



# Research on the Coordination Degree of Higher Vocational Education and Industrial Structure Based on System Coupling Model--The Case of Guangdong Province

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**Abstract.** In this paper, the MATLAB software is adopted to develop the system coupling model to calculate the comprehensive index and coupling level of the two systems of higher vocational education structure and industrial structure in Guangdong Province from year 2015 to year 2021. In addition, the dynamic evolution and development characteristics of the coupling relationship between the two systems is analysed. The higher vocational education (HVE) is closely related to the development of the economy and society, and to the transformation of the industry structure. During the continuously increasing of the demand for the professional technical and skilled talents in various industries is, the coordination between the regional restructuring of HVE and the changes in industrial structure have become the issue. In this paper, the structure of HVE from four aspects: talent cultivation, social service, education investment and discipline structure were analyzed. The empirical analysis was conducted on the changes of HVE structure and industrial structure, the development of comprehensive evaluation level, and the coupling coordination posture in Guangdong Province. First, it is about the comprehensive evaluation level. The growth rate of comprehensive indices of industrial structure in Guangdong Province is prominently lower than that of HVE structure in the sample period, and its development level starts to be higher than that of industrial structure in 2020, which is mainly resulted from the lag of HVE development in matching talent demand, professional setting and industrial structure transformation, as well as the inadequate development of industrial structure. The second is the change in the development trend of the coupling and coordination between the two. 2015-2021, the coupling and coordination degree of the two systems as a whole suggests a gradually increasing tendency, 2015 is at the stage of near coordination, 2016-2018 is at the grinding stage of barely coordination, 2019-2020 reaches the stage of primary coordination, and the growth rate increases from 2020, and by 2021 to achieve advanced coordination coupling. Based on the empirical results, we propose suggestions for better coordination between the higher vocational education structure and the industrial structure.

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**Keywords:** System Coupling Model; Structure of higher vocational education; Industrial structure; Coordinated development.

## 1 Introduction

In the "China Vocational Education Development Report 2012-2022", it is pointed out that China should further promote the transformation and upgrading of its industrial structure and take the path of higher quality development, while vocational education is the type of education most closely aligned with industry, which can continuously optimise the supply of human resources and provide strong talent support for China's economic development<sup>[1]</sup>. The Party's 20th Congress has also placed an unprecedented level of importance on vocational education, with the issuance of the Opinions on Deepening the Reform of Modern Vocational Education System Construction in December 2022 and the joint issuance of the Implementation Plan for the Action of Empowering the Integration of Industry and Education in Vocational Education (2023-2025) by the National Development and Reform Commission and eight other departments in June 2023, with the aims to speed up the resolution to the problem of low recognition of vocational education and the problem of "two skins" between talent training and industrial development<sup>[2]</sup>. The development of higher vocational education (HVE) should deepen the structural reform on the supply side of vocational education, and promote the regional layout of HVE structure and industrial structure to meet the market demand and match the industrial structure. HVE is an indispensable part of higher education and an important part of vocational education, which is responsible for cultivating diversified and integrated talents to meet industrial demands, technological changes and economic transformation. At this stage, plenty of issues regarding HVE, e.g., the homogenization of vocational colleges, the lagging development of teaching materials, curriculum design and professional planning can not keep up with the growth requirements of enterprises, and the integration of industry and education is more superficial, etc. Therefore, two main issues of the coordinated development of industrial structure are urgent to be solved. The first is to strengthen the ability to promote industry with education and education with industry, accelerate the formation of positive interaction between industry and education and deeper integration of industry and education. The second is to investigate and deal with the structure of HVE.

