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Article

Studies on the quantification and time-sequence development of integration of industry and education level in higher vocational education-based on the panel data of China's provincial from 2016 to 2022

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Abstract: An extensive assessment index system was developed to evaluate the integration of industry and education in higher vocational education. The system was designed using panel data collected from 31 provinces in China between 2016 and 2022. The study utilized the entropy approach and coupled coordination degree model to examine the temporal and spatial changes in the level of growth of the integration of industry and education in higher vocational education, as well as the factors that impact it. In order to examine how the integration of industry and education in higher vocational education develops over time and space, as well as the factors that affect it, we utilized spatial phasic analysis, Tobit regression model, and Dagum's Gini coefficient. The study's findings suggest that between 2016 and 2022, the integration of industry and education in higher vocational education showed a consistent improvement in overall development. Nevertheless, there are still significant regional differences, with certain areas showing limited levels of integration, while the bulk of regions are either in a state of low integration with high clustering or low integration with low clustering. Most locations showed either a "low-high" or "low-low" level of agglomeration, indicating a significant degree of spatial concentration, with a clear trend of higher concentration in the east and lower concentration in the west. The progress of industrial structure and the degree of regional economic development have a substantial impact on the amount of integration of industry and education in higher vocational education. There is a notable increase in the amount of integration between industry and education in higher vocational education, which has a favorable effect. Conversely, the local employment rate has a substantial negative effect on this integration. Moreover, the direct influence of industrial structure optimization is restricted. The Gini coefficient of the development level of integration of industry and education in higher vocational education exhibits a slight rising trend. Simultaneously, there is a varying increase in the Gini coefficient inside the group and a decrease in the Gini coefficient between the groups. The disparities in the level of integration between Industry and Education in the provincial area primarily stem from inter-group variations across the locations. To promote the integration of industry and education in higher vocational education, it is recommended to strengthen policy support and resource allocation, address regional disparities, improve professional configuration, and increase investment in scientific and technological innovation and talent development.

Keywords: higher vocational education; integration of industry and education; coupling coordination degree; spatial correlation; Tobit model; degum Gini coefficient

1. Introduction

Given the swift progress of China's economy and society, there is now a significant emphasis on reforming and innovating the methods used to cultivate talent in the education sector. One of the notable advancements in China is the widespread implementation and promotion of the integration of industry and education (IIAE), which is a new and innovative educational paradigm. The notion of integrating industry and education was initially introduced in the Decision of the State Council on Accelerating the Development of Modern Vocational Education, which was announced in 2014. This was subsequently expanded upon and advanced in the Opinions of the General Office of the State Council on Deepening the Integration of Industry and Education. The 2019 Implementation Program for the Reform of the National Vocational Education has provided additional clarification on the key guiding principle of "Deep IIAE, Dual School-Enterprise and People". Recently, there has been a growing focus on integrating industry and education, as seen by the establishment of industry colleges, the collaboration between industry and education businesses, the development of industry and education cities, and the formation of industry and education communities. The proposal and implementation of the IIAE model holds significant practical importance in tackling the issues now encountered by China's vocational education sectors. These factors encompass the disparity between the curriculum and industry requirements, the insufficient practical skills possessed by students, the sluggish progress in establishing dual-teacher training programs, and the scarcity of valuable internships and training opportunities. However, when considering high-quality development, the level of integration between industry and education in higher vocational education (HVE) varies significantly both temporally and geographically. As a result, the current condition of imbalanced and insufficient development continues. Hence, assessing the amount of integration between industry and education in HVE holds immense importance in advancing the high-quality growth of contemporary vocational education and the sustainable progress of regional industries.

Currently, there is a significant amount of academic study being conducted on the IIAE. Several academics are currently studying the logical process of integrating industry and education (Liu et al., 2017; Luo, 2016; Yang et al., 2019; Zhou, 2018), the underlying meaning and features (Chen et al., 2014; Sun, 2017; Wang, 2014; Yang, 2014), the practical consequences (Pan and Wang, 2019; Wang and Du, 2022; Zhang et al., 2021; Zhuang, 2021), and the recommended approach for implementation (Chen, 2018; Hu and Zhang, 2019; Li and Liu, 2019; Xie, 2019). In addition, several academics are involved in the process of combining industry and education in relation to particular professions, such as the "1 + X" certificate (Du et al., 2019; Qin, 2020; Wang and Wang, 2019), the reformation of talent training methods (Shi and Hao, 2019; Zeng, 2022; Zhang, 2018), the establishment of dual-teacher teacher teams (Gu, 2019; Lou and Cen, 2020; Lu and Deng, 2021), and other related initiatives. Several researchers have performed regional case studies, namely focusing on Hainan (Liu and Chen, 2022; Wang et al., 2017), Guangdong (Chen, 2020; Chen, 2022), Jiangsu (Shi and Zhang, 2021), Zhejiang (Shen, 2017), and Chongqing (Ma, 2022). English terminology used in foreign nations to describe the IIAE primarily revolve around concepts such as university-industry collaboration, university-industry cooperation, industry-education integration, cooperative education, and similar terms. Foreign scholars have predominantly examined the implications, traits, structure, functioning, influential elements, and management of the merger of industry and education.

Alshehri et al. suggested that integrating industry and education can cultivate talents, improve the workforce, leverage technological advancements, foster collaboration in scientific research, and encourage entrepreneurial practices (Alshehri and Ebrahim, 2016). Whittle et al. argued that the IIAE should be interpreted as the coordination of education and socio-economic development, vocational school curricula, and the teaching mode advocated by Whittle and Hutchinson (2012). Lemos et al. and Dutrenit et al. categorized the relationship between industry and education into four distinct forms: two-way form, business form, service form, and traditional form (Lemos, 2017; Dutrenit and Arza, 2015). Their research focused on understanding the organization and mechanism of this integration. Franco et al. (2015) examined the incentive and manner in which teachers (or researchers) engage in the IIAE. Their research revealed a strong correlation between individual motivation to participate and motivation to participate in school. When examining the factors that impact the merging of industry and education, it becomes clear that the conditions of the school play the most significant role in this integration. These factors, namely the professional environment, teacher expertise, and administrative authority, influence the school's capacity to acquire and comprehend information on the integration of business and education. Consequently, this has an impact on the drive to execute the merger of industry and education (Chang, 2006; Santoro and Chakrabarti, 2002). Enterprises play a crucial role in the convergence of industry and education. The level of collaborative behavior will be influenced by the incentive and desire of corporations to engage with schools. Typically, businesses that prioritize immediate financial gain are less likely to participate in collaborative efforts. Therefore, when schools cooperate with such businesses, the possibility of negative consequences for pupils is increased (Siegel and Waldman, 2003). Lindelöf et al. suggested that the IIAE relies on the requirements of school and enterprise growth. However, they argue that the state should act to guarantee the efficient functioning of the integration model (Lindelof and Lofsten, 2004).

While there has been a significant body of research on the incorporation of industry and education in academia, there has been comparatively less focus on empirical research regarding the IIAE in HVE. Additionally, there has been limited investigation into the measurement and factors that influence the IIAE in HVE. The current study on the incorporation of industry and education in HVE is inadequate, especially when it comes to examining the spatial and temporal changes, factors that influence it, and regional disparities in this area. This is because it is challenging to get the appropriate level of quality in the merger of industry and education in HVE. This study utilizes academic research to develop a complete assessment index system for the IIAE in HVE. The study uses panel data from 31 provinces in China, spanning from 2016 to 2022, as a sample. The entropy approach (Liu and Zheng, 2023; Pan and Weng, 2021) and linked coordination degree (Liu and Zheng, 2023; Pan and Weng, 2021) were utilized. The study utilizes various analytical methods, including the model, spatial measurement (Geng and Tian, 2023), Tobit regression model (Liu and Liu, 2024), and Dagum's Gini coefficient (Shi, 2023), to thoroughly examine the coupling and coordination mechanism, spatial correlation, influencing factors, and geographical variations in the IIAE in HVE. The purpose of this analysis is to support the future growth of research in this sector. The extensive and comprehensive research conducted in the field of integrating industry and education in HVE will offer a more varied and focused approach to the high-quality advancement of this integration. Moreover, it will offer a stronger theoretical foundation and practical direction for the development of appropriate policies and operational procedures.

2. Materials and methods

2.1. Construction of the indicator system

2.1.1. Development of the HVE system

The Opinions on Deepening the Reform of the Construction of Modern Vocational Education System represents a significant policy document, which aims to guide the in-depth development of vocational education in China. It clarifies the orientation shift of vocational education functions, focuses on serving the comprehensive development of human beings, and embodies a profound understanding of the nature and goals of vocational education. Consequently, this study employs the methodology of Liu and Liu (2024) to select four secondary indicators, including funding input, teacher input, enterprise input, and employment level. Additionally, it combines this with the Annual Quality Report of HVE about the IIAE to select the level of school-enterprise cooperation as a secondary indicator. This yields a total of five secondary indicators, which are further divided into twenty-two tertiary indicators (**Table 1**).

