Vocational Education in Hainan, China: Structural Mismatch and Time Lag in Major, Industry and Employment

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Abstract: Higher vocational education plays a vital role in regional economic transformation and industrial upgrading, especially amid the Hainan Free Trade Port's expansion. With rising demand for technical expertise, aligning Hainan's vocational programs with local industry needs is crucial. This study uses 2023 data to examine the differences among the major, industrial, and employment structures in Hainan's vocational institutions. Utilizing grey correlation analysis on panel data from 2016 to 2022, the research quantifies the interrelationships and time lag effects among these structures. Findings reveal significant misalignments between academic majors offered, regional industrial demands, and graduates' employment outcomes. Notably, the industrial structure directly influences academic major configuration with a six-year lag, while its indirect effect via employment structure shows a 12-year lag. These results highlight the dynamic interplay between education and market requirements, underscoring the need for proactive curriculum adjustments. Based on these insights, it is recommended that Hainan's vocational institutions optimize their major offerings, strengthen collaboration with industry stakeholders, and establish dynamic monitoring and early warning systems. Such measures will help shorten the time lag between training and market demand, ensuring that graduates are well-equipped with skills to meet evolving industrial needs.

Keywords: Deviation, Employment Structure, Grey Correlation, Higher Vocational College, Industrial Structure, Major Structure, Time Lag Effect

1. Introduction

As China's economic development has entered a new stage of high-quality growth, vocational education has become increasingly important in promoting regional economic transformation, industrial upgrading, and the cultivation of technical and skilled talent. Especially against the backdrop of the growing demand for technical talents in the local economy, this demand has driven innovation in the major setup of vocational education, necessitating its alignment with regional industrial development to cultivate talents with practical application abilities. To this end, on February 23, 2019, the Central Committee of the Communist Party of China and the State Council issued China Education Modernization

2035 (The State Council of the People's Republic of China, 2019a), emphasizing that "accelerating the development of modern vocational education, continuously optimizing the structure and layout of vocational education. Promoting the organic connection and deep integration of vocational education with industrial development and concentrating efforts to build a number of high-level vocational colleges and majors with Chinese characteristics. Optimizing the talent cultivation structure, comprehensively using enrolment plans, employment feedback, funding, standards, evaluations, and other methods to guide higher education institutions and vocational schools to timely adjust their academic discipline structures."

On March 29, 2019, the Ministry of Education and the Ministry of Finance issued the Opinions on the Implementation of the Plan for the Construction of High-Level Higher Vocational Schools and Specialties with Chinese Characteristics (The State Council of the People's Republic of China, 2019b), or the "Double-Higher Plan," which marks the state's strategic investment in the field of higher vocational education with the intention of improving overall quality and service capacity. On March 12, 2021, the Outline of the Fourteenth Five-Year Plan for the National Economic and Social Development of the People's Republic of China and the Visionary Goals for 2035" states (The State Council of the People's Republic of China, 2021a), "Enhance the adaptability of vocational and technical education. Highlight the characteristics of the types of vocational and technical (technician) education, push forward reform and innovation in depth, optimize the structure and layout, and vigorously cultivate technical and skilled personnel."   On October 12, 2021, the General Office of the Central Committee of the Communist Party of China (CPC) and the General Office of the State Council issued the Opinions on Promoting the High-Quality Development of Modern Vocational Education (The State Council of the People's Republic of China, 2021b), which further clarified the direction of the reform of vocational education, and put forward important initiatives such as promoting the vertical coherence of vocational education at different levels, optimizing the structure of the supply of vocational education, and dynamically adjusting the professional settings in accordance with the needs of industry.

On December 21, 2022, the General Office of the CPC Central Committee and the General Office of the State Council issued the Opinions on Deepening the Reform of the Construction of a Modern Vocational Education System (The State Council of the People's Republic of China, 2022), which deepened the reform of the vocational education system and put forward strategic tasks such as exploring a new model for the construction of a modern vocational education system at the provincial level, creating a municipal industry-education consortium, and upgrading the key school-running capacity of vocational schools. On June 8, 2023, the National Development and Reform Commission (NDRC) and other departments issued the Implementation Plan for Vocational Education Industry-Education Integration Empowerment and Enhancement Actions (2023-2025) (The State Council of the People's Republic of China, 2023), which clarifies the specific goals and action plans for industry-education integration, promotes better integration of industrial needs into the whole process of talent training through industry-education integration, and optimizes the structure of human resources supply. At the 2024 National Education Conference, General Secretary Xi Jinping explicitly pointed out that it is necessary to "build a vocational education system with vocational and popularization integration and industry-education fusion, and vigorously cultivate great national craftsmen, skilled craftsmen, and highly skilled talents.", this important exposition provides a clear direction for the development of higher vocational education.

The aforementioned policy not only emphasizes the urgency of cultivating technical and skilled talents closely integrated with the local economy and highly compatible with the development needs of industries and enterprises, but also clearly outlines strategic measures to enhance educational quality by strengthening the "Five Golds" construction, namely creating "Gold Majors, Gold Courses, Gold Teachers, Gold Facilities, and Gold Textbooks." However, despite the positive role of national policies in promoting vocational education reform, the alignment between the majors offered by vocational colleges and regional industrial structure still requires improvement. This has led to a shortage of technical talent in certain industries, directly affecting the supply–demand balance in the job market. Therefore, an in-depth exploration of how vocational colleges can achieve a positive interaction between major and industrial structures, as well as the impact of major settings on employment structure, holds significant practical importance for cultivating high-quality technical and skilled talent that meets the needs of local economic development. This study aims to explore, through empirical

analysis, the matching degree between the professional settings of Hainan's higher vocational colleges and the regional industrial structure and its impact on the employment structure, with a view to providing scientific basis for the optimization of professional settings in Hainan's higher vocational colleges and universities.

2. Literature Review

2.1 Adaptability of Vocational Education Major Structure to Industrial Structure

Research on the adaptability of major vocational education structures to industrial structures has exhibited diverse characteristics at the provincial level. Wang and Han (2024) conducted an empirical analysis of the major setups at 50 higher vocational colleges in Zhejiang and pointed out significant structural issues, such as gradient differences and insufficient majors. Li (2024) further emphasized the mismatch between the major development of higher vocational education and regional industrial needs in the coastal areas of Jiangsu, highlighting the importance of adjusting the major setup. Ma and Li (2022), on the other hand, explored the contribution of Jiangsu higher vocational education to industrial development, suggesting that the major structure of higher vocational education should be optimized to enhance its service capability and adaptability.

Su and Ning (2021) analysed the appropriateness of vocational computer education in Hunan from 2014 to 2019 in relation to the development of new business formats and clarified the supply situation of vocational computer education in the province. Liu and Chen (2022) conducted research on the major offerings of 14 vocational colleges in Hainan and proposed the need to optimize the alignment with the demands of emerging industries in the modern service and tourism sectors. Ma (2023) revealed the negative impact of the outdated structure of higher vocational majors in Chongqing on economic transformation, highlighting the inconsistency between the major offerings and economic development. Gui (2023) analysed the adaptability of majors in Jiangsu vocational colleges to industries in four dimensions: concentration, redundancy, deviation, and matching, revealing many existing issues. Du (2023) believes that there is a phenomenon of disorderly development between the adjustment of the major structure of higher vocational education in Hubei Province and the evolution of the industrial structure. The main reasons are the difficulties in adjusting the major structure, the major setup not meeting national requirements, and the lack of deep cooperation between schools and enterprises. Chen (2023) conducted an empirical analysis of the matching situation between higher vocational major settings and industrial development from two dimensions: the overall situation of Guangdong and the internal city differences. Xu (2022) discussed the impact of industrial structure on the major structure of higher vocational education and proposed corresponding adjustment strategies to better meet the industrial development needs of Zhejiang Province. Hu et al. (2024) analysed the supporting role of higher vocational education quality in industrial structure changes, emphasizing the close relationship between education quality and major setup. Ma et al. (2020) studied the correlation between the academic discipline layout of universities and the industrial structure in the Guangdong-Hong Kong-Macao Greater Bay Area. Significant structural deviations were found between the secondary and tertiary industries in the Greater Bay Area.

Although numerous studies have provided theoretical support for the major setup of higher vocational colleges, the current results still mainly focus on static adaptability analyses in specific regions. The relative lack of dynamic adaptability research limits the ability of higher vocational education major setups to respond to the industry's rapidly changing demands. Therefore, the focus should be on exploring how vocational colleges can flexibly adjust their major offerings in a dynamic environment to achieve higher adaptability, in line with industrial development.

2.2 Interaction between the Structure of Higher Vocational Education Majors and the Structure of Industries and Employment

In research on the interaction between higher vocational education majors, industries, and employment, the current findings mainly focus on the relationship between the structure of majors and the structure of industries, particularly the role of major settings in promoting local economic

development. Studies indicate that the setting of majors directly affects the employment rate and the quality of graduates, especially during periods of industrial structural change. In this context, the supply and demand theory provides an important theoretical framework for related research, emphasizing the interaction between supply and demand in the market and effectively explaining how vocational colleges dynamically adjust their major offerings based on regional industrial needs.