Guangdong, whose economy ranks first in China, has become the window for China to introduce foreign economy, culture, science and technology since the year 1978 when is the beginning of the reform and opening up, and become the province of vocational education. The GDP of the year 2022 is 12.91 trillion yuan, ranking the first in China for 34 consecutive years, which shows that Guangdong's economic development is very rapid, the industrial structure is transforming and upgrading quickly and the demand for skilled talents is also increasing. There is an urgent need for higher vocational colleges to transform and upgrade, improve quality, strengthen service and technology empowerment, further help the students of higher vocational to shape their own comprehensive quality and ability. Thus, high-quality industrial labour forces could be provided for industrial development; there is an urgent need for higher-level and high-quality vocational colleges, especially to expand the supply of undergraduate

vocational education. There is an urgent need for more higher-level and higher-quality vocational colleges and universities, especially to expand the supply of technical and skilled talents at the undergraduate level to inject a more powerful impetus for the construction of the industries with innovative technology in the twin areas. Owing to the location and unique position of Guangdong Province and the urgent demand in developing HVE, analyzing the coupling and coordination of the structure between HVE and industrial structure has prominent academic value and practical significance for Guangdong Province.

This paper is aimed at constructing an evaluation index system that can comprehensively consider both HVE and industrial structure in Guangdong Province, followed by quantitatively analyzing the development and evolution trend of coordination between HVE structure and industrial structure in Guangdong Province from year 2015 to year 2021 through the entropy value method and coupling coordination degree model based on the MATLAB software. Therefore, this paper is able to provide empirical reference and decision basis for better promoting the coordinated development of HVE structure and industrial structure in Guangdong Province.

## 2 Literature Review

The Coupling theory is a theory that has emerged in recent years to study the interaction relationship between elements in various types of systems. Distinguished from the coupling theory in electromagnetism, the concept of coupling in management and economics refers to the process of transferring, interacting and even integrating information or energy in two or more objective things. Aleš Kocourek (2018) Comparing data on the structure of higher education and industrial development in 125 countries for 16 years from 1999 to 2014, the study concluded that the development of higher education is significant and has a positive correlation with the economic development of each country<sup>[3]</sup>. Drucker (2015) has selected the data on the structure of industry and higher education in the U.S. from 1987-1997 for the correlation analysis using a non-causal regression model, which argues that U.S. economic diversity, industrial specialization, and competitive structure regulate the U.S. college and university system through their effects on the job market<sup>[4]</sup>. Tang, Zhibin and Shi, Weiping (2015) have pointed out that the relationship between vocational education and the development of industry inherently is inherently natural and close, and the mutual development between them requires the construction of a synergistic innovation mechanism. Also, they have put forward the basis and main contents of the construction of the innovation mechanism<sup>[5]</sup>. Zhou Qiliang and Fan Hongzhong (2020), by using the panel data of 287 cities in China, have used a two-step systematic GMM model to analyze that higher education human capital aggregation has a positive influence on upgrading the structure of industry in large, medium and small cities, and the positive impact it produces and the magnitude of its rise and fall, and the negative impact is more prominent in cities in the eastern region<sup>[6]</sup>. He, Ju-Lian (2013) have selected panel data from 2000-2009 in China to measure the status of higher education human capital and industrial structure. The results indicate that higher education human capital can effec-

tively promote the optimization and upgrading of industrial structure<sup>[7]</sup>. Yu, Li, Song, Rong, and Zhao, Chenye (2023) have verified that the higher education development of cities in Guangdong-Hong Kong-Macao Greater Bay Area was uneven from 2010 to 2017, and the economic development among cities had a clear gradient distribution pattern<sup>[8]</sup>. Minjie Wang, Jing Tan, and Minghao Fu (2021) has studied the relationship between HVE on inputs and economic growth in China through provincial panel data, and concluded that there is a double threshold effect between the two at the national level, which can promote economic growth after crossing the threshold value<sup>[9]</sup>.

By combing the existing relevant research results, we found that: first, there more empirical studies have been conducted on the development correlation between education structure and industrial structure in a certain region, which mainly use cross-sectional data for many years for comparative analysis to explore the coordination between professional development, professional structure, employment of graduates in higher education and the industry and economy development, but few studies have used multi-year data to focus on higher vocational However, few studies use multi-year data to focus on HVE, especially on the coordination of the structure between HVE and industry development in Guangdong Province. Secondly, most of the existing studies on HVE and industrial structure are on the basis of the present situation, but the structure development of industry and HVE is developmental and regular, so it is necessary to have a certain long time span in the investigation process and to analyze and predict the advances and rules. Therefore, in this paper, a comprehensive evaluation index system is established by the coupled relationship and coordination of the structure between HVE and industry. In addition, the development trend of coupling and coordination between them and the influencing factors is studied by combining the current situation survey with the data change pattern of Guangdong Province for 7 years from 2015 to 2021. At last, the improvement path of the coupled relationship of the structure between HVE and industry in Guangdong Province is proposed to provide decision support.

