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Can Big Data Pilot Zones Empower the Development of New Quality Productivity?

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Abstract: The development of new quality productivity (NQP) is a crucial driving force for promoting high-quality economic development, and the study of its drivers is vital for socio-economic development. Therefore, this paper examines the establishment of national big data pilot zones (BDPZs) as a quasi-natural experiment, based on the data of 284 cities in China from 2014 to 2022, using the difference-in-differences (DID) method and the mediation effect model, and empirically analyzes the impact effects and transmission channels of the establishment of BDPZs on NQP. The study finds that: (1) the establishment of BDPZs has a significant impact on improving the level of NQP in pilot zones, and the conclusion remains valid after a series of robustness tests; (2) Mechanism analysis demonstrates that the establishment of BDPZs enhances the development of NQP by advancing the development of digital inclusive finance and fostering green technological innovation; (3) Heterogeneity analysis reveals that the establishment of BDPZs helps to promote the level of NQP in key cities and non-resource cities. This study not only enriches the theoretical framework between the establishment of BDPZs and NQP, but also reinforces the positive impact of data factors on NQP, while providing significant policy implications for advancing high-quality economic development.

Keywords: New Quality Productivity; Big Data; Data Factors; Digital Inclusive Finance; Green Technology Innovation.

1. Introduction

In September 2023, General Secretary Xi Jinping first put forward the innovative concept of "new quality productivity" during his visit to China's Heilongjiang Province, and pointed out that "integrating scientific and technological innovation resources, leading the development of strategic emerging industries and future industries, and accelerating the formation of new quality productivity capacity". Compared with the traditional productivity, the new quality productivity is an advanced productivity quality state that takes innovation as the leading role, gets rid of the traditional economic growth mode and productivity development path, which has the characteristics of high technology, high efficiency and high quality, and conforms to the new development concept. It is generated by revolutionary breakthroughs in technology, innovative allocation of production factors, and deep transformation and upgrading of industries, with the leap of workers, labor materials, labor objects and their optimal combinations as the basic connotation, and the substantial increase of total factor productivity as the core symbol. It is characterized by innovation, the key is high quality, and the essence is advanced productivity (Wu et al., 2024). In 2024, the "Report on the Work of the Chinese Government" also clearly stated that "we will vigorously promote the construction of a modern industrial system and accelerate the development of new quality productivity." In July 2024, the Third Plenary Session of the 20th Central Committee of the Communist Party of China once again put forward: "Improve the institutional mechanism for developing new quality productivity according to local conditions" and "Improve relevant rules and policies, accelerate the formation of production relations that are more compatible with new quality productivity, and promote the agglomeration of various advanced production factors to develop new quality productivity". The concept of "new quality productivity" points out the way for the high-quality development of China's economy and scientific and technological innovation, which has important theoretical significance and profound practical significance (Song, 2024), and also brings guiding significance for deepening and expanding of the modernization of the Chinese modernization in the new era (Hu, 2023). Therefore, accelerating the cultivation and development of NQP is a crucial driving force for promoting high-quality economic development.

With the rapid development of science and technology and the popularization of the Internet, big data has become an important part of the global economy, which has profoundly changed the basic composition of China's social productivity and become a new driving force for the formation and development of NQP. On the one hand, as a fundamental strategic resource, big data has emerged as a strategic core production factor leading a new round of technological revolution and transformation, and has a leading and transforming effect on traditional economies (Yang et al., 2022). It plays an irreplaceable role in propelling scientific and technological innovation, driving industrial transformation, and optimizing the allocation of production factors, thereby laying the foundation for the formation and development of NQP. At the scientific and technological level, the combination of big data with cutting-edge technologies such as cloud computing, and artificial intelligence has driven fundamental changes in the paradigm of scientific research and the mode of technological development; At the industrial level, the deep integration of big data with cutting-edge technologies such as cloud computing, artificial intelligence, and 5G significantly facilitates the digitalization, networking, and intelligent transformation of traditional industries, propels the transformation and upgrading of traditional industries, gives rise to a series of new industries, new forms, and new modes, and drives the formation and development of NQP (Xu et al., 2022). On the other hand, the core of NQP is new factors. As a critical national production factor, big data is spearheading profound transformations in the field of

production, giving birth to new labor materials, breeding new labor objects, and cultivating new labor forces, becoming a new driving force to promote and lead economic and social development, thus promoting the formation and development of NQP (Feng and Lin, 2024).

