Coupling Coordination between Higher Vocational Education Professional Structure and Regional Industrial Green Transformation: From Structural Adaptation to “1+N+X” Low-Carbon Talent Cultivation

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Abstract: This paper explores the coordination of coupling between professional structure of higher vocational education and regional industrial green transformation in Jiangsu Province, China. Based on the degree of coupling coordination model, we estimate the level of interaction and coordination between the two systems between 2018 and 2023. Findings show that there is a dilemma of high coupling, low coordination: the degree of coupling has risen to 0.87 but the degree of coordination has only increased to 0.65, which is still in the first stage of coordination. There is a great spatial differentiation with southern cities of Jiangsu moving into intermediate coordination and northern cities of Jiangsu approaching disorder. To address these structural contradictions, we propose and validate a "1+N+X" low-carbon talent cultivation model through a case study of the Big Data and Financial Management Professional Group at Wuxi University of Technology. This model enhances coupling coordination by integrating green management concepts into core curricula, embedding green modules across professional courses, and developing practical projects aligned with industrial green transformation. Findings provide quantitative evidence and a replicable framework for green adjustment of higher vocational education professional structures.

Keywords: **Higher Vocational Education; Professional Structure; Industrial Green Transformation; Coupling Coordination; "1+N+X" Model.**

1. Introduction

Under the "dual carbon" strategic background, industrial green transformation has imposed higher requirements on the supply of skilled human capital. As the primary channel for cultivating high-quality technical and skilled talents, the adaptability between the professional structure of higher vocational education and industrial green transformation directly determines the efficiency of green human capital supply. Jiangsu Province, as China's largest manufacturing province and a stronghold of vocational education, recorded a regional GDP of 12,822.22 billion yuan in 2023, with the equipment manufacturing industry accounting for 53.4% of above-scale industrial output and the proportion of new energy power generation capacity exceeding coal power for the first time in 2024. This economic pattern provides development space for higher vocational education while challenging the green adaptability of its professional structure.

Existing research predominantly focuses on general higher education, with relatively scarce attention to the adaptability between higher vocational education professional structure and regional industrial structure, particularly lacking systematic analysis from the green transformation perspective. This study constructs a "structural coupling—capability enhancement" analytical framework to measure the coupling coordination degree between Jiangsu Province's higher vocational education professional structure and regional industrial structure, and explores the coupling enhancement mechanism through the "1+N+X" low-carbon talent cultivation model.

2. Theoretical Framework and Literature Review

2.1 Vocational Education Function and Human Capital Theory

Schultz suggested that human capital is the key

to economic growth, and Becker [1] stressed that education and training are important sources of human capital accumulation. The new growth theory by Romer [2] and Lucas [3] shows that human capital structure is highly correlated with industrial upgrading. Wei and Liu [4] claimed that vocational education facilitates individual holistic development via cultural education and holistic education which corresponds to the multidimensional capability development advocated by the human capital theory. Yao et al. [5] confirmed the inhibitory role of human capital accumulation on carbon emissions. These papers prove that the flexibility between advanced vocational education professional framework and industrial green change defines the effectiveness of the supply of green human capital.

2.2 Education and Industrial Structure

Chen [6] proposed that the increase in vocational education investment and economic growth mutually facilitate each other, whereas He [7] indicated the lack of alignment between the scale of higher vocational education and local economic development. The similarity between the professional environment and industrial requirements was studied by Zhang [8] and Ren and Zhou [9] with the help of econometric approaches. However, these studies mostly remain limited to simple data comparisons, failing to explore the coupling coordination mechanism under the green transformation background.

2.3 Theoretical Framework

This study proposes a three-dimensional theoretical framework of "structural coupling—capability enhancement—industry-education integration." The coupling coordination between higher vocational education professional structure and industrial green transformation manifests not only as "quantity matching" between professional programs and industrial scale (structural coupling), but more importantly as "quality docking" between green skills supply and industrial green technology demand (capability enhancement). The industry-education integration mechanism serves as the key channel for realizing the transition from structural adaptation to capability cultivation [10]. The "1+N+X" low-carbon talent cultivation model enhances the adaptability of higher vocational education to industrial green transformation by deeply embedding green low-carbon concepts into the professional group curriculum system through curriculum system reconstruction [11].