### **3 Model and data**

#### **3.1 Indicator system construction**

Industrial structure and HVE structure are two large systems that affect each other and are complex, involving many contents and a wide range. Therefore, with the purpose to build a index system construction with sufficient rationality, scientificity and comprehensiveness, it is the basis for the next correct study of the coupled relationship between the aforementioned two systems. In this paper, in accordance with the principles that the results are scientific, the indicators are representative and the data are available, we will develop a comprehensive evaluation index system rely on the concepts of the structure of both HVE structure and industry, with reference to previous related researches and relevant indexes from the Bureau of Statistics, from the following aspects: HVE structure will be selected from four latitudes of talent cultivation, social service, education input and discipline structure, and industrial structure will be selected from 17 indexes. The structure of HVE and industry structure will be evaluated

by selecting 6 observation points from two latitudes of industrial material capital structure and industrial talent capital structure.

This study obtains the statistics of Guangdong Province from 2015 to 2022 as the research sample. The index data are mainly from the Guangdong National Economic and Social Development Statistical Bulletin and Guangdong Education Statistical Yearbook, etc. The index system is summarized in the following Table 1.

**3.2 Determination of indicator weights based on the entropy weighting method**

In this section, the entropy weighting method is adopted to determine the indicator weights and the specific measurement process is as follows:

**3.2.1 Pre-processing of raw data Pre-processing of raw data.**

Considering the influence of each indicator on the evaluation target and the inconsistency of the scale and magnitude among the indicators, the three levels of indicators in the comprehensive evaluation index system of the structure of both HVE structure and industry were standardised in accordance with the extreme difference method.

The original data is firstly standardized, assuming that evaluation indicators with the number of  $n$  are given  $X_1, X_2, \dots, X_n$ , where  $X_j = \{x_{1j}, x_{2j} \dots, x_{mj}\}$ , the following formula is used to standardize each indicator to obtain the standardized value of each indicator,  $X' = [x'_{ij}]_{m \times n}$ .

For benefit-based indicators, the standardisation is as follows:

$$x'_{ij} = \frac{x_{ij} - \min\{x_i\}}{\max\{x_i\} - \min\{x_i\}} \tag{1}$$

For cost-based indicators, the standardised approach is as follows:

$$x'_{ij} = \frac{\max\{x_i\} - x_{ij}}{\max\{x_i\} - \min\{x_i\}} \tag{2}$$

Where  $x_{ij}$  denotes the original value of the  $j$ th indicator for the  $i$ th city and  $x'_{ij}$  denotes the standardised value of the  $j$ th indicator for the  $x'_{ij}$ th city. The  $\max\{x_{ij}\}$  and  $\min\{x_{ij}\}$  denote the maximum and minimum values of the original indicator respectively.

Then, on top of the normalization, the following formula is used for the leveling process to obtain the leveled data  $Y = [y_{ij}]_{m \times n}$

$$y_{ij} = x_{ij} + 0.001 \tag{3}$$

**3.2.2 Calculate the percentage of indicators.**

Calculate the weight of the sample value of indicator  $j$  in city  $i$  for that indicator:

$$P_{ij} = \frac{y_{ij}}{\sum_{i=1}^n y_{ij}} \tag{4}$$

**3.2.3 Calculating the information entropy of an indicator.**

the information entropy of each indicator was determined by the following equation in line with the definition of information entropy:

$$E_j = -\ln(m)^{-1} \sum_{i=1}^m p_{ij} \ln p_{ij} \tag{5}$$

where, if  $p_{ij} = 0$ , then  $p_{ij} \ln p_{ij} = 0$ .

