



A Study of the Digital Economy Based on the “Entropy-Coupling” Model-Taking Guangdong Province as an Example

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Abstract. Digital trade is also actively advocated to drive high-quality economic development through digitalization. However, existing assessments often focus on aggregate, neglecting the structural reasons behind macroeconomic changes. Guangdong Province, as a forefront of China’s digital economy development, has significant research value regarding its development status and internal coordination. In view of this, the present research employs the entropy-coupling model to conduct an empirical analysis of the development of digital economy in Guangdong Province from 2020 to 2024. Macroeconomically, the entropy weight method is employed to measure its overall development level; macroeconomically, the coordination relationship among the three subsystems of digital finance, digital trade, and digital consumption is assessed. The study finds that Guangdong Province’s digital economy is growing, with a growth rate as high as 2117%. Further investigation of each subsystem reveals that digital finance is developing faster than digital trade, while digital consumption is developing more slowly.

Keywords: Digital Economy, Entropy-Coupling Model, Guangdong Province

1 Introduction

With the iteration of technology and the upgrading of AI, the digital economy keeps expanding steadily. As stated in the Global Digital Economy White Paper (2024) published by the China Academy of Information and Communications Technology, the aggregate digital economic volume of five leading economies—the US, China, Germany, Japan and South Korea — surpassed 33 trillion US dollars in 2023, representing an annual growth above 8%; meanwhile, the digital economy made up over half of their overall GDP (Guo & Zhu, 2024). [1]. Liu Liehong, The director of the National Bureau of Data mentioned the added value created by China’s core digital economic sectors was projected to top 12 trillion RMB in 2023, which took up roughly 10% of the national GDP. In 2026, China officially entered the “15th Five-Year Plan” period. Subsequently, the “15th Five-Year Plan” adopted by China in

March 2026 clearly proposed to “deepen the construction of digital China”, and set a quantitative target that by 2030, the added value of the core digital economy industries would account for 12.5% of GDP (State Council of the People’s Republic of China, 2026) [2]. This marks that the development of the digital economy is shifting from scale expansion to the pursuit of quality, efficiency and collaboration. Therefore, analyzing the overall development level and internal coordination mechanism helps to assess the quality of development and identify key shortcomings, thereby providing a scientific basis for optimizing policy supply.

There is a lot of research on the development of the digital economy in the academic community. For example, Wang and Li (2026) conducted an empirical analysis on the digital economy empowering innovative development. They constructed four dimensions of indicators: integration foundation, integration process, integration environment and integration effect. They used the entropy weight method to measure the comprehensive score and found that it showed a trend of “rise-fall-rise again” [3]. Yang and Wang (2026) used the weighted entropy value method to measure the development level of the digital economy and the regional economic resilience level. They analyzed the relationship between the digital economy, the upgrading of residents’ consumption structure and the regional economic resilience and revealed that the digital economy has a significant promoting effect on the regional economic resilience [4]. Zheng, Liu and Geng (2024) used provincial panel data in China to conduct an empirical study on the promoting effect of the digital economy on the resilience of the industrial chain and clarified the driving mechanism of the digital economy on the industrial level at the macro level [5]. Liu and Tong (2026) built a set of assessment indicators reflecting how mature the digital economy grows, and adopted the entropy value method to assign weights and calculate scores for provinces covered within the Yangtze River Economic Area. Their empirical findings demonstrated obvious gaps in digital economic progress across various areas, thus revealing the development pattern of the downstream leading and the middle and upper reaches catching up [6]. Hu, Huang and Sun (2026) analyzed the impact of the digital economy on rural cultural revitalization. First, they used the entropy method to calculate the digital economy and rural cultural revitalization index, and then built a model for empirical testing. Ultimately, their research confirms that the digital economy promotes rural cultural revitalization by driving technological advancement and increasing disposable income for rural residents.[7].