Table 1. Indicator system for the IIAE in HVE.

Goal layer	Factor layer	Indicator layer	Unit	Attribute	Weight
The development of HVE	Funding input	Annual per-student government funding level	CNY	+	5.08%
		Annual per-student government special funds	CNY	+	11.63%
		Per-student teaching and research equipment value	CNY/student	+	10.81%
		Per-student on-campus practical teaching positions	positions/student	+	8.03%
	Teacher investment	Student-teacher ratio	-	+	0.76%
		Proportion of full-time teachers with dual skills	%	+	0.53%
		The proportion of full-time teachers with senior professional technical positions	%	+	1.16%
	Enterprise investment	Value of on-campus practical teaching equipment provided by enterprises	10,000 CNY	+	7.35%
		Total annual class hours provided by part-time enterprise teachers	class hours	+	4.39%
		Annual payment for part-time enterprise teachers	10,000 CNY	+	13.80%
	Employment level	Number of employed graduates	people	+	3.42%
		Employment rate	%	+	0.19%
		Local employment rate	%	+	1.18%
		Monthly income	CNY	+	1.06%
		Proportion of self-employed graduates	%	+	2.59%
		The proportion of graduates promoted within three years	%	+	0.76%

Table 1. (*Continued*).

Goal layer	Factor layer	Indicator layer	Unit	Attribute	Weight
	Level of school-enterprise cooperation	Number of majors with school-enterprise co-developed textbooks	books/majors	+	4.66%
		Annual income from technical services provided to enterprises by schools	10,000 CNY	+	13.29%
		Number of employees trained for cooperative enterprises by schools	person-times	+	5.35%
		The proportion of school-enterprise co-developed courses to total courses offered	%	+	1.80%
		Proportion of majors with cooperative enterprises to total majors offered	%	+	0.59%
		The proportion of students order-trained by key cooperative enterprises to full-time vocational students	%	+	1.58%
Industrial development	Industrial scale	GDP	100 million CNY	+	9.93%
		Per capita GDP	CNY	+	7.84%
		Added value of other industries (services)	100 million CNY	+	10.46%
		Total retail sales of consumer goods	100 million CNY	+	10.61%
	Industrial quality	Proportion of R&D expenditure to regional GDP	%	+	5.30%
		Proportion of technical market transaction volume to GDP	%	+	18.65%
		Proportion of enterprises with R&D activities	%	+	5.48%
		Proportion of new product development expenditure to main business income	%	+	5.65%
	Industrial structure	The added value of secondary and tertiary industries to GDP	%	+	2.00%
		Theil index of industry	-	-	1.04%
		The ratio of added value of secondary industry to tertiary industry	%	+	9.33%
	Industrial profit	Per capita added value of employees in secondary industry	10,000 CNY/person	+	5.49%
		Per capita added value of employees in tertiary industry	10,000 CNY/person	+	5.21%
	Industrial sustainability	Sulfur dioxide emissions	10,000 tons	-	0.93%
		Electricity consumption	100 million kWh	-	2.08%

Source: Cai and He (2023), He and Wu (2019), He et al. (2024), Liu and Liu (2024), Song and Li (2019),

2.1.2. Industrial development system

China's socio-economic development has entered a new phase, that of high-quality development. This entails improving quality and cultivating excellence, a process that has been underway since the country's high-speed development. High-quality development, however, is more focused on the scale, quality, structure, profit, and sustainability of the development process. Accordingly, this study has selected five secondary indicators, including industrial scale, industrial quality, industrial structure, industrial income, and industrial sustainability, as well as fifteen tertiary indicators to construct the index system of the industrial development system (**Table 1**).

2.2. Data sources

The data presented regarding the progress of HVE in this study is obtained from the Annual Quality Report on HVE, which includes data from more than 1,400 higher vocational colleges and universities nationwide. The report covers the period from 2016 to 2022. The statistics are categorized based on the province where the school is situated. The statistics on the industrial development system in this study are obtained from panel data collected from the 31 province levels across China spanning from 2016 to 2022. The data sources consist of the China Statistical Yearbook, the China Education Statistical Yearbook, and the China Science and Technology Statistical Yearbook. The data is completed by employing linear interpolation to fill any missing variables.

2.3. Research methods

2.3.1. Entropy method

The entropy method is a widely utilized approach in data analysis. It is based on the concept of information entropy, which is used to assess the discrete nature of data and determine the importance and value of evaluation indicators. This method has significant application value in the fields of multi-indicator decision analysis and comprehensive evaluation. The greater the information entropy of a system, the higher the discrete degree of its data, which indicates a greater degree of uncertainty or variation contained in the data. Conversely, the greater the information entropy, the higher the degree of discrete data, and the greater the degree of uncertainty or variation. In this study, the entropy method is employed to calculate the coupling and coordination degree of HVE and industrial development. The specific calculation steps are as follows:

1) Programmability of indicators

In this study, let x_{ij} be the original data of the indicator and x'_{ij} be the normalized data. To avoid the occurrence of $x'_{ij} = 0$, it is necessary to define the positive indicator as:

$$x'_{ij} = \frac{x_{ij} - x_{jmin}}{x_{jmax} - x_{jmin}} \times 0.9999 + 0.0001 \tag{1}$$

It is necessary to define the negative indicator as:

$$x'_{ij} = \frac{x_{jmax} - x_{ij}}{x_{jmax} - x_{jmin}} \times 0.9999 + 0.0001 \tag{2}$$

where i is the number of evaluation years and j is the number of evaluation indicators.

2) Calculation of entropy values for evaluation indicators

Let E_j be the information entropy of the *j-th* item indicator; let constant

$$\mathrm{K} = \frac{1}{\ln \mathrm{m}} P_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}}$$

represents the proportion of indicator j in year i within that indicator. Consequently, there are:

$$E_j = -K \sum_{i=0}^{m} (P_{ij} \ln P_{ij}) \tag{3}$$

3) Calculation of weights of evaluation indicators

Let θ_j be the entropy value (weight) of the *j-th* indicator. Then, there are:

$$\theta_j = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)} \tag{4}$$

For the *j-th* indicator, the greater the entropy weight, the more significant the impact of the indicator on the system. Conversely, the lesser the entropy weight, the lesser the impact of the indicator on the system.

4) Composite score calculation

$$S_i = \sum_{i=1}^{n} \theta_j \times P_{ij} \tag{5}$$

2.3.2. Coupling coordination degree model

The term “coupling” originally refers to the interaction between two or more vibrating systems. However, in the present context, it is understood to encompass a broader range of interconnected systems or modes of motion that are influenced by interactions. These connections and influences can be multifaceted, exhibiting both positive and negative aspects. The coupling degree is employed as a measure to quantify the degree of such interconnections between systems, which directly reflects the interdependence of the systems. Given the extensive applicability of the coupling degree to diverse problems, this model is selected to assess the intertwined relationship between HVE and industrial development. The specific operational steps are as follows.

1) Construction of the coupling degree model

Let $X_1, X_2, \dots, X_m$ be m indicators for evaluating HVE, and $Y_1, Y_2, \dots, Y_m$ be n indicators for evaluating industrial development. The combined development value of the two indicators is then:

$$U(X) = \sum_{i=1}^{m} \alpha_i X_i' \tag{6}$$

$$U(Y) = \sum_{i=1}^{m} \beta_i Y_i' \tag{7}$$

$$0 \ll U(X) \ll 1，0 \ll U(Y) \ll 1 \tag{8}$$

The $U(X)$ and $U(Y)$ variables represent the comprehensive level of development of HVE and industry, respectively. The α_i and β_i variables represent the weights of the evaluation indexes of the two systems, respectively. The X'_i and Y'_i variables represent the standard values in the two systems. The coupling coordination degree is calculated as follows:

$$C = \frac{2\sqrt{U(X) \times U(Y)}}{U(X) + U(Y)} \tag{9}$$

The coupling degree, denoted by the letter C, is defined as a ratio between 0 and 1. When C is equal to 0, it indicates that the two systems are in an irrelevant state and develop in the direction of no need. Conversely, when C is equal to 1, the coupling degree is the largest, which indicates that the systems are benignly coupled with each other and tend towards a new, orderly structure. As C increases, it represents that the collaboration between the systems is more obvious and the coupling is more powerful.

2) Construction of the coupling coordination degree model

Although the coupling degree is used to measure the degree of interaction and interdependence between different systems or modules, the coupling degree itself does not contain information about the development level of a system. This means that even if there is a high degree of coupling between two systems, it is not possible to determine whether the development levels of these two systems match or whether they are evolving in concert. Therefore, there is a need to introduce the coupling coordination degree. The degree of coupling coordination not only considers the interactions and interdependencies between systems but also assesses the actual level of development achieved by these systems in the context of synergistic growth. In comparison to the coupling degree model, the coupling coordination degree demonstrates a greater capacity for explanatory power. The coupling coordination degree is calculated as follows:

$$D = \sqrt{C \times W} \tag{10}$$

$$W = a \times U(X) + b \times U(Y) \tag{11}$$

The degree of coupling coordination, denoted by D, is defined as the comprehensive evaluation index of the coupled system, denoted by W. The coefficients, a and b, are determined by the researcher and must satisfy the constraint that $a + b = 1$. Based on existing research results, it is assumed that the two factors are equally important. Therefore, $a = b = 0.5$ is used in this study.