**3.2.4 Calculation of information entropy redundancy.**

The redundancy of each indicator is calculated according to the formula given as below:

$$d_j = 1 - E_j \tag{6}$$

**3.2.5 Calculate the weighting of each indicator.**

On the basis of the redundancy of information entropy for each indicator, the weights of each indicator were obtained as follows:

$$w_j = \frac{d_j}{\sum_{j=1}^n d_j} \tag{7}$$

**Table 1.** Comprehensive evaluation index system of higher vocational education structure and industrial structure

1st-level index	2nd-level index	3rd-level index	Unit	Indicator weights
Structure of higher vocational education	Talent Development	Number of higher vocational schools	stitute	0.0209
		Number of students in school	10,000 persons	0.0909
		Number of graduates	person	0.0336
	Social Services	Number of people staying in local employment	person	0.0685
		Amount of vertical research funds received	10,000 Yuan	0.0278
		Horizontal technical services to the amount of money	10,000 Yuan	0.0361
	Education input	Annual per pupil financial allocation amount	Yuan	0.0399
		Total number of faculty and staff on board	person	0.0164
		Comprehensive institutions	%	0.0304
	Discipline Structure	Science and Engineering College	%	0.0748
		Forestry colleges and universities	%	0.0384

		Medical Schools	%	0.0339
		Finance and Economics Colleges	%	0.1907
		Teacher training colleges	%	0.0395
		Sports institutions	%	0.0335
		Art Institutes	%	0.0341
		Political and law schools	%	0.1907
		The proportion of output value of the primary industry in GDP	%	0.1391
	Industrial physical capital structure	The proportion of output value of the secondary industry in GDP	%	0.1464
		The proportion of output value of the tertiary industry in GDP	%	0.1330
Industry Structure		The ratio of employed persons in primary industry to total employed persons	%	0.1269
	Industrial Talent Capital Structure	The ratio of employed persons in the secondary industry to total employed persons	%	0.3324
		The ratio of employed persons in the tertiary industry to total employed persons	%	0.1222

### 3.3 Comprehensive evaluation model

By normalizing the data pairs, the comprehensive score  $f(x)$  for the structure of HVE and the comprehensive score  $g(y)$  for the industrial structure in Guangdong Province from 2015 to 2021 were calculated respectively, with the following formula:

$$f(x) = \sum_{i=1}^m \lambda_i' x_{ij} \tag{8}$$

$$g(y) = \sum_{i=1}^m \lambda_i y'_{ij} \tag{9}$$

Where  $\lambda_i$  is the weight of the index, the higher the  $f(x)$ , the higher the system development level, and therefore the trend of the composite score of Guangdong Province from 2015-2021 can be calculated.

### 3.4 Construction of a coupled coordination model

#### 3.4.1 Coupling degree function.

Coupling is a concept originated from physics and refers mainly to the phenomenon of multiple elements, the interaction between various systems. The coupling degree function is mainly adopted to measure the closeness of the relationship between the

elements and whether the interaction is appropriate. The structure of both HVE and the industry are two systems that are independent of each other and affect each other. In line with the coupling theory, the coupling degree function is constructed and the expression formula is:

$$C = \left\{ \frac{f(x) \times g(y)}{\left[ \frac{f(x) + g(y)}{2} \right]^2} \right\}^{0.5} \tag{10}$$

Where  $f(x)$  and  $g(y)$  are the comprehensive scores of the structural system of HVE and the industry, respectively;  $c$  is the coupling degree and takes the value range of  $[0,1]$ . The higher the value of  $c$ , the higher the degree of association between various systems; at  $c = 0$ , the two systems are in a state of disorderly development with no mutual relationship; at  $c = 1$ , the highest degree of association between the two systems.

With the purpose to reflect the coupling and coordination between the structure of HVE and the industry, this paper employs the median value method to classify the coupling degree ( $C$  value) in accordance with the evaluation criteria of the coupling and coordination degree in the existing literature (Table 2).