Specifically, Ma and Zhang (2017) discussed the coupling coordination between higher education, industry, and employment, emphasizing the interdependence among the three. Zhao and Qu (2024) conducted an in-depth analysis of the coupling coordination degree model and grey relational degree model, examining the structural patterns of higher education disciplines in China from 2011 to 2021 and their coupling with the industrial structure. Zhao et al. (2024) studied the interrelationship between industry, education, and employment based on the employment input-output framework and explored their interactive impacts. Zhou (2022), based on 20 years of panel data from 287 prefecture-level and above cities, studied the impact of the coupling coordination degree between higher education and industrial structure on employment structure, further revealing the relationship between higher education and the job market. Zhou et al. (2023) study the relationship between China's industrial and employment structures and their dynamic links with economic growth. The study found that an increase in structural bias reduces the efficiency of resource allocation. The impact of industrial structure on employment structure is gradually increasing and relatively slow; however, its impact on economic growth is more pronounced in the early stages. The impact of economic growth on the industrial structure is lagging and long-term, whereas its impact on the employment structure is initially strong and then weakens. The impact of changes in the employment structure on the industrial structure is related to the flow of labour between industries. The impact of employment structure optimization on economic growth is most significant in the early stages.

Tao et al. (2019) conducted an empirical analysis of the changes in industrial structure and employment in Zhejiang Province based on time series data from 1986 to 2018. The study found that the direction and speed of changes in industrial structure have a significant impact on employment. The direction of changes in the industrial structure is positively correlated with employment, whereas the speed of changes in the industrial structure is negatively correlated with employment.

However, most studies still primarily focus on the alignment between academic disciplines and industrial structures, with relatively few discussions on the comprehensive impact of academic majors on employment structures. Research involving supply and demand relationships is also relatively scarce, and there is currently a lack of in-depth analysis on how vocational education can promptly respond to market changes.

Additionally, research on the time-lag effect provides a new perspective to understand the interactions between the three. Shen (2018) analysed the lag issue in the interaction between the structure of higher vocational education and industrial structure using panel data, emphasizing the delayed effect of adjustments in higher vocational education on economic development. Zou et al. (2018) used a regression model to analyse the coordination between the structure of higher vocational majors and the industrial structure, pointing out that there is a significant lag in their responses. Sun and Wang (2023) focused on the interaction mechanisms between the structure of higher education, industrial structure, and employment structure, emphasizing the bidirectional impact of lag effects on market supply and demand. Zhu et al. (2024) studied the adaptability of the discipline structure of higher education in the three northeastern provinces to the industrial structure and employment structure and found that the response of the major setup in this region to industrial demand is still insufficient.

Overall, research on the interactions between these three structures has vast exploration potential. Efforts should be dedicated to exploring ways to promote positive interactions between the major, industrial, and employment structures of vocational colleges through effective policies and practical

measures, thereby driving the coordinated development of vocational colleges and the regional economy.

Through a review of the aforementioned literature, it is clear that academia has placed more emphasis on adaptability research among higher vocational majors and industries. However, research on the structure of higher vocational majors, the structure of industries, and the structure of employment, especially studies focusing on time lags, is lacking.

Extant research on the adaptability of vocational education majors and industrial structures has focused on several provinces in China, especially Zhejiang, Jiangsu, Hunan, and Chongqing. However, as a depression of modern vocational education in China, relevant studies in Hainan Province are still insufficient, and higher vocational education in Hainan Province faces a number of challenges, including the disconnect between industrial structure and major structure, and the special needs of regional economic development. The existing body of research is predominantly focused on economically developed regions and does not adequately delve into the unique characteristics of Hainan Province. The promotion of free trade port policy in Hainan Province has led to a rapid transformation in its industrial structure, particularly in the domains of the modern service industry, tourism, and emerging industries. This has necessitated an urgent review of the structural settings of higher vocational colleges and universities to align them with the evolving needs of the local economy. Consequently, there is significant theoretical and practical value in examining the relationship between the structural settings of higher vocational colleges and the industrial structure in Hainan Province.

Most extant studies have employed quantitative analysis methodologies, chiefly the coupling coordination degree model, grey correlation degree model, and regression analysis model, to explore the relationship between the major setting of higher vocational colleges and industrial structure (Wang and Han, 2024; Li, 2024; Ma and Li, 2022; Su and Ning, 2021; Ma, 2023). These methods have facilitated the revelation of the impact of industrial structural changes on the setting of higher vocational majors. However, they tend to remain at a level of static adaptability and lack continuous attention to dynamic changes. The industrial structure of Hainan Province is undergoing rapid transformation, and its ability to adapt to major settings in the face of dynamic changes, particularly those driven by emerging industries and policy shifts, remains a subject of limited exploration. To address this knowledge gap, this study introduces a lag effect analysis to further explore the dynamic supply and demand relationship between the major settings of higher vocational colleges and universities and the regional industrial and employment structure. This study aimed to quantify the specific impact of the lag effect on economic development.

Literature on this subject has largely relied on data at the provincial or regional level, particularly through empirical analyses of time-series data, to reveal the matching relationship between the major settings of higher vocational colleges and the industrial structure (Gui, 2023; Chen, 2020; Liu, 2021; Zhao 2024); however, there is a relative paucity of data in Hainan Province, and existing studies have paid less attention to the specific industrial demand and link between higher vocational education and the job market in Hainan Province. The Hainan Province has a relatively homogeneous industrial structure and is undergoing a transition from traditional to modern services and emerging industries. Consequently, by conducting in-depth research on how to adjust the major settings of higher vocational institutions according to the needs of local economic development, this study will focus on collecting relevant industry data and data from higher vocational colleges and universities in Hainan Province, and we will explore how Hainan Province can better serve the local economy by optimizing professional settings.

A review of the extant literature reveals a paucity of research that directly addresses the adaptability of higher vocational colleges' major settings and industrial structures. This is particularly salient in the context of the Hainan Province, a special economic region that merits greater attention. To address this lacuna, the present study explores the dynamic interaction between higher vocational

education, industry, and employment structure by introducing methodologies such as lagged effect analysis and grey correlation analysis. These approaches will provide a theoretical foundation and empirical substantiation for the optimization of professional settings in higher vocational colleges and universities in Hainan Province. Specifically, this study examines strategies to enhance the employment competitiveness of graduates by optimizing major settings, promoting the coordinated development of regional industry and employment structure, and providing an impetus for the high-quality growth of Hainan Province's economy.

3. Methods

3.1 Data Source

The data on the structure of higher vocational education majors come from the Hainan Province Education Statistical Yearbook, the industry data come from the Hainan Province Statistical Yearbook, and the employment data of higher vocational colleges come from the Hainan Province Higher Vocational Education Quality Annual Report.

3.2 Methods

3.2.1 Deviation Analysis

Referring to the approaches of scholars such as Su and Ning (2021), Shen (2017), and Zhang (2020), the formulas for the deviation between major and industry, industry and employment, and major and employment were constructed, incorporating structural deviation.

$$D_{Z-C} = \frac{Major_i}{GDP_i} - 1 \tag{1}$$

Formula (1) represents the deviation between the major structure and the industrial structure, where $Major_i$ is the proportion of majors offered in i-th industry, and GDP_i is the proportion of the output value of the i-th industry.

$$D_{C-J} = \frac{GDP_i}{Employment_i} - 1 \tag{2}$$

Formula (2) represents the deviation between industrial structure and employment structure, where GDP_i is the proportion of output value of the i-th industry, and $Employment_i$ is the proportion of employment population in the i-th industry.

$$D_{Z-J} = \frac{Major_i}{Employment_i} - 1 \tag{3}$$

Formula (3) represents the deviation between the major structure and the employment structure, where $Major_i$ is the proportion of majors offered in i-th industry, and $Employment_i$ is the proportion of employed population in i-th industry.