The degree of coupling coordination can be divided into different intervals and used as the evaluation standard for the degree of coupling coordination. This study employs the uniform distribution function method, which is a mainstream segmentation method in the academic world, to discriminate the degree of coupling coordination and classify it into different categories, as shown in **Table 2**.

Table 2. The criteria for classifying the degree of coupling and coordination.

Coupling coordination level	Coupling coordination degree (D) value range	Coordination grade	Degree of coordination
Low Level (Disordered Development)	[0.0–0.1]	1	Extremely Uncoordinated
	[0.1–0.2]	2	Severely Uncoordinated
	[0.2–0.3]	3	Moderately Uncoordinated
Middle Level (Transitional Development)	[0.3–0.4]	4	Mildly Uncoordinated
	[0.4–0.5]	5	On the Verge of Uncoordination
	[0.5–0.6]	6	Barely Coordinated
	[0.6–0.7]	7	Primarily Coordinated
High Level (Coordinated Development)	[0.7–0.8]	8	Moderately Coordinated
	[0.8–0.9]	9	Well Coordinated
	[0.9–1.0]	10	Excellently Coordinated

2.3.3. Spatial correlation analysis

1) Spatial weighting matrix

Spatial measurement analysis is conducted using the geographic adjacency matrix. According to Equation (12), the adjacency between regions can be expressed in the form of a matrix. In this matrix, "0" signifies that two regions are not adjacent, while "1" indicates that two regions are adjacent.

$$w_{ij} = \begin{cases} 0 \\ 1 \end{cases} \tag{12}$$

2) Spatial autocorrelation measures

Global *Moran's I* Index. The Global *Moran's I* Index is a spatial statistical analysis tool utilized to assess the similarity or difference in attribute values of neighboring areas within the overall region. The value range of this index is limited to the interval [−1, 1]. When the global *Moran's I* index is close to −1, it indicates that the attribute values of neighboring regions exhibit a significant negative correlation, i.e., their attribute values are distributed in a manner that is disparate or opposed. A value close to 1 indicates a high degree of positive correlation between the attribute values of the regions in question, with a clear spatial clustering or similarity. Conversely, a value close to 0 indicates that the attribute values of the regions are independent of each other in spatial distribution, with no obvious spatial correlation. The calculation method is as described in Equation (13).

$$x = \frac{\sum_{i=1}^{n} \sum_{j \neq i}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{s^2 \sum_{i=1}^{n} \sum_{j \neq i}^{n} w_{ij}} \tag{13}$$

where x_i and x_j are the observations in region *i* and region *j*, $\bar{x}$ is the respectively, s^2 is the sample mean, w_{ij} is the spatial weight matrix, and *n* is the sample size.

Local *Moran's I* index. The local *Moran's I* index is a spatial statistical index used to measure the degree of association between the attribute values of a particular region and its neighboring regions and takes a range of values. The index can reveal patterns of agglomeration or dispersion within a localized space, which is important for understanding spatial heterogeneity within a region. Specifically, the local *Moran's I* index I_i reflects the similarity or difference in attribute values between a given region and its neighboring regions. When I_i is positive, it indicates that there is agglomeration of the same type of elements between the region and its neighboring regions, i.e., regions with similar attribute values are spatially adjacent to each other; whereas when I_i is negative, it indicates that there is agglomeration of different types of elements between the region and its neighboring regions, i.e., regions with large differences in attribute values are spatially adjacent to each other. Based on the localized *Moran's I* index, the type of agglomeration in each province can be identified. The calculation method is as in Equation (14):

$$I_i = \frac{x_i - \bar{x}}{s^2} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x}) \tag{14}$$

2.3.4. Tobit regression model

It can be reasonably assumed that the formation of the coupling coordination degree is primarily influenced by interactions within the coupled subsystems. Therefore, this study aims to identify the key factors that have a significant impact on the coupling coordination degree between the two systems of HVE development and industrial development. These factors will be used as the core explanatory variables for regression analysis. In order to reveal the coupled coordination mechanism in greater detail, several secondary factors from outside the coupled coordination system are also selected as control variables to consider the potential influence of the external environment on the coupled coordination degree of the system. As the measurements of the coupled coordination model are presented as non-negative random variables in the [0, 1] interval, this property makes the explanatory variables incompatible with the assumption of normal distribution that is usually required in linear regression (OLS). Consequently, to overcome this limitation, the Tobit model was selected to construct the regression equation in this study.

$$D_{it} = \alpha + \beta_1 IF_{it} + \beta_2 EF_{it} + \varepsilon_{it} \tag{15}$$

The above equation represents the coupling coordination degree of each region in 2016–2022. The variables D_{it} and i represent the coupling coordination degree and the provinces, respectively. The variable t represents the years. The variable IF represents the core explanatory variables affecting the coupling coordination degree. These include the number of graduates natively employed *(x1)*, the local employment rate of graduates (*x2*), the rationalization of the industrial structure (*x3*), and the seniorization of the industrial structure(*x4*). The variables *c1* to *c5* represent the control variables (*EF*). These include the regional economic development level (*c1*), the government macro-input level (*c2*), the science and technology innovation level (*c3*), the labor production level (*c4*), and the school-enterprise input level (*c5*). The variables α, β_1, and β_2 represent the coefficients of each variable. The variable ε_{it} represents the random error term. The control variables, *EF*, include the regional economic development level *(c1)*, government macro-input level *(c2)*, science and technology innovation level *(c3)*, labor production level *(c4)*, and school-enterprise input level *(c5)*. The coefficients of each variable, α, β_1, and β_2, and the random error term, ε_{it}, are also included. Among the core explanatory variables, industrial structure rationalization *x3* and industrial structure advanced *x4* are measured following the study of Gan et al. (2011). Among the control variables, the regional economic development level *c1* is selected based on the per capita GDP of each region, and the government macro-input level *c2* is selected based on the per capita per the proportion of the whole society's research expenditure to the GDP is employed as a proxy for the level of scientific and technological innovation. The GDP of each place is divided by the employed population of each place to obtain labor productivity. Finally, the amount of horizontal technical service, the number of technical transactions, the value of teaching equipment provided by enterprises, the annual honorarium paid to part-time teachers from enterprises, and the annual income of technical services provided by schools to enterprises are aggregated to obtain the level of university-enterprise input. The value of on-campus practice provided by the enterprise is included in the input level of the school enterprise. This value is calculated by summing the amount of horizontal technical services, the number of technical transactions, the value of teaching equipment provided by enterprises, the annual honorarium paid to part-time teachers from enterprises, and the annual income of technical services provided by schools to enterprises.

2.3.5. Dagum Gini coefficient

The Dagum Gini coefficient, used as a research tool to measure the inequality of factor distribution, exhibits its unique benefits and practical significance in this work. The Dagum Gini coefficient is used to measure and break down the variations in the level of integration between industry and education in HVE across the 31 provinces of China from 2016 to 2022. It not only provides an overall measure of the differences, but also further categorizes these differences into three parts: The intra-group Gini coefficient, the inter-group Gini coefficient, and the hyper-variable density. The study categorizes the 31 provinces into four groups: the eastern area, the central region, the western region, and the northeastern region, using the division method of the National Bureau of Statistics (NBS). The intra-group Gini coefficient measures the level of inequality inside a particular region, whereas the inter-group Gini coefficient measures the level of inequality between different regions. The hyper-variance density indicates if the inequalities are caused by the overlapping of these regions. The computation process of the Dagum Gini coefficient is as follows:

$$G_{ij} = \frac{\sum_{h=1}^{n_i}\sum_{k=1}^{n_j}|D_{ih} - D_{jk}|}{n_i n_j\left(\overline{D_i} + \overline{D_j}\right)} \tag{16}$$

$$G = G_N + G_J + G_C = \sum_{i=1}^{4} G_{ii}p_i s_i + \sum_{i=1}^{4}\sum_{j\neq i} G_{ii}p_i s_i B_{ij} + \sum_{i=1}^{4}\sum_{j\neq i} G_{ii}p_i s_i (1 - B_{ij}) \tag{17}$$

The variables *i* and *j* denote distinct regions. The variables n_i and n_j denote the quantities of provinces that pertain to regions *i* and *j*, respectively. The variables D_{ih} and D_{jk} reflect the level of development of integrating industry and education in HVE in the *h-th* province and city within region *i* and the *k-th* province within region *j*, respectively. The variables $\overline{D_i}$ and $\overline{D_j}$ indicate the mean value of the IIAE development in HVE in region *i* and region *j*, respectively. *G* is the overall Gini coefficient of the IIAE development level of HVE across all provinces. G_N, G_J, and G_C correspond to the intra-group Gini coefficient, inter-group Gini coefficient, and hypervariance density, respectively. p_i denotes the ratio of the number of provinces within region *i* to the total number of provinces and municipalities denoted by *r*. The proportion of the IIAE development level in region *j* to the IIAE development level of HVE in all provinces within the sample is denoted by s_j. The symbol B_{ij} represents the relative influence between region *i* and region *j*.

