



Impact of AI on High-Quality Development Based on Entropy Method and Coupling Coordination Degree Model —Taking Guangdong Province as an Example

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Abstract. This study focuses on Guangdong Province to investigate the level of high-quality development before and after the impact of AI. Using the entropy method and coupling coordination degree model, this study conducts indicator evaluation and analysis on selected high-quality development data of Guangdong Province from 2019 to 2023, thereby better exploring the relationship between AI technology and high-quality development. The study found through analysis that: 1) Guangdong's overall high-quality development level before and after the impact of AI showed a V-shaped recovery and upward trend, indicating that AI technology empowerment and policy dividends are the key driving forces for this trend; 2) The study of the three subsystems revealed that the economic development score accelerated after 2020, while the social stability and environmental sustainability subsystems showed a trend of first declining and then rising, indicating the empowering value of AI in industrial upgrading, people's livelihood services, and environmental governance; 3) Coupling and coordination analysis showed that the system as a whole shifted from the disordered stage before the impact of AI to the coordinated stage after the impact of AI, and reached a high-quality coordination level under the influence of AI, reflecting that the subsystems were greatly affected by AI and showed a positive influence from the AI.

Keywords: High-quality development, AI, Entropy method, Coupling coordination degree model

1 Introduction

In October 2020, the Fifth Plenary Session of the 19th CPC Central Committee explicitly stated that the theme of economic and social development during the 14th Five-Year Plan period should be promoting high-quality development. Building on this, the 15th Five-Year Plan, proposed for 2025, sets even higher requirements for high-quality development. Meanwhile, AI, as a strategic force leading a new round of technological revolution and industrial transformation, is driving the digital transformation of various industries, injecting new impetus into high-quality development. Against this backdrop,

research on high-quality development has garnered widespread attention within the academic community.

At the national level, Shi and Zhang (2019) measured the level of high-quality economic development of cities above the prefecture level across the country and found that there are significant differences between the east and west and between the city size, with the eastern region and large cities leading in both development and growth rate [1]. This finding of regional imbalance has also been confirmed in specific industry studies. For example, Zhang et al. (2021) constructed an indicator system and used the AHP-entropy weight method to measure the field of digital agriculture. They pointed out that although the overall level of digital agriculture in China has continued to improve, it still presents a "east-central-west" ladder-type difference pattern [2]. At the provincial and urban agglomeration level, Fan and Wu (2021) selected China's provincial panel data from 2014-2017, constructed a digitization index system, and used the DEA-Malmquist index method to explore the conclusion that digitization significantly promotes economic growth and high-quality development and is positively moderated by education and capital levels [3]. Chen et al. (2023) took the Beijing-Tianjin-Hebei region as an example and used the entropy weight method and DEA-Malmquist index method to measure and analyze it. They found that the digital economy not only directly promotes the high-quality development of the local economy, but also has a significant spatial spillover effect on the surrounding areas by optimizing the industrial structure and empowering technological innovation [4]. At the city level, At the municipal level, Liu and Wang (2022), based on panel data from 254 prefecture-level cities and above, found that the digital economy can significantly promote the green and high-quality development of cities, and that there is a "digital divide" effect, which is achieved through the triple mechanism of optimizing the industrial structure, stimulating innovation, and enhancing public awareness [5]. Xie et al. (2023) extend the research perspective to artificial intelligence, based on the panel data of Chinese cities in 2010-2019, found that artificial intelligence significantly promotes the high-quality development of manufacturing industry, and the effect is realized through optimizing factor endowment and enhancing human capital, and financial support can strengthen this effect [6].

In summary, previous studies have conducted in-depth discussions on the connotation and driving mechanisms of high-quality development at multiple scales. However, there is still room for further exploration in the emerging interdisciplinary field of AI and high-quality development: the impact mechanism of AI technology on high-quality development is not yet clear, Based on this, this study, drawing on existing findings, attempts to use the entropy method to measure the level of high-quality development in Guangdong Province under the influence of AI at the macro level, and uses a coupled coordination degree model to analyze its internal coordination relationships at the meso level.

2 Study Area, Analysis Methods and Data Sources

2.1 Study Area

This study selects Guangdong Province as the research area. In terms of social development, Guangdong has a resident population of 127 million, a high level of urbanization, and is the core engine of the Guangdong-Hong Kong-Macao Greater Bay Area, giving it significant advantages in technological innovation and talent aggregation. Meanwhile, Guangdong has achieved remarkable results in ecological environment governance, with the concentrations of the six major air pollutants meeting standards for 10 consecutive years, and the AQI compliance rate reaching 95.8% in 2024. Therefore, this study, focusing on Guangdong, not only reflects the advanced and typical nature of its development but also helps to deeply analyze the multidimensional paths to high-quality development at the regional level.