3.2.2 Entropy Method

The entropy method belongs to the category of objective-weighting methods. This method avoids the interference of human factors in the process of determining the weight coefficients and objectively reflects the importance of each evaluation index within the comprehensive evaluation index system. As one of the most commonly used methods for calculating comprehensive indicators, this study uses the entropy method to assign weights to the structure of higher vocational education majors and the economic structure, and calculates the comprehensive score of the economic structure, laying the groundwork for subsequent grey relational analysis. The specific calculation steps are as follows:

First, the indicators were standardized. In this study, let X_{ij} be the original data of the indicators, and X_{ij}' be the data after normalization. The calculation formula is shown in (4), where i represents the number of evaluation years and j represents the number of evaluation indicators. Next, calculate the entropy value of the indicators, as shown in formula (5), where $y_{ij} = x_{ij}' / \sum_{i=1}^{m} x_{ij}'$ is the proportion of the i th indicator in the j th year; then, calculate the weight of the indicators, as shown in formula (6); finally, calculate the comprehensive score of the indicators, as shown in formula (7).

$$x_{ij}' = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} (i = 1,2,...,m; j = 1,2,...,n) \tag{4}$$

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

$$W_i = 1 - E_j / \sum_{j=1}^{n} (1 - E_j) \tag{6}$$

$$U_i = W_i \times x_{ij}' \tag{7}$$

3.2.3 Grey Relational Analysis

Based on the comprehensive score of the economic structure in Hainan obtained using the entropy method mentioned above, this study employs the grey relational model to analyse the correlation between the structure of higher education disciplines and the economic structure in Hainan. The steps for constructing the model are as follows.

The first step was to determine reference and comparison sequences. Use the comprehensive score U_x of the economic structure as the reference sequence $X_o = \{x_o(1), x_o(2),..., x_o(n)\}$, and use the various indicators in the structure of higher vocational education majors as the comparison sequence $X_i = \{x_i(1), x_i(2),..., x_i(n)\}$ Among them, i represents the number of indicators in the sequence, and n represents the number of years.

Step two, data normalization. Owing to the different statistical standards of the selected data indicators, the mean method was used to normalize the selected indicators, as shown in Equations (8) and (9).

$$x_o' = x_o(k) \frac{1}{n} \sum_{k=1}^{n} x_o(k); k = 1,2,...,n \tag{8}$$

$$X_i' = x_i(k) \frac{1}{n} \sum_{k=1}^{n} x_i(k); k = 1,2,...,n \tag{9}$$

Step three, calculate the absolute difference between the two levels is calculated. See formulas (10) and (11):

$$M = \max_i \max_k |x_o'(k) - x_i'(k)| \tag{10}$$

$$m = \min_i \min_{x_k} |x_o'(k) - x_i'(k)| \tag{11}$$

Step four, calculate the grey correlation coefficient is calculated. As shown in formula (12), where $\theta_{oi}(K)$ represents the grey correlation coefficient, and p is the distinguishing coefficient, usually set to $p = 0.5$.

$$\theta_{oi}(K) = \frac{m + pM}{|x_o'(k) - x_i'(k)| + pM} \tag{12}$$

Step five, calculate the degree of gray correlation. As shown in formula (13), where θ_{oi} represents the grey correlation degree.

$$\theta_{oi} = \frac{1}{n}\sum_{k=1}^{n}\theta_{oi}(k); i = 1,2,...,m \tag{13}$$

3.2.4 Moore value

The Moore value, also known as the Moore structural change value, reflects the detailed dynamic process of changes within each structure. The calculation formula is as follows.

$$E = arcCosM_t^{+} = arcCos\frac{\sum_{i=1}^{n}(W_{i,t}\cdot W_{i,t+1})}{\sqrt{\sum_{i=1}^{n}W_{i,t}^2}\cdot\sqrt{\sum_{i=1}^{n}W_{i,t+1}^2}} \tag{14}$$

Among them, $W_{i,t}$ represents the proportion of industry i in period t, $W_{i,t+1}$ represents the proportion of industry i in period $t+1$, E is the Moore value, indicating the degree of change in industrial structure between period t and period $t+1$, the larger E indicates a greater degree of change in industrial structure, with a range of $[0,\pi/2]$.

3.2.5 Grey Absolute Correlation Degree Model

First, we determine the features and behaviour sequences.

Let the system characteristic sequence $X_o = \{x_o(1), x_o(2),...,x_o(n)\}$, system behaviour sequence $X_i = \{x_i(1), x_i(2),...,x_i(n)\}$, the lengths of the two are equal. Let $X_o^o = \{X_o^o(1), X_o^o(2),...,X_o^o(n)\}$ is the origin of X_o's zero image, $X_i^o = \{X_i^o(1), X_i^o(2),...,X_i^o(n)\}$ is the initial zeroed image of X_i. The calculation formula for the origin zeroing image is $X_i^o(k) = X_i(k) - X_i(1)(i = 0,1,2,...,m; k = 1,2,...,n)$.

Second, the Grey relational degree was calculated.

$$|S_o| = |\sum_{k=2}^{n-1}X_o^o(k) + \frac{1}{2}X_o^o(n)| \tag{15}$$

$$|S_i| = |\sum_{k=2}^{n-1}X_i^o(k) + \frac{1}{2}X_i^o(n)| \tag{16}$$

$$|S_i - S_o| = |\sum_{k=2}^{n-1}[X_i^o(k) - X_o^o(k)] + \frac{1}{2}[X_i^o(n) - X_o^o(n)]| \tag{17}$$

$$\theta_{oi} = \frac{1 + |S_o| + |S_i|}{1 + |S_o| + |S_i| + |S_i - S_o|} \tag{18}$$

Among them, θ_{oi} is the gray absolute correlation between X_o and X_i, and $0 \leq \theta_{oi} \leq 1$.

4. Results and Analysis

4.1 Overview of Higher Vocational Majors in Hainan Province

As indicated in Figure 1, in 2023, Hainan Province will have 14 independently established higher vocational colleges (including one undergraduate-level vocational university, hereinafter the same), distributed across five cities and counties (seven in Haikou, four in Sanya, one in Wenchang, one in Qionghai, and one in Chengmai). They are mainly concentrated in Haikou and Sanya, respectively connecting with the main industries of their respective cities and counties, effectively integrating into and serving the regional economic development. From the perspective of the types of institutions, among the 14 higher vocational colleges in Hainan Province, there are 6 public institutions, accounting

for 42.86% of the higher vocational colleges in Hainan Province; 1 mixed-ownership institution, accounting for 7.14%; There are 7 private colleges, accounting for 50.00% of the total number of higher vocational colleges in Hainan Province. Among these were one vocational bachelor's degree university (Hainan Vocational University of Science and Technology), one high-level vocational college with Chinese characteristics, one national model higher vocational college, six high-level higher vocational colleges in Hainan Province, and six schools for the construction (cultivation) of high-level major clusters in Hainan Province.

Table 1

Overview of Hainan Vocational Colleges

School name	Location	Nature of Organization	Short Title	School Honors
Hainan College of Economics and Business	Haikou	Public Schools	JM	High-Level Vocational College With Chinese Characteristics National Model Higher Vocational College
Hainan Vocational University	Haikou	Mixed Ownership School	HZ	National Model Higher Vocational College National Model Higher Vocational College
Hainan Vocational College of Politics and Law	Haikou	Public Schools	ZF	Construction (Cultivation) Of High-Level Major Clusters In Hainan Province
Hainan College of Software Technology	Qionghai	Public Schools	RJ	National Model Higher Vocational College
Hainan College of Foreign Studies	Wenchang	Public Schools	WY	National Model Higher Vocational College
Hainan Provincial Sports Academy	Haikou	Public Schools	TY	
Hainan Technology and Business College	Haikou	Private Schools	GS	Construction (Cultivation) Of High-Level Major Clusters In Hainan Province
Hainan Health Management College	Chengmai	Private Schools	JK	
Hainan Health Vocational College	Haikou	Public Schools	WS	Construction (Cultivation) Of High-Level Major Clusters In Hainan Province
Hainan Vocational University of Science and Technology	Haikou	Private Schools	HK	National Model Higher Vocational College

School name	Location	Nature of Organization	Short Title	School Honors
Sanya Aviation and Tourism College	Sanya	Private Schools	HK	National Model Higher Vocational College
Sanya Institute of Technology	Sanya	Private Schools	LG	Construction (Cultivation) Of High-Level Major Clusters In Hainan Province
Sanya City College	Sanya	Private Schools	CS	Construction (Cultivation) Of High-Level Major Clusters In Hainan Province
Hospitality Institute of Sanya	Sanya	Private Schools	ZR	Construction (Cultivation) Of High-Level Major Clusters In Hainan Province

4.1.1 Overview of the scale and setup of the major

In 2023, Hainan Province's higher vocational colleges had a total of 116,705 full-time regular higher vocational students, including 74,879 students from regular high schools, 20,880 students from secondary vocational schools, 6,332 students enrolled through social recruitment, and 14,614 students from other sources, averaging 8,336 students per school. Hainan Province's higher vocational colleges offered 55 major clusters and 82 key majors, with 502 majors offered across all schools, averaging 35.86 majors per school and 232 students per major. These data not only reflect the continuous appeal of vocational education as a type of education but also indicate that the adjustment of majors in higher vocational colleges has stabilized under the backdrop of Hainan's free trade port.