2.3.6. Grey prediction GM(1,1)

A grey prediction model, designated GM(1,1), was employed to forecast the coupling coordination of the regions in 2025. The following steps were taken to achieve this objective.

Firstly, define the original sequence.

$$X_0 = [X_0(1), X_0(2), \dots X_0(m)], X_0(k) \geq 0, k = 1,2,\dots, m \tag{18}$$

Secondly, the original sequence is accumulated to the first order to obtain the accumulated generating sequence.

$$X_1 = [X_1(1), X_1(2), \dots X_1(m)], X_1(k) = \sum_{i=1}^{k} X_0(i), k = 1,2,\dots, m \tag{19}$$

Again, establish a first-order linear differential equation of X_1.

$$\frac{dX_1}{dt} + aX_1 = \mu \tag{20}$$

Finally, the first-order linear differential equation is solved by using the least squares method to obtain the prediction model.

$$x_1^P \hat{X}(k+1) = [X_n(1) - \frac{\mu}{a}]e^{-ak} + \frac{\mu}{a}, k = 1,2,\dots m \tag{21}$$

Among them, μ is the gray action quantity, a is the gray development coefficient. If the test result satisfies both $P > 0.7$ and $C < 0.65$, the prediction result is relatively reliable.

3. Results

3.1. Analysis of the coupling coordination degree

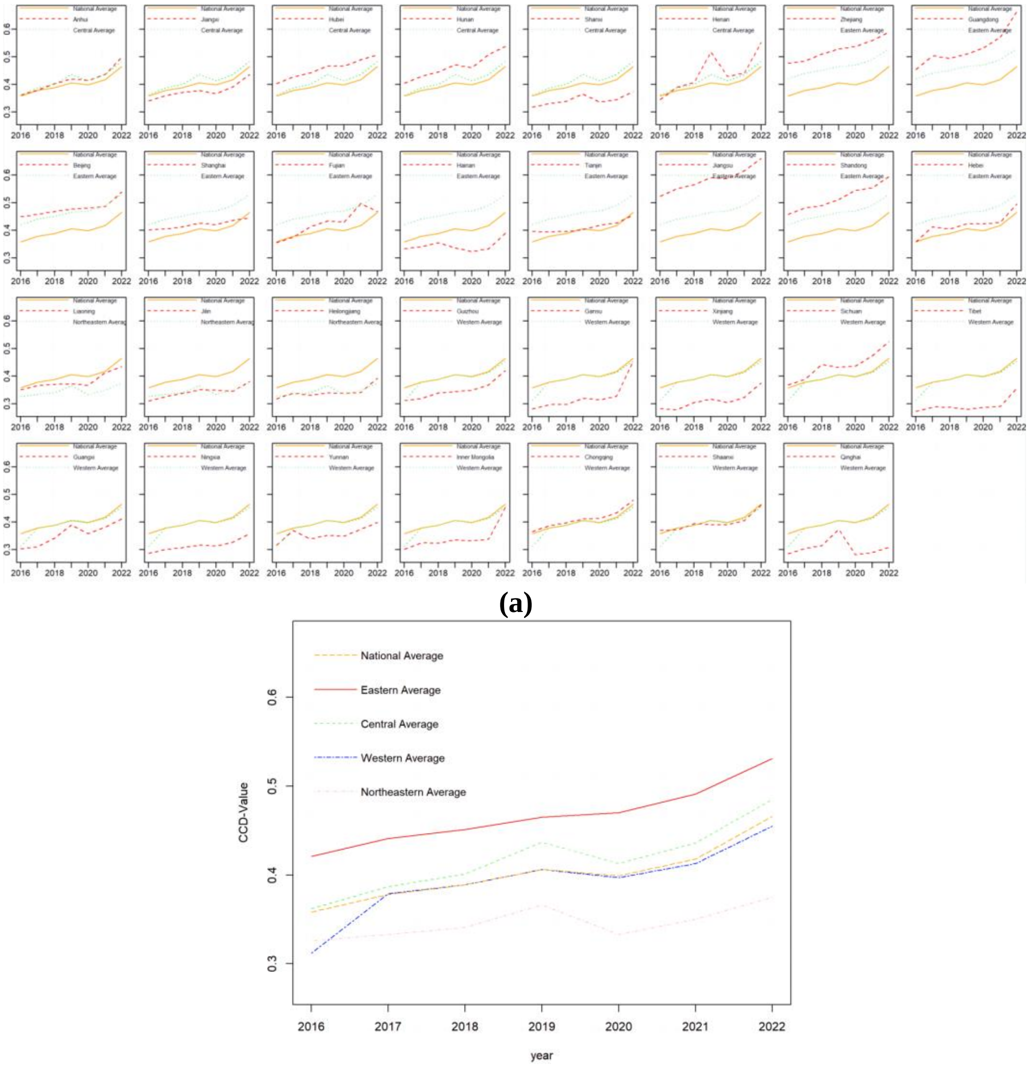
The degree of IIAE in HVE in each region is calculated and presented in **Table 3**. To facilitate a more intuitive observation and comparison of the trends in the degree of IIAE in HVE in each region, the trend graphs for the East, the Middle East, the West, the Northeast, and the entire country are plotted in **Figure 1**.

Table 3. The level of IIAE in HVE by location for the period 2016–2022.

Province	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Anhui	0.363	0.38	0.403	0.421	0.415	0.437	0.499
Beijing	0.45	0.458	0.469	0.477	0.481	0.486	0.539
Fujian	0.356	0.376	0.413	0.434	0.429	0.497	0.468
Gansu	0.282	0.297	0.298	0.321	0.315	0.328	0.455
Guangdong	0.454	0.505	0.495	0.51	0.533	0.572	0.666
Guangxi	0.303	0.31	0.343	0.39	0.358	0.381	0.412
Guizhou	0.312	0.319	0.339	0.344	0.35	0.369	0.421
Hainan	0.334	0.341	0.355	0.337	0.324	0.333	0.39
Hebei	0.358	0.413	0.404	0.424	0.423	0.429	0.496
Henan	0.345	0.39	0.408	0.518	0.43	0.442	0.553
Heilongjiang	0.317	0.339	0.331	0.339	0.338	0.341	0.393
Hubei	0.403	0.428	0.442	0.467	0.467	0.49	0.507
Hunan	0.404	0.43	0.445	0.472	0.461	0.509	0.538
Jilin	0.311	0.327	0.338	0.351	0.35	0.345	0.381
Jiangsu	0.524	0.551	0.566	0.592	0.587	0.616	0.662
Jiangxi	0.341	0.36	0.371	0.378	0.367	0.391	0.436
Liaoning	0.351	0.367	0.37	0.373	0.367	0.414	0.435
Inner Mongolia	0.302	0.325	0.323	0.337	0.332	0.338	0.454
Ningxia	0.287	0.301	0.307	0.316	0.313	0.328	0.358
Qinghai	0.286	0.305	0.315	0.374	0.282	0.29	0.309
Shandong	0.458	0.481	0.491	0.512	0.545	0.554	0.596
Shanxi	0.317	0.331	0.339	0.365	0.336	0.345	0.374
Shaanxi	0.37	0.372	0.394	0.39	0.39	0.406	0.463
Shanghai	0.402	0.405	0.413	0.427	0.421	0.437	0.446
Sichuan	0.369	0.389	0.442	0.432	0.437	0.474	0.526
Tianjin	0.396	0.394	0.396	0.403	0.419	0.426	0.456
Tibet	0.272	0.289	0.287	0.28	0.287	0.29	0.357
Xinjiang	0.281	0.278	0.305	0.318	0.304	0.323	0.376
Yunnan	0.316	0.37	0.339	0.352	0.35	0.374	0.399
Zhejiang	0.477	0.485	0.51	0.529	0.538	0.56	0.59
Chongqing	0.366	0.388	0.397	0.412	0.414	0.434	0.48
National Average	0.358	0.378	0.389	0.406	0.399	0.418	0.466
Eastern Average	0.421	0.441	0.451	0.465	0.47	0.491	0.531

Table 3. (*Continued*).

Province	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Central Average	0.362	0.387	0.401	0.437	0.413	0.436	0.485
Western Average	0.312	0.379	0.389	0.406	0.397	0.413	0.455
Northeastern Average	0.326	0.333	0.341	0.366	0.333	0.35	0.375



(a)

(b)

Figure 1. The trends in the level of IIAE in HVE. **(a)** the trends in the level of IIAE in HVE at the provincial, regional, and national levels; **(b)** the trends in the level of IIAE in HVE across the East, Central, West, Northeast, and Nationwide regions.

