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The Coupling and Coordination of Digital Economy and New Quality Productivity: An Analysis of the Current Development Situation of Chinese Provinces

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Abstract: The deep integration of the digital economy and new productive forces is an inevitable trend and an important way to promote the high-quality development of productivity. This study takes 30 provinces (regions) in China as research objects and constructs an evaluation system of digital economy and new productive forces indicators. It examines the coupling coordination relationship and dynamic evolution trend between the digital economy and new productive forces in these 30 provinces (regions) from 2012 to 2022. The results indicate that: (1) The levels of digital economy and new productive forces show an upward trend. An overall data analysis reveals significant differences and spatial distribution imbalances among provinces, with high-level regions mainly concentrated in the eastern coastal areas and slower growth in the central and western regions. (2) The coupling coordination degree between the digital economy and new productive forces shows an overall upward trend, improving from slight disorder to near disorder, but the overall level is still low. The coupling coordination development in the eastern region is relatively better, while the central and western regions remain in a state of severe disorder.

Keywords: Digital Economy; New Productive Forces; Coupling Coordination Degree; Provincial Development; Dynamic Evolution

1. Introduction

The new quality productivity (NQP) concept, first proposed in September 2023, represents the development direction of advanced productivity, including the integration of scientific and technological innovation resources to guide the development of emerging industries and promising industries. This NQP relies on technological innovation, especially the productivity forms brought about by the information technology revolution. The development of the digital economy (DE) has created a new mode of resource allocation driven by data, regulated by algorithms, and powered by computing. This is the basic logic for generating NQP. Based on traditional productivity, the DE operates through a "data-algorithm-computing" mechanism, optimizing resource allocation, and transforming traditional productivity into NQP through technology-driven intelligence. This transformation not only promotes changes in production relations but also advances the development of NQP. Essentially, NQP represents a leap in productivity driven by the new wave of information technology revolution, with digital technology at its core. [1] The DE provides the technological foundation and application scenarios for NQP, while NQP, in turn, offers innovative impetus and development pathways for the DE. The coordinated development and coupling of the DE and NQP emphasize the mutual promotion and deep integration between the two. [2] Finally, this coordinated development through the application of technological innovation and digital technology improves resource utilization efficiency, reduces environmental damage, and achieves economic growth and sustainable development at the same time. There is a complementary relationship between NQP and the DE. The formation and development of NQP continuously provide innovative impetus for the DE, while the development of the DE, in turn, feeds back into NQP, further promoting its optimization and enhancement. Therefore, in-depth research on the coupling and coordination relationship between the DE and NQP is of great significance for optimizing production organization forms and factor allocation methods, promoting economic structure optimization and industrial upgrading, and enhancing sustainable development capabilities.

The coordinated development of the DE and NQP faces numerous challenges due to factors such as economic level, geographical location, and resource availability. There are disparities in the development of the DE across different regions, with varying levels of infrastructure development and uneven distribution of the high-quality labor force needed for NQP, influenced by regional economic differences. Additionally, limited market resource supply, insufficient investment in innovation and research and development, and obstacles to the coordinated development of industrial chains are key factors affecting coupling coordination. To enhance the coupling coordination degree between the two, efforts must be made in various aspects including economic policies, infrastructure construction, and human resource development.

Based on this, the study aims to evaluate the development level of NQP and the DE in China using panel data from 30 provinces (regions, municipalities) from 2012 to 2022, and to explore the coupling coordination relationship between NQP and the DE. Through empirical research, the study will propose policy recommendations to improve the coupling coordination degree between the two, providing reference and guidance for related theoretical research and policy implementation.

In the research on the DE and NQP, scholars mainly focus on the mutual influence between the two. Liu et al. focuses on the integration of the DE and the real economy, exploring the different mechanisms of digital-real integration in terms of element integration, demand-side transformation, and industry integration. It also analyzes the optimized pathways through which deep integration of digital and real economies promotes the development of NQP. [3]Liu et al. used manufacturing enterprises as the research sample and utilized data from A-share listed companies from 2018-2022 to discuss the mechanism of the impact of digital transformation on the NQP of manufacturing enterprises and its heterogeneity characteristics. [4] But Wang et al. used data from A-share listed companies from 2011 to 2022 as a sample for empirical analysis, the study explores the impact mechanism of digital transformation on the NQP of enterprises. The results indicate that the impact of digital transformation on the NQP of enterprises exhibits a "U-shaped" characteristic, meaning that after reaching a certain level, the effect of digital transformation on NQP shifts from suppression to promotion. [5]Zhao et al. used the entropy method to measure the comprehensive level of NQP in 30 provinces (regions, municipalities) of China from 2012 to 2022, the study empirically examines the effects and mechanisms of the DE empowering NQP from multiple dimensions. The research concludes that the DE not only enhances the NQP of the local region but also exhibits significant spatial spillover effects, contributing to the improvement of NQP in neighboring regions. [6]

Some scholars also study NQP as a mediating variable, exploring how the DE impacts other variables by influencing NQP. Chen used panel data from 31 provinces in China from 2013 to 2022, this study examines the impact and mechanisms of the DE on rural industrial modernization. The research concludes that the DE can enhance rural industrial modernization by promoting the improvement of NQP. [7] Tang（2024）used data from 30 provincial administrative units in China from 2011 to 2022 as a research sample, the study employs fixed effects models, mechanism models, and threshold panel models to empirically analyze the impact of the DE on the modern industrial system with Chinese characteristics. The research results indicate that the DE has a significant positive impact on the modern industrial system with Chinese characteristics and can enhance this system by promoting NQP. [8]

Some scholars have also studied the coupling and coordination relationship between the DE and NQP across different regions, Jiang et al. used the entropy weight method to measure the development level of DE and NQP in cities along the Yellow River Basin from 2011 to 2022, the study employs the coupling coordination degree model to analyze the spatiotemporal evolution pattern of their coupling coordination development. Moran's I is used to analyze the spatial correlation, and the grey model GM(1,1) is applied to predict the coupling coordination development from 2023 to 2028. [9]

Although existing research has explored the coupling and coordinated development of the DE and new quality productivity, there are still some shortcomings. First, there is a lack of studies focusing on the coupling and coordinated relationship between the DE and NQP at the provincial level, with few analyses of their dynamic changes. Second, the differences in coupling coordination between various regions at the provincial level have not been deeply analyzed. Therefore, this paper constructs an evaluation system for the development of the DE and NQP, aiming to examine the coupling and coordination relationship between the DE and high-quality development of manufacturing in China as a whole and in various regions, as well as their spatiotemporal evolution characteristics, providing empirical evidence for the development of the DE and NQP in China.

2. Theoretical Analysis of the Coupling and Coordination between the DE and New Quality Productivity

2.1 Pathways of Influence of the Digital Economy on New Quality Productivity

1. Promoting Technological Innovation: The DE fosters the development of NQP through aspects such as data security, storage, value-added applications, and talent cultivation. The formation of NQP emphasizes the importance of innovation elements, enhancing the role of advanced production factors and innovative productivity empowered by digital technology, making innovation-driven growth the core driving force. Information and communication technology provides the impetus for innovation, with the DE breaking traditional supply and demand models and economic paradigms, creating a more inclusive, shared, and open-source economic ecosystem. This injects innovative momentum into the development of NQP, promoting high-quality growth.

2. Optimizing Resource Allocation: Data is a key production factor in the DE, with everything interconnected and activities across various industries being digitized. This provides a foundation for the development of NQP, enhancing production efficiency and innovation capability. The DE accelerates the pace of data sharing, circulation, and application. Applications such as the platform economy, industrial internet, and data space can capture and integrate massive market data in real-time, providing unprecedented information transparency for participants, significantly improving market efficiency.

3. Transforming Production Models: The DE promotes industry integration, achieving value increments through integration with traditional industries. The infiltration and development of the DE across various industries will accelerate the construction of new economic paradigms, changing the structure of the real economy and enhancing production efficiency. The development of NQP provides market demand for industrial digitalization, promoting the optimization and upgrading of industrial structures. This allows traditional industries to transform and upgrade through digitalization, moving towards high-tech and high-value-added industries.

4. Enhancing Human Capital: The core element of NQP in the DE era is promoting industrial innovation through technological innovation, with high-quality talent being a prerequisite for industrial development. Therefore, measures to cultivate cutting-edge technological talent and build talent training systems are crucial for the development of emerging and future industries. In the DE field, it is necessary to continuously enhance talent quality and innovation capability through education and training, and talent introduction. Moreover, providing learning and application pathways for digital skills tailored to workers of different ages and occupations, thereby comprehensively enhancing people's digital literacy.

5. Optimizing Industrial Structure: Digital infrastructure provides a platform for NQP, promoting industry integration development. Through the deep integration of digital technology with the real economy, traditional industries achieve digital and intelligent development. This not only enhances the competitiveness and innovation capacity of traditional industries but also gives rise to a

number of emerging industries and new growth points. The formation and development of NQP have strategic significance for the high-quality development of the DE. Formed through breakthroughs in key and disruptive technologies, this productivity is crucial to the development of the DE, creating a favorable technological environment for its high-quality growth and driving the transformation and upgrading of digital industries.

2.2 Pathways of Influence of New Quality Productivity on the Digital Economy

1. Driving Technological Innovation: NQP relies on high technology, high efficiency, and high-quality production factors, promoting the development of the DE through technological innovation. The technological breakthroughs brought by NQP can be applied to the DE, improving data processing capabilities, enhancing network speeds, and strengthening information security, promote the development of the DE.
2. Enhancing Market Demand: NQP improves the quality of products and services, increasing market competitiveness and creating new market demand. This demand drives the development of the DE, leading to the growth in demand for digital products and services, and facilitating the expansion and upgrading of the DE.
3. Optimizing Resource Allocation: NQP optimizes resource allocation through highly efficient production methods and management models, enabling more effective use of production factors. This optimization capability, in turn, enhances the efficiency of the DE, allowing it to better integrate and utilize resources, thereby improving overall economic efficiency.
4. Promoting Industrial Upgrading: NQP drives the transformation and upgrading of traditional industries, shifting them towards high-tech and high-value-added industries. This industrial upgrading provides broad market space and application scenarios for the development of the DE, promoting deep integration between the DE and the real economy, and facilitating overall industrial upgrading.
5. Enhancing Human Capital: The development of NQP requires high-quality talent, driving the upgrading of education and training systems and cultivating a large number of talents with digital skills and innovative capabilities. These high-quality talents provide intellectual support for the development of the DE, promoting its innovation and growth.

3. Research Design

3.1 Evaluation Index System

In constructing the evaluation index system of DE and NQP, this study comprehensively considers the characteristics of DE and the multidimensional attributes of NQP. Specifically, the evaluation system is divided into two categories: DE development indicators and NQP indicators, as shown in Table 1.

The construction of DE development indicators covers three levels: digital infrastructure, digital innovation input and DE output. In terms of the measurement of digital infrastructure, this study adopts six indicators: the number of Internet domain names, the number of Internet broadband access users, the number of Internet access ports, the density of mobile base stations, the penetration rate of mobile phones and the length of long-distance optical cables per unit area. The measurement of digital innovation input is analyzed through six indicators: the number of employees in the information service industry, the number of computers used per 100 employees in enterprises, the number of websites owned by each 100 enterprises, the number of R&D personnel in industrial enterprises above designated size, the R&D expenditure of industrial enterprises above designated size and the number of R&D project topics of industrial enterprises above designated size. The measurement of DE output includes seven indicators: the proportion of software business revenue in GDP, the proportion of information technology service revenue in GDP, the proportion of total telecommunications business in GDP, the proportion of enterprises with e-commerce transaction activities, the proportion of corporate e-commerce in GDP, the total amount of technology contracts and the number of patent applications. In addition, the digital inclusive finance index is also taken into consideration to reflect the role of the DE in promoting financial inclusion. The construction of the NQP index starts from the three perspectives of innovation, green and digital, and selects 15 secondary indicators for measurement. The measurement of innovative productivity adopts four indicators: industrial innovation funds of industrial enterprises above designated size, full-time equivalent of research and development (R&D) personnel of industrial enterprises above designated size, number of patents authorized by region, and business income of high-tech industries. The measurement of green productivity is characterized by five indicators: the ratio of energy consumption to GDP, the ratio of comprehensive utilization of industrial solid waste to production, the ratio of industrial wastewater discharge to GDP, the ratio of industrial SO2 emissions to GDP, and the ratio of industrial water consumption to GDP. The measurement of digital productivity includes six indicators: the ratio of optical cable line length to regional area, the total amount of telecommunications business, the number of Internet broadband access ports, software business income, integrated circuit output, and e-commerce sales.

Table 1. Evaluation Index System for Regional New Quality Productivity and Digital Economy

Subsystem	Secondary indicators	Specific elements
New Quality Productivity	Innovation Productivity	Industrial innovation expenditure of industrial enterprises above designated size
		Full-time equivalent of R&D personnel in industrial enterprises above designated size
		Number of patents authorized by region
		Business income of high-tech industries
	Green Productivity	Ratio of energy consumption to GDP
		Ratio of comprehensive utilization of industrial solid waste to generation
		Ratio of industrial wastewater discharge to GDP
		Ratio of industrial SO_2 emissions to GDP
		Ratio of industrial water consumption to GDP
	Digital Productivity	Ratio of optical cable line length to regional area
		Total telecommunications business
		Number of internet broadband access ports
		Software business income
		Integrated circuit output
		E-commerce sales
Digital Economy	Digital Infrastructure	Number of internet domain names
		Number of internet broadband access users
		Number of internet access ports
		Density of mobile base stations
		Mobile phone penetration rate
		Length of long-distance optical cable per unit area
	Digital Innovation Investment	Number of employees in the information services industry
		Number of computers used per 100 employees in enterprises
		Number of websites owned per 100 enterprises
		Number of R&D personnel in industrial enterprises above designated size
		R&D expenditure of industrial enterprises above designated size
		Number of R&D projects of industrial enterprises above designated size
	Digital Economy Output	Proportion of software business income to GDP
		Proportion of information technology services income to GDP
		Proportion of total telecommunications business to GDP
		Proportion of enterprises engaged in e-commerce activities
		Proportion of e-commerce in enterprises to GDP
		Total turnover of technology contracts
		Number of patent applications and authorizations
		Digital inclusive finance index

3.2 Coupling Coordination Degree Model

The coupling coordination degree model is a model used to evaluate the interaction between different systems, widely applied in fields such as economics, environmental science, and social sciences. Its core idea is to quantitatively assess their mutual influence and coordination level by calculating the coupling degree and coordination degree between systems. The coupling degree measures the intensity of interaction between two systems, usually calculated through methods such as correlation analysis or collinearity analysis. A higher coupling degree value indicates a stronger interaction between systems. The advantage of the coupling coordination degree model lies in its ability to systematically and quantitatively evaluate the interaction and coordination between different systems, helping researchers identify potential problems between systems and propose improvement strategies. The classification standard for coupling coordination degree follows an arithmetic difference of 0.1 as referred to by academia,[10] Dividing the range [0,1] into ten stages with different coordination levels.

3.3 Selection of Indicators and Data Sources

This study selects the period from 2012 to 2022 as the research timeframe. Due to the absence of some data for Tibet and the Hong Kong, Macau, and Taiwan regions, the study focuses on 30 provinces, autonomous regions, and municipalities in mainland China. The data is sourced from the "China Statistical Yearbook," the "China Education Yearbook," and the annual statistical yearbooks. Missing data is supplemented using interpolation methods.

4. Analysis of Calculation Results

4.1 Time Trends of the Digital Economy and New Quality Productivity

The trend in the development indices of the DE and NQP across 30 provinces in China from 2012 to 2022 is illustrated in Figure 1. The research results indicate that the development of the DE shows an upward trend during the observation period, with the DE development index rising from 0.085 to 0.168. In 2012, the development index of the DE was relatively low, but it grew year by year, especially accelerating after 2016. By 2022, the DE development index had reached a new peak, showing significant development in the regional DE during this observation period.

From 2012 to 2022, the NQP in the 30 provinces of China initially showed an upward trend, followed by relative stability. The overall trend showed a slight fluctuation of rising first and then slightly decreasing, with little change after 2018. The development index of NQP was at a low level in 2012, but overall showed a fluctuating upward trend. Compared with the DE, the growth rate of NQP was relatively slower, with slight declines in some years. Despite this, the development index of NQP generally increased from 2012 to 2022, indicating a gradual enhancement in the level of NQP during this period.

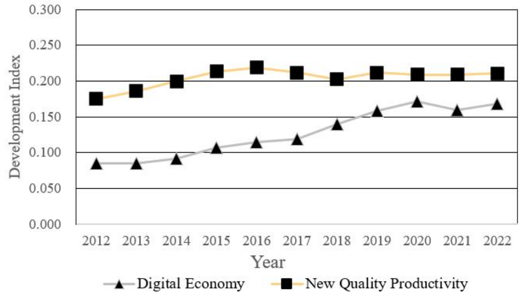

Figure 1. Time Trends of the Digital Economy and New Quality Productivity in China from 2012 to 2022

4.2 Regional Differences in Digital Economy and New Productivity

Based on the measurement results of the DE and NQP, and drawing on previous academic research, the regions are divided into three major economic belts: eastern, central, and western.

From the average DE levels of each region from 2012 to 2022, the DE shows a significant gradient decrease across the regions. Specifically, the eastern region has the highest level of DE, while the central and western regions gradually decrease. During the sample period, the national average DE level was 0.127, with the eastern region averaging 0.204, significantly higher than the national average. In economically developed coastal areas such as Guangdong, Jiangsu, Beijing, Shanghai, and Shandong, the DE was high during the observation period, with construction levels significantly ahead of other regions. The eastern region showed a significant upward trend during the observation period, with the average DE level rising from 0.128 in 2012 to 0.270 in 2020, and stabilizing from 2021 to 2022, increasing from 0.270 to 0.274.

The central region's DE average was 0.098, somewhat below the national average, with relatively consistent levels among its provinces. Hubei, Hunan, and Henan performed relatively well, with averages above the national level during the observation period, while other provinces lagged behind. The central region's DE consistently increased, rising from 0.063 in 2012 to 0.095 in 2016, followed by a slight decline in 2017 and an increase again until 2022, reaching 0.133, above the national average.

The western region had the lowest overall DE average at 0.072. Shaanxi and Sichuan's levels were slightly below but close to the national average, while other provinces showed a significant gap. The western region's DE trend was similar to the central region, increasing from 0.057 in 2012 to 0.103 in 2020, but slightly declined to 0.086 in 2021 and 2022.

Based on the DE and NQP measurement results, and considering the regional average data during the observation period, spatial distribution maps of the DE and NQP indices are drawn, as shown in Figures 2 and 3.

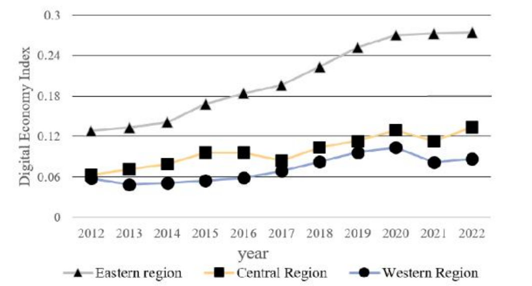

Figure 2. Spatial Distribution of China's Digital Economy Index, 2012-2022

From the average value of new mass productivity water in each region in 2012-2022, the new mass productivity level shows a significant gradient decreasing trend among regions. The eastern region has the highest level of new matter productivity, while the central and western regions are lower than and converge with the eastern region. During the sample period, the overall average value of the national NQP level is 0.204, and the overall average value of the NQP level in the eastern region is 0.350, which is better than the national average overall. In the more economically developed eastern coastal region, the level of NQP was higher during the observation period, and the construction level was significantly ahead of other regions. The eastern region shows a significant rising and then falling trend during the observation period, and the overall mean value of the level of NQP in the eastern region rises from 0.298 to 0.384 between 2012 and 2016, showing a significant rising trend. While in 2017 to 2022 there is a small decline, the NQP level from 0.368 to 0.350. The overall mean value of the NQP level in the central region is 0.144, which is a certain gap compared to the national average, and the trend of changes in the observation period in this region is similar to that in the eastern region. During the observation period, the central region as a whole shows a trend of first increase, then decrease and then stabilization. the overall mean value of NQP in the central region increased from 0.145 to 0.165 between 2012 and 2015, showing a small year-on-year increase. a slight decrease was observed in 2016-2018, and the level of NQP remained almost unchanged from 2019 until 2022, showing a slight growth trend as a whole. a slight growth trend. The overall mean value of new mass productivity in the western region is 0.072, which is the lowest among the three regions. During the observation period, the overall trend in the western region shows a partial upward trend, with the overall mean value of new mass productivity in the western region increasing from 0.074 to 0.112 between 2012 and 2022, showing a yearly increase.

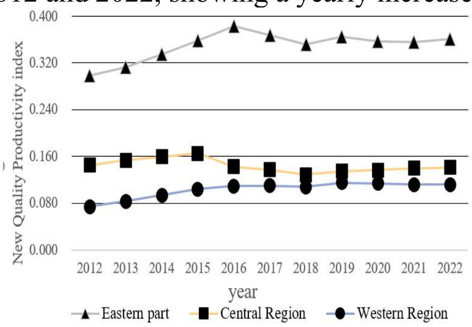

Figure 3. Spatial Distribution of China's New Quality Productivity Index, 2012-2022

4.3 Temporal Analysis of the Coupling Coordination between the Digital Economy and New Quality Productivity

1. The coupling coordination calculation results of the DE and NQP in each province are shown in Table 2, and the overall trend is illustrated in Figure 4. Overall, from 2012 to 2022, the coupling coordination degree between the DE and NQP in the 30 provinces of China generally showed an upward trend, with fluctuations ranging between 0.323 and 0.407. Starting from a slightly uncoordinated state of 0.323 in 2012, it has been growing

continuously, reaching a peak of 0.407 in 2020. Since 2019, the coupling coordination degree has been around 0.4, indicating that the DE and NQP have entered a nearly uncoordinated stage.

Before 2020, the development of the DE and NQP in each province was in a slightly uncoordinated state. During this period, the DE developed rapidly, while the improvement in NQP lagged behind. The digital transformation of NQP still needs to be further advanced and has not yet synchronized with the growth of the DE.

From 2020 onwards, the coupling coordination degree increased significantly, shifting from a slightly uncoordinated state to a nearly uncoordinated state. As provinces (regions) increased their emphasis on the DE, they improved the application rate of data elements and the coverage of digital infrastructure, significantly enhancing the development level of the DE. Meanwhile, addressing the shortcomings of NQP, provinces (regions) adopted effective measures to promote the orderly flow of production factors and rational distribution of industries, constructing an industrial layout of coordinated development and forming a new economic growth driver in manufacturing.

Overall, the development of the DE and NQP exhibits a high degree of coupling, but the coupling coordination degree is relatively low. This reflects a close interdependence between the two. However, to further enhance the overall quality and efficiency of the economy, continuous efforts are needed to promote the coordinated development between the DE and NQP.

Table 2. Results of Coupling and Coordination of Digital Economy and New Quality Productivity, 2012-2022

Provinces	2012 Year	2013 Year	2014 Year	2015 Year	2016 Year	2017 Year	2018 Year	2019 Year	2020 Year	2021 Year	2022 Year	Averages
Beijing	0.504	0.529	0.549	0.574	0.596	0.603	0.614	0.643	0.654	0.669	0.647	0.598
Tianjin	0.314	0.336	0.357	0.373	0.386	0.373	0.380	0.408	0.450	0.377	0.381	0.376
Hebei	0.287	0.303	0.317	0.333	0.347	0.358	0.394	0.414	0.374	0.367	0.376	0.352
Shanxi	0.344	0.355	0.356	0.356	0.270	0.289	0.310	0.280	0.286	0.271	0.320	0.312
Inner Mongolia	0.209	0.223	0.235	0.248	0.259	0.262	0.234	0.251	0.255	0.248	0.252	0.243
Liaoning	0.341	0.358	0.365	0.365	0.352	0.325	0.331	0.347	0.353	0.349	0.359	0.350
Jilin	0.257	0.267	0.275	0.282	0.245	0.244	0.253	0.269	0.279	0.257	0.260	0.263
Heilongjiang	0.249	0.262	0.265	0.304	0.293	0.245	0.245	0.262	0.266	0.250	0.253	0.263
Shanghai	0.450	0.471	0.529	0.565	0.598	0.591	0.581	0.596	0.613	0.622	0.640	0.569
JIANGSU	0.670	0.597	0.612	0.645	0.676	0.682	0.696	0.716	0.739	0.749	0.763	0.686
Zhejiang	0.481	0.490	0.510	0.553	0.566	0.563	0.578	0.617	0.631	0.632	0.595	0.565
Anhui	0.288	0.309	0.326	0.348	0.362	0.370	0.387	0.419	0.435	0.409	0.426	0.371
Fujian	0.343	0.352	0.369	0.395	0.424	0.446	0.449	0.455	0.403	0.416	0.420	0.407
Jiangxi	0.234	0.244	0.256	0.285	0.304	0.326	0.349	0.341	0.359	0.348	0.352	0.309
Shandong	0.455	0.503	0.492	0.510	0.524	0.524	0.501	0.507	0.531	0.555	0.586	0.517
Henan	0.359	0.380	0.404	0.436	0.461	0.388	0.397	0.410	0.423	0.418	0.430	0.410
Hubei	0.331	0.355	0.370	0.395	0.363	0.368	0.380	0.405	0.414	0.419	0.438	0.385
Hunan	0.321	0.334	0.349	0.360	0.372	0.345	0.354	0.378	0.402	0.402	0.424	0.367
Hunan	0.591	0.616	0.607	0.670	0.704	0.718	0.757	0.795	0.804	0.816	0.834	0.719
Guangxi	0.343	0.219	0.231	0.243	0.250	0.256	0.278	0.308	0.330	0.323	0.324	0.282
Hainan	0.194	0.216	0.229	0.250	0.249	0.253	0.273	0.286	0.288	0.268	0.223	0.248
Chongqing	0.259	0.286	0.308	0.328	0.335	0.341	0.354	0.372	0.384	0.354	0.370	0.336
Sichuan	0.324	0.344	0.367	0.389	0.395	0.419	0.447	0.467	0.439	0.428	0.438	0.405
Guizhou	0.216	0.237	0.247	0.268	0.313	0.325	0.324	0.295	0.312	0.294	0.305	0.285
Yunnan	0.256	0.271	0.285	0.303	0.302	0.316	0.301	0.331	0.344	0.308	0.317	0.303
Shannxi	0.279	0.298	0.315	0.332	0.322	0.323	0.340	0.375	0.391	0.384	0.381	0.340
Gansu	0.231	0.247	0.258	0.228	0.257	0.294	0.323	0.353	0.350	0.310	0.315	0.288
Qinghai	0.177	0.184	0.157	0.163	0.165	0.175	0.204	0.214	0.216	0.180	0.175	0.183
Ningxia	0.167	0.172	0.179	0.184	0.176	0.195	0.211	0.222	0.223	0.197	0.201	0.193

2. From a regional perspective, by 2022, five provinces—Beijing, Shanghai, Jiangsu, Guangdong, and Zhejiang—had achieved a coupling coordination level between NQP and the DE that was above the initial coordination level, with Guangdong reaching a

well-coordinated level. As economically developed provinces in China's eastern region, Beijing, Shanghai, Jiangsu, Guangdong, and Zhejiang lead in the high-quality development coupling coordination of NQP and the DE. These provinces not only lead in digital infrastructure construction but also demonstrate significant advantages in innovation capability, industrial upgrading, and green development.

In the eastern region, Hainan had the lowest coupling coordination degree, ranking 26th among the 30 provinces in China during the observation period, indicating a moderately uncoordinated state. In the relatively underdeveloped western region, Sichuan's average coupling coordination degree ranked 9th, significantly higher than Hainan, indicating a slightly uncoordinated state. Guangdong, the eastern region with the highest average coupling coordination degree, was in a well-coordinated state, while Qinghai, the western region with the lowest average coupling coordination degree, had an average of 0.193, indicating a severely uncoordinated state. As of the end of 2022, 18 provinces in China still had a low coupling coordination degree, below the nearly uncoordinated state. Only five eastern provinces—Beijing, Shanghai, Jiangsu, Guangdong, and Zhejiang—were at or above the initial coordination level, indicating a considerable gap in the coupling coordination level of NQP and the DE between provinces. The overall level in each province needs to be improved.

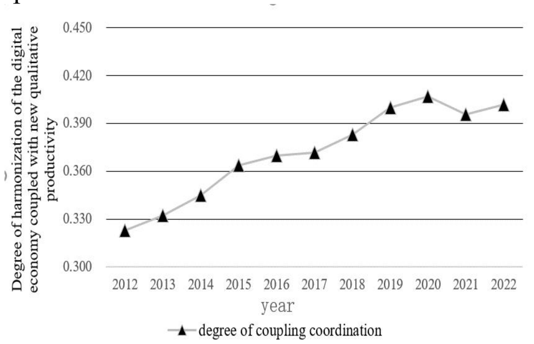

Figure 4. Changes in the Degree of Coordination of the Coupling of Digital Economy and New Quality Productivity in China, 2012-2022

5. Conclusions and Recommendations

During the observation period from 2012 to 2022, the development of the DE across 30 provinces in China showed a significant upward trend, with the DE development index increasing from 0.085 to 0.168. In 2012, the DE development index was relatively low but grew year by year, particularly accelerating after 2016. By 2022, the DE development index had reached a new high, demonstrating significant progress in regional digital economies during this period. Simultaneously, during these ten years, the NQP in the 30 provinces of China initially showed an upward trend and then remained relatively stable. Although the overall trend showed fluctuations of rising first and then slightly decreasing, the changes in each year after 2018 were not significant. The development index of NQP was at a low level in 2012 but generally showed a fluctuating upward trend. Compared with the DE, the growth rate of NQP was relatively slower, with slight declines in some years. However, from 2012 to 2022, the development index of NQP still generally increased, indicating a gradual enhancement of NQP during this period.

From 2012 to 2022, the coupling coordination degree between the DE and NQP in the 30 provinces of China generally showed an upward trend, fluctuating between 0.323 and 0.407. Starting from 0.323 (slightly uncoordinated) in 2012, the coupling coordination degree continuously increased, reaching a peak of 0.407 in 2020. Since 2019, the coupling coordination degree has remained around 0.4, indicating that the DE and NQP entered a nearly uncoordinated stage. Before 2020, the DE in each province developed rapidly, while the improvement in NQP lagged behind and did not achieve synchronized growth with the DE. From 2020 onwards, the coupling coordination degree increased significantly, shifting from slightly uncoordinated to nearly uncoordinated. By 2022, the coupling coordination level between the DE and NQP in five provinces—Beijing, Shanghai, Jiangsu, Guangdong, and Zhejiang—had reached above the initial coordination level, with Guangdong achieving a well-coordinated level. By the end of 2022, 18 provinces in China still had a low coupling coordination degree, below the nearly uncoordinated level. The coupling coordination levels of NQP and the DE varied significantly between provinces, with overall levels needing improvement.

Based on the above research conclusions, the following three policy implications are proposed:

1.Strengthening Digital Infrastructure Construction: To further enhance the coupling coordination level of the DE and NQP, provinces should increase investment in digital infrastructure, especially in relatively underdeveloped areas. Improving internet access, broadband coverage, and the construction of mobile base stations provides a solid foundation for the development of the DE. Meanwhile, governments should actively promote the application of 5G and IoT technologies to facilitate the digital transformation of various industries. Enhancing the coverage and quality of digital infrastructure can effectively reduce regional development disparities and promote coordinated development nationwide.

2.Promoting Technological Innovation and R&D Investment: Increasing investment in technological innovation and R&D is key to enhancing NQP. Governments should encourage enterprises, particularly in high-tech and green technology sectors, to increase R&D investment through policy incentives and financial support. Establishing a sound innovation ecosystem, promoting industry-university-research collaboration, and improving the conversion rate of scientific and technological achievements are crucial. Additionally, attracting and cultivating high-quality scientific and technological talents enhances innovation capabilities and promotes the coordinated development of NQP and the DE. This approach not only improves production efficiency and product quality but also injects new vitality into economic growth.

3.Promoting Regional Coordinated Development: To address the imbalance in the development of the DE and NQP across regions, governments should formulate differentiated regional development strategies. Providing more policy support and financial investment to slower-developing regions helps promote the rational allocation of resources and optimize industrial layouts, reducing regional disparities. Furthermore, establishing regional cooperation mechanisms to facilitate the cross-regional flow of information, technology, and talent forms a pattern of regional linkage development. Promoting the coordinated development of eastern developed regions with central and western regions achieves balanced regional economic growth, thereby enhancing the overall quality and efficiency of the national economy.

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