ISSN 2616-5902 Vol. 6, Issue 8: 134-141, DOI: 10.25236/AJBM.2024.060820

Research on the Coupling Relationship and Coordinated Development of New Quality Productivity and New Urbanization—Taking Heilongjiang Province as an Example

Wenhao Cheng

School of Economics, Harbin University of Commerce, Harbin, 150028, China

Abstract: *In the face of the complex economic situation at home and abroad, the development of new quality productivity to activate rural e-commerce and other industries to help rural revitalisation and new urbanisation is the key to promote China's high-quality development. Based on the panel data of Heilongjiang province from 2010 to 2022, the article uses entropy weight-TOPSIS method, coupling coordination degree model, Spearman correlation analysis and stepwise regression method to explore the coupling relationship and coordinated development of new quality productivity and new urbanisation in Heilongjiang province. The results of the study show that the comprehensive development level and the coupling coordination degree of the two systems of new quality productivity and new urbanisation in Heilongjiang Province have been increasing year by year, and the development mode has changed from new urbanisation dominated by new quality productivity to new quality productivity dominated by new quality productivity to new urbanisation lagged by new quality productivity, and the coupling coordination level has changed from extremely dysfunctional to moderately dysfunctional. The level of economic development, technological innovation, industrial structure, infrastructure construction and ecological environment all have a significant positive impact on the coupled and coordinated development of the two systems.*

Keywords: *New quality productivity; New urbanisation; Coupled coordination*

1. Introduction and literature review

In the face of the complex economic situation at home and abroad, China has put forward the strategic goal of high-quality development, aiming to transform the traditional crude growth model and achieve more efficient, fairer and sustainable development. The concept of new quality productivity emphasises the importance of integrating scientific and technological innovation resources and leading the development of strategic emerging industries and future industries, with the aim of accelerating the formation of productivity with a new level of quality to support the high-quality development of China's economy and to achieve the strategic goal of a strong socialist modernised country. The "14th Five-Year Plan" proposes to accelerate the transformation of the urban development mode, continuously improve the new urbanisation strategy, and enhance the quality of urban development with new infrastructure construction as the starting point. How to promote the high-quality development of new urbanisation while developing new productive forces deserves in-depth discussion.

In view of this, based on the panel data of Heilongjiang Province in China from 2010 to 2022, the article uses entropy weight-TOPSIS method, coupling coordination degree model, Spearman correlation analysis and stepwise regression method to explore the coupling relationship and coordinated development status of new quality productivity and new urbanisation in Heilongjiang Province. The study aims to provide theoretical and practical basis for promoting the research on new productivity and new urbanisation in Heilongjiang Province, promoting the development of new urbanisation with new productivity as the base to optimise the town layout and drive the development of modern towns, and creating conditions for the diffusion and application of new productivity with new urbanisation as the guide.

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2. Research methodology and data sources

2.1 Research methodology

Through a series of rigorous quantitative analyses, this study explores in depth the intrinsic links between new quality productivity and new urbanisation, and seeks to reveal the mechanisms and optimisation paths of their synergistic progress.

2.1.1 Data pre-processing

Firstly, we pre-processed the collected raw data to address the issue of missing values and used a multivariate linear fitting process to fill in the missing values. We normalised the raw data dimensionlessly using a polar standardisation method and calculated the standardised value x'_{ij} for the jth indicator in year i:

Positive indicators:

$$x'_{ij} = \frac{x_{ij} - min_{ij}}{max_{ij} - min_{ij}} \tag{1}$$

Negative indicators:

$$x'_{ij} = \frac{max_{ij} - x_{ij}}{max_{ij} - min_{ij}} \tag{2}$$

Where, x'_{ij} represents the standardised data of the jth indicator of the ith sample; x_{ij} represents the actual value of the jth indicator of the ith sample; max_{ij} and min_{ij} represent the maximum and minimum values of the jth indicator of the time taken by the sample, respectively.