According to the Ministry of Education's "Directory of Vocational Education majors (2021) in 2023, Hainan's higher vocational colleges offered 17 other major categories of majors besides the Resource Environment and Safety category and the Energy, Power, and Materials category. The college with the most major categories offered was HZ, which had 13 major categories, covering 31 majors. The institution with the fewest major categories is TY, which offers only the Education and Physical Education categories, covering six majors. The institution with the most majors was GS, which offered 52 majors. Each institution has different development orientations, leading to varying plans for major categories and numbers, but all have developed distinct major characteristics during their growth periods, as shown in Table 2.

Table 2

Hainan Vocational Colleges Major Setup in 2023

School name	Number of major categories	Coverage rate of major categories	Number of majors	Coverage rate of the number of majors
JM	7	36.84%	44	5.91%
HK	12	63.16%	44	5.91%
WY	5	26.32%	29	3.90%
TY	1	5.26%	6	0.81%
HK	10	52.63%	48	6.45%

School name	Number of major categories	Coverage rate of major categories	Number of majors	Coverage rate of the number of majors
CS	12	63.16%	29	3.90%
LG	8	42.11%	18	2.42%
ZR	6	31.58%	28	3.76%
GS	11	57.89%	52	6.99%
HZ	13	68.42%	31	4.17%
RJ	7	36.84%	28	3.76%
WS	2	10.53%	11	1.48%
JK	4	21.05%	13	1.75%
ZF	6	31.58%	17	2.28%

4.1.2 The major structure is aligned with the industry situation

The vocational colleges in Hainan generally exhibit a characteristic of focusing on the tertiary industry in their major offerings, while the majors related to the secondary and primary industries are relatively few, maintaining an overall major structure of "three-two-one." As shown in Table 3, the two institutions, CS and HZ, follow the "3-2-1" model, while the TY and WY follow the "3-0-0" model. The remaining 10 institutions follow the "3-2-0" model. Under the guidance of the "14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035" of Hainan Province, Hainan Province has established a layout of four major industries: tourism, modern services, high-tech industries, and tropical characteristic high-efficiency agriculture, aiming to promote the diversification and high-quality development of Hainan Province's economy. Nevertheless, the current major setup in vocational colleges in Hainan Province still tends to favour traditional fields closely related to the tertiary industry, such as finance and commerce, tourism, and cultural arts. This major layout aligns with Hainan's existing industrial structure and plays a supporting and promoting role in the local economic development. However, this emphasis on traditional fields in major settings also exposes the lag in the education system's ability to adapt to the needs of industrial transformation and upgrading, as well as the development of new business models, new technologies, and new industries. In particular, the limited establishment of majors for emerging industries such as high-tech industries, biotechnology, new energy, and new materials may weaken the competitiveness of Hainan Province in the new round of the technological revolution and industrial transformation

Table 3

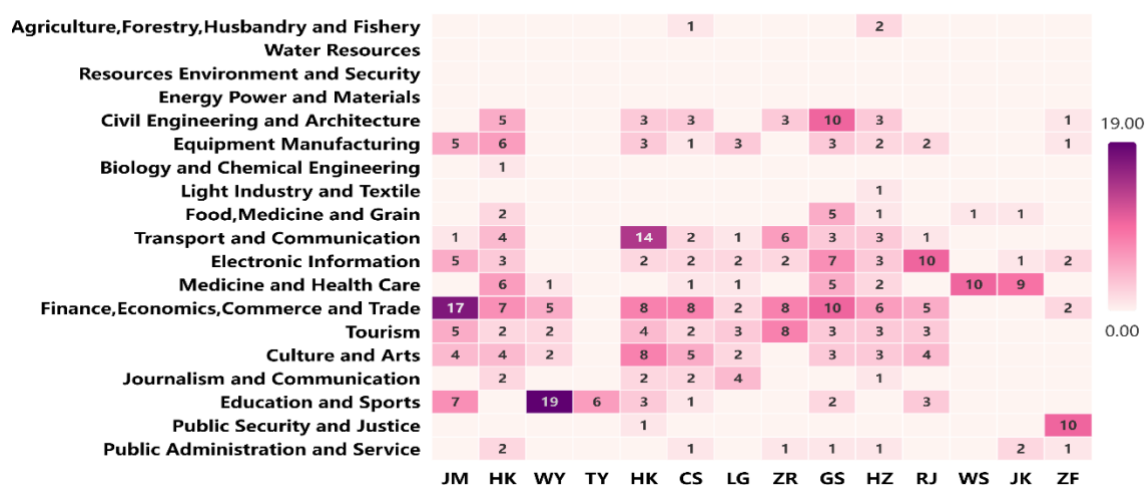*Major Structure and Enrolment Situation of Higher Vocational Colleges in Hainan, 2023*

School name	Major number			Proportion of majors			Planned enrollment numbers for the major			Proportion of enrollment in major programs		
	Primary industry	Secondary industry	Tertiary industry	Primary industry	Secondary industry	Tertiary industry	Primary industry	Secondary industry	Tertiary industry	Primary industry	Secondary industry	Tertiary industry
JM	0	5	39	0.00%	11.36%	88.64%	0	368	4116	0.00%	8.21%	91.79%
HK	0	14	30	0.00%	31.82%	68.18%	0	448	1552	0.00%	22.40%	77.60%
WY	0	0	29	0.00%	0.00%	100.00%	0	0	1740	0.00%	0.00%	100.00%
TY	0	0	6	0.00%	0.00%	100.00%	0	0	302	0.00%	0.00%	100.00%
HK	0	6	42	0.00%	12.50%	87.50%	0	456	3271	0.00%	12.24%	87.76%
CS	1	4	24	3.45%	13.79%	82.76%	16	168	611	2.01%	21.13%	76.86%
LG	0	3	15	0.00%	16.67%	83.33%	0	230	540	0.00%	29.87%	70.13%
ZR	0	3	25	0.00%	10.71%	89.29%	0	183	1417	0.00%	11.44%	88.56%
GS	0	18	34	0.00%	34.62%	65.38%	0	1548	4507	0.00%	25.57%	74.43%
HZ	2	7	22	6.45%	22.58%	70.97%	240	587	2154	8.05%	19.69%	72.26%
RJ	0	2	26	0.00%	7.14%	92.86%	0	103	1898	0.00%	5.15%	94.85%
WS	0	1	10	0.00%	9.09%	90.91%	0	32	1245	0.00%	2.51%	97.49%
JK	0	1	12	0.00%	7.69%	92.31%	0	53	1194	0.00%	4.25%	95.75%
ZF	0	2	15	0.00%	11.76%	88.24%	0	178	1663	0.00%	9.67%	90.33%

4.1.3 Major Categories Across Colleges

As shown in Figure 1, from the overall layout of the major categories of majors in Hainan's higher vocational colleges, these colleges exhibit a clear industry preference and adaptability to the needs of regional economic development in their major settings. The Finance and Trade category and the Electronic Information category each have 11 institutions offering majors, leading in numbers. The tourism (10 institutions) and transportation (9 institutions) categories were closely followed. The major categories were the Biological and Chemical Engineering category and the Light Industry and Textile category, each with only one institution offering majors.

Figure 1

Distribution of Major Categories in Hainan Vocational Colleges in 2023

Major Category	JM	HK	WY	TY	HK	CS	LG	ZR	GS	HZ	RJ	WS	JK	ZF
Agriculture,Forestry,Husbandry and Fishery								1		2				
Water Resources														
Resources Environment and Security														
Energy Power and Materials														
Civil Engineering and Architecture		5			3	3		3	10	3				1
Equipment Manufacturing	5	6			3	1	3		3	2	2			1
Biology and Chemical Engineering			1											
Light Industry and Textile										1				
Food,Medicine and Grain		2							5	1		1	1	
Transport and Communication	1	4			14	2	1	6	3	3	1			
Electronic Information	5	3			2	2	2	2	7	3	10		1	2
Medicine and Health Care		6	1			1	1		5	2		10	9	
Finance,Economics,Commerce and Trade	17	7	5		8	8	2	8	10	6	5		2	
Tourism	5	2	2		4	2		8	3	3	3			
Culture and Arts	4	4	2		8	5	2		3	3	4			
Journalism and Communication		2			2	2	4			1				
Education and Sports	7		19	6	3	1			2		3			
Public Security and Justice					1									10
Public Administration and Service		2				1		1	1	1			2	1

Scale: 0.00 – 19.00

From the major layout of the 14 higher vocational colleges in Hainan shown in Figure 1, it can be seen that the characteristic majors of each college are different, and homogeneous competition has not yet been fully formed. The niche distribution is relatively dispersed, which ensures the characteristic development of the colleges. The types of resources are diverse, and their allocation is relatively appropriate, highlighting the major advantages of each college.