2.2 Research Methods and Data Sources

Entropy Method. Entropy method is an evaluation method that objectively determines weights based on the degree of variation of indicator data. In this study, this method is used to assign weights to indicators related to high-quality development in Guangdong Province in order to achieve objective comprehensive measurement [7]. The specific formula is as follows:

1)Data standardization. Let m be the number of sample years and n be the number of indicators; X_{ij} represent the standardized value of the j -th indicator in the i -th year ($i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$); $\max x_j$ and $\min x_j$ are the maximum and minimum values of the j -th indicator, respectively. To avoid non-positive values, the standardized data are offset by 0.0001. Positive indicators: $X_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j} + 0.0001(1)$; Negative indicators: $X_{ij} = \frac{\max x_j - x_{ij}}{\max x_j - \min x_j} + 0.0001(2)$

2)Calculate the weight of the indicators. $p_{ij} = \frac{X_{ij}}{\sum_{i=1}^m X_{ij}}$ j -th indicator in year i is: (3)

Calculate the entropy value of the index. The entropy value of the $e_j = -\frac{1}{\ln m} \sum_{i=1}^m p_{ij} \ln(p_{ij})$ j -th index is: (4), where $\frac{1}{\ln m}$ is the normalization coefficient ($k = \frac{1}{\ln m}$).

3)Calculate the coefficient of difference and the weight of the indicators. Coefficient of difference: $g_i = 1 - e_i(5)$; Weight of indicators: $w_j = \frac{g_i}{\sum_{j=1}^n g_i}(6)$

4)Calculate the overall score. The overall score for each year is: $S_i = \sum_{j=1}^n w_j \times X_{ij}(7)$

Coupled coordination degree model. The coupling coordination degree model is used to quantify the correlation strength and synergistic development equilibrium of interactions among multiple systems. This study focuses on three major subsystems: economic development, social stability, and environmental sustainability. The model is used to analyze the dynamic coordination relationship of the subsystems inherent in the

high-quality development of Guangdong Province under the influence of artificial intelligence [8] [9]. The specific calculation steps and formulas are as follows:

1) Calculation of the comprehensive development index of subsystems. Based on the weight (w_j) and standardized values (X_{ij}), the comprehensive development index of the three primary subsystems is calculated as follows: Comprehensive index of economic development subsystem: $A = \sum_{j=1}^5 w_j \times X_{ij}$ (8); Comprehensive index of social stability subsystem: $B = \sum_{j=6}^{10} w_j \times X_{ij}$ (9); Comprehensive index of environmental sustainability subsystem: $C = \sum_{j=11}^{15} w_j \times X_{ij}$ (10). Among them, the values of A, B, C and are all in the range of [0,1]. The closer the value is to 1, the higher the development level of the subsystem.

2) Coupling Degree Calculation. The coupling degree (G) reflects the degree of interdependence and interaction among the three subsystems, and its value ranges from [0,1]. The higher the coupling degree G is, the closer and more synchronized the development levels of each subsystem are. The formula is as follows: $G = \sqrt[3]{\frac{A \times B \times C}{(\frac{A+B+C}{3})^3}}$ (11)

3) Coupling Coordination Degree Calculation. Coupling coordination degree (D) is a composite index of coupling degree and comprehensive development level. It reflects both the strength of system correlation and the balance of development. The value range is [0,1]. The larger the value, the higher the coordinated development level of the system. The formula is as follows: $D = \sqrt{G \times T}$, $T = \alpha A + \beta B + \gamma C$ (12). Where G is the coupling degree, T is the comprehensive development level index, A, B and C are the comprehensive development indices of the three subsystems, α and β , γ and are the weights of the subsystems. The weights are calculated by formulas (1)-(6).

Based on existing research, the coupling coordination degree is divided into 10 levels, as shown in Table 1 below.

Table 1. Coupling and Coordination Level Classification

D value	Level	D value	Level
[0,0.1)	Extreme Disorder	[0.5, 0.6)	Barely coordinated
[0.1,0.2)	Severe disorder	[0.6,0.7)	Primary Coordination
[0.2,0.3)	Moderate disorder	[0.7,0.8)	Intermediate Coordination
[0.3,0.4)	Mild disorder	[0.8, 0.9)	Good coordination
[0.4, 0.5)	On the verge of disorder	[0.9,1.0)	High-quality coordination

Data Sources. This study selected data from Guangdong Province from 2019 to 2023 as the research sample. The data mainly came from the Guangdong Statistical Yearbook, the Guangdong Social Development Bulletin, and the Guangdong Ecological Environment Status Bulletin. For a small number of missing data within the study period, regression analysis was used to fill in the missing data to ensure the completeness of the data and the reliability of the analytical conclusions.