In summary, current research remains at the macro-level of comprehensive evaluation, such as using entropy to measure the digital economy, impact assessment, and regional comparisons, but it fails to explain its internal structural dynamics. Furthermore, existing research focuses on a single dimension, failing to consider the digital economy as an organic whole composed of key subsystems. This study aims to provide a basis for the balanced and coordinated development of the digital economy in Guangdong Province and even China, contributing to the achievement of sustainable and high-quality development during the 15th Five-Year Plan period.

2 Study Area, Research Methods, and Data Sources

2.1 Study Area

This study selects Guangdong Province as the research area. Guangdong's GDP exceeded 14 trillion yuan in 2024, ranking first in the country for 37 consecutive years, creating more than one-tenth of the national economic output with less than 2% of the country's land area. In digital finance, in 2026, the incremental value created by Guangdong's financial sector increased by 1.24 trillion-yuan year-on-year, with a growth rate of 4%, and the securities transaction volume reached 319.5 trillion-yuan, making up roughly 1/9 of the whole country's aggregate volume, providing a market foundation for digital finance. Within the digital trade sector, Guangdong's total import and export volume leads China, and its cross-border e-commerce is booming, providing ample space for digital trade transformation. Regarding digital consumption, in 2025, Guangdong's permanent resident population exceeded 120 million, and more than 1.26 million new enterprises were established in 2024, constituting a huge market and consumption potential, and providing continuous impetus for digital consumption. In summary, Guangdong possesses significant advantages and rich experience in all three major areas of the digital economy, making it an ideal sample for examining the digital economy.

2.2 Research Methods

This paper adopts a quantitative research approach. For the purpose of examining the overall development status of Guangdong Province's digital economy and the synergistic relationships among its internal subsystems, a mature “entropy-coupling” integrated model is selected for analysis. The objective weighting advantage of the entropy method, combined with the coupling coordination model, can effectively reveal the level and structural characteristics of digital economic development.

Entropy method. This approach evaluates the developmental status of every individual subsystem as well as the comprehensive development level of the whole system. Its theoretical basis is the information entropy theory, which uses information entropy to measure the dispersion of data. The greater the dispersion of the index value, the more information there is, and the higher the weight in the evaluation. In this study, the three subsystems of digital finance, digital trade and digital consumption are objectively weighted, the entropy value of each index is calculated to determine the objective weight, and then the comprehensive development index of each system and the whole is calculated. The specific calculation formula is as follows:

1) Standardize the indicators, and shift all of them by 0.0001 to ensure that no zero occurs in the data analysis: positive:

$$B_{ij} = \frac{A_{ij} - \min(A_{ij})}{\max(A_{ij}) - \min(A_{ij})} + 0.0001 \quad (1)$$

Negative:

$$B_{ij} = \frac{\max(A_{ij}) - A_{ij}}{\max(A_{ij}) - \min(A_{ij})} + 0.0001 \quad (2)$$

2) Calculate the proportion of the i -th sample value under the j -th indicator

$$P_{ij}: P_{ij} = \frac{B'_{ij}}{\sum_{i=1}^g B'_{ij}} \quad (0 \leq P_{ij} \leq 1, i = 1, \dots, g, j = 1, \dots, h) \quad (3)$$

3) Calculate the entropy value of the j -th indicator

$$E_j: E_j = -k \sum_{i=1}^g P_{ij} \ln P_{ij} \quad (k = \frac{1}{\ln g}, \text{ or } 0 \leq E_j \leq 1) \quad (4)$$

4) Calculate the difference coefficient of the j -th indicator D_j :

$$D_j = 1 - E_j \quad (5)$$

5) Calculate the weight of the j -th indicator

$$W_j: W_j = \frac{D_j}{\sum_{j=1}^h D_j} \quad (6)$$

6) The linear weighting method is applied to compute the comprehensive evaluation scores of digital finance, digital trade and digital consumption:

$$U_i = \sum_{j=1}^h B_{ij} W_j \quad (7)$$

Compare all U -value evaluation results. The higher the comprehensive evaluation score, the better the result.