2.1.2 Entropy weight method

The entropy weight method is used to determine the weight of each evaluation indicator. The entropy weight method calculates the information entropy of the indicators to measure their contribution to the evaluation system, and the weight allocation is automatically adjusted according to the information size of the indicators, which reduces the interference of subjective judgement.

$$\begin{cases} w_j = a_j / \sum_{j=1}^{n} a_j \\ a_j = 1 - \frac{1}{ln\, m} \sum_{i=1}^{m} \left(\frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} ln \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} \right) \end{cases} \tag{3}$$

Where $i = 1,2, \cdots, m$; $j = 1,2, \cdots, n$; w_j is the weight of the jth indicator; a_j is the coefficient of variation of the jth indicator; x'_{ij} is the data after standardisation of the jth indicator of the ith sample.

In assessing the respective combined development levels of the NQPS and the NUMS, we have adopted an approach known as linear weighted integrated evaluation. The calculation formula is as follows:

$$\begin{cases} y_i = \sum_{j=1}^{m} w_j x'_{ij} \\ \sum_{j=1}^{m} w_j = 1 \end{cases} \tag{4}$$

$$\begin{cases} u_i = \sum_{j=1}^{m} v_j y'_{ij} \\ \sum_{j=1}^{m} v_j = 1 \end{cases} \tag{5}$$

Where $y_i (i = 1,2)$ represents the comprehensive system evaluation index, i.e. the comprehensive development level of the system, for new quality productivity and new urbanisation, respectively. $u_i (i = 1,2 \cdots 14)$ represents the value of each indicator for the two systems, new quality productivity and new urbanisation, respectively.

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2.1.3 TOPSIS method

In order to establish the evaluation model of new quality productivity and new urbanisation system, this study adopts entropy weight TOPSIS method. The specific implementation steps are as follows:

(1) Data standardisation process. This step can directly use the standardisation matrix P_{ij} determined in the entropy weight method.

(2) Determine the indicator weights and establish the weighted decision matrix. The weight vector w_j of the entropy weighting method introduced earlier is considered in the decision matrix, and the weighted normalised decision matrix is obtained by multiplying each row of the correlation coefficient matrix R with its weight w_j:

$$V = \begin{bmatrix} v_{11} & \cdots & v_{1n} \\ \vdots & \ddots & \vdots \\ v_{m1} & \cdots & v_{mn} \end{bmatrix} = \begin{bmatrix} r_{11} \cdot w_1 & \cdots & r_{1n} \cdot w_1 \\ \vdots & \ddots & \vdots \\ r_{m1} \cdot w_m & \cdots & r_{mn} \cdot w_m \end{bmatrix} \tag{6}$$

(3) Distance calculation. Calculate the distances D^+ and D^- of the evaluation vectors to the positive ideal solution and the negative ideal solution, respectively, for different identical zones.

$$D^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_i^+)^2} \, (i = 1,2,...,m) \tag{7}$$

$$D^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_i^-)^2} \, (i = 1,2,...,m) \tag{8}$$

v_i^+ and v_i^- denote positive and negative ideal solutions, respectively, in terms of the maxima and minima of row i of the matrix.

(4) Calculate the closeness C_j of different uses to the optimal solution:

$$C_j = \frac{D^-}{D^- + D^+} (1 \le j \le n) \tag{9}$$

The larger C_j in the formula indicates that the jth indicator is closer to the optimal level. The value of the closeness C_j ranges from 0 to 1, where the indicator effect is best when C_j=1 and worst when C_j=0.