3 Evaluation and Analysis of High-Quality Development Under the Impact of AI

3.1 Construction of the Indicator System

In constructing the evaluation index system for high-quality development in Guangdong Province under the influence of AI, this paper strictly follows the principles of scientificity, systematicness and operability. It combines the national strategic deployment on high-quality development, fully refers to existing research results [10-11], and focuses on the applicability of the indicators at the Guangdong provincial level to ensure that the index system has both theoretical rationality and practical explanatory power. This study constructs an evaluation index system for high-quality development in Guangdong Province under the influence of AI, comprising 3 primary indicators and 15 secondary indicators. In the economic development dimension, five indicators are selected: GDP growth rate, per capita GDP, the proportion of new economy added value, the proportion of tertiary industry GDP, and R&D expenditure, aiming to measure economic growth momentum, structural optimization, and innovation-driven capacity. In the social stability dimension, indicators include per capita disposable income, Engel coefficient, urban-rural income ratio, the proportion of education, culture, and entertainment expenditure, and urbanization rate, used to assess people’s well-being and social structural changes. In the environmental sustainability dimension, indicators include per capita park green space area, sewage treatment rate, AQI compliance rate, energy consumption reduction rate per unit of GDP, and forest coverage rate, characterizing ecological carrying capacity and environmental governance effectiveness. The weights of all indicators are objectively determined using the entropy method (Formulas 1-6), as shown in Table 2.

Table 2. Evaluation System of High-Quality Development Indicators in Guangdong Province under the Influence of AI (2019-2023)

Primary Indicators	Code	Secondary Indicators	Unit	Weight	Property
Economic Development	X1	GDP growth	%	8.30%	positive
	X2	GDP per capita	Yuan	5.55%	positive
	X3	The proportion of new economy added value	%	7.12%	positive
	X4	The proportion of the tertiary sector’s GDP	%	4.09%	positive
	X5	R&D funding	100 million yuan	6.18%	positive
Social stability	X6	per capita disposable income	Yuan	6.35%	positive
	X7	Resident Engel coefficient	%	6.12%	negative
	X8	Urban-rural per capita income ratio	%	5.42%	negative
	X9	Residents’ spending on education, culture and entertainment	%	4.68%	positive
	X10	urbanization rate	%	7.68%	positive
Environmental sustainability	X11	per capita park green space area	m ²	8.10%	positive
	X12	Wastewater treatment rate	%	9.73%	positive
	X13	AQI compliance rate	%	7.51%	positive
	X14	Forest coverage	%	4.08%	positive
	X15	Energy consumption reduction rate per unit of GDP	%	9.09%	positive

3.2 Comprehensive Analysis

Substituting the relevant data on high-quality development in Guangdong Province from 2019 to 2023 into formulas (1) to (7), the comprehensive scores for each year are shown in Fig.1. Overall, the level of high-quality development in Guangdong Province during the study period showed a shallow V-shaped recovery and upward trend of “first decline and then rise”. The comprehensive score increased from 0.923 in 2019 to 2.672 in 2023, reflecting the continuous strengthening of the momentum of high-quality development in Guangdong Province (Fig.1).

Specifically, the score dropped briefly from 0.923 to 0.867 in 2019-2020. This was due to the sudden impact of the COVID-19 pandemic, which slowed economic growth and restricted social activities, thus inhibiting Guangdong Province’s high-quality development process in the short term. After 2021, the level of high-quality development rebounded rapidly and continued to rise, with the overall score jumping from 0.867 in 2020 to 2.672 in 2023. This significant improvement was driven by multiple factors: first, the continued release of policy dividends from the national “14th Five-Year Plan” and Guangdong Province’s industrial digital transformation, promoting economic restructuring and increased investment in innovation.