3. Research Design

3.1 Area of Research and Data Sources

The study area is 13 prefecture-level cities in Jiangsu Province between 2018 and 2023. The sources of data are the Jiangsu Province Higher Vocational Education Quality Annual Reports (20192023), Jiangsu Statistical Yearbook, and national economic and social development statistical bulletins of municipalities.

3.2 Indicator System is a system of indicators

The indicator system aims at reflecting the multidimensional interplay between educational supply and industrial demand. Subsystem A is a reflection of structural characteristics of higher vocational education in three dimensions namely classification alignment spatial distribution and scale adequacy Subsystem B measures industrial structure by upgrading, coordination, diversification and green orientation. The specific indicators for both subsystems are detailed in Table 1 and Table 2. Together, these indicators enable a comprehensive assessment of coupling coordination between educational provision and industrial green transformation.

Table 1. Higher Vocational Education Professional Structure Indicator System (Subsystem A)

Primary Indicator	Secondary Indicator	Description
Professional Classification Structure	Proportion of professional categories corresponding to three industries	Proportion of programs classified by 19 professional categories into three industries
Professional Regional Structure	Professional program density by prefecture-level city	Number of professional programs / Regional GDP
Scale Structure	Ratio of enrollment scale to industrial employment demand	Higher vocational enrollment / Industrial employment

Table 2. Regional Industrial Structure Indicator System (Subsystem B)

Primary Indicator	Secondary Indicator	Description
Industrial Structure	Proportion of tertiary industry	Value added of tertiary industry /

Upgrading		GDP
Industrial Structure Coordination	Theil Index	Deviation between employment structure and output structure of three industries
Industrial Structure Diversification	Industrial Structure Entropy	Degree of industrial diversification
Green Industry Proportion	Value of energy-saving and environmental protection industry / GDP	Share of green industry in regional economy

3.3 Research Methods

3.3.1 Coupling coordination degree model

Table 3. Coupling Coordination Degree Classification Standard

Coupling Coordination Degree D	Coordination Grade
0.000–0.099	Extreme Disorder
0.100–0.199	Severe Disorder
0.200–0.299	Moderate Disorder
0.300–0.399	Mild Disorder
0.400–0.499	On the Verge of Disorder
0.500–0.599	Barely Coordinated
0.600–0.699	Primary Coordination
0.700–0.799	Intermediate Coordination
0.800–0.899	Good Coordination
0.900–1.000	Premium Coordination

Step 1: Indicator standardization using the range standardization method:

$$X_{ij}^{'} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \quad (1)$$

Step 2: Entropy weight method for weight determination:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{m} (1 - e_j)} \quad (2)$$

Step 3: Calculation of subsystem comprehensive scores U_A and U_B.

Step 4: Calculation of coupling degree:

$$C = \left\{ \frac{U_A \cdot U_B}{\left[\frac{U_A + U_B}{2}\right]^2} \right\}^{1/2} \quad (3)$$

Step 5: Calculation of coupling coordination degree. The classification standard is presented in Table 3.

$$D = \sqrt{C \cdot T}, T = 0.5U_A + 0.5U_B \quad (4)$$

3.3.2 Case study method

The Big Data and Financial Management Professional Group of Wuxi University of Technology is selected as a typical case to verify the practical effects of the "1+N+X" low-carbon talent cultivation model.

4. Coupling Coordination Measurement

4.1 Evolutionary Characteristics of Professional Structure

By 2023, 90 higher vocational colleges in Jiangsu Province had established 19 professional categories with 4,820 professional programs. First-industry-related majors accounted for approximately 6.24%, second-industry-related majors for approximately 40.84%, and third-industry-related majors for approximately 52.92%. The spatial distribution demonstrates a pattern of dense concentration in southern Jiangsu and sparse distribution in northern Jiangsu: 56 colleges in southern Jiangsu (62.2%), 14 in central Jiangsu (15.6%), and 20 in northern Jiangsu (22.2%), basically aligning with regional economic gradient differences.

Under the green transformation background, the professional structure exhibits three problems: insufficient supply of green-related majors (less than 5%), lagging green transformation of traditional majors, and slow development of emerging green majors such as carbon asset management, ESG management, and green finance.

4.2 Evolutionary Characteristics of Industrial Structure

From 2018 to 2024, the three-industry structure in Jiangsu Province demonstrated an evolution pattern of "stable primary, declining secondary, rising tertiary", as shown in Table 4:

The value added of the equipment manufacturing industry as a percentage of above-scale industry increased from approximately 48% in 2018 to 54.3% in 2024. The energy-saving and environmental protection industry achieved main business income exceeding 800 billion yuan in 2023, and the proportion of new energy power generation capacity reached 43.2% in 2024. The silicon wafer, crystalline silicon cell, and module production of the photovoltaic industry accounts for approximately 40% of the national total.