2.1.4 Coupling coordination degree

(1) Model elaboration

This study constructs a coordination assessment model suitable for analysing the interaction of dual systems, specifically designed to provide insight into the degree of coordination between the new quality productivity system and the new urbanisation system. The model is as follows:

$$C = \frac{\sqrt{y_1 y_2}}{y_1 + y_2} \tag{10}$$

Where C refers to the degree of coordination between the new quality productivity system and the new urbanisation system. Due to the complexity and multi-dimensional characteristics of the new quality productivity and new urbanisation system, the coupling coordination degree model is used to assess the coupling relationship and coordination level between the two systems. The formula of the coupling coordination degree model is

$$D = \sqrt{C \times T} \tag{11}$$

Where D represents the value of the coupling coordination degree of the two systems, $T = \alpha y_1 + \beta y_2$ represents the comprehensive evaluation index of the two systems, and α and β are coefficients to be determined. Due to the differences in the degree of interaction between the two systems, and the existence of a close and complex link between the new quality productivity and new urbanisation combined with the research of the relevant literature [1], α is assigned a value of 0.6 and β is assigned a value of 0.4.

(2) Grade classification of coupling coordination degree

In order to assess the coupling coordination degree between the new quality productivity system and

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the new urbanisation system, based on the research and practice in recent years, we propose the following hierarchical classification criteria, as shown in Table 1, in order to directly reflect the coupling coordination status between these two systems.

Table 1: Classification Criteria for the Grade and Type of Coordination Degree of the Coupling of New Quality Productivity and New Urbanisation System

Degree of coupling coordination	Level of coordination	Degree of coupling coordination	Level of coordination	Degree of coupling coordination	Level of coordination
0.00~0.09	Extreme disorder	0.40~0.49	On the verge of becoming dysfunctional	0.80~0.89	Good coordination
0.10~0.19	Severe disorder	0.50~0.59	Sue for coordination	0.90~1.00	Quality coordination
0.20~0.29	Moderate disorder	0.60~0.69	Primary coordination		
0.30~0.39	Mild disorder	0.70~0.79	Intermediate level coordination		

In order to identify the key influencing factors for the development of urban ecological civilisation and tourism industry and optimise the adjustment, the contribution model is used to focus the analysis, accurately diagnose the development status of the two systems, and guide the adjustment of focused strategies. The formula is:

$$Z_{ij} = \left(w_j x'_{ij} / \sum_{j=1}^{m} w_j x'_{ij}\right) \times 100\% \quad (12)$$

Where Z_{ij} is the degree of obstacle of the jth indicator of the ith system, the larger Z_{ij} indicates the greater the degree of constraint of the indicator on the system.

2.2 Data sources

This paper adopts the panel data of China's Heilongjiang Province from 2010 to 2022 as the research sample, and the data come from the National Bureau of Statistics, Heilongjiang Statistical Yearbook, China Labour Statistical Yearbook, China Energy Statistical Yearbook, and China Science and Technology Statistical Yearbook from 2010 to 2022.

3. New quality productivity and new urbanisation even and coordinated relationship

3.1 Establishment of the indicator system

When selecting indicators, the theoretical analysis method is used and relevant literature is summarised to summarise the indicator system applicable to this paper. According to the research of Lu Jiang et al [2], the new quality productivity is divided into three level I indicators: scientific and technological productivity, green productivity and digital productivity. The new urbanisation system mainly consists of 4 I indicators of population urbanisation, economic urbanisation, social urbanisation and ecological urbanisation. The indicators of the system and their weights are shown in Table 2.

The development of Heilongjiang Province in recent years shows that both new quality productivity and new urbanisation have made remarkable progress. In terms of the weights of the indicators of the new quality productivity system, green ecological construction and digital construction occupy an important position. In the new urbanisation system, residents' income (B22) is the core force supporting the development of new urbanisation, while the dominant role of the secondary industry in the economy remains strong. Secondly, the level of urban medical services and employment status are important considerations for urban social development, in which the cultural level of residents (B33) has a significant impact on the level of cultural development. In the process of eco-urbanisation, the indicators of forest coverage, green coverage and green space per capita have similar weights, indicating that they are of equal importance in promoting the new urbanisation process.