**Table 2.** Criteria for the division of coupling phases

Low-level coupling	Primary coupling	Intermediate coupling	Advanced coupling
$0 \leq C \leq 0.3$	$0.3 < C \leq 0.5$	$0.5 < C \leq 0.8$	$0.8 < C \leq 1.0$

**3.4.2 Coupling coordination function.**

The coupling degree is mainly employed to measure the coupling effect between multiple systems, but if there is just a common low or common high situation between two data, it may also present a high coupling degree in the expression of the function result, so it is difficult to express whether there is a synergistic amplification effect and overall efficacy between HVE structure and industrial structure just by the high or low value of the coupling degree. Therefore, with the purpose to reveal the degree of coordination between HVE structure and industrial structure, the function of coupling coordination degree is used here aimed at further evaluating the coordination status of the development of the two systems, and the formula is:

$$D = \sqrt{CT} \tag{11}$$

$$T = \alpha f(x) + \beta g(y) \tag{12}$$

In the above two formulas,  $D$  is the coupling and coordination degree between HVE structure and industry structure, also called the coupling and coordination index, the value of  $D$  ranges from 0 to 1, the higher the value of  $D$  indicates the better coordination between the two systems;  $T$  is the comprehensive evaluation index, which can indicate the development level of coupling and coordination between HVE structure



and industrial structure.  $\alpha$  and  $\beta$  are undetermined coefficients, which reveal the relative importance of HVE structure and industrial structure, the average value of  $\alpha$  and  $\beta$  here is 0.5.

In order to analyse the coupling and coordination between the structure of HVE and the industrial structure in Guangdong Province more comprehensively, the coupling coordination degree  $D$  was divided, as shown in Table 3<sup>[10]</sup>.

**Table 3.** Classification criteria for coupling coordination levels

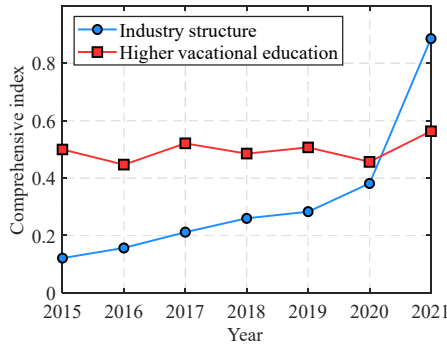
Type	Judgment interval	Coupling coordination phase
Dysfunctional decline type $0 \leq D < 0.4$	[0, 0.1)	Severe disorder
	[0.1, 0.2)	Highly disorder
	[0.2, 0.3)	Moderate disorder
	[0.3, 0.4)	Mild disorder
Reconciliation overload type $0.4 \leq D < 0.6$	[0.4, 0.5)	On the verge of disorder
	[0.5, 0.6)	Barely disorder
Coordinated development type $0.6 \leq D \leq 1$	[0.6, 0.7)	Primary disorder
	[0.7, 0.8)	Intermediate disorder
	[0.8, 0.9)	Senior disorder
	[0.9, 1]	Superior disorder

## 4 Empirical results

### 4.1 Comprehensive evaluation level of higher vocational education structure and industrial structure

#### 4.1.1 Analysis of the structure of higher vocational education in Guangdong Province.

As presented in Fig.1, the structure of HVE in Guangdong Province is in a state of year-on-year increase from 2015 to 2021, and the increase from 2020 to 2021 is particularly obvious. In terms of the specific data of each indicator, the values of each indicator of HVE, e.g., talents cultivation, social services and education investment increase yearly. From 2015 to 2021, the number of higher vocational schools in Guangdong Province will increase from 81 to 93, with the ratio of public to private higher vocational colleges remaining at 5:2, with public higher vocational colleges taking the main responsibility for HVE. The number of graduates increased from 221,300 to 282,600, and higher vocational colleges delivered more skilled talents to the society; the amount of vertical research funding increased from RMB 91,325,000 to RMB 41,205,820,000 in 2015, a 4.5-fold increase in 7 years, and the amount of horizontal technical services increased from RMB 95,111,000 to RMB 1,507,000 in 2015. The annual average financial allocation for students increased from RMB12,874 to RMB19,597.95, which shows that the research level, social service capacity and education investment of higher vocational colleges are also improving.