Coupling and Coordination Model. The coupling degree illustrates how strongly different systems interact with one another, while coordination degree measures the level of their benign interaction. This model judges from a micro perspective whether the systems are “high-level synergy” or “low-level dependence” (He Kaifei, 2025) [8]. This study adopts this model to compute the coupling coordination level linking the three subsystems with the overall system, so as to judge the synergy and health status of the internal structure of the digital economy. Specifically, by calculating the coupling degree (C) and the comprehensive development index (T), the coupling coordination degree (D) is finally obtained.

7) Based on existing literature, this study involves two subsystems; accordingly, the formula for calculating the coupling degree is expressed as:

$$C = 3 \times \left[\frac{U_1 U_2 U_3}{(U_1 + U_2 + U_3)^3} \right]^{\frac{1}{3}} \quad (8)$$

8) Coupling Coordination Degree Model:

$$D = \sqrt{C \times T}$$
 (9)

$$T = \alpha_1U_1 + \alpha_2U_2 + \alpha_3U_3$$
 (10)

where D denotes the coupling coordination degree among digital finance, digital trade and digital consumption, with a value ranging from 0 to 1. T serves as the composite evaluation index of the three subsystems, which mirrors the contribution of their respective development levels to the overall coordination degree. Parameters α_1 , α_2 and α_3 are the comprehensive evaluation index, calculated by weight. The coupling coordination standard referenced in this study is as follows: Coordination level classification: referring to the academic standard, the D value is categorized into 10 levels, such as 0-0.09 is extremely uncoordinated, 0.90-1.00 is excellent coordination, etc. (Table 1).

Table 1. Criteria for Classifying Coupling Coordination Degree

D value range	level	degree	D value range	level	degree
[0.0~0.1)	1	Extreme Disorder	[0.5~0.6)	6	Barely Coordinated
[0.1~0.2)	2	Severe Disorder	[0.6~0.7)	7	Primary Coordination
[0.2~0.3)	3	Moderate Disorder	[0.7~0.8)	8	Intermediate Coordination
[0.3~0.4)	4	Mild Disorder	[0.8~0.9)	9	Good Coordination
[0.4~0.5)	5	Verge Of Disorder	[0.9~1.0]	10	High-Quality Coordination

2.3 Data Sources

All empirical data adopted in this paper are extracted from the Guangdong Statistical Yearbook, covering the time window from 2020 to 2024. In view of a small number of missing observations, the regression interpolation approach is employed to complement the dataset.

3 Research and Analysis

3.1 Design and Construction of the Indicator Evaluation System

Table 2. Indicator System for Measuring Digital Economy Performance across Guangdong Province (2020-2024)

Indicator 1	Indicator 2	Unit	Property	Weight (%)
Digital Finance	RMB deposit balance of financial institutions	USD 100 million	positive	6.22
	RMB loan balance of financial institutions	100 million yuan	positive	5.91
	Household deposits in financial institutions across the province	100 million yuan	positive	6.95
	Property insurance company premium income	10,000 yuan	positive	7.66
	Property insurance company claims payments	Ten thousand yuan	positive	11.89

Indicator 1	Indicator 2	Unit	Property	Weight (%)
Digital consumption	per capita consumption expenditure of all residents in the province	Yuan	positive	5.33
	per capita disposable income of urban residents in the province	Yuan	positive	5.23
	Per capita consumption expenditure of rural residents in all cities of the province	Yuan	positive	4.94
	Per capita consumption expenditure on transportation and communication of residents in the province	Yuan	positive	6.62
	Retail sales of goods by wholesale and retail enterprises above the designated size	100million yuan	positive	4.94
	Total import and export volume	100million yuan	positive	4.82
	Outward direct investment	USD10000	positive	7.04
	Actual amount of foreign capital utilized	USD10001	positive	4.47
	General trade export value	100million yuan	positive	6.09
	Operating profit of information transmission, software and information technology services	100million yuan	positive	11.89

Based on the characteristics of Guangdong Province and in accordance with scientific rigor, rationality, and data availability, a set of primary indicators was constructed, with digital finance, digital trade, and digital consumption as the first-level indicators. Each primary indicator has four secondary indicators, as shown in Table 2. The data was then substituted into formulas (1)–(6) to obtain the indicator weights.