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Table 2: Weights of indicators in the new quality productivity subsystem and the new urbanisation subsystem in Heilongjiang Province

System	Level I indicators and weights	Level II indicators and weights	Level II indicator units	Type of indicator
A New Quality Productivity	A1 Technological productivity (0.208)	A11 Number of domestic patents granted (0.281)	size	Positive indicator
		A12 Business income from high-tech industries (0.233)	thousand yuans	Positive indicator
		A13 Funding for product innovation in regulated industries (0.207)	ten thousand yuans	Positive indicator
		A14 Full-time equivalents of R&D personnel in the regulated industry (0.279)	hour	Positive indicator
	A2 Green productivity (0.549)	A21 Energy consumption/GDP (0.144)	%	Counterindicator
		A22 Industrial water use/GDP (0.264)	%	Counterindicator
		A23 Comprehensive use of industrial solid waste/generation of industrial solid waste (0.150)	%	Positive indicator
		A24 Industrial wastewater discharges/GDP (0.149)	%	Counterindicator
		A25 Industrial SO^2 emissions/GDP (0.293)	%	Counterindicator
	A3 Digital productivity (0.243)	A31 IC production (0.155)	hundred million pieces	Positive indicator
		A32 Total telecommunication services (0.289)	billion yuans	Positive indicator
		A33 Number of Internet broadband access ports (0.175)	ten thousand units	Positive indicator
		A34 Revenue from software operations (0.176)	ten thousand yuans	Positive indicator
		A35 E-commerce sales (0.204)	ten thousand yuans	Positive indicator
B New Urbanisation	B1 Urbanisation of population (0.246)	B11 Urban population density (0.235)	persons/km^2	Positive indicator
		B12 Urban registered unemployment rate (0.283)	%	Counterindicator
		B13 Share of urban population (0.236)	yuan	Positive indicator
		B14 GDP per capita (0.246)	%	Positive indicator
	B2 Economic urbanisation (0.229)	B21 Share of secondary and tertiary industries in GDP (0.314)	%	Positive indicator
		B22 Per capita disposable income of urban households (0.372)	yuan	Positive indicator
		B23 Gas penetration rate (0.314)	%	Positive indicator
	B3 Social urbanisation (0.285)	B31 Number of beds in medical institutions (0.347)	sheets/thousand	Positive indicator
		B32 Water penetration rate (0.323)	%	Positive indicator
		B33 Tertiary education enrolment per 100,000 population (0.330)	size	Positive indicator
	B4 Ecological urbanisation (0.240)	B41 Forest cover (0.332)	%	Positive indicator
		B42 Greening coverage in built-up areas (0.334)	cm^2	Positive indicator
		B43 Parkland area per capita (0.334)	m^2/person	Positive indicator

3.2 Comprehensive development level of new quality productivity and new urbanisation system in Heilongjiang province

Heilongjiang Province's NQP system shows an overall upward trend from 2010 to 2022 (see Figure

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1), and its level of ecological civilisation construction grows in tandem, from 0.21 to 0.75. The development during this period can be outlined in three stages: initial period (2010-2013) of slow growth, with NQP increasing from 0.21 to 0.308; mid-term period (2013-2020) Faster development, with NQP jumping to 0.82, especially most notably in 2014-2015 and 2019-2020, with outstanding growth in the telecoms industry, contributing 0.71, and the e-Information industry becoming a key driver; Late stage (2020-2022) stabilisation, with NQP slightly retracing its course to 0.75, and with growth in science and technology sales of 0.18 becoming the biggest driver, showing that Scientific and technological progress continues to boost new quality productivity[3-6].

New urbanisation in Heilongjiang Province from 2010-2022 experienced three stages of development: rapid rise in the early stage (2010-2015, the level increased from 0.02 to 0.36, the dominant factor is GDP and income growth); smooth development in the middle stage (2015-2019, the level increased slightly to 0.645, with balanced growth in all cities and counties); high speed growth in the late stage (2019-2022, the level surges to 0.85, focusing on industrial upgrading and ecological improvement). The overall level rises from 0.02 to 0.84, demonstrating a clear path of transformation and upgrading.

