling and coordination development level of the P-E-T-E system in Zhongyuan urban agglomeration is evaluated. As shown in Table 6.

Table 6: Type of P-E-T-E coupling coordination model of Zhongyuan urban agglomeration

Year	coupling degree	D	development stage	Coordination level
2010	0.4436	0.1873	Antagonism	Serious disorder
2011	0.8312	0.2851	high-level	Mod disorder
2012	0.9015	0.3056	high-level	Mild disorder
2013	0.8765	0.3410	high-level	Mild disorder
2014	0.9299	0.3556	high-level	Mild disorder
2015	0.9560	0.3911	high-level	Borderline disorder
2016	0.9723	0.4428	high-level	Borderline disorder
2017	0.9799	0.4816	high-level	Borderline disorder
2018	0.9934	0.5371	high-level	Grudging coordination
2019	0.9741	0.5846	high-level	Grudging coordination

It can be seen from Table 6 that the coupling degree of the composite system has been in the rising stage, and has been in the high level coupling stage since the coupling antagonistic stage in 2010. The coupling coordination degree of P-E-T-E system is in the overall trend of coordination. From 2010 to 2011, the coupling coordination degree of the system increased from 0.1783 to 0.2851, passing the stage of serious imbalance. From 2012 to 2014, the coupling coordination degree of the system increased by 0.05 and has been in the stage of mild imbalance. From 2015 to 2017, the coupling coordination degree of the system increased by 0.0905 and has been in the stage of near imbalance. From 2018 to 2019, the coupling coordination degree of the system increased by 0.0475, and the system is in the stage of barely coordination.

4.3. Grey prediction of system coupling coordination degree

The fractional order FGM (1,1) prediction model is established by using the coupling co-dispatch of the P-E-T-E system of the Central Plains urban agglomeration from 2010 to 2019. The fitting values of the coupling degree of the system are shown in Table 7:

Table 7: Fitting value of system coupling degree

particular year	actual value	Fractional orderFGM(1,1)
2010	0.1873	0.1873
2011	0.2851	0.2769
2012	0.3056	0.3038
2013	0.3410	0.3334
2014	0.3556	0.3658
2015	0.3911	0.4014
2016	0.4428	0.4405
2017	0.4816	0.4833
2018	0.5371	0.5304
2019	0.5846	0.5820
MAPE	-	1.38%

It can be seen from Table 7 that the MAPE of fractional-order FGM (1,1) model meets the requirements of allowable error. Taking the minimum MAPE as the objective function, the fitting effect of fractional-order FGM (1,1) is the best and the prediction effect is more accurate when the order is 0.999973. Using the data from 2010 to 2019, we can get the predicted value of the model from 2020 to 2024, as shown in Table 8 below.

Table 8: Predicted values of system coupling coordination degree fractional FGM (1,1) model

particular year	Estimate
2020	0.6387
2021	0.7008
2022	0.7690
2023	0.8438
2024	0.9259

It can be seen from Table 8 that from 2020 to 2024, the coupling coordination degree of the system increased continuously, from 0.6387 to 0.9259, an increase of 0.2872, with an average annual growth rate of 0.0899. The system coupling coordination degree is 0.6387 in 2020, and the system is in the primary coordination stage. From 2021 to 2022, the system is in the intermediate coordination stage. The system coupling coordination degree is 0.8438 in 2023, and the system is in the good coordination stage. The system coupling coordination degree is 0.9259 in 2024, and the system has reached the stage of high-quality coordination.

From the perspective of prediction, the coordinated development trend of the composite system in the future is good, and the coupling coordination degree of the system is steadily rising. Therefore, in the later development process, while maintaining the current level of development, more attention should be paid to the coordinated development of various subsystems.

5. Conclusion and prospect

In order to explore the coordinated development level of the Central Plains urban agglomeration, this paper constructs an improved coupling coordination degree model for the four dimensions of the population - economy - science and technology - environment system, and then uses the fractional

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order FGM (1,1) model to predict the evolution direction of the coupling coordination degree of the Central Plains urban agglomeration from 2020 to 2024. From the result, the construction of the system model provides certain practical significance for judging the level of coordinated development between other provinces or cities, and can also provide decision-making basis for regional economic adjustment, education, scientific and technological investment and environmental protection.

(1) In the past 10 years, the comprehensive evaluation index of the composite system has generally been on the rise, and the coupling coordination degree of the system has also changed from the serious imbalance in the past to the grudging coordination today. This is due to the response to the call of the rise of the Central Plains of China, Henan Province has increased investment in education, economy, scientific research and environmental protection, and coordinated development in all aspects.

(2) Based on the fractional-order FGM (1,1) model, the coupling co-dispatch of the system in Henan Province from 2020 to 2024 is predicted, and the results show that the coordination level is moving forward from primary coordination to high-quality coordination. As the location of most cities in the Central Plains urban agglomeration, Henan Province can coordinate resources in all aspects in the process of future development, so as to realize the rise of the Central Plains.

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