Time evolution analysis. As illustrated in **Table 3** and **Figure 1**, from 2016 to 2022, the national level of IIAE in HVE exhibits a notable upward trend. In 2022, the national average level rose by 30.17% compared to that in 2016. In total, 22 provinces exhibited a level of IIAE in HVE below 0.5 in 2022, representing 70.96% of the national sample. Specifically, after seven years of development, the coupling coordination degree of each province has exhibited varying degrees of growth. The number of provinces that have reached the level of barely coordinated and above has increased by eight compared with that of 2016. However, there are only two locations in Guangdong and Jiangsu that have reached the primary coordination level. The primary coordination has been achieved by seven provinces, including Shandong and Zhejiang, which have reached the degree of barely coordinated. Thirteen provinces, including Anhui and others, are on the verge of being out of order. Nine provinces, including Hainan, are mildly out of order.

Spatial difference analysis. Given the vast territory of China, each region exhibits significant differences in the structure of industrial development and the optimal allocation of resources. These differences inevitably lead to geospatial non-equilibrium in the level of IIAE in HVE. As illustrated in **Figure 1**, the development level of IIAE in HVE in the eastern region of China is leading, followed by the central region, followed by the western region, while the northeastern region is relatively lagging. Despite the continued significant difference between the east and the central and western regions, this gap is gradually narrowing. Concurrently, the difference between the central and western regions and the northeastern region is gradually expanding. Among the four major regions, the level of IIAE in the eastern and central regions is higher than the national average. This reflects the positive results of these regions in promoting the integration of HVE and industry. Specifically, the highest value of the coupling coordination degree appeared in Guangdong province in 2022, reaching 0.666, while the lowest value appeared in the Tibet region in 2016, only 0.272. This pronounced disparity not only reflects the uneven development of the IIAE in China's HVE but also further substantiates the distinctive pattern of large spatial disparities. It can be observed that the spatial disparity in the level of IIAE in China's HVE is pronounced, manifesting the spatial characteristics of "East > Central > West > Northeast." Moreover, the provinces of Jiangsu, Guangdong, and Zhejiang have consistently demonstrated a high level of coordination in the IIAE in HVE for an extended period. These provinces are located on the eastern coast and have a robust industrial foundation, a high level of economic development, and a robust scientific and technological innovation ecosystem. This has attracted a significant number of high-level and high-skilled talents, which has in turn facilitated the advancement of these provinces in the aforementioned integration. Nevertheless, it is equally important to acknowledge that even the Jiangsu and Guangdong provinces are only at the primary coordination stage in 2022. Furthermore, no province in China has yet entered the intermediate coordination or above stage in the level of development of the IIAE in HVE. This indicates that it is a long process to achieve the leap in the coupling coordination degree. Long-term moderate and mild dysfunction in the region, including Hainan, Heilongjiang, Jilin, Ningxia, Qinghai, Shanxi, Tibet, Xinjiang, Yunnan, Gansu, Guangxi, Guizhou, Jiangxi, Inner Mongolia, Liaoning, and Shaanxi, among others. The degree of coordination between these provinces has been less than 0.4 for an extended period. Most of these provinces are located in the central, western, and northeastern regions, where resource allocation is limited, economic development is below average, there is a lack of talent attraction, and scientific and technological innovation is underdeveloped. Additionally, industrial development is constrained, and there is a shortage of talent. The dearth of scientific and technological innovation and the constrained advancement of industry have resulted in a protracted period of minimal integration between industry and HVE.

3.2. Spatial correlation analysis

3.2.1. Global spatial autocorrelation

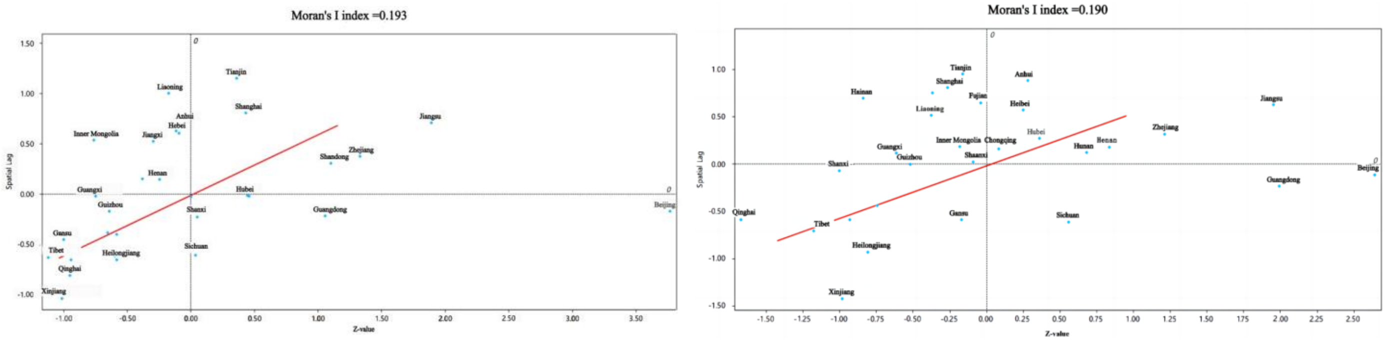
The results of the global *Moran's I* index for the coupling coordination degree are presented in **Table 4**. Overall, the global *Moran's I* indexes are all significantly positive, indicating that the IIAE in HVE has spatial autocorrelation and a spatial clustering effect. Concerning time, the global *Moran's I* index based on the geographic adjacency matrix exhibits a small fluctuation trend, and the spatial clustering effect shows volatility over time.

Table 4. The global index of coupling harmonization for the period 2016–2022.

Year	***Moran's I*** **index**	E(I)	sd(I)	***z*-value**	***p*-value**
2016	0.193	–0.033	0.101	1.954	0.025
2017	0.189	–0.033	0.123	1.923	0.027
2018	0.190	–0.033	0.119	1.931	0.027
2019	0.190	–0.033	0.120	1.927	0.027
2020	0.248	–0.033	0.111	2.428	0.008
2021	0.276	–0.033	0.104	2.676	0.004
2022	0.190	–0.033	0.102	1.927	0.027

3.2.2. Local spatial autocorrelation

The local *Moran's I* index of the coupling coordination degree allows for the in-depth analysis of the spatial clustering characteristics of the IIAE in HVE in China. The results presented in **Table 5** and **Figure 2** demonstrate that the majority of regions in China exhibit a "low-high" or "low-low" agglomeration state, indicating a strong spatial agglomeration. The "high-high agglomeration" is primarily observed in the economically more developed eastern and central regions, where the level of IIAE in HVE is relatively high, exhibiting a strong spatial spillover effect. This has a positive driving effect on the development of IIAE in neighboring regions. In contrast, the coupling coordination degree of "low-high agglomeration" regions is lower, but the coupling coordination degree of their neighboring regions is higher. This phenomenon indicates that these regions are lagging in the development of the IIAE in HVE. Concurrently, they are influenced by the radiation of neighboring high-level regions. The "low-low agglomeration" regions are predominantly located in the western and northeastern regions, where the level of IIAE in HVE is generally low and lacks obvious growth momentum, forming a relatively backward spatial agglomeration situation. It is noteworthy that the phenomenon of "high and low agglomeration" is most prevalent in provinces such as Beijing, Guangdong, and Sichuan. These areas exhibit a high degree of coupling coordination, yet the coupling coordination of neighboring provinces is comparatively low, indicating a "polarization" phenomenon. This polarization may be attributed to the advantages of these regions in terms of resources, policies, and other factors. However, it may also exacerbate the regional imbalance.



(a) **(b)**

Figure 2. *Moran's I* Index scatter plot for the years 2016 and 2022. **(a)** year=2016; **(b)** year=2022.

Table 5. Localized spatial autocorrelation of the level of industry-education integration in HVE across locations based on the geographic proximity matrix, 2016 and 2022.

Agglomeration state	Year=2016	Year=2022
HH	Tianjin, Shanghai, Jiangsu, Zhejiang, Shandong	Hebei, Jiangsu, Zhejiang, Anhui, Shandong, Henan, Hubei, Hunan, Chongqing
LH	Hebei, Inner Mongolia, Liaoning, Anhui, Fujian, Jiangxi, Henan, Hainan	Tianjin, Inner Mongolia, Liaoning, Shanghai, Fujian, Jiangxi, Guangxi, Hainan, Shaanxi
LL	Shanxi, Jilin, Heilongjiang, Guangxi, Guizhou, Yunnan, Tibet, Gansu, Qinghai, Ningxia, Xinjiang	Shanxi, Jilin, Heilongjiang, Guizhou, Yunnan, Tibet, Gansu, Qinghai, Ningxia, Xinjiang
HL	Beijing, Hubei, Hunan, Guangdong, Chongqing, Sichuan, Shaanxi	Beijing, Guangdong, Sichuan

Furthermore, the IIAE in China's HVE is undergoing a continual process of evolution, reflecting the broader trend of regional integration. For instance, the provinces of Hebei and Anhui, which were classified as part of the "low-high agglomeration" in 2016, and Hubei, Hunan, and Chongqing, which were designated as part of the "high-low agglomeration," have transitioned to the "high-high agglomeration" quadrant in 2022. In 2022, Hebei and Anhui, and Hubei, Hunan, and Chongqing, which were previously categorized as "high and low agglomeration," have transitioned to the first quadrant of "high and high agglomeration," indicating a notable advancement in the IIAE in HVE and a favorable trend of regional synergistic development. Conversely, Shanghai, which was previously categorized as a "high agglomeration" in 2016, is projected to transition to the "low agglomeration" quadrant in 2022. This shift may be influenced by a multitude of factors, including policy adjustments and alterations in resource allocation.