4.1.4 Major concentration and agglomeration

The "Annual Report on the Quality of Higher Vocational Education in Hainan Province 2023" points out that in 2023, the higher vocational education in Hainan Province continues to focus on the strategic positioning of "three zones and one centre," aiming to build an important hub for the dual circulation of domestic and international markets. Each vocational college is deepening the integration of industry and education, enhancing the ability of their majors to serve the industry, meticulously planning the structure of vocational education majors, and ensuring that the major offerings are closely aligned with the development needs of Hainan Province's four leading industries; tourism, modern services, high-tech industries, and tropical characteristic efficient agriculture as well as the twelve key industries. This strategy has significantly enhanced the alignment between major education and local industrial chains, achieving a synergistic resonance between educational content and industrial development.

The concentration of majors refers to their distribution across different schools. The more schools offer the same major, the lower the concentration of that major, and the higher the duplication of that major. Conversely, the higher the concentration of a major, the more distinct are its

characteristics. The situation of the top ten majors by student enrolment in provincial vocational colleges in 2023 is shown in Table 4.

Table 4

Majors with High Duplication Rates in Hainan Vocational Colleges in 2023

Major code	Major name	Major category name	Number of institutions established	Number of enrolled students	Establishing a duplication rate
520201	Nursing	Medicine and Health Care	5	7931	35.71%
530302	Big Data and Accounting	Finance, Economics, Commerce and Trade	11	5449	78.57%
510202	Computer Network Technology	Electronic Information	6	3653	42.86%
590202	Human Resources Management	Public Administration and Service	5	3642	35.71%
540101	Tourism Management	Tourism	11	3358	78.57%
440501	Engineering Costing	Civil Engineering and Architecture	7	3345	50.00%
510203	Software Technology	Electronic Information	7	2925	50.00%
540106	Hotel Management and Digital Operations	Tourism	11	2866	78.57%
460702	New Energy Vehicle Technology	Equipment Manufacturing	7	2822	50.00%
530701	E-Commerce	Finance, Economics, Commerce and Trade	9	2746	64.29%

As shown in Table 4, in 2023, among the top ten majors with the highest number of majors set up in Hainan vocational colleges, nursing, big data, and accounting had more than 5,000 students each. The duplication rate for the four major types of big data: accounting, tourism management, hotel management, and digital operations, exceeds 70%. This aligns with Hainan's development of a modern service industry dominated by tourism and hospitality, indicating that Hainan's vocational colleges

exhibit a phenomenon of homogenization in the layout of these majors, lacking distinct major characteristics and concentration.

Table 5 shows that among the 14 higher vocational colleges in Hainan, there are four schools with a concentration of three or below, accounting for 28.57% of the total number of higher vocational colleges in Hainan. Compared to Liu and Chen's (2021) study, the major concentration of the three higher vocational colleges, ZR, WS, and JK, increased by 55.6%, 10%, and 8.3%, respectively. The major concentration in TY remained unchanged, while that in the remaining ten higher vocational colleges generally decreased, with a decline of 37.38%.

Table 5

Major Concentration of Higher Vocational Colleges in Hainan, 2023

School name	JM	HK	WY	TY	HK	CS	LG	ZR	GS	HZ	RJ	WS	JK	ZF
Number of major categories	7	12	5	1	10	12	8	6	11	13	7	2	4	6
Number of majors	44	44	29	6	48	29	18	28	52	31	28	11	13	17
Major concentration	4.89	3.67	5.80	6.00	4.80	2.42	2.25	4.67	4.73	2.38	4.00	5.50	3.25	2.83

Changes in the concentration of majors reflect adjustments and optimizations in the major offerings of higher vocational colleges. It is not difficult to see that 10 institutions, including those in JM, have reduced the redundancy in their major offerings and enhanced the differentiation and specialization of their majors to meet market demands and promote educational diversity.This change helps to improve the quality of education and students' employ ability, and it may also be related to the reallocation of educational resources by institutions to better serve local economic and industrial development. The increase in the concentration of majors at the three institutions, including ZR, reflects the strengthening of these institutions' major advantages and characteristics in specific fields. The increase in concentration may be due to increased investment by the institutions in these major clusters or closer integration with local industrial chains to meet the demand for specialized talent in specific industries, the concentration of TY means that the major setup in this field has become relatively stable or that the development strategy of institutions in this area has not undergone significant changes. Overall, changes in the concentration of majors in Hainan's vocational colleges reflect the flexibility and responsiveness of these institutions in adapting to local industrial development and educational needs.

4.2 Analysis of the Deviation in the Structure of Higher Vocational Majors, Industrial Structure, and Employment Structure in Hainan Province

4.2.1 Major Concentration and Agglomeration

The deviation between the major and industrial structures is calculated according to Formula (1). Table 6 shows a certain degree of discrepancy between the major structure of Hainan vocational colleges and the industrial structure, as evidenced by the changes in deviation. The deviation of the primary industry is -91.53%, indicating that the major setup is relatively insufficient compared to industrial demand, which is related to the trend of the decreasing proportion of the primary industry in Hainan's industrial structure; the deviation of the secondary industry is -9.18%, which is close to a balanced state but still has a slight deviation. This means that the major setup is aligned with the

demands of the secondary industry; however, there is still room for fine-tuning. The deviation of the tertiary industry is 32.93%, indicating that the major setup is relatively excessive compared with the demand of the industry. Although this is related to Hainan's strategy of vigorously developing modern services, tourism, and high-tech industries, further research found that compared to 2022, the number of majors in the primary and secondary industries at Hainan vocational colleges has decreased, while the number of majors in the tertiary industry has increased significantly, reflecting the impact of educational policies and market trends on major offerings.

Table 6

Deviation Between Higher Vocational Education Major Structure and Industry Structure in Hainan Province in 2023

Proportion	Primary industry	Secondary industry	Tertiary industry
Major structure	1.69%	17.42%	80.90%
Industrial structure	19.96%	19.18%	60.86%
Deviation	-91.53%	-9.18%	32.93%

Overall, although the major setup in the primary industry is negatively correlated with the industry's absorption capacity, this aligns with Hainan Province's goal of promoting tropical characteristic efficient agriculture, indicating that vocational colleges have the potential to expand their major offerings in this field. The major configuration of the secondary industry basically meets current demands, but it still needs to transition towards emerging fields such as resource environment, energy materials, bioengineering, and light industry textiles to support industrial upgrading. Although the major setup in the tertiary industry is relatively excessive, this excess is somewhat reasonable given its dominant position in the economy of Hainan Province. However, in response to the demand for transformation of the tertiary industry, vocational colleges need to make structural adjustments in their major layouts to adapt to the development of tourism, modern services, and high-tech industries. It is evident that the major layout of vocational colleges in Hainan should align with the local industrial development strategy, grasping the growth potential of emerging industries while also considering the modernization needs of traditional industries and ensuring a precise alignment between education and industrial demands.

4.2.2 Deviation between Industrial Structure and Employment Structure

The deviation between the industrial and employment structures was calculated using Formula (2). As shown in Table 7, the proportion of primary industry in the industrial structure is relatively low, accounting for less than 20%, but it occupies a higher proportion (32.6 %) in the employment structure. The negative deviation indicates that the primary industry absorbs more job opportunities than its actual contribution to the economy, leading to inefficient allocation of human resources and surplus rural labour. The proportion of the secondary industry is also relatively low, but its employment structure ratio is even lower at only 11%. The positive deviation indicates that the secondary industry's economic contribution is much higher than its employment absorption capacity, suggesting that this industry has high production efficiency and is characterized by being technology-intensive with low labour absorption, which means that it needs to enhance its attractiveness to the workforce, and the tertiary industry dominates, accounting for 56.5% of the employment structure. A positive deviation indicates that the employment contribution of the tertiary industry is close to its economic contribution; however, there is still a gap. This suggests that the tertiary industry performs well in terms of absorbing employment, meeting market demand, and maintaining a healthy structure and economic output.

Table 7

Deviation of Industrial Structure and Employment Structure in Hainan Province, 2023

Proportion	Primary industry	Secondary industry	Tertiary industry
Industrial structure	19.96%	19.18%	60.86%
Employment structure	32.6%	11.0%	56.5%
Deviation	-38.77%	74.39%	7.71%

Overall, the employment absorption capacity of the primary industry is significantly higher than its actual contribution to the economic structure, showing considerable negative deviation. This reflects the industry's high dependence on labour, especially in rural areas, leading to issues of labour surplus and inefficient allocation of human resources. However, secondary industries exhibit a positive deviation from their employment absorption capacity. Although this industry makes a significant economic contribution, its employment structure is relatively low, indicating that it is primarily technology- and capital-intensive, with high production efficiency but limited labour demand. The tertiary industry, as the leading sector of Hainan Province's economy, has an employment structure and economic contribution that are relatively well-matched, demonstrating a strong capacity to absorb labour. However, despite the small degree of deviation, there is still room for improvement in the alignment between the employment structure and economic output in the tertiary industry. This can be achieved by further optimizing the structural layout to enhance its dual contribution to the local economy and employment.