3.2 Comprehensive and Subsystem Analysis

First, the overall development score of Guangdong Province's digital economy during 2020–2024 was calculated. By feeding the processed data into Equations (1) to (7), the comprehensive evaluation scores for the study period are derived, as illustrated in Figure 1. On the whole, the scores present a continuous rising trajectory, climbing from 0.042 in 2020 to 0.931 in 2024, representing an approximate 21-fold increase over the five-year period.

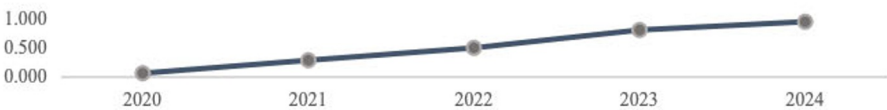


Fig. 1. Guangdong Province's Comprehensive Score for Digital Economy (2020-2024)

To investigate the development status of each digital economy subsystem in Guangdong Province, the processed data are imported into Equations (1)–(7) to calculate the corresponding evaluation scores for the 2020–2024 period, as presented in Fig. 2. Overall, the growth rates of the three subsystems rank in descending order as follows: digital finance, digital trade, and digital consumption.

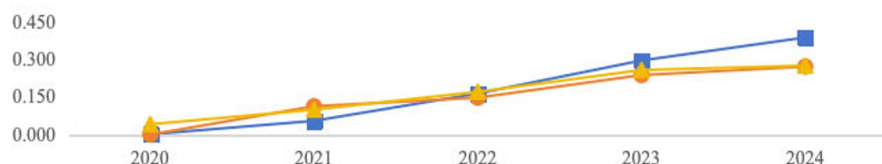


Fig. 2. Index values for each component of Guangdong's digital economy (2020-2024)

For digital finance, its index value rose from 0.001 in 2020 up to 0.386 in 2024, representing a growth rate of 38,500%. Development was slower in 2020-2021 (0.001 $\rightarrow$ 0.054) because digital transformation was still in its early stages and infrastructure was under construction. The growth rate accelerated after 2021, especially during 2022-2023 when digital finance experienced a leapfrog growth (0.163 $\rightarrow$ 0.295), mainly driven by the increased penetration of digital payments. Simultaneously, regulators encouraged the development of “inclusive finance” and supported financial institutions in using big data and AI technologies for credit risk assessment. Inclusive finance products have transitioned from offline to online and will become intelligent in the future.

Digital trade grew from 0.041 points in 2020 to 0.274 points in 2024, representing a growth rate of 568%. The growth rate slowed after 2020-2021 (0.041 $\rightarrow$ 0.099), mainly due to logistical disruptions caused by the global pandemic, and the fact that traditional foreign trade enterprises were facing difficulties in digital transformation. In early 2022, with the entry into force of the RCEP agreement, the implementation of policies for cross-border e-commerce comprehensive pilot zones, and the construction of the “Digital Silk Road,” digital trade gradually increased. The growth rate from 2022 to 2024 was particularly significant (0.170 $\rightarrow$ 0.274), thanks to the application and development of cloud computing and IoT technologies, which greatly improved the efficiency of cross-border trade.