In the HH zone, the number of provinces nearly doubles and gathers to the east coast and central region. These regions and the neighboring regions essentially belong to the high-value zone, characterized by active economic development, high sustainability of industrial development, and the gathering of high-quality higher vocational colleges and universities. In the LH zone, the number of regions increases by one, with Hainan, Inner Mongolia, Liaoning, and Fujian being the only exceptions. This indicates that these regions are undergoing a process of positive development, driven by the neighboring regions, which are becoming larger. In 2022, Tianjin and Shanghai fell into the LH zone, indicating that although the level of coordination between the two places has improved, the gap with the neighboring regions has expanded, and the surrounding areas are now playing a more prominent role. The provinces of Guangxi, Chongqing, and Guizhou have been incorporated into the HL zone, indicating that the level of coordination among these three regions has improved. Concurrently, the gap between these regions and their neighboring areas has narrowed, with neighboring regions exerting a pull effect. The LL zone encompasses a greater number of provinces and regions and is primarily concentrated in the western and northern regions. Overall, the situation in this zone is relatively stable. However, Guangxi entered the LH zone in 2022, indicating that its influence on neighboring regions is evident, and its coordinated development is beginning to impact the neighboring regions. In the HL zone, the distribution of provinces is relatively dispersed, with a nearly doubled number. These geographic areas exhibit strong HVE and industrial development capabilities, as well as relatively high levels of coordination. However, they demonstrate a less pronounced radiating effect on the surrounding areas and, to a certain extent, exhibit a polarization effect.

3.3. Influence factor analysis based on Tobit regression modeling

Tobit regression analysis was conducted using Stata 18.0, employing Equation (16). The findings are displayed in **Table 6**. **Table 6** shows that, with the exception of the variable indicating the rationalization of industrial structure (*x3*), all other eight factors passed the significance test at the 5% statistical level. This suggests that the factors chosen for the study play a critical role in the IIAE in HVE.

Table 6. Results of the Tobit regression analysis of the development of the IIAE in HVE between the years 2016 and 2022.

D	Coefficient	St. Err.	*t*-value	*P*-value
x1	9.49×10^{-7}***	7.58×10^{-8}	12.51	0.000
x2	−0.0006815***	0.000144	−4.73	0.000
x3	0.0363067	0.0275607	1.32	0.189
x4	0.022011***	0.0037682	5.84	0.000
c1	0.0536387***	0.0101559	5.28	0.000
c2	9.97×10^{-8}**	4.40×10^{-8}	2.26	0.025
c3	0.0360952***	0.0060549	5.96	0.000
c4	0.0011996***	0.0002115	5.67	0.000
c5	6.05×10^{-10}***	1.55×10^{-10}	3.90	0.000
_cons	−0.3425058***	0.0986589	−3.47	0.001
LR chi2(8) = 457.73				
Prob > chi2 = 0.0000				
Pseudo $R^2 = -0.9689$				

***$p < 0.01$，**$p < 0.05$，*$p < 0.1$.

The advanced industrial structure (*x4*) has the most significant impact on the development level of the IIAE in HVE among the major explanatory variables. This suggests that there is a positive correlation between the amount of industrial advancement and the degree of IIAE in HVE. The advanced industrial structure encourages higher vocational institutions and universities to modify their professional arrangements, foster technical and talented individuals that align with industrial progress, and meet the demands of industrial development. The correlation between the local employment rate ($x2$) and the development level of IIAE in HVE is strongly negative. This means that as the local employment rate increases, the development level of IIAE in HVE decreases. There are four possible causes for this: Firstly, the process of allocating resources. Excessive focus on short-term job training may lead to neglecting the important task of integrating industry and education in a comprehensive manner, as well as hindering long-term development. Consequently, there may be a discrepancy between the curriculum of HVE and the requirements of the industry, resulting in a decrease in the level of collaboration between industry and education. Furthermore, the aspect of education quality. A high employment rate may suggest that vocational institutions value employment rates more than the quality of work. This can be observed as a prioritization of expedient student training to fulfill immediate workforce demands, rather than offering comprehensive and directly applicable industry education. This strategy may also diminish the correlation between HVE and industry, so impacting the degree of integration between industry and education. Furthermore, alterations in market demand. Given the fast and unpredictable changes in market demand, it may be essential to allocate additional time and resources to adapt the curriculum of HVE to match the advancements in new technologies and developing sectors. If the rate of change in the labor market surpasses the rate at which higher vocational schools adapt their curriculum, it could lead to a decrease in the level of industry and education integration. Furthermore, another aspect to consider is policy orientation. An excessive focus on short-term employment indicators in policy orientation may unintentionally neglect the importance of integrating industry and education during the production period. This may also result in a narrow emphasis on the contribution of higher vocational schools to the growth of local employment rates, instead of prioritizing the strengthening of their collaboration with industry.

Of all the control variables, the regional economic development level ($c1$) has the most significant impact on the development level of the IIAE in HVE. There are four things that may be related to this: Gross Domestic Product (GDP) per capita is a crucial metric that indicates the level of economic development in a region or country. The increase in GDP per capita signifies the expansion of economic activity and the rise in residents' income, hence enabling greater resources and support for HVE. The economic growth enables the government and businesses to allocate additional resources to HVE. This includes upgrading teaching facilities, increasing compensation for teachers, and expanding opportunities for practical training. These efforts contribute to the overall progress of HVE. Furthermore, economic expansion often involves the development and reorganization of industrial sectors. The demand for highly qualified technical and professional individuals will increase due to the creation of new sectors and the transformation and upgrading of established industries. The level of development of the IIAE in HVE plays a crucial role in developing talented individuals and immediately impacts the optimization of the industrial structure and the sustainable development of the economy. Thus, an increase in per capita GDP will facilitate a more comprehensive integration between HVE and industry, leading to enhanced relevance and efficacy in talent development. Moreover, the rise in per capita GDP typically coincides with the enhancement of inhabitants' quality of life and the advancement of the consumption pattern. The industry's need for highly skilled individuals will be fueled by a rise in consumer demand for high-quality products and services. This requirement will additionally enhance the collaboration between HVE and industry, fostering extensive cooperation between the two parties in talent cultivation, technological research, and development, thereby enhancing the advancement of the IIAE. Government policies are crucial in fostering the growth of the IIAE in HVE. With the rise in per capita GDP, the government may introduce supplementary measures to promote the progress of HVE and industry. These policies may encompass tax incentives, financial assistance, and collaborative project efforts. Implementing these regulations will foster a more favorable environment and circumstances for collaboration between HVE and industry, while promoting the further IIAE.

3.4. Regional difference analysis based on the Dagum Gini coefficient

Table 7 displays the extent of disparity and the percentage of contribution to the advancement of the IIAE in HVE. The Gini coefficient, which measures the inequality in the development level of IIAE in HVE, has shown a little increase from 0.097 in 2016 to 0.104 in 2022. This suggests that the disparities in the level of development of the IIAE. In China's provincial areas, there is a growing discrepancy in HVE between different regions. The Gini coefficient within this group has somewhat increased, whereas the Gini coefficient between the groups has shown a downward trend. This suggests that there are variations in the level of development of the IIAE in HVE, both within and among different locations. The discrepancies in the progress of integrating production and education in HVE, both within and across regions, are also undergoing transformation. An analysis of Dagum's Gini coefficient components shows that the contribution rate of intergroups has decreased over time. However, it still represents a significant proportion, remaining over 55%. On the other hand, the impact of intragroup and hypervariable density on the development level of IIAE in HVE in China's provincial areas is relatively low. This suggests that the differences in development mainly stem from intergroup disparities between regions, with the differences caused by the cross-over and overlapping of regions being relatively minor. The low density suggests that the variations in the level of industrial and educational integration in China's provincial areas are primarily attributed to intergroup disparities between regions, while differences resulting from the intersection and overlap of regions are relatively insignificant. The overlap leads to relatively insignificant inconsistencies.

Table 7. The Dagum Gini coefficient and contribution rate results.