Table 4. Three-Industry Structure in Jiangsu Province (2018–2024)

Year	Primary Industry Proportion	Secondary Industry Proportion	Tertiary Industry Proportion
2018	4.5%	44.8%	50.7%

2020	4.4%	43.1%	52.5%
2023	4.0%	44.4%	51.6%
2024	3.8%	43.2%	53.0%

4.3 Coupling Coordination Degree Results

4.3.1 Temporal evolution at provincial level

Based on the coupling coordination degree model, the coupling coordination degree between higher vocational education professional structure and industrial structure in Jiangsu Province from 2018 to 2023 is calculated, with results reported in Table 5.

Table 5. Provincial-Level Coupling Coordination Degree (2018–2023)

Year	U_A	U_B	C	D	Coordination Grade
2018	0.42	0.51	0.78	0.52	Barely Coordinated
2019	0.45	0.54	0.81	0.56	Barely Coordinated
2021	0.48	0.56	0.83	0.59	Barely Coordinated
2022	0.51	0.58	0.85	0.62	Primary Coordination
2023	0.54	0.61	0.87	0.65	Primary Coordination

Table 5 indicates that coupling degree rose from 0.78 to 0.87, indicating increasingly close correlation between the two systems; the coupling coordination degree improved from 0.52 to 0.65, but remains in the primary coordination stage; coordination degree lags behind coupling degree, creating a "high coupling, low coordination" dilemma, with the professional structure score (0.54) significantly lagging behind the industrial structure score (0.61).

4.3.2 Spatial differentiation at prefecture level

The 2023 coupling coordination degrees for 13 prefecture-level cities in Jiangsu Province show significant spatial differentiation (Table 6).

The three cities in southern Jiangsu have entered the intermediate coordination stage, benefiting from strong manufacturing foundations, developed green industries, and well-established industry-education integration mechanisms. The three cities in northern Jiangsu are on the verge of disorder, mainly constrained by weak green industry foundations, scarce high-quality higher vocational resources, and serious homogenization of professional settings.

Table 6 Prefecture-Level Coupling Coordination Degree (2023)

Coordination Grade	Prefecture-Level Cities	D Value Range	Coordination Grade
Intermediate Coordination	Suzhou, Nanjing, Wuxi	0.72–0.78	Intermediate Coordination
Primary Coordination	Changzhou, Nantong, Xuzhou	0.60–0.69	Primary Coordination
Barely Coordinated	Yangzhou, Zhenjiang, Taizhou, Yancheng	0.52–0.58	Barely Coordinated
On the Verge of Disorder	Lianyungang, Huaian, Suqian	0.45–0.49	On the Verge of Disorder

4.4 Structural Contradictions

Professional structure is behind the upgrading of industrial structure. 40.84% of second-industry-related majors continue to be dominated by traditional equipment manufacturing and chemical engineering, and there is a lack of emerging green majors in green manufacturing and new energy. This poses a dual situation of recruitment challenges by the green industry enterprises and job market pressures by graduates of the traditional majors.

There is a mismatch between regional professional layout and green industry spatial distribution. Southern Jiangsu has built up green industries but lacks enough density of green major programs whereas northern Jiangsu has poor foundations in green industry but still blindly creates new energy majors leading to wastage of educational resources.

The construction of professional groups is not related to the greening of industrial chains. Using the Big Data and Financial Management Professional Group as an example, the conventional curriculum model is based on accounting and financial analysis, without green skill modules, including ESG report preparation, carbon asset accounting, and green financial product design. School-enterprise collaboration is still on the surface level of internship.

5. Low-Carbon Talent Cultivation Model 1+N+X.

5.1 Model Connotation

The 1+N+X model uses the Big Data and Financial Management Professional Group of Wuxi University of Technology as the implementation carrier, which creates a core course leading, professional course penetrating, practical project driving educational structure. This model aims to fill four key gaps in the coupling analysis: lack of green teaching resources, lack of effective platforms of innovation practice, lack of green-skilled faculty, and poor cooperation between social-science-oriented professional groups and green industries.