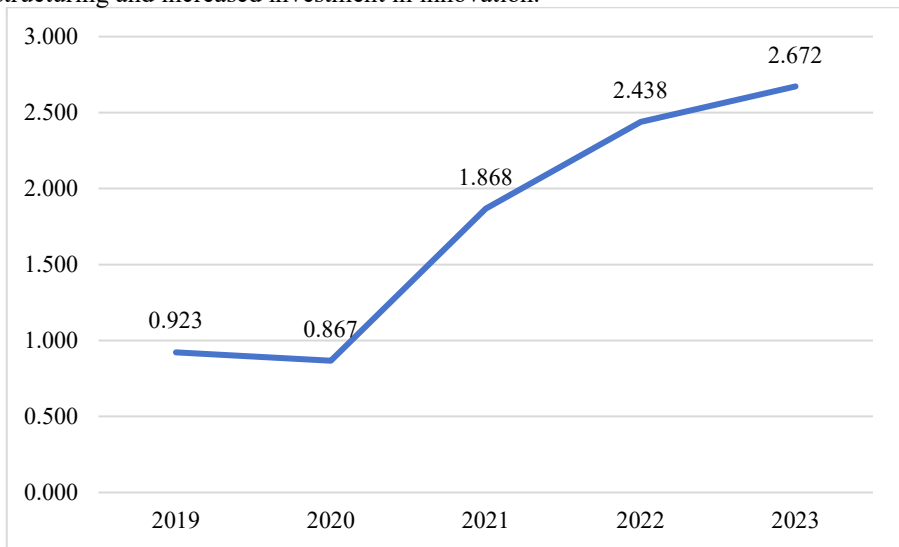


Fig. 1. Comprehensive score of Guangdong Province’s high-quality development indicators under the influence of AI (2019-2023)

3.3 Subsystem Analysis

From 2019 to 2023, Guangdong Province's three major subsystems for high-quality development exhibited differentiated growth trajectories. Their trend evolution was influenced by external factors while also closely linked to AI empowerment and policy support (Figure 2).

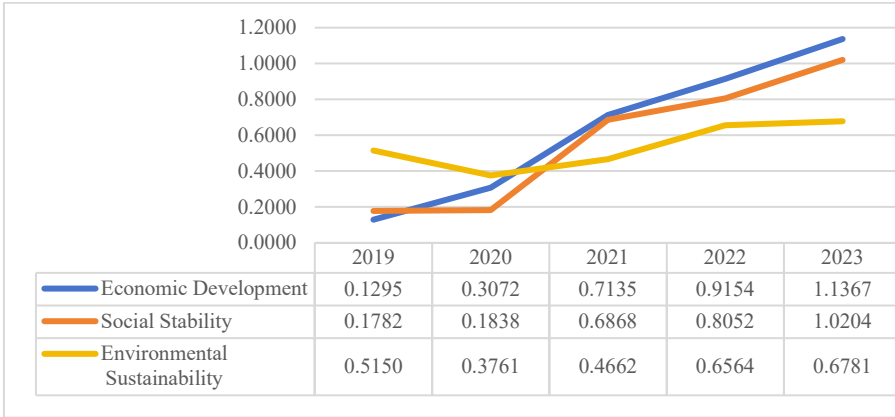


Fig. 2. AI-Influenced Scores of Guangdong Province's High-Quality Development Indicator Evaluation Subsystem (2019-2023)

The economic development subsystem score showed an overall accelerating upward trend. From 2019 to 2020, the score increased by only 0.1777, reflecting a relatively slow growth rate. This was due to the pandemic's impact causing short-term disruptions in industrial chains, coupled with AI applications being in their infancy, limiting their full contribution to economic growth. After 2021, as Guangdong advanced industrial digital transformation, widespread AI adoption, and substantially increased R&D funding, the share of new economy value added rose. Economic growth momentum shifted toward innovation-driven development, propelling the subsystem score to leapfrog growth.

The Social Stability subsystem score rose only marginally from 0.1782 in 2019 to 0.1838 in 2020, reflecting temporary pressures on household income and public services during the pandemic. Post-2021, with normalized pandemic control and the implementation of policies for common prosperity and public service systems under the 14th Five-Year Plan, AI significantly empowered digital governance and smart city initiatives. This propelled the subsystem score to 0.6868 in 2021, with sustained growth indicating a marked enhancement in the quality of Guangdong's social development.

The Environmental Sustainability subsystem scored 0.5150 in 2019 but exhibited a pattern of short-term decline followed by steady recovery. In 2020, affected by the pandemic, delays in environmental projects and temporary adjustments to regulatory measures caused the score to drop to 0.3761. After 2021, with the continuous advancement of Guangdong's 14th Five-Year Plan for ecological and environmental protection, and the integrated application of AI technology in environmental monitoring, energy management, and pollution prevention, the score rebounded to 0.6781 in 2023, reflecting a sustained enhancement in ecological carrying capacity.