In order to fully leverage the aggregation effect of data factors and the basic strategic resource role of big data, the Chinese government clearly issued the "Outline of Action for Promoting the Development of Big Data" in 2015, which explicitly states that "regional pilot projects should be carried out, we must accelerate the deployment of big data, deepen the application of big data, speed up the construction of a strong data force, and push forward the construction of national big data comprehensive pilot zones". These initiatives aim to promote the effective integration of big data infrastructure within regions, and facilitate the centralized aggregation and efficient utilization of data resources. In the same year, the 13th Five-Year Plan for National Economic and Social Development of the People's Republic of China adopted by the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China once again proposed the implementation of the national big data strategy, emphasized that "big data as a basic strategic resource, fully implement measures to promote the development of big data, and accelerate the promotion of the sharing and opening up of data resources and the development and application of data resources, and support the transformation and upgrading of industry". Therefore, can region-oriented big data development policies (the establishment of national BDPZs) enhance the level of NQP? What are the mechanisms and transmission channels? This paper will deeply analyze how the establishment of BDPZs empowers the development of regional NQP, and provide policy recommendations to fully leverage the empowering role of BDPZs.

2. Literature Review

2.1. The connotation and influencing factors of NQP

As an important driving force of the new round of scientific and technological and industrial revolutions, NQP is a modern new form of productivity with innovation playing the leading role, data elements as the core, and high-tech applications as the main feature (Li and Liao, 2023). The proposal of NQP has become a frontier field of scholars' attention. Regarding the research on the theoretical aspects of NQP, NQP represents a novel form and qualitative state derived from traditional productive forces under the production conditions of informatization and digitalization due to the continuous breakthrough and innovation of science and technology and the continuous upgrading and development of industries, which is characterized by outstanding innovation, extensive permeability, efficient quality enhancement, observable dynamism and remarkable integration (Du et al., 2023). Feng and Lin (2024) believed that the NQP is proposed on the basis of traditional productivity, which is the result of a qualitative transformation of social productivity after a long period of accumulation and development to reach a certain stage, and it is the "leap" of productivity under the new round of scientific and technological revolution and industrial transformation (Du et al., 2023). It is a productivity led by innovation, especially the productivity of revolutionary breakthroughs in key technologies, which is different from traditional productivity development methods that rely on large resource inputs and high energy consumption (Zhou and Xu, 2023), it represents an advanced productivity quality that meets the requirements of high-quality development (Wang and Cheng, 2024). Sheng (2024) suggested that the formation of NQP is a process of profound transformation, which is the gradual replacement of traditional productive forces by advanced productive forces, represents a qualitative leap in the level of productivity, which promotes the acceleration of socio-economic development towards a higher quality, more efficient and more sustainable development model, while simultaneously giving rise to new workers, new labor objects and new labor materials. Hong (2024) argued that the NQP can be summarized as new technology, new energy sources, new industries, and a digital economy that promotes the integration of these three.

Regarding the research on the influencing factors of NQP, Wei et al. (2024) based on provincial-level data in China, showed that the reform of big data institutions has effectively raised the level of NQP by creating a good digital innovation ecosystem led by digital innovation subjects, supported by digital innovation platforms, and protected by digital innovation environments. Wu and Duan (2025) found that the Industrial Internet promotes the development of regional NQP through improving regional innovation efficiency, driving the modernization of industrial chains, and promoting the upgrading of industrial structures. Xu et al. (2025) demonstrated that the digital economy fosters the development of NQP by improving the efficiency of green innovation. Yuan et al. (2025) discovered that the openness of public data enhances the level of NQP through effective markets and promising government. Yao et al. (2025) revealed that digital infrastructure empowers the development of NQP by fostering technological innovation, enhancing the efficiency of factor allocation, and driving the upgrading of industrial structures. Gao et al. (2025) concluded that the pilot policy of new urbanization can promote the level of NQP.

2.2. Economic consequences of the establishment of national BDPZs

With the rapid development of science and technology and the popularization of the Internet, big data has emerged as a crucial component of the global economy. Existing studies have explored the policy effects of the establishment of national BDPZs from the perspectives of innovation-driven, green development, industrial structure upgrading, total factor productivity improvement and financial development. In terms of innovation-driven development, some scholars have found through panel data analysis of prefecture-level cities that BDPZs enhance the innovation capacity of cities by fostering mass entrepreneurship and innovation, advancing industrial structure upgrading, and optimizing resource allocation (Xu et al., 2022; Zhang et al., 2023); Ren et al. (2023) based on data from Chinese listed enterprises, argued that the establishment of national BDPZs can effectively promote enterprises' green technological innovation by improving the level of human capital, alleviating enterprises' financing constraints, and enhancing the intensity of regional environmental regulation. Regarding green development, Liu and Xiao (2024) based on sample data from Chinese cities, demonstrated that the establishment of BDPZs can reduce carbon emissions by raising public awareness of environmental protection and enhancing the green innovation capacity of cities; Shen and Wang (2024) used the