Year	Gini Coefficient				Contribution Rate (%)		
	Overall	Within Group Gw	Between Group Gb	Super Variance Density Gt	Within Group Contribution Gw	Between Group Contribution Gb	Super Variance Density Contribution Gt
2016	0.097	0.019	0.070	0.008	19.924%	72.050%	8.027%
2017	0.098	0.020	0.069	0.008	20.703%	70.691%	8.606%
2018	0.098	0.021	0.067	0.011	21.131%	67.970%	10.899%
2019	0.102	0.022	0.065	0.015	21.613%	64.099%	14.288%
2020	0.111	0.024	0.074	0.013	21.296%	66.909%	11.795%
2021	0.115	0.025	0.073	0.017	22.033%	63.608%	14.359%
2022	0.104	0.025	0.060	0.018	24.182%	58.283%	17.535%

The analysis of Gini coefficient variations within Dagum’s group (**Table 8**) shows a consistent rise in the Gini coefficients across the four main locations. Consequently, the variations in the amount of IIAE in HVE have intensified across different locations within the four major regions. The average Gini coefficient across the four regions reveals that the eastern region has the highest Gini coefficient, indicating that the disparities in the level of development of the IIAE in HVE are most pronounced in various locations within the eastern region. The Gini coefficient in the western area is the second highest. Furthermore, the Gini coefficient of the center region is significantly greater than that of the northeast, positioning it in third place. The Gini coefficient in the northeast region is the lowest, suggesting that the disparities in the level of development and IIAE in the three northeastern provinces are the least pronounced. The average Gini coefficient between the east and the west is 0.15, significantly surpassing the Gini coefficients observed in other regions. This suggests that there is a significant disparity in the level of development of IIAE in HVE, between the Eastern and Western regions. The average Gini coefficient between the east and the west is very high, however the average Gini coefficient between the west and the northeast is 0.06, which is lower than the average Gini coefficients of other regions. This suggests that there is a significant level of IIAE in HVE across the western and northeastern regions. The average inter-group Gini coefficient between the West and the Northeast is 0.06, which is lower than the inter-group Gini coefficient between the other regions. Furthermore, this suggests that the disparity in the amount of IIAE in HVE is generally insignificant between the Western and Northeastern regions.

Table 8. Results of the decomposition of the differences in Dagum’s Gini coefficient.

Year		2016	2017	2018	2019	2020	2021	2022
Within Group	Northeast	0.027	0.026	0.025	0.021	0.018	0.044	0.03
	East	0.078	0.08	0.076	0.084	0.09	0.093	0.096
	Central	0.049	0.051	0.052	0.07	0.064	0.072	0.069
	West	0.06	0.064	0.071	0.068	0.077	0.083	0.08

Table 8. (*Continued*).

Year		2016	2017	2018	2019	2020	2021	2022
Between Group	East and Northeast	0.128	0.125	0.133	0.139	0.151	0.153	0.14
	East and Central	0.092	0.088	0.082	0.084	0.098	0.1	0.096
	East and West	0.152	0.15	0.146	0.141	0.163	0.164	0.134
	Central and Northeast	0.06	0.065	0.078	0.105	0.087	0.099	0.103
	Central and West	0.087	0.092	0.097	0.113	0.107	0.114	0.101
	West and Northeast	0.056	0.058	0.058	0.053	0.059	0.072	0.066

3.5. Prediction of coupling coordination based on GM(1,1)

The level of IIAE in HVE nationwide in 2025 was measured using the grey model GM(1,1), as shown in **Table 9**.

According to the data shown in **Table 9**, the coupling coordination degree of the majority of Chinese provinces has shown a rise compared to the year 2022. It is worth mentioning that 12 provinces have made significant progress, advancing to a higher level. Additionally, Guangdong and Jiangsu have reached an intermediate level of cooperation. Henan, Hunan, Shandong, and Zhejiang have achieved a primary level of coordination, while Anhui, Fujian, Hebei, and Chongqing have also achieved a primary level of coordination. Despite achieving a higher level of development, the provinces of Xinjiang and Yunnan are still on the brink of being out of sync. Furthermore, several regions are still in the early stages, suggesting that enhancing the degree of coupling coordination is a time-consuming endeavor. Attaining a substantial advancement in the short term is difficult, and noticeable variations persist among different regions. The coupling coordination degree of each location in 2025 is categorized by level and displayed in **Table 10**. **Table 10** indicates that the degree of coupling coordination at the primary coordination level, specifically above the eastern coast of the region, is mostly influenced by the level of dysfunction in the central, western, and northeastern regions. Furthermore, most provinces with a low level of coupling coordination demonstrate a comparable level of coupling coordination.

Table 9. The level of IIAE in HVE by region in 2025.

Province	Value	Province	Value	Province	Value	Province	Value
Anhui	0.55	Hebei	0.517	Liaoning	0.47	Sichuan	0.592
Beijing	0.564	Henan	0.606	Inner Mongolia	0.465	Tianjin	0.487
Fujian	0.559	Heilongjiang	0.398	Ningxia	0.38	Tibet	0.362
Gansu	0.482	Hubei	0.559	Qinghai	0.29	Xinjiang	0.413
Guangdong	0.747	Hunan	0.604	Shandong	0.67	Yunnan	0.406
Guangxi	0.469	Jilin	0.397	Shanxi	0.382	Zhejiang	0.653
Guizhou	0.467	Jiangsu	0.717	Shaanxi	0.489	Chongqing	0.522
Hainan	0.375	Jiangxi	0.459	Shanghai	0.469	-	-

Table 10. The coupling coordination degree of various regions in 2025.

Coupling coordination levels	The interval of coupling coordination degree D-value	Coordination level	The degree of coupling coordination	Including regions
Low-level (disorderly development)	[0.2–0.3]	3	Moderate imbalance	Qinghai
Middle -level (transitional development)	[0.3–0.4]	4	Mild disorder	Hainan, Heilongjiang, Jilin, Ningxia, Shanxi, Tibet
	[0.4–0.5]	5	Borderline disorder	Gansu, Guangxi, Guizhou, Jiangxi, Liaoning, Inner Mongolia, Shaanxi, Shanghai, Tianjin, Xinjiang, Yunnan
	[0.5–0.6]	6	Strenuously coordinated	Anhui, Beijing, Fujian, Hebei, Hubei, Sichuan, Chongqing
	[0.6–0.7]	7	Primary coordination	Henan, Hunan, Shandong, Zhejiang
High-level (coordinated development)	[0.7–0.8]	8	Intermediate coordination	Guangdong, Jiangsu

4. Conclusions and discussion

4.1. Conclusion

The study utilized panel data from 31 provinces in China spanning the years 2016 to 2022. We developed a comprehensive assessment framework for the IIAE in HVE. The entropy approach and coupled coordination degree model were utilized in conjunction with spatial analysis. The study utilized a phasic analysis, Tobit regression model, Dagum Gini coefficient, and spatial and temporal evolution analysis to examine the level of growth of the IIAE in HVE and the factors that impact it. The subsequent deductions were made.

The degree of IIAE in HVE is still rather limited. Between 2016 and 2022, the coupling coordination degree of the development level of the IIAE in HVE in each province showed a consistent increasing trend. It is evident that over time, every region has made substantial advancements in the incorporation of HVE and industry. Nevertheless, the general degree of development remains rather modest. In 2016, only the province of Jiangsu in China has achieved a level of IIAE in HVE that was considered slightly coordinated or above. In 2022, Guangdong and Jiangsu were added to this number. In 2022, the number of provinces experiencing dislocation and surpassing the degree of coordination and growth climbed to nine, which includes Jiangsu and Guangdong. The number of provinces experiencing dislocation and beyond the degree of coordination has reduced from 30 in 2016 to 22 in 2022. China's economic transition and pursuit of high-quality development are placing pressure on HVE to align with industry progress. Despite the crucial role that HVE plays in developing practical and technical skills, it faces obstacles in terms of aligning with industrial development. This lack of alignment has led to a limited integration between industry and education.

Regional differences exist in the IIAE within HVE. Geographically, the combination of industry and education in China's HVE typically follows a spatial pattern known as "East High, West Low," with significant regional differences. The amount of integration between industry and education in the eastern coastal provinces, like as Jiangsu, Zhejiang, and Guangdong, is often higher compared to the central, western, and northeastern regions. This pertains to the higher level of economic progress, industrial composition, and distribution of educational resources in the eastern region. Despite starting from a lower initial level, the growth rates in the central and western areas in recent years indicate their endeavors to narrow the gap with the eastern regions. The Northeast region has undergone consistent albeit somewhat sluggish expansion, necessitating additional governmental backing and resource allocation. In contrast, the Gini coefficient for the IIAE in HVE shows a moderate rising trend from 2016 to 2022, indicating that the gaps between provinces are steadily growing. While the inter-group Gini coefficient has decreased, the inter-group contribution rate has consistently exceeded 55%. This suggests that the disparities between provinces and regions are the main cause of variations in the development level of IIAE in HVE in HVE. The intra-group Gini coefficient is highest in the eastern region, suggesting that the disparities within this region are more pronounced compared to other economically advanced regions.