4.2.3 Deviation between Major Structure and Employment Structure

The graduation data were oriented towards the three industries from the provincial and school-level "Annual Quality Report of Higher Vocational Education" to calculate the proportion of the major structure while also calculating the deviation between the major structure and the employment structure, as shown in Table 8.

Table 8

Deviation between Higher Vocational Majors and Employment in Hainan Province in 2023

Proportion	Primary industry	Secondary industry	Tertiary industry
Major structure	3.28%	25.09%	71.63%
Employment structure	32.6%	11.0%	56.5%
Deviation	-89.94%	128.09%	26.78%

Table 8 shows that the major and employment structures of higher vocational education in Hainan Province show significant deviations in the three major industries. The proportion of major structures in the primary industry is 3.28%, far lower than the employment structure proportion of 32.60%, with a deviation of -89.94%. This extreme negative deviation indicates that the primary industry's major supply is insufficient, failing to match the high demand for labour in this field. This may be because the primary industry has a lower technical level and production efficiency, leading to a large concentration of labour.

The proportion of specialized majors in the secondary industry was 25.09%, while the proportion of employment structure was only 11.00%, resulting in a deviation of 128.09%. This high positive deviation reflects that specialized majors in vocational education in the secondary industry far exceed the demand in the job market. This is especially true in technology-intensive industries, where the demand for labour is relatively low, leading to a disconnect between supply and actual employment.

The proportion of specialized structures in the tertiary industry is 71.63%, the proportion of employment structure is 56.50%, and the deviation is 26.78%, indicating that the majority in this industry is slightly higher than the employment demand. Although the tertiary industry dominates the economy of Hainan Province, the supply of specialized skills is relatively reasonable, and there may be an oversupply in certain areas such as tourism and modern services.

4.3 Analysis of the Grey Correlation and Time Lag of the Structure of Higher Vocational Majors, Industrial Structure, and Employment Structure in Hainan Province

4.3.1 Grey Relational Analysis

Referencing Liu et al. (2024)'s approach, use the entropy method and grey relational model to conduct grey relational analysis. Using the entropy method formula (4)-(7), the comprehensive scores of Hainan Province's economic structure from 2016 to 2023 were calculated, as shown in Table 9 below.

Table 9

Comprehensive Scores of Hainan Province's Economic Structure from 2016 to 2023

Year	2016	2017	2018	2019	2020	2021	2022	2023
Economic structure	0.7666	0.6597	0.5514	0.4899	0.3419	0.2865	0.3045	0.2816

Based on the comprehensive score of Hainan Province's economic structure obtained from Table 9 and using the grey relational model formulas (8)–(13), the correlation between the vocational education structure and the economic structure of Hainan Province was analysed. The grey relational degree levels are listed in Table 10.

Table 10

Grey Relational Grade Table

Level	Excellent	Good	General	Difference
Value	>0.95	>0.8	>0.6	<=0.6

According to the analysis in Table 11, the correlation of major categories such as Finance Economics Commerce and Trade, Education and Sports, Transport and Communication, Tourism, Electronic Information, Medicine and Health Care are all above 0.6, indicating that the vocational majors in these fields are significantly related to the economic structure of Hainan Province, reflecting the important position of these related industries in the regional economy. However, major disciplines with a correlation below 0.6, such as Public Security and Justice, Culture and Arts, and Equipment Manufacturing, show relatively weak adaptability to the current economic structure of Hainan Province, reflecting that the demand for these major fields in the regional economy is relatively limited or lagging behind, which indicates that the seven major fields of study with a high correlation to the economic structure have played an important role in the adjustment of Hainan Province's economic structure, while the contribution of the other 12 fields of study to the economic structure is relatively insignificant.

Table 11

Grey Relational Degree between Hainan Province's Economic Structure and Higher Vocational Education Major Structure

Evaluation items	Relational Degree	Rank
Finance, Economics, Commerce and Trade	0.761	1
Education and Sports	0.665	2
Transport and Communication	0.622	3
Tourism	0.622	4
Electronic Information	0.618	5
Medicine and Health Care	0.605	6
Civil Engineering and Architecture	0.601	7
Public Security and Justice	0.581	8
Culture and Arts	0.579	9
Equipment Manufacturing	0.57	10
Public Administration and Service	0.563	11
Food, Medicine and Grain	0.553	12
Agriculture, Forestry, Husbandry and Fishery	0.55	13
Journalism and Communication	0.546	14
Biology and Chemical Engineering	0.545	15
Energy Power and Materials	0.544	16
Light Industry and Textile	0.544	17
Resources Environment and Security	0.544	18
Water Resources	0.543	19

4.3.2 Analysis of the Time Lag Between Major Structure, Employment Structure, and Industrial Structure

4.3.2.1 Moore Value Analysis

Referring to the methods of scholars such as Ma and Zhang(2017), Shen(2018), and Zhu et al.(2024), Moore values were calculated, and a time-lag analysis was conducted using data on the proportion of graduates by major categories from 2016 to 2023 in Hainan Province's higher vocational colleges, the GDP proportion of the three major industries, and the employment proportion of the three

major industries. Moore value calculation formula (14) was applied to calculate the Moore values of the major, industrial, and employment structures of Hainan Province's higher vocational colleges from 2016 to 2022, as shown in Table 12.

Table 12

Moore Values of the Three Structures in Hainan Province from 2016 to 2022

Year	Industrial structure	Employment structure	Major structure
2016	0.0446	0.0246	0.1351
2017	0.0349	0.0451	0.1489
2018	0.0208	0.0047	0.0700
2019	0.0196	0.1421	0.0995
2020	0.0229	0.0104	0.0821
2021	0.0241	0.0277	0.1430
2022	0.0110	0.0116	0.1290

As shown in Table 12, between 2016 and 2022, the regional industrial structure exhibited a relatively stable trend of change: despite experiencing a decline and slight recovery, the overall fluctuation was relatively small; the employment structure of the population, after a rapid rise in 2017, saw a significant decline in 2018, then quickly rebounded in 2019 and fluctuated again, showing considerable uncertainty; the structure of higher vocational majors also saw a significant decline in 2018, but subsequently gradually rebounded, indicating that its adjustment process lagged behind the changes in the industrial structure; overall, compared to the adjustments in industrial structure, the changes in employment structure and major structure appear to be more dynamic and sensitive, reflecting quicker adaptive adjustments and higher volatility. It is evident that, compared to the adjustment of the industrial structure, the adjustments in the employment structure of the population and the structure of higher vocational majors show more drastic fluctuations and significant instability.

4.3.2.2 Time Delay Analysis of the "Three Structures" Based on the Grey Absolute Correlation Degree Model and Time Shift Method

There exists a complex interactive relationship between the major structure, employment patterns, and industrial structure of vocational education, with the three mutually influencing and evolving simultaneously. First, with the optimization and upgrading of the industrial structure, it directly determines the direction of talent cultivation in higher vocational colleges, prompting schools to adjust their major offerings based on industry needs to meet the market demand for diverse talents. Secondly, the transformation of the industrial structure has also driven changes in the employment structure, and these changes in the employment structure, in turn, have influenced the establishment and adjustment of higher vocational majors, playing a "mediating" role. However, due to the uncertainty in the job market and the long training period for talent development, there is a certain lag in the interaction between the structure of higher vocational majors, employment structure, and industrial structure, making it impossible for them to occur simultaneously.

The changes in industrial structure not only directly affect the adjustment of higher vocational major structures but also indirectly influence them through the employment structure as an intermediary; when the major structure of higher vocational education affects changes in the industrial structure, this impact manifests in two forms of lag: direct delay and indirect delay through the

employment structure. Thus, using the grey absolute correlation degree model formulas (15)–(18), specific calculations and analyses of these two lags were conducted.

Based on formulas (15)–(18), the absolute grey relational degree of the three-structure Moore values with a step size of 0 to 6 is calculated; the specific method is to select the Moore values of the major and industrial structures from 2016 to 2012 as the characteristic benchmark sequence, while using the Moore values of the industrial structure and employment structure, and the employment structure and major structure from 2016 to 2022 as the behavioral sequence, by performing a time shift on the behavior sequence, with each shift being one year and the step size T being the time unit of the shift, the grey absolute correlation degree at each time point is gradually calculated, and the time delay T corresponds to the step length when the grey absolute correlation reaches its maximum value.

From Table 13, it can be seen that from 2016 to 2022, the direct lag of industrial structure on higher vocational major structure is 6 years, the lag of industrial structure on population employment structure is also 6 years, and the impact of population employment structure on higher vocational major structure also reaches its maximum correlation after 6 years; therefore, the regional industrial structure not only has a significant impact on the higher vocational education major structure through direct influence after 6 years, but also indirectly affects the higher vocational education major structure through the employment structure, with an indirect lag of 12 years, indicating that the changes in industrial structure have a relatively significant time lag effect on the major setup of higher vocational colleges, and this lag has a strong stability and regularity, revealing the dual mechanism of the impact of industrial structure adjustment on talent cultivation structure, both directly influencing the structure of higher vocational majors and indirectly adjusting major settings through employment structure, thereby highlighting the close relationship between higher vocational education and regional economic development.