Digital consumption grew from 0.000 points in 2020 to 0.271 points in 2024, reaching a growth rate of $+\infty$ (infinity, since the base was 0). This subsystem demonstrated robust growth potential. The base was extremely low in 2020-2021, but explosive growth was already evident (0 $\rightarrow$ 0.113). During this period, the pandemic restricted offline consumption scenarios, forcing residents to rapidly shift their consumption behavior online. Demand for fresh food e-commerce, online education, and remote work increased significantly. At the policy level, governments at all levels actively promoted the construction of the “Internet+” consumption ecosystem to ensure people's livelihoods and stabilize the economy. The growth rate slowed slightly in 2021-2022 (0.113 $\rightarrow$ 0.147) due to the impact of the pandemic on offline consumption, lowered residents' income expectations, suppressed some discretionary consumption, and the underdeveloped digital infrastructure in rural areas. From 2022 onwards, the growth rate of digital consumption accelerated again (0.147 $\rightarrow$ 0.237) and moved towards high-quality development. During this period, the widespread adoption of 5G networks, the penetration of new business models such as

live-streaming e-commerce, and the growth of residents' income jointly promoted the prosperity of digital consumption.

3.3 Coupling Assessment

Inputting the dataset into formulas (8)-(10) generates the coupling analysis results displayed in Fig.3 and Table 3. The study found that the coupling status for Guangdong Province's digital economy covering 2020 through 2024 experienced a development transition from imbalance (2020-2021) to coordination (2022-2024).

Table 3. Digital Economy Coupling Score in Guangdong Province (2020-2024)

Year	C Value	T Value	D Value	Coordination Level	Degree
2020	1.000	0.010	0.100	1	Extreme Disorder
2021	0.914	0.256	0.484	5	On the verge of disorder
2022	0.993	0.499	0.704	8	Intermediate Coordination
2023	0.997	0.842	0.916	10	High-quality coordination
2024	1.000	0.990	0.995	10	High-quality coordination

The development stages can be further subdivided into two main categories: imbalanced development and coordinated development. The first stage, imbalanced development (2020-2021), went from extreme imbalance to near-imbalance. Although the coupling degree (C-value) was high, indicating strong interaction, the overall coordination index (T-value) was extremely low, reflecting a structural imbalance in overall development. Specifically, digital trade was impacted by the global pandemic, with cross-border logistics hindered and growth sluggish. While digital consumption shifted online due to restrictions on offline activities, it was mainly concentrated on daily necessities, resulting in a single structure and limited impact on the real economy. Digital finance was in its early stages of development, lacking sufficient risk control and data accumulation to effectively support financial needs. At the policy level, cross-departmental coordination mechanisms were not yet sound, and the data element market was absent, leading to barriers between subsystems. Technologically, uneven coverage of new infrastructure such as 5G and data centers, along with inconsistent technical standards, hindered interconnectivity between systems.

The second stage, the coordinated development stage (2022-2024), saw the digital economy leap from intermediate to high-quality coordination, with all indicators showing a steep upward curve. Digital finance acted as an accelerator, and the widespread adoption of digital payments provided efficient and low-cost settlement infrastructure for trade and consumption. Big data risk control and supply chain finance technologies significantly improved the credit and capital flow efficiency of digital trade. Digital trade and digital consumption mutually promoted and coordinated with each other.

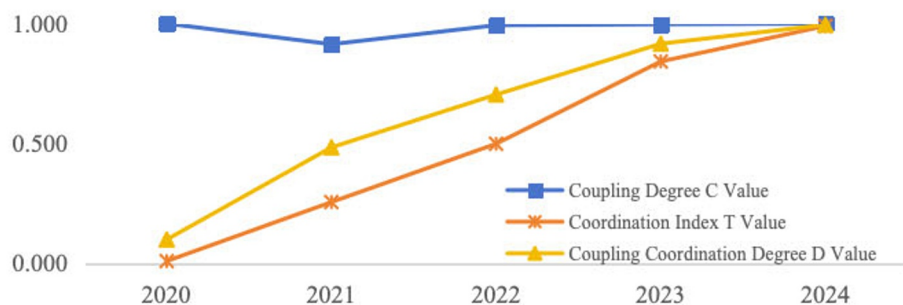


Fig. 3. Coupling and Coordination Degree of Digital Economy in Guangdong Province (2020–2024)