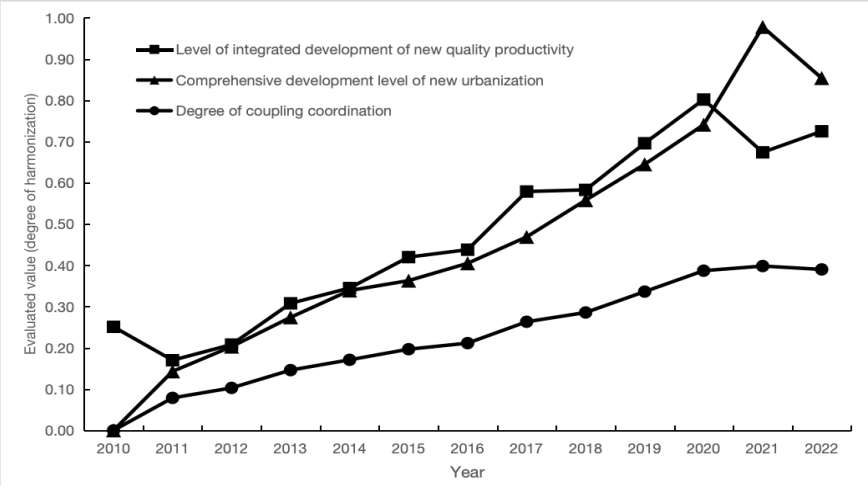

Figure 1: Comprehensive Development Level and Coupling Coordination Degree of New Quality Productivity and New Urbanisation in Heilongjiang Province

3.3 Degree of coupling and coordination between new quality productivity and new urbanisation system

Between 2010 and 2022, the coupled coordination degree of new quality productivity and new urbanisation system in Heilongjiang province increased from 0.079 to 0.39, showing an optimisation trend. The seven-year development is divided into four dislocation phases, with extreme to mild dislocation in the early stage and then a period of low-level co-ordination, which has accelerated since 2016 but the overall level of co-ordination is still low. Coordination types switch frequently, with alternating lags between urbanisation and new quality productivity development, during which there are two periods of synchronised development, in particular 2011 to 2016 and 2018 to 2019, when the two are paced and advancing. New urbanisation leads the way from 2020 to 2022, becoming a key driver in pulling new quality productivity upwards[7-8].

4. Factors affecting the development of new quality productivity and new urbanisation in Heilongjiang Province

4.1 Analysis of influencing factors

In order to be able to further explain the influencing factors of the coupling and coordination degree of the new quality productivity and new urbanisation systems, this paper carries out indicator screening and evaluation through Spearman correlation coefficient and stepwise regression analysis, and elaborates on the influencing factors of the two systems and their interactions with the help of multiple linear regression model.

As shown in Table 3, the Spearman correlation coefficient shows that among the 27 indicators, A12, A13, A32, A34, A35, B11 and B33 are not significantly correlated with the degree of coupling and

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coordination D of the two systems of new quality productivity and new urbanisation. This indicates that these indicators are not key factors influencing the development of the new quality productivity and new urbanisation systems.

Table 3: Spaerman correlation coefficient regression

Factor	Correlation coefficient	Factor	Correlation coefficient	Factor	Correlation coefficient
A11	0.747(0.003***)	A31	0.847(0.000***)	B21	-0.912(0.000***)
A12	0.484(0.094*)	A32	0.022(0.943)	B22	0.995(0.000***)
A13	-0.022(0.943)	A33	0.989(0.000***)	B23	0.973(0.000***)
A14	-0.874(0.000***)	A34	-0.467(0.108)	B31	0.973(0.000***)
A21	-0.995(0.000***)	A35	0.088(0.775)	B32	0.995(0.000***)
A22	-0.995(0.000***)	B11	0.588(0.035**)	B33	0.505(0.078*)
A23	-0.945(0.000***)	B12	-0.739(0.004***)	B41	0.812(0.001***)
A24	-0.973(0.000***)	B13	0.995(0.000***)	B42	0.967(0.000***)
A25	-0.984(0.000***)	B14	0.857(0.000***)	B43	0.882(0.000***)
Note: ***, **, * represent 1 per cent, 5 per cent and 10 per cent significance levels, respectively.					