Table 13

Grey Absolute Correlation Degree Between Different Structures at Various Step Sizes T

Step Sizes	Industrial→Major	Industrial→Employment	Employment→Major
0	0.7525	0.7942	0.7105
1	0.6705	0.7824	0.6073
2	0.6344	0.7278	0.5360
3	0.7547	0.7819	0.6063
4	0.6934	0.8030	0.5695
5	0.7443	0.7525	0.5534
6	0.7741	0.8262	0.7665

5. Discussion

5.1 Differences in the Alignment Between Vocational Education Major Structure and Industrial Structure

The issue of matching major offerings and industry demands in Hainan's vocational education, particularly deficiencies in the primary industry sector, has been frequently mentioned in the literature. According to research by Wang and Han (2024) on vocational colleges in Zhejiang, there are similar imbalances in major structures in that region, especially in the shortage of agriculture-related majors. Currently, the proportion of majors related to primary industry in Hainan is only 1.69%, which is far

below the demand ratio in the regional economy. This highlights a severe shortage of agricultural technical talent, making it difficult to meet the needs of modernization. This supply-demand gap indicates that Hainan's vocational education is significantly lagging in meeting the development needs of the industry, especially in the agricultural sector. According to Li(2024), the mismatch between industry and education major settings often leads to limited local economic growth in the coastal areas of Jiangsu Similarly, in Hainan, changes in industrial structure require vocational colleges to adjust their major settings more promptly to ensure the supply of labour and technical support for agriculture and other basic industries(Liu and Chen,2022).

For the secondary industry, although the major setup in Hainan is generally balanced with employment demand, there is still a significant lag in talent supply in emerging industries, especially in fields such as energy materials and environmental resources. This issue is also reflected in Ma & Li (2019) 's study of vocational colleges in Jiangsu Province, which suggests that vocational colleges should promptly adjust their major offerings according to the needs of emerging industries. As for the tertiary industry, the major offerings in Hainan are overly concentrated in the traditional service and tourism sectors, which aligns with the nationwide imbalance in major offerings at vocational colleges pointed out by Zhao and Qu (2024).Overproduction has led to employment pressure for graduates, particularly the surplus of low-skilled positions, which has become a key factor restricting improvement in employment quality.

5.2 Mismatch Between the Structure of Vocational Education Majors and Employment Structure

The mismatch between supply and demand in Hainan's vocational education is particularly prominent in the interaction between industrial structure and employment structure. According to Zhou (2021)'s research, the coupling coordination between the education structure and the employment market directly affects the employment rate of graduates. In Hainan's higher vocational colleges, the employment proportion in the primary industry is as high as 32.6%, but the proportion of related majors is only 3.28%, which leads to the ineffective transformation of rural labour into efficient modern agricultural talents. This imbalance not only restricts the process of agricultural modernization but also fails to fully leverage the supporting role of vocational education in the transformation of the local economy. Similarly, Shen (2018) pointed out that the structural adjustment of vocational education has a significant lag effect, affecting the coordination between market supply and demand. Hainan's vocational colleges still lag in responding to changes in industrial structure, failing to promptly adjust their major offerings to adapt to shifts in the job market.

For the secondary industry, excessive major has led to increased employment pressure, with graduates facing a "supply exceeds demand" situation in certain fields, especially in traditional manufacturing and some low-tech positions. Ma and Zhang (2020) also emphasized that if the major offerings of higher vocational colleges are disconnected from the demands of the job market, it will inevitably lead to a decline in the employment rate of graduates. Moreover, the employment ratio in Hainan's tertiary industry is 60.86%, but the proportion of related majors is as high as 80.90%, creating a situation of oversupply. An imbalance in the employment structure may exacerbate the surplus of low-skilled positions, while the supply of high-skilled positions is insufficient, further suppressing the employment competitiveness of vocational college graduates.

5.3 Time Lag Effect and the Response Mechanism of Higher Vocational Education

The adjustment of major offerings in Hainan's higher vocational education exhibits a significant time lag effect, a problem that has been validated by multiple domestic studies. Zhao et al. (2020) proposed that there is often a time lag between the adjustment of major offerings in higher vocational colleges and changes in industry and employment structures. This is especially true in rapidly changing industrial environments, where a lag in educational supply can lead to either a shortage or surplus of talent. Hainan vocational colleges are also facing similar challenges, especially in emerging industries such as information technology, energy, and environmental protection. The lag in major adjustments has already begun to affect the technological innovation and talent cultivation in these industries. Zou (2018) analysed the coordination between the structure of higher vocational majors and the industrial

structure using a regression model and found a significant lag effect. This phenomenon also exists in Hainan's higher vocational education system, limiting its ability to support industrial transformation.

To overcome this issue, Hainan vocational colleges should strengthen their alignment with the local economy and industries and establish a more flexible mechanism for adjusting majors. Simultaneously, improving the market feedback mechanism to promptly convey changes in industry demand to the education supply side will help alleviate the mismatch between supply and demand and the time-lag effect.

6.   Conclusions

This study employed methods such as deviation analysis, grey relational analysis, and time lag effect analysis to investigate adaptability issues between the major structure of higher vocational education and the industrial and employment structures in Hainan Province. Empirical analysis revealed a mismatch between the supply of majors in higher vocational education and the local economic demand in Hainan, as well as a lag in the response of higher vocational education to industrial structure adjustments. Based on the empirical analysis, the following two key conclusions were drawn:

6.1   There Is a Significant Supply-Demand Mismatch Between the Structure of Higher Vocational Majors and the Industrial and Employment Structures in Hainan Province

The primary industry's major setup shows a significant negative deviation from both the employment and industrial structures, with a deviation of -89.94% from the employment structure. This indicates that although the primary industry occupies a large proportion of the employment structure (32.60%), the supply of specialized majors in higher vocational education is far from sufficient, failing to meet its demand for labour. At the same time, the technological level of the primary industry is relatively low, production efficiency lags, and it relies heavily on a large workforce. Support from vocational education in technical fields such as modern agriculture and ecological agriculture is insufficient, limiting the transformation and upgrading of industry and improving productivity.

The major set-up in the secondary industry shows a significant deviation from employment and industrial structures, with a clear oversupply of majors. The deviation from the employment structure is 128.09% and that from the industrial structure is 5.91%. Although this industry is characterized by being technology-intensive and capital-intensive, the actual demand for labour is relatively low. This results in the number of graduates trained in vocational education far exceeding the employment absorption capacity, leading to a mismatch between supply and demand, wasting educational resources, and difficulty for graduates to find matching positions in the local market.

Tertiary industry, as the leading sector of Hainan's economy, has a relatively good alignment between its major setup and employment demand, as well as the industrial structure. However, the deviation from the employment structure was 26.78% and the deviation from the industrial structure was 10.77%. This indicates that in certain areas of the tertiary industry, especially traditional services and tourism, there is a certain degree of oversupply in major setup, leading to a saturated job market. Although the supply-demand matching degree of the tertiary industry is relatively high, optimization is still needed in some low value-added sectors. Particularly in high-end services and innovative industries, it is urgent to adjust the major layout to better support industrial upgrading and economic transformation.

6.2   There is a Significant Time Lag Effect in the Dynamic Matching of the Structure of Higher Vocational Majors, Industrial Structure, and Employment Structure in Hainan Province

Research has shown that the adjustment of the industrial structure in Hainan Province has a significant lag effect of six years on the major setup of higher vocational education. This means that, when local industries undergo changes, the major setup of Hainan's higher vocational colleges, owing to complex factors such as major adjustments, training majors, and resource allocation, has not been able to make adaptive adjustments quickly, thereby weakening its role in supporting local economic transformation and industrial upgrading.

Simultaneously, changes in employment structure also have a six-year lag effect on feedback on higher vocational major structures. Changes in labour market demand have not been conveyed in a timely manner to the decision-making level of higher vocational education, leading to a long-term misalignment between talent cultivation and market demand, which has exacerbated employment difficulties. This lag effect not only causes higher vocational colleges to respond slowly in the rapidly changing job market but also restricts their role in the dynamic adjustment of labour supply and demand.

Although Hainan's higher vocational colleges have a high degree of alignment with local economic needs in key industries, such as finance and trade, tourism, and electronic information, they are slow to respond to changes in industrial structure and employment demands, with significant lag effects.

Moreover, the supply demand matching issue in Hainan's higher vocational education is not only reflected in the mismatch and lag within individual industries but also presents an overall systemic lag phenomenon. There exists a complex interrelationship among the industrial structure, employment structure, and major structure, but this adjustment process does not proceed synchronously, especially with the supply-demand deviation being most prominent between the primary and secondary industries. This systemic lag effect further exacerbates the delay in vocational education's response to local economic demands, leading to a reduction in the efficiency of educational resource allocation and weakening its ability to drive regional economic transformation and improve the quality of talent supply.