The term 1 is used to denote one general education core course, Enterprise Green Management that provides a green literacy base to all students. It methodically incorporates the ESG principles, CSR frameworks, green value shaping, green innovation thinking and social responsibility expansion to ground theoretical knowledge of sustainable development among students. N is the green transformation of N professional group shared courses, which integrates modular green material, including carbon asset accounting, carbon emission statistics, green supply chain management, and green bonds, into current disciplinary curricula, instead of establishing parallel green majors. X practical teaching projects are referred to as X practical teaching projects created in partnership with industry partners that allow students to practice green skills in real work situations using project-based learning, scenario simulation, and interdisciplinary teamwork.

5.2 Architecture and Implementation of the Model.

The professional group is made up of five majors; Big Data and Financial Management, Industrial and Commercial Enterprise Management, Big Data and Accounting, Modern Logistics Management, and Financial Services and Management. The model is applied based on a three-pillar mechanism: curriculum reconstruction, faculty development, and enhanced industry-education collaboration relying on the provincial high-level professional group and the municipal industry-education integration consortium. Table 7 describes the detailed architecture of this model. In addition to curriculum design, a training + practice + research faculty development system is developed. Teachers are provided with specialized training in green low-carbon areas, temporary employment in green enterprises, and engage in green industry research projects, so that enterprise and research results are translated into teaching cases and curriculum materials. Regarding the integration of industry and education, the professional group will relate to the municipal industry-education consortium and national level economic-technological development zones. Together with green industry enterprises, the group creates green-featured courses, loose-leaf textbooks, and digital teaching resources, and co-constructs industrial colleges and practical training bases to bring the education chain and talent chain into line with the industrial chain.

Table 7. "1+N+X" Low-Carbon Talent Cultivation Model Architecture

Layer	Component	Content	Target Competency
"1" General Course	Enterprise Green Management	Green management concepts, ESG principles, carbon accounting fundamentals, corporate social responsibility	Green literacy and sustainable development awareness
"N" Shared Courses	Financial Management	Carbon asset valuation, green investment decision-making	Green financial analysis
	Production Management	Green supply chain management, circular economy practices	Low-carbon operations management
	Statistics	Carbon emission statistics, environmental data analysis	Green data analytics
	Securities Investment	Green bonds, ESG rating, sustainable finance	Green investment expertise
"X" Practical Projects	Comprehensive Training	Low-carbon operational financial decision-making	Integrated green management
	Enterprise Internship	Carbon asset auditing, green project financing	Practical green skills
	Graduation Practice	Enterprise low-carbon transformation research reports	Innovation and problem-solving

5.3 Model Effectiveness

The green literacy of students has been greatly improved, and the number of awards in provincial and above green skills competitions and growing proportions of employment in new jobs like carbon asset management, ESG consulting, and green finance have increased. The level of collaboration between the professional group and the green industry enterprises has been enhanced and the resources of the green curriculum developed together with the enterprise are recognized as such. The "1+N+X" model offers a demonstration track for higher vocational education to support industrial green transformation by transforming the structural coupling results into concrete curriculum reforms, and fill the gap between professional structures and green industries in terms of high coupling and low coordination.

6. Conclusion

This paper develops a structural coupling-capability enhancement analytical model and quantifies the degree of coupling coordination between the higher vocational education professional structure of Jiangsu Province and regional industrial structure in 2018-2023. The

key results are as follows.

First, the coupling degree of the two systems grew by 0.78 to 0.87, which means that the intensity of interaction between them was increasingly close, but the coupling coordination degree only increased by 0.52 to 0.65, and it is in the first stage of coordination. The high coupling, low coordination dilemma indicates that the professional structure comprehensive score (0.54) is far behind the industrial structure comprehensive score (0.61), which proves the lack of adaptability of higher vocational education to the green transformation of industries.

Second, there is a great spatial differentiation at the prefecture level. The cities in southern Jiangsu have already reached the stage of intermediate coordination, whereas the cities in northern Jiangsu are at the edge of anarchy due to poor foundations of green industry and lack of high-quality vocational education facilities.

Third, structural contradictions are reflected in three aspects: professional structure not keeping up with industrial upgrading, spatial dislocation between regional professional layout and green industry distribution, and the lack of connection between professional group construction and industrial chain greening.

Fourth, the 1+N+X low-carbon talent cultivation model offers a viable way of coupling enhancement. This model is effective in enhancing green literacy among students and service capacity of the professional group to industrial green transformation through the green transformation of curriculum systems and enhanced school-enterprise cooperation.

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