3.4 Coupling and Coordination Analysis

Substituting the subsystem score data into formulas (8)-(12) for coupling coordination analysis, the results are shown in Table 3 and Fig.3. Guangdong Province's high-quality

development system has undergone a transformation from imbalance to coordination. Specifically, 2019-2020 was the imbalance stage, with the coupling coordination degree D value ranging from 0.172 to 0.203. Starting in 2021, it entered the coordination stage. With the deep integration of AI and the synergistic efforts of policies, the D value rapidly increased from 0.677 to 0.995, achieving a leap from primary coordination to high-quality coordination, indicating that the three subsystems have formed a virtuous cycle of coordinated development.

Table 3. The Coupling of High-Quality Development in Guangdong Province under the Influence of AI (2019-2023)

Year	G value	T value	D value	Level	Degree
2019	0.2240	0.1840	0.2030	3	Moderate disorder
2020	0.4460	0.0660	0.1720	2	Severe disorder
2021	0.9550	0.4790	0.6770	7	Primary Coordination
2022	0.9960	0.8200	0.9030	10	High-quality coordination
2023	1.0000	0.9900	0.9950	10	High-quality coordination

During the imbalance phase of 2019-2020, the G value rose from 0.224 to 0.446, indicating enhanced interaction between subsystems. The D value decreased from 0.203 to 0.172, indicating a failure of coordination among subsystems, urgently requiring the introduction of new momentum or internal adjustments within the subsystems to balance the existing high-quality system.

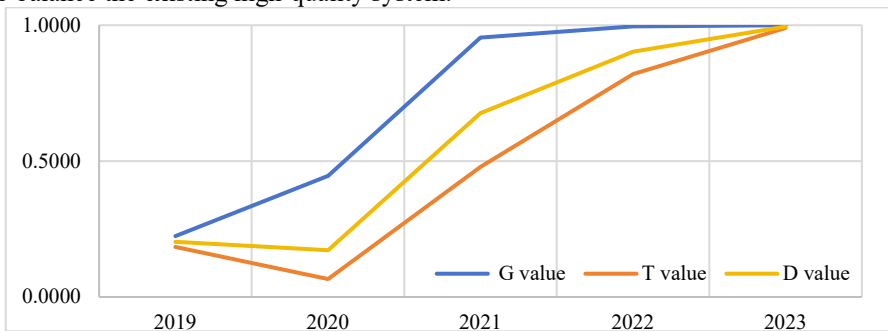


Fig. 3. Coupling changes in high-quality development in Guangdong Province under the influence of AI (2019-2023)

From 2021 to 2023, the system as a whole entered a stage of coordinated development. The G-value continuously increased from 0.955 to 1.000, indicating a highly close and positive interaction among the three subsystems. Simultaneously, the T-value jumped from 0.479 to 0.990, reflecting that under the dual-engine drive of AI and policies, economic growth resilience increased, social welfare levels improved, and environmental carrying capacity was enhanced, with each subsystem achieving synergistic improvement. Building on this foundation, the D-value steadily rose from 0.677 to 0.995, and the system coordination level improved from “basic coordination” to “high-quality coordination.”

4 Conclusion

Based on the entropy method and the coupling coordination degree model, this study measures and analyzes the level of high-quality development in Guangdong Province under the influence of AI from 2019 to 2023. The main conclusions are as follows: (1) The overall level of high-quality development shows a V-shaped recovery and upward trend of “first decline and then rise”. AI technology empowerment and policy dividends are the key driving forces for this trend; (2) The scores of the two subsystems of economic development and social stability increased from 0.1295 and 0.1782 to 1.1367 and 1.0204 respectively, and the environmental sustainability subsystem also recovered to 0.6781, reflecting the empowering value of AI in industrial upgrading, people’s livelihood services and environmental governance; (3) The coupling coordination analysis shows that the system as a whole has successfully shifted from the imbalance stage (2019-2020) to the coordination stage (2021-2023) and reached a high-quality coordination level, reflecting that a virtuous development pattern of deep integration and mutual promotion has been formed among the subsystems.

To promote high-quality development in a steady and sustainable manner, Guangdong Province should take a multi-pronged approach. At the government level, it should strengthen the deep integration of AI in industrial transformation, social governance, and green and low-carbon development, and improve digital infrastructure and cross-departmental collaboration mechanisms. Enterprises should actively invest in AI research and development and application scenarios, accelerating the implementation of technologies in key areas such as intelligent manufacturing and smart environmental protection.

While this study employed multiple methods and dimensions to conduct a systematic analysis of AI and Guangdong Province’s high-quality development, limitations in scope and time prevented the implementation of cross-province comparisons and longer-term longitudinal comparisons. Future research could expand to a larger regional sample to further validate the universality and dynamic development of the findings.

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