7.   Innovations and Limitations

7.1   Innovations

Therefore, the marginal contribution of this study lies in the application of deviation analysis, which combines grey relational analysis and lag effect analysis to construct an interactive model of higher vocational education, industrial structure, and employment structure.

First, using the grey relational analysis method, we studied the degree of matching between the major structure of higher vocational colleges and the industrial structure, demonstrating its unique advantages in the face of data uncertainty. Second, by introducing a lag effect analysis, we explore the dynamic supply–demand relationship between the major setup of higher vocational colleges and the regional industrial and employment structure, quantifying the specific impact of this lag effect on economic development.

This study aims to provide a theoretical basis and empirical support for the optimization of the major structure of vocational colleges in Hainan with the expectation of enhancing the degree of matching between talent supply and industrial demand through resource allocation optimization, improving graduates' employment competitiveness, and promoting the coordinated development of regional industrial and employment structures, thereby driving the regional economy to achieve high-quality growth.

7.2   Limitations

This study evaluates the current situation of the major industrial and employment structure of higher vocational education in Hainan Province using a combination of deviation analysis and time lag. However, further improvements are required.

First, due to the lag in data release, this study's static analysis is limited to data collected from higher vocational institutions in Hainan by 2023. As of the completion of the studies, the data from higher vocational institutions in Hainan Province in 2024 were not released, so the latest data will be used in future research.

Second, following 2015, the Ministry of Education modified the catalogue of major categories of higher vocational education, resulting in substantial alterations to the names of major categories from 2015 onward. Consequently, a dynamic analysis of the data span was employed, and future policy samples could undergo further updates for comparative analysis.

Third, it should be noted that the present study exclusively incorporated data from Hainan Province. Therefore, expanding the scope to encompass data from more extensive regions should be considered, with the objective of facilitating cross-regional comparative research and analysis.

7.3   Policy Implications

7.3.1 Optimize the Configuration of Major Structures Should Be Optimized to Precisely Match the Industry's Development Needs

To address the mismatch between supply and demand in Hainan's higher vocational education and enhance the alignment between talent cultivation and industrial development, Hainan's higher vocational colleges should dynamically adjust their major offerings in conjunction with the "14th Five-Year Plan for National Economic and Social Development of Hainan Province and the Vision for 2035" and the needs of the Hainan Free Trade Port construction.

In the primary industry, to address talent shortage in the fields of modern agriculture, forestry, and fisheries, it is encouraged to establish majors such as "Modern Agricultural Technology, Ecological Agriculture," and Marine Fisheries Resource Management to promote the modernization of agriculture, forestry, and fisheries.

The secondary industry focuses on fields such as clean energy, new materials, and intelligent manufacturing, establishing specialized majors in "New Energy Materials Technology" and "Industrial Robot Applications" to support green development and industrial transformation, avoiding overcapacity in traditional industries. At the same time, in conjunction with the development of Hainan's low-altitude economy, it encourages the establishment of a "Drone Technology Application" major to cultivate high-skilled talent that meets the emerging technological demands of drone logistics and eVTOL.

The tertiary industry will focus on developing high value-added services, centering on the digital economy and data security needs of the Hainan Free Trade Port. It will guide the establishment of majors such as "Information Security Technology Applications," reduce the proportion of traditional service industry majors such as tourism management, and shift towards emerging fields such as smart tourism and cultural creativity.

Moreover, by empowering the construction of major connotations with artificial intelligence, we can improve the knowledge and competency maps of various disciplines and enhance their alignment with industry and employment opportunities.

7.3.2 Deepen the Integration of Industry and Education Mechanisms and Promote Collaborative Innovation and Cooperation Between Schools and Enterprises

Industry-academia collaboration plays an important role in maintaining a balance between supply and demand in higher vocational education. According to supply and demand theory, enterprises, as the demand side of the industry, can directly participate in the setting of majors and the development of courses through in-depth cooperation with higher vocational colleges, thereby enhancing the relevance and effectiveness of higher vocational education supply.

Hainan vocational colleges should leverage the policy support of the "Ten Measures to Support the Integration of Industry and Education in Vocational Education in Hainan Province" to encourage enterprises to participate in the school's teaching management process, jointly establish training bases and targeted training majors, and collaboratively build an ecosystem of deep integration between industry and education so that talent cultivation can more precisely meet market demands. Simultaneously, the government should implement incentive policies, such as tax breaks, intellectual property protection, and benefit-sharing, to stimulate enterprises' intrinsic motivation to continuously participate in higher vocational education.

On this basis, we should solidify the construction of a modern vocational education system at the provincial level, strengthen the integration of industry and education at the municipal level, and build a community of industry-education integration to enhance the alignment of skilled talent training with the needs of local economic and social development as well as compatibility with the transformation and upgrading needs of industry and enterprises.

Focusing on key areas of construction of the Hainan Free Trade Port, such as digital trade, tropical efficient agriculture, marine information technology, shipping services, aviation tourism, new media tourism, and intelligent language processing, we will jointly build a number of industry-education integration communities. By enhancing the ability and level of collaborative talent cultivation between industry and education, we can inject strong talent vitality and intellectual momentum into the high-quality development of the Hainan Free Trade port.

7.3.3 Build a Data Monitoring and Early Warning System to Dynamically Match the Development Needs of Education and Key Sectors

To enhance the flexible response of Hainan's higher vocational education supply to market demand, education and human resources authorities should jointly establish a big data monitoring and early warning system to help higher vocational colleges achieve dynamic adjustments in their major offerings. According to supply and demand theory, changes in market demand need to be monitored in real time to ensure that the education supply responds promptly to changes in industry demand.

Through big data platforms, collecting and analysing talent supply and demand information can assist Hainan's higher vocational colleges in regularly adjusting their major offerings, ensuring alignment with the job market, shortening adjustment cycles, and enhancing the agility of the higher vocational education supply.

In addition, the platform should play a warning role, monitor the enrolment and employment performance of various majors in real time, issue warnings for majors with insufficient enrolment or poor employment performance, and urge higher vocational colleges to adjust their enrolment scales in a timely manner based on data to avoid resource waste.

Simultaneously, the government should release reports on the demand for higher vocational majors and employment quality, guiding higher vocational colleges to optimize their major structures, especially in Hainan's four leading industries and 12 key areas. This should include financial support and policy incentives to promote the development of the relevant majors. This not only helps to dynamically adjust the supply of majors but also enhances supply–demand matching in key areas through early warning mechanisms, promoting the rational allocation and efficient use of higher vocational education resources.

7.3.4 Addressing the Time Lag Effect to Enhance the Adaptability Speed of Higher Vocational Education

To address the time-lag effect in Hainan's higher vocational education, the government and institutions must work together to promote systemic reforms.

From the government's perspective, it is essential to first establish a dynamic talent demand forecasting mechanism based on the industrial structure and employment adjustments. By utilizing information such as the quality assessment of vocational college majors, industrial statistical data, and employment demand statistics, a warning system that aligns with industrial and employment structures can be created, thereby providing a scientific basis for the adjustment of vocational education.

Simultaneously, vocational colleges should gain greater autonomy by shortening their adjustment cycle for major settings to enhance their sensitivity to market changes. This is particularly important because it relies on big data market warning mechanisms to monitor real-time changes in the demand for skilled technical personnel across various industries, thereby reducing the risk of supply–demand mismatches. Based on supply-demand theory, shortening the supply adjustment time can effectively reduce the likelihood of supply-demand imbalance.

Moreover, Hainan vocational colleges should adhere to "moderate and proactive" development, combining their own educational characteristics and goal positioning, scientifically predicting future trends in industrial structure adjustments and changes in talent demand in the labour market, and shortening the lag in adjusting industrial and employment structures.

In this process, enhancing the adaptability of the industry to the teaching staff is crucial. Promoting the construction of "dual-qualified" teachers, inviting corporate engineers and industry mentors to participate in teaching, and ensuring that course content can be updated in sync with

industrial technological changes are essential for comprehensively improving the adaptability of vocational education to changes in industry demands.

8.   Co-Author Contribution

The authors affirmed that there is no conflict of interest in this article. Author 1: Xia Liu carried out the statistical analysis, coordinated the research process, and revised the manuscript critically for important intellectual content. Author 2: Yuli Wang conducted the literature review and participated in the preparation of the research methodology. Author 3: Yunge Gao contributed to data collection and preliminary analysis. Author 4: Shanshan Li supported the fieldwork and data organization. Author 5: Xuan Zhuang contributed to the interpretation of the results and participated in manuscript revision. Author 6: Hongfeng Zhang (*Co-corresponding author) supervised the overall project and provided critical feedback on the manuscript.

9.   Acknowledgements

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