**Fig. 1.** Change in the composite index of higher vocational education and the composite index of industrial structure in Guangdong Province from 2015 to 2021

The past five years, the Guangdong Provincial Government has issued 21 pieces of local legislation, development plans and special policies for the development of HVE, and officially launched the construction of provincial vocational education bases in 2014, with a total of 16 institutions and 110,000 students enrolled in the Guangdong Vocational Education City by 2022, which has greatly improved the capacity and service level of HVE. With the purpose to strengthen the construction of high-level vocational colleges and professional clusters, the provincial government will provide 130 million yuan in 2021-2022 to support 14 national "double-high plan" vocational colleges and universities to complete their construction projects in a quality and timely manner.

In 2021, Guangdong Meizhou Vocational and Technical College and Guangdong Chaozhou Health Vocational College enrolled students for the first time after being registered and permitted by the Ministry of Education, and all levels in the province achieved full coverage of higher vocational colleges. As for the development of industrial structure, the region of HVE is mainly around the new regional development pattern of "One Belt, one core and one region". There are 72 vocational colleges in the Pearl River Delta region, 13 vocational colleges in the coastal economic zone and 8 vocational colleges in the northern ecological development zone, as shown in Table 4.

**Table 4.** Regional Distribution of Higher Education Institutions in Guangdong Province, 2021

Region	Number of institutions	Region	Number of institutions
Guangzhou	46	Shantou	2
Shenzhen	3	Chaozhou	1
Foshan	4	Jieyang	2
Dongguan	4	Shanwei	1
Zhongshan	2	Maoming	4
Zhuhai	2	Yangjiang	1
Zhaoqing	3	Shaoguan	1
Huizhou	4	Qingyuan	3
Yunfo	2	Meizhou	1

**4.1.2 Analysis of the industrial structure of Guangdong Province.**

Guangdong's GDP reaches RMB12.91 trillion in 2022, with an increase of 1.9% compared to the last year. The statistics summarized in Table 5 suggests that during 2015-2021, the industrial structure of Guangdong Province is dominated by the secondary and tertiary industries. In addition, the industrial structure of Guangdong Province is dominated by the secondary and tertiary industries. The proportion of the primary and secondary industries in GDP shows a downward trend, while the proportion of the tertiary industry shows a slow rise. The results indicates that the proportion of the three industrial structures in Guangdong Province in 2021 is 4.0:40.4:55.6, with the tertiary industry accounting for the highest proportion.

**Table 5.** Share of three industries in Guangdong Province, 2015-2021 (%)

Year	Proportion of primary industry	Proportion of secondary industry	Proportion of tertiary industry
2015	4.3	45.4	50.3
2016	4.7	43.2	52.1
2017	3.9	42.1	54
2018	3.8	41.4	54.8
2019	4	40.2	55.8
2020	4.3	39.5	56.3
2021	4	40.5	55.5

Source: Guangdong Statistical Yearbook 2015-2022, Statistical Bulletin on National Economic and Social Development of Guangdong Province

**4.2 The coupled and coordinated structure of higher vocational education and industrial structure**

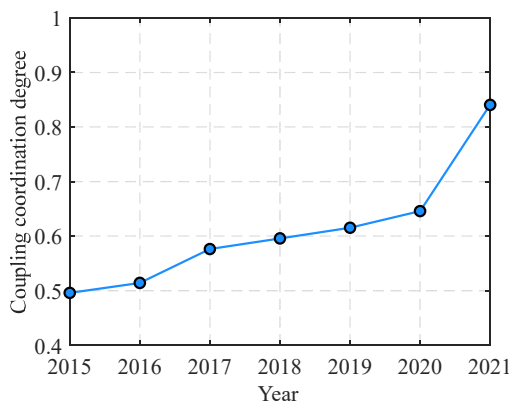
The MATLAB software was used to compute the integrated evaluation model and the coupling coordination model for the data, the final level of coupled and coordinated changes of HVE structure and industrial structure in Guangdong Province from 2015 to 2021 is shown in Table 6.