Several factors influence the level of development of the IIAE in HVE. The increase in local work opportunities and the sophisticated industrial infrastructure have had a beneficial influence on HVE, facilitating student employment. Nevertheless, the rise in employment has also revealed a discrepancy between HVE and the needs of industries, maybe due to a delay in updating instructional materials or a sluggish response to market dynamics. The streamlining of the industrial structure has had a minimal direct effect on the merger of industry and education. The manifestation of the adjustment effect may require a certain amount of time. The level of IIAE is significantly influenced by economic development, government intervention, scientific and technological innovation, labor productivity, and collaboration between schools and enterprises. The degree of IIAE is heavily impacted by a country’s economic development, the government’s participation in the sector, the amount of scientific and technological advancement, the efficiency of labor, and the extent of collaboration between schools and businesses. These elements can result in significant enhancements in the quality and flexibility of HVE for industry, as well as fostering a stronger link between higher vocational schools and industry.

The combination of the IIAE in HVE exhibits notable regional disparities and undergoes dynamic transformations in terms of development level. The IIAE in China’s provincial areas exhibits notable variations in development levels and undergoes dynamic shifts in spatial and temporal evolution. The marginal rise in the national Gini coefficient indicates a progressive widening of the inequality in development levels among provinces. Nevertheless, the variations in the intra-group and inter-group Gini coefficients offer valuable insights into the fundamental reasons for this disparity and the trajectory of its development. The within-group Gini coefficients of the four major regions are all increasing, suggesting that the disparity in development within each region is growing, especially in the eastern region. Furthermore, the disparities in the inter-group Gini coefficient among regions also indicate the unequal level of growth and IIAE in HVE across different regions, with the most significant disparity observed between the eastern and western regions. In terms of contribution rate, the between-group contribution rate remains the primary factor, while seeing a decrease. This suggests that the disparity in development between provinces and regions remains the primary factor influencing the overall level of development. The rates of intra-group contribution and hypervariable density contribution are rather low, but they are also exhibiting an upward trend. This suggests that the disparities within and between regions caused by overlapping are steadily intensifying.

4.2. Discussion

The data on the degree of coupling and coordination demonstrate that between 2016 and 2022, the level of IIAE in HVE in China has shown a significant upward trend, with an average annual increase of 4.17%. This indicates that China has made positive progress in promoting the level of i IIAE in HVE with industry over the past few years. Nevertheless, more than 70% of provinces have an integration level below 0.5, indicating that there is still considerable room for improvement in the national level of IIAE. Regionally, the eastern region has the highest IIAE level, which may be related to its stronger industrial foundation and economic development. In contrast, the central, western, and northeastern regions exhibit relatively lower levels of IIAE, which may be attributed to the allocation of resources, the level of economic development, and the attractiveness of talent. Notably, while provinces such as Jiangsu and Guangdong demonstrate superior performance in the IIAE, no province in China has yet reached the intermediate coordination stage or above in the development of the IIAE. This indicates that the advancement of the IIAE is a protracted and incremental process that necessitates persistent endeavors and policy backing. For instance, it is crucial to reinforce the distribution of resources to the central, western, and northeastern regions to augment local economic development, in addition to enhancing the appeal of talent. Furthermore, regions with a more robust industrial base, such as Jiangsu and Guangdong, are encouraged to continue to deepen the IIAE as a means of driving the development of other regions.

Moran’s index data indicate that the global *Moran’s I* index is significantly positive between 2016 and 2022. This indicates that the level of IIAE in HVE has a spatial clustering effect across the country. The existence of this clustering effect may be due to the influence of economic ties and policy orientation between regions. The volatility of the global *Moran’s I* index may reflect the adjustment of development policies and strategies for the IIAE in different regions, as well as changes in the external economic environment. The “high-high agglomeration” regions are mainly concentrated in the more economically developed eastern and central regions, which have a high level of IIAE and a strong spatial spillover effect. This may be related to their strong industrial base and high-quality educational resources. The existence of “low-high agglomeration” and “low-low agglomeration” regions indicates the unevenness of the level of IIAE in HVE in China. These regions may require more policy support and resource allocation to promote the level of IIAE. The polarization of the “high and low agglomeration” regions indicates that despite the high level of IIAE in certain provinces, their driving effect on the surrounding regions is limited. This may be addressed through regional cooperation and policy coordination. For instance, interregional economic cooperation and the sharing of educational resources could be strengthened to reduce the development gap between regions. Furthermore, it would be beneficial to consider the formulation of targeted strategies for the IIAE, particularly in regions with low concentrations of both industries. This would facilitate the advancement of the IIAE in these regions.

The Tobit regression analysis data indicate that the positive influence of an advanced industrial structure (*x4*) on the development level of the IIAE in HVE is the most significant. This suggests that an advanced industrial structure can effectively promote the adjustment of the professional layout of higher vocational colleges and the cultivation of technical and skilled talents to adapt to the needs of industrial development. The negative influence of the local employment rate (*x2*) indicates that an overemphasis on short-term employment and a neglect of the deep IIAE may result in a mismatch between the content of education and the demands of industry and a reduction in the level of IIAE. The considerable positive influence of regional economic development level (*c1*) indicates that an increase in the level of economic development provides more resources and support for HVE, thereby promoting the development of IIAE. The level of government macro-input, scientific and technological innovation capacity, labor productivity, and the level of school and enterprise input are also statistically significant, suggesting that these factors play a positive role in promoting the development level of IIAE in HVE. The positive influence of an advanced industrial structure on the IIAE can be enhanced by the government and higher vocational colleges and universities through the optimization of industrial layout and professional settings, as well as strengthened collaboration with industry. In contrast, the negative impact of local employment rates can be mitigated by higher vocational colleges and universities through the prioritization of quality employment and deeper integration with industries, thereby improving the long-term career development potential of graduates. Furthermore, it is necessary to increase macro-investment in HVE, improve scientific and technological innovation, enhance labor productivity, and promote school-enterprise cooperation. These measures will facilitate the joint promotion of the IIAE in HVE.

The Dagum Gini coefficient data indicate that the slight increase in the overall Gini coefficient between 2016 and 2022 suggests that the disparities in the level of development of IIAE in HVE between Chinese provinces and regions are gradually increasing. This reflects the imbalance in the allocation of educational resources, industrial development, and policy support in different regions. The rising trend of the intra-group Gini coefficient and the decreasing trend of the inter-group Gini coefficient indicate that the differences within regions are increasing, while the differences between regions are relatively decreasing. This is due to the unbalanced development within regions or the increase in inter-regional cooperation and resource sharing. The contribution rate between groups has decreased, yet it remains at a high level. This indicates that inter-regional differences remain the primary source of differences in the level of development of IIAE in HVE. Consequently, the education sector must pay attention to and take measures to reduce inter-regional disparities in education and industrial development. Concerning intra-regional differences, the eastern region exhibits the largest intra-regional differences, while the northeastern region exhibits the smallest. The Northeast may appear to be more balanced than other regions due to its relatively lower overall economic and industrial development, which has resulted in smaller differences in the level of IIAE in education. Consequently, there is a particular need to enhance the balanced allocation of educational resources in the weaker economic regions to reduce inter- and intra-regional differences. It is recommended that inter-regional educational cooperation and resource sharing be encouraged, particularly between eastern and western regions, to promote the balanced development of the level of IIAE in HVE.

4.3. Policy recommendations

Strengthen policy support and resource allocation. To enhance the level of IIAE in HVE, the government should increase financial investment, especially in the central western, and northeastern regions, to reduce regional development differences. In terms of policy, school-enterprise cooperation should be encouraged, and enterprises should be incentivized to participate in vocational education through tax concessions, capital subsidies, and other measures. Concurrently, the government may establish a dedicated fund to support initiatives for the IIAE and facilitate the synchronization and updating of educational content in alignment with industrial requirements. Furthermore, the government should provide guidance and assistance to higher vocational colleges and universities, to optimize their curricula and enhance students' practical skills and innovation abilities.

Coordinate regional differences and optimize professional structure. Higher vocational colleges and universities should address regional differences in equal pay, optimize the professional structure and layout, and prioritize the development of professions closely related to the local economy. Schools should enhance vocational guidance for students, provide more internship opportunities that are connected with the job market, and ensure that students can equally enjoy the economic opportunities brought by education. Furthermore, higher vocational colleges and universities should collaborate with local governments and enterprises to analyze regional economic development trends and adjust professional settings promptly to align with market demands.

Increase investment in scientific and technological innovation and talent cultivation. Higher vocational colleges and universities should strengthen R&D cooperation with enterprises and jointly develop new technologies and products. Schools should enhance the scientific research capabilities and practical experience of their teaching staff, and provide students with opportunities to engage with cutting-edge science and technology. These measures will enhance labor productivity and facilitate the deep integration of HVE and industry. Concurrently, higher vocational institutions should prioritize talent cultivation, offer a range of learning pathways, and cultivate students' innovative thinking and problem-solving abilities.

4.4. Limitations and future work

This paper is subject to certain limitations. Primarily, the data available for analysis is limited to the year 2022, which may not fully reflect the most recent developments in each region. Secondly, the global Moran index, which is based on both economic and geographic distance matrices, has not yet yielded significant results, and spatial autocorrelation analysis cannot be performed.

In subsequent research, we will continue to collect and organize the latest data to reflect the latest degree of IIAE across the country. We will also consider using the economic geography matrix and gravity model for spatial autocorrelation analysis.

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