The remaining variables after elimination of irrelevant variables were used as independent variables, and the coupling coordination degree D was used as the dependent variable in a stepwise iterative regression analysis (backward method) to screen out the factors with significant effects (Table 4) with the formula:

$$D = 0.129A_{11} + 0.014A_{14} - 0.075A_{21} - 0.033A_{23} - 0.173A_{31} + 0.181A_{33} \\ -0.028B_{14} - 0.071B_{21} - 0.090B_{23} + 0.604B_{31} + 0.067B_{41} + 0.188B_{43} \quad (13)$$

R2 = 0.99 means that the 12 factors explain 99.0 per cent of the causes of change, and, the D-W value of 1.107 is close to 2, indicating that there is no autocorrelation in the model. The model shows that the new quality productivity and the new urbanisation system have a less significant positive influence relationship on the coupling coordination degree, A11, A14, A33, B31, B41, B43 all have a significant positive influence on it, and A21, A23, A31, B14, B21, B23 have a significant negative influence on it.

Table 4: Stepwise regression analysis results

	Unstandardised coefficient		Standardised coefficient	t	p	Significance	
	B	Standard error	Beta			Tolerances	VIF
Constant	1987.239	0.000	-	0.01	0.01	-	-
A11	5.644E-5	0.000	0.129	0.01	0.01	0.013	3.533
A14	4.820E-6	0.000	0.014	0.01	0.01	0.037	2.247
A21	-16.707	0.000	-0.075	0.01	0.01	0.005	3.569
A23	-0.010	0.000	-0.033	0.01	0.01	0.033	3.633
A31	-0.780	0.000	-0.173	0.01	0.01	0.084	1.944
A33	0.001	0.000	0.181	0.01	0.01	0.046	2.941
B14	-1.969E-5	0.000	-0.028	0.01	0.01	0.026	3.450
B21	-0.071	0.000	-0.071	0.01	0.01	0.035	3.947
B23	-0.100	0.000	-0.090	0.01	0.01	0.015	2.335
B31	5.822E-5	0.000	0.604	0.01	0.01	0.006	1.243
B41	0.429	0.000	0.067	0.01	0.01	0.016	2.427
B43	1.140	0.000	0.188	0.01	0.01	0.026	3.928
R^2	0.99						
Adjustment of R^2	0.99						
F	p=0.01						
D-W value	1.107						

5. Conclusions

This paper explores the coupled and coordinated development of new quality productivity and new urbanisation in Heilongjiang Province in the context of, using entropy weight-TOPSIS method, coupled

ISSN 2616-5902 Vol. 6, Issue 8: 134-141, DOI: 10.25236/AJBM.2024.060820

coordination model, Spearman correlation analysis and stepwise regression method, analyses the degree of coupled coordination between the new quality productivity and new urbanisation system and its influencing factors in Heilongjiang Province, constructs the mechanism of coupled coordination between the new quality productivity and the new urbanisation system, and reveals the law of coupled coordination of the new quality productivity and new urbanisation system in the time dimension. time dimension reveals the law of coupling and coordinated development of new quality productivity and new urbanisation in Heilongjiang Province. The conclusions are as follows through empirical evidence:

Both the new quality productivity and new urbanisation in Heilongjiang province show a rising trend year by year. The development pattern of the two has gradually shifted from the dominance of new productivity to the dominance of new urbanisation, and the development speed of the two systems is similar. The degree of coordination between the two couplings also increases year by year, changing from extreme dissonance to moderate dissonance, and at the same time, it is consistent with the trend of the development index of urban new quality productivity. From 2010 to 2022, the development of new urbanisation outperforms the NQP and gradually shows a leading role for the NQP. In terms of influencing factors, the new quality productivity and new urbanisation system have a less significant positive influence on the coupling coordination degree, with A11, A14, A33, B31, B41 and B43 all having a significant positive influence, and A21, A23, A31, B14, B21 and B23 having a significant negative influence.

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