4 Conclusion and Discussion

This study adopts an entropy-coupling framework to quantify the digital economy within Guangdong Province. Findings indicate that Guangdong's digital economy achieved a growth rate as high as 2117% from 2020 to 2024. Among its subsystems, digital finance developed faster than digital trade, while digital consumption grew at a slower pace. A further coupling analysis reveals the inner development situation of Guangdong's digital economy shifted from imbalance (2020–2021) to coordination (2022–2024), highlighting the supporting role of policies and technologies.

To promote high-quality and coordinated development of Guangdong's digital economy during the 15th Five-Year Plan period, efforts should focus on integrating digital finance, digital trade and digital consumption, with joint support from the government and enterprises. Specifically, the government can introduce policies on data security and orderly data flow, enhance digital finance's empowerment of real trade, and launch targeted incentives to guide resources into key areas such as intelligent manufacturing. Enterprises should strengthen technological innovation to address shortcomings in digital trade services, aligning with government policies.

Limited by time and research scope, this study only covers Guangdong's data from 2020 to 2024. Future research can expand the scope to conduct cross-regional comparison and deeper analysis.

References

1. Guo Qian, & Zhu Yuying. (July 3, 2024). The digital economy will usher in multiple policy benefits. State Council Information Office website. Retrieved May 26, 2026, from http://www.scio.gov.cn/live/2024/34328/xgbd/202407/t20240716_855424_m.html.
2. State Council of the People's Republic of China. (2026). Deepening the Construction of Digital China and Enhancing the Level of Digital and Intelligent Development. Published in the Outline of the 15th Five-Year Plan for National Economic and Social Development

- of the People's Republic of China (Part IV). China Government Website. Retrieved May 26, 2026, from https://www.gov.cn/yaowen/liebiao/202603/content_7062633.htm.
3. Wang Ziwei, Li Ruxia. Research on the Measurement of the Integration and Development Level of Technological Innovation and Industrial Innovation under the Empowerment of Digital Economy [J]. *Journal of Yulin University*, 2026, 36(03):74-80+85. DOI:10.16752/j.cnki.jylu.2026.03.011.
 4. Yang Peiqing, Wang Fengxu. Digital Economy, Consumption Structure Upgrading and Regional Economic Resilience [J]. *Journal of Northwest University (Philosophy and Social Sciences Edition)*, 2026, 56(03):137-151. DOI:10.16152/j.cnki.xdxbsk.2026-03-013.
 5. Zheng Linchang, Liu Jingzhi, Geng Aomiao. Can the digital economy enhance the resilience of the industrial chain? [J]. *Journal of Shanxi University (Philosophy and Social Sciences Edition)*, 2026, 49(03):144-155. DOI:10.13451/j.cnki.shanxi.univ(phil.soc.).2026.03.015.
 6. Liu Panpan, Tong Haifang. Research on the measurement level of high-quality development of digital economy in Yangtze River Economic Belt [J]. *Knowledge Economy*, 2026, (12): 19-22. DOI: 10.15880/j.cnki.zsjj.2026.12.028.
 7. Hu Shiwen, Huang Jiaqi, Sun Xiaodong. An Analysis of the Impact Mechanism of Digital Economy on Rural Cultural Revitalization: An Empirical Test Based on Panel Data from 40 Cities in the Yangtze River Delta Region [J/OL]. *Journal of Zhejiang Ocean University (Humanities Edition)*, 1-12 [2026-05-26]. <https://link.cnki.net/urlid/33.1403.C.20260515.1630.002>.
 8. He Kaifei. A Study on the Coupling and Coordination of New Productivity and Digital Economy Development in China [D]. *Jiangxi University of Finance and Economics*, 2025. DOI:10.27175/d.cnki.gjxcu.2025.001558.

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