establishment of national BDPZs as a natural experiment to investigate the impact of digital industrialization (represented by big data) on urban energy conservation development. The study discovered that digital industrialization influences urban energy conservation development by driving industrial sector output growth, promoting industrial upgrading, stimulating green technology innovation, and mitigating resource mismatch. In terms of industrial structure upgrading, Yang (2023) found that the establishment of BDPZs promotes industrial structure upgrading by enhancing technological innovation and improving financial deepening levels. Wei et al. (2022) argued that the establishment of BDPZs can significantly facilitate the ecological transformation of urban industries. In terms of improving total factor productivity, Shi and Sun (2022) revealed that the establishment of BDPZs can improve enterprise total factor productivity by promoting enterprise innovation, improving the efficiency of capital factor allocation, optimizing the allocation of labor factors, and improving the data empowerment effect of enterprises; Lyu et al. (2024) used national BDPZs as a quasi-natural experiment, demonstrated that the digital economy can enhance green total factor productivity by promoting technological innovation, optimizing industrial structures, and improving resource misallocation. In the realm of financial development, Wang et al. (2024) utilized the establishment of national BDPZs as a quasi-natural experiment to explore the impact of data factor agglomeration on the development of urban green finance. The study revealed that data factor agglomeration effectively enhances the development of urban green finance by facilitating industrial structure upgrading and driving digital technology innovation; Li et al. (2024) demonstrated that data factor agglomeration can facilitate the development of digital inclusive finance by promoting digital technology innovation and attracting the agglomeration of digital talent. Additionally, some scholars have also found that the establishment of BDPZs can enhance market transaction efficiency and urban production efficiency, promote high-quality development of the regional economy (Su et al., 2023), and improve urban ecological resilience (Zhang et al., 2024).

In general, the existing research has not yet explored the impact of the establishment of BDPZs on NQP, but the existing research has deeply analyzed the impact of BDPZs on industrial structure upgrading, total factor productivity enhancement, and technological innovation advancement, thereby laying a foundation for the study of NQP. Based on this foundation, this paper employs the establishment of national big data pilot zones as a quasi-natural experiment to investigate the impact of the establishment of BDPZs on NQP. The possible marginal contributions of the research of this paper mainly include three aspects: (1) This paper takes the policy initiative of the establishment of national big data comprehensive pilot zones as a research opportunity to explore its impact on NQP based on the urban perspective; (2)This study integrates BDPZs, digital inclusive finance, green technology innovation and NQP into a unified theoretical framework, empirically analyzing the mediating role of digital inclusive finance and green technology innovation in the relationship between the establishment of BDPZs and NQP; (3)Considering the regional differences, this paper explores the heterogeneity of the impact of the establishment of BDPZs on NQP in different regions.

3. Research Hypotheses

3.1. Big data pilot zones and new quality productivity

The establishment of national BDPZs plays an indispensable and central role in strengthening and leveraging the agglomeration effect of data elements, unleashing innovation vitality, promoting the clustering of big data industries, and driving continuous upgrading and optimization of digital infrastructure (Zhang and Li, 2024). First, the core objective of the establishment of national BDPZs is to leverage the agglomeration effect of data elements, activate the new kinetic energy of data, and unleash the power of innovation. The core of NQP is new factors. As a critical national factor of production, data elements are leading profound transformations in the field of production, giving birth to new labor materials, breeding new labor objects, and cultivating new labor forces, thus forming data productivity, becoming a new driving force to promote and lead economic and social development, thereby facilitating the formation of NQP (Feng and Lin, 2024). Secondly, the establishment of BDPZs not only strengthens the construction level of regional digital infrastructure but also facilitates the effective integration of relevant data resources, fully plays a foundational resource and innovation engine function of data as a key production factor, empowers the formation and development of NQP (Sun et al., 2023). Finally, the establishment of national big data pilot zones provides strong support for the agglomeration and vigorous development of big data industries by optimizing digital infrastructure and implementing a series of targeted policy preferences and industrial support strategies, thereby effectively facilitating the agglomeration and development of big data industries (Qiu and Zhou, 2021). At the same time, the establishment of BDPZs has also attracted the landing of high-tech enterprises and the inflow of high-tech talents, which favorably promotes the agglomeration of digital talents. This meets the urgent demand for digital talents in pilot zones, provides a solid talent guarantee for the sustainable development of pilot zones, and stimulates the vitality of research and innovation, thereby driving the advancement of NQP (Song et al., 2024). Based on the above analysis, the following hypotheses are proposed.

Hypotheses 1: The establishment of BDPZs has a significant impact on the improvement of NQP.

3.2. The mediating role of digital inclusive finance

Big data plays an important role in promoting financial development, enhancing the efficiency and universality of financial services, fostering the innovation of financial products and services, and strengthening the ability of financial risk management and prevention. The construction of big data pilot zones can fully leverage the demonstration and driving role of new infrastructure construction, promote the improvement of information communication and payment settlement systems, provide crucial guarantees for the innovative development of digital inclusive