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An Empirical Analysis of the Digital Economy Enabling NQP

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Abstract: The 2024 Government Work Report of China explicitly emphasizes the need to "vigorously promote the construction of a modern industrial system and accelerate the development of new quality productivity (NQP)," underscoring the critical importance of NQP in the current era. This paper assesses the development of the provincial digital economy across four dimensions: digital infrastructure, digital industrialisation, industrial digitalisation, and digital governance. Simultaneously, the development of provincial NQP is measured through three dimensions: technological innovation, industrial innovation, and factor innovation. Using the Kernel density estimation method, this study analyzes the dynamic evolution of NQP development in China from multiple perspectives. Additionally, a double fixed-effects model is employed to empirically examine the role of the digital economy in empowering NQP, and a random forest approach is applied to investigate the "non-linear spillover effect" of the digital economy on NQP development. The findings of this study are as follows: (i) The digital economy significantly advances NQP, primarily by promoting technological innovation, optimizing employment structures, and enhancing factor synergy, with digital industrialization being a key driver of this progress. (ii) The digital economy exhibits a non-linear spillover effect on NQP development.

Keywords: NQP, Digital Economy, Kernel Density Estimate, Random Forest, Fixed-Effects Model.

1. Introduction

Academic research on the connotation of NQP primarily explores the following dimensions: First, NQP represents a significant advancement over traditional productivity. Liu Zhibiao, considering the context of social and technological change, posits that NQP is fundamentally characterized by the "arithmetic power" it embodies[1]. Second, NQP entails a qualitative enhancement of productivity components. Wang Guocheng and colleagues argue that its core lies in the qualitative transformation of workers, labor materials, and labor objects, as well as their optimal combination[2]. Finally, NQP integrates both the "new" and the "quality" aspects, with Zhou Wen and co-authors emphasizing that science and technology innovation play a pivotal role in driving this form of productivity[3].

The existing academic literature has also examined the intrinsic link between the elements of the digital economy and NQP. Cui Yun's research highlights that digital technology fosters the development of production factors and empowers various aspects of social reproduction, thereby driving the growth of NQP[4]. Additionally, the logical connection between the digital economy and

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NQP has been investigated. Wu Wensheng and others suggest that the digital economy can enhance NQP by promoting technological innovation and optimizing employment structures[5].

2. Variable Measurement

2.1. Explanatory variable: digital economy

Based on the core essence of digital economy, this paper systematically constructs a complete set of digital economy index system, and deeply analyses the conditions, applications and policy environment for its development. A comprehensive index of digital economy development level is set as the core of the assessment framework, which considers four dimensions of digital economy development from the macro level: digital infrastructure, digital industrialisation, industrial digitisation and digital governance. These four dimensions cover the prerequisites for the development of the digital economy, the prosperity of the ICT (Information and Communication Technology) industry, the in-depth integration of digital technology with traditional industries, and the external environment that supports the development of the digital economy, respectively. Further refined, we selected 12 sub-indicators to fully reflect various aspects of the digital economy.

2.2. Explained variable: NQP

The unique feature of NQP is that it no longer relies excessively on traditional means of production and resources, but pays more attention to the incorporation and use of modern factors such as innovation, science and technology and information technology. Specifically, the main features of NQP are reflected in the following aspects:

Firstly, in the field of new technology, the cultivation and formation of NQP cannot be separated from the support of science and technology innovation. In particular, the radical change of the traditional mode of production by scientific and technological innovation has provided a strong impetus for the development of NQP.

Secondly, in the area of new industries, NQP realises a comprehensive upgrade of production methods by promoting industrial innovation and stimulating industrial change. This not only helps to enhance the competitiveness of industries, but also injects new vigour into the sustainable development of the economy.

Finally, in terms of new factors, NQP has achieved an overall improvement in production efficiency and productivity levels through the innovative reorganisation and application of production factors. This innovative restructuring not only optimises the allocation of resources, but also improves the efficiency of resource use, laying a solid foundation for the development of NQP.

Based on the above connotation and main features of NQP, this paper constructs a scientific and reasonable comprehensive evaluation index system of NQP from the three dimensions of technological innovation, industrial innovation and factor innovation.

2.3. Control and mediating variables

Table 1: Control and mediating variables.

	Variable	Symbol
Control variable	Level of human capital	hum
	innovation capacity	inno
	Total factor productivity	pro

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Table 1: (continued).

Mediating variable	Level of economic development	Eco
	Technology innovation	tech
	employment structure	job
	Elementary synergy	elem

3. Analysis of the dynamic evolution of the development of NQP in China

In order to enhance the diversity of analysis perspectives and the relevance of the research conclusions, 30 provinces and cities (due to the large amount of missing data, Tibet is not included in the scope of this research) were divided into three regions, namely, East, Central and West, and analyzed comparatively, and the specific results of the division are as follows The specific results are shown in the table below:

Table 2: Eastern, central and western divisions.

Region	Province
Eastern	Fujian, Shanghai, Tianjin,Liaoning, Jiangsu, Shandong, Hebei, Guangdong, Hainan, Beijing, Zhejiang
Central	Heilongjiang, Hunan, Shaanxi, Hubei, Jilin, Jiangxi, Henan, Anhui
Western	Gansu, Inner Mongolia, Yunnan, Qinghai, Xinjiang, Chongqing, Guangxi,, Guizhou, Shaanxi, Ningxia, Sichuan

Kernel density estimation, a non-parametric method, effectively assesses the dynamic evolutionary trends within a sample distribution by employing a smoothing function to align with the data. The empirical distribution function it produces is:

$$F_n(y) = \frac{1}{n}\sum_{i=1}^{n} I(x_i \le y) \tag{1}$$

Here, n represents the number of provinces. The function I(z) is a conditional indicator, where I(z)=1 if z is true, and I(z)=0 if z is false. Consequently, the density function of the random variable X under this method is expressed as:

$$f(x) = [F_n(x+h) - F_n(x-h)] = \frac{1}{nh}\sum_{i=1}^{n} K[(x_i - x)/h] \tag{2}$$

Where, x represents the mean, and the observations are assumed to be independent and identically distributed. K denotes the kernel density, while h represents the window width, which is typically chosen to be small to enhance accuracy. The kernel density function itself serves as a weighting or smoothing function and generally satisfies the following criteria:

$$K(x) \ge 0, K(x) = K(-x), \int_{-\infty}^{+\infty} K(x)dx = 1, \sup K(x) < +\infty, \int_{-\infty}^{+\infty} K^2(x)dx < +\infty$$

The main function of the Kernel function is to smooth the transformation or weighting, in this paper, the Gaussian kernel function is used for estimation and analysis, the Kernel function formula is specified as follows:

$$f(x) = \frac{1}{\sqrt{2\pi}}\exp(-\frac{x^2}{2}) \tag{3}$$

From Figure 1, the peak of the curve as a whole is near the position of the index of 0.1, indicating that the development level of China's NQP is still low, but the peak of the curve of the kernel density of NQP gradually moves to the right in the distribution position, indicating that the level of

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development of China's NQP in all provinces is gradually improving. In the distribution pattern of the function, the width of the curve changes from the width of small differences gradually becomes larger, and the width of the peak as a whole expands, indicating that the phenomenon of low-level aggregation of NQP has slowed down nationwide, and the level of NQP in some regions develops faster, and the development of the imbalanced situation occurs. In terms of the ductility of the function curve, compared with 2019, the kernel density curve in 2022 becomes flatter, and the right trailing tail gradually becomes longer, indicating that the level of NQP develops rapidly in some provinces, and the gap between provinces gradually increases. As a whole, the level of NQP in China is increasing year by year.

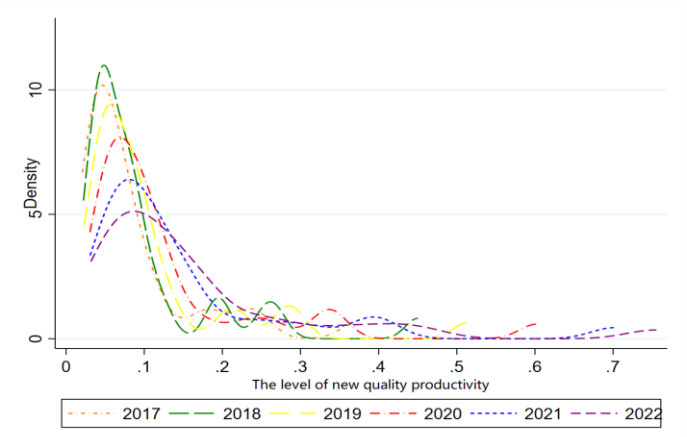

Figure 1: Kernel density map of overall national NQP.

4. Empirical Analysis of the Digital Economy Enabling NQP Development

As a non-physical factor of production, digital requires the help of many links in order to form higher industrial development benefits, this study analyses the path of the digital economy affecting the development of NQP from the three perspectives of scientific and technological innovation, employment structure and elementary synergy.

4.1. Model set-up

A double fixed model is used to study the impact of the digital economy on the development of NQP. The model is set up as:

$$S_{it} = \alpha + \beta \cdot dig_{it} + \sum_{j} \gamma_j \cdot (X_{it})_j + \mu_i + \delta_t + \varepsilon_{it} \quad (4)$$

Where, i represents the province, t represents the year, denotes the level of NQP, indicates the level of digital economy development, and captures the degree of the digital economy's impact on NQP. A series of control variables are included, along with individual fixed effects and time fixed effects, to account for random perturbations.

To move forward to explore the pathway through which the digital economy influences NQP, a mediated effects model is set up as follows:

$$InterVar_{it} = \alpha + \beta_1 \cdot dig_{it} + \sum_{j} \gamma_j \cdot (X_{it})_j + \mu_i + \delta_t + \varepsilon_{it} \quad (5)$$

$$S_{it} = \alpha + \beta_2 \cdot dig_{it} + \beta_3 \cdot InterVar_{it} + \sum_{j} \gamma_j \cdot (X_{it})_j + \mu_i + \delta_t + \varepsilon_{it} \quad (6)$$

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where $InterVar_{it}$ is the intermediary variable.

4.2. Benchmark regression

The impact of the digital economy on the level of development of NQP was tested using model (4) and the results are presented in the table below:

Table 3: Direct impact of the digital economy on the development of NQP.

Variable	(1)	(2)
dig	0.874** (18.460)	0.716** (10.732)
hum		-0.025 (-0.504)
inno		0.859** (7.859)
pro		-0.043 (-1.062)
eco		-0.231 (-1.280)

* p<0.05 ** p<0.01 t-values in parenthesis

In Table 3, the first and second columns present the regression results of the double fixed model, first without and then with the inclusion of control variables. The coefficient of dig is notably greater than 0.7 at the 1% significance level, regardless of whether control variables are included, indicating that the digital economy significantly fosters the development of NQP. Additionally, the coefficient for the control variable, innovation capacity (inno), converges significantly around 0.9, suggesting that enhancing a region's innovation capacity can strongly drive the growth of local NQP.

4.3. Benchmark regression

We proceed to examine the coefficients of models (5) and (6). To do this, we first examine the coefficients of model (5) and model (6) separately. If both coefficients are statistically significant, we can assume that the mediating effect is significant; on the other hand, if at least one coefficient is not significant, we need to further verify its reliability with the help of Bootstrap method. The detailed test results for the mediating variables of technological innovation (tech), employment structure (job) and elementary synergy (elem) are presented in the following table.

Table 4: Mediating effects of the digital economy on the development of NQP.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
dig	0.826** (21.143)	0.686** (11.111)	0.389** (6.128)	0.758** (10.557)	0.788** (6.889)	0.716** (10.732)
tech		0.821** (7.834)				
job				0.389** (5.600)		
elem						0.226** (4.067)

Columns (1), (3), and (5) of Table 4 present the regression results of the digital economy on the mediating variables: technological innovation, employment structure, and elementary synergy. Meanwhile, columns (2), (4), and (6) display the results of the regressions of the digital economy and technology innovation, employment structure and elementary synergy on NQP, respectively.

Table 4 demonstrates that the digital economy has a significantly positive effect on all three mediating variables. Furthermore, each of these mediating variables—technological innovation,

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employment structure, and elementary synergy—exerts a significantly positive influence on NQP development. This suggests that these factors mediate the relationship between the digital economy and the advancement of NQP.

4.4. Non-linear spillover effects

In order to deeply explore the possible non-linear spillover effects of the digital economy on the development of NQP, we used Random Forest to fit The digital economy's bias towards the development of NQP. As shown in Figure 2:

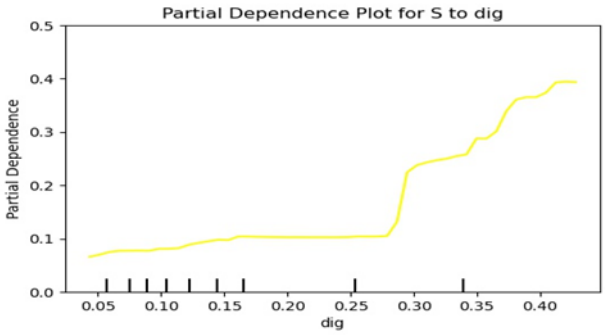

Figure 2: Biased dependence of NQP development on the digital economy.

In Figure 2, the horizontal axis represents the level of digital economy development, while the curve illustrates the bias dependence function. The figure reveals a consistently significant positive correlation between the development of NQP and the digital economy. However, the strength of this influence varies across different stages. Specifically, in the early stages of digital economy development, the positive correlation curve is relatively flat, indicating a weaker marginal effect. As the digital economy progresses and its development level crosses the threshold between 0.25 and 0.45, the situation shifts markedly, and the potential of the digital economy is more fully realized.

5. Conclusion

(i) the digital economy significantly promotes the development of NQP, mainly through the promotion of scientific and technological innovation, optimisation of the employment structure, and the promotion of factor synergy, and the digital industrialisation is a key dimension of the promotion;

(ii) there is a non-linear spillover effect of the digital economy on the development of NQP, With the further development of the digital economy, when its level of development crosses the interval of 0.25 to 0.45, the positive marginal effect of the digital economy on the development of NQP increases significantly, showing a steeper curve trend. This fully indicates that, after a certain threshold has been reached by the digital economy, the driving effect on NQP will be more significant and become an important force in promoting economic transformation and upgrading.

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