$f(x)$  indicates the role of each element of the three-level indexes in the comprehensive evaluation index system of HVE structure, and  $g(y)$  indicates the role of each element of the three-level indicators within the partial system of the comprehensive evaluation index of industrial structure. if  $f(x) < g(y)$ , the degree of development of HVE structure is relatively lagging behind in comparison with the degree of development of industrial structure; if  $f(x) > g(y)$ , the opposite is true. Table 6 shows that the value of  $f(x)$  increases steadily from 2015 to 2021, with a larger increase in 2020-2021, while  $g(y)$  is in a more stable state, fluctuating above and below the value of 0.5.  $f(x)$  has been lagging behind compared to  $g(y)$  from 2015 to 2020, suggesting that the development of HVE structure lags behind compared to industrial structure, and only in 2021 does  $f(x)$  is larger than  $g(y)$ .

With respect to the coupling degree, the coupling degree of both HVE structure and industrial structure in Guangdong Province is greater than 0.79, which is a state of high coupling degree, indicating that the degree of mutual influence and interaction between the two systems is high, but the specific development level of the two systems needs to be analyzed together with the results of the coupling coordination degree function. From the comprehensive evaluation index T value of the coordinated development of the two systems, the overall D value from 2015-2021 is in a rising state (as shown in Figure 2:). In 2015, it is at the stage of near coordination. During 2016-2018, it is at the grinding stage of barely coordination. During 2019-2020, it reaches the stage of primary coordination. The growth rate began to increase in 2020, and advanced coordinated coupling was achieved by 2021. the level of development of HVE structure and industrial structure is rapidly increasing, and the coordination of the two systems is also on a substantial ascendent trend, reaching the stage of advanced coordination in 2021.

**Table 6.** Evaluation results of the coupling and coordination between higher vocational education structure and industrial structure

W	$f(x)$	$g(y)$	Cou-pling(C)	T-value	Coupling coordination(D)	Coordination level
2015	0.1211	0.4997	0.7925	0.3104	0.496	On the verge of coordination
2016	0.1565	0.4469	0.8766	0.3017	0.5143	Reluctantly coordinated
2017	0.2116	0.5211	0.9064	0.3664	0.5763	Reluctantly coordinated
2018	0.2597	0.4853	0.9531	0.3725	0.5958	Reluctantly coordinated
2019	0.283	0.507	0.9589	0.395	0.6154	Primary coordination
2020	0.3813	0.4566	0.996	0.4189	0.6459	Primary coordination
2021	0.8858	0.5632	0.9749	0.7245	0.8404	Senior Coordination



**Fig. 2.** The change of coupling coordination between higher vocational education structure and industrial structure in Guangdong Province from 2015 to 2021

## 5 Conclusions and recommendations

The structure of HVE and industrial structure is a coupled system formed by the interaction between education and economic growth. A comprehensive investigation of the elements of the structure of HVE and industrial structure system helps us to better understand the coupling relationship between HVE and industrial structure, in accordance with the coupling coordination degree (CCD) model as the theoretical basis. This paper analyses the structural development of HVE and the change of industrial structure in Guangdong Province from 2015 to 2021, as well as the comprehensive evaluation level and the development trend of coupling and coordination between the two. It is found that the degree of correlation and interaction between HVE structure and industrial structure in Guangdong Province is strong, and the coupling degree (C value) is basically above 0.8 and 0.9. The level of coupling and coordination between the two is not high from 2015 to 2020, and is at the stage of near coordination, barely coordination and primary coordination, and only rises to the advanced coordination stage in 2021, which indicates that the HVE disciplines and specialties in Guangdong Province have not kept pace with the industrial structure of Guangdong Province, The dynamic adjustment of HVE structure is not strong enough until 2020. With the development of Qingyuan Vocational Education City and undergraduate vocational education in 2021, as well as the enhancement of quality and efficiency of vocational education, the structure of HVE is undergoing transformation and upgrading, so the coupling coordination degree will grow faster by 2021. In modern society, the development of HVE has been integrated with the upgrading of industrial structure and economic development. If the structure of HVE cannot go with the trend of the times, economic changes and industrial upgrading, there will be a disconnection between HVE and industrial structure, therefore, efforts should be made to improve the coupling coordination between the two. This study makes the following suggestions for the development of HVE:

One is to take the demands of industry as the guide and focus more on serving economic and social growth. Although the government, enterprises and schools are constantly exploring the practical mode and pilot construction of the integration of industry and education, the situation of "emphasizing teaching over industry" still exists in vocational education in practice, which is primarily manifested in the fact that more higher vocational schools have difficulties in linking the specific production practice of enterprises with professional education and teaching activities due to the factors of capital, venue, equipment and personnel. The teaching and learning activities of higher vocational schools are not in line with the specific production practices of enterprises, and there is a certain lag in the construction of professional curricula, innovation of teaching methods and updating of practical training contents, which makes it difficult to adapt to the rapid change of technological innovation and industrial research and development. The degree of integration of industry and education is not high. In this context, to further improve the quality and efficiency of HVE and promote the integration of industry and education, it is more important to combine it with the local regional development strategy, the transformation and upgrading of industrial structure and the demand for human capital in the market.

Second, improve policy support and deepen the reform of the vocational education system. Actively build a regional linkage and a mechanism for synergistic development of government, industry, enterprises and schools. Combining the key industries in the province and the regional advantages and own characteristics of the local cities to which the schools belong, the government can use industrial parks as the basis to focus on building municipal industry-education consortia that have the functions of talent training, innovation and entrepreneurship, and promoting high-quality development of industrial economy. According to the development of industrial clusters and realistic needs, the government should make overall planning for the construction of higher vocational colleges' professional clusters in the provincial area, transform the professional development of scattered higher vocational colleges into clusters, and actively adjust the scale of each profession from enrollment - employment, import and export control in both directions, so as to dovetail with the changes of regional industrial structure and cultivate We will actively adjust the scale of each major to meet the changes of regional industrial structure, so as to cultivate high-level and high-quality technical and skilled talents to satisfy the requirement of high-end industries and high-end industrial growth.

Thirdly, we should improve the "two-teacher" teaching team and promote the in-depth combination of information technology and education teaching. We will effectively improve the ideological and political quality and professional ethics of teachers in higher education institutions, focus on cultivating their professional theoretical knowledge and practical operation ability, and flexible employment mechanisms, accelerate the formulation of framework standards for teachers' informatization teaching ability, and strengthen the training of teachers' informatization teaching ability; build a number of informatization benchmark schools, develop a number of high-quality online open courses, and set up a number of education informatization teaching reform projects To promote the reform of the online and offline hybrid teaching mode, and to promote the continuous improvement of teaching quality.

Fourth, to enhance the adaptability of talent cultivation and open up channels for higher vocational graduates to further their studies. In many cases, HVE is the "second" choice for parents and children, and it is not very competitive in the job market. With the purpose to develop HVE, it is necessary to further open up the channels for higher vocational graduates to further their studies, as well as the channels for switching between different stages and types of education, so that students have more room for choice. We should actively expand the pathway to grow and succeed for students, and establish a batch of high-level vocational schools and majors that meet the can satisfy the requirement of the economic and social development and technical skill cultivation, with secondary vocational schools as the foundation, higher vocational specialties as the primary role and vocational bachelor's degrees as the traction. We will further improve the adaptability of higher vocational education to educate the talents and maximize the space for diversified growth of students, so that the competitiveness and attractiveness of vocational education will become stronger and stronger.

The coupled coordination degree model has become an effective evaluation and research tool to study the degree of balanced development of the region. In this study, the comprehensive evaluation model and the coupled coordination degree model is

adopted, which can reflect the change of the coordination degree between the HVE and the industrial structure of Guangdong Province in the past seven years. However, the relationship between the two systems (i.e., the HVE and the industrial structure, respectively) is far more complex than the idealized model. Therefore, the further research on the reasons and the solutions is expected to be performed in combination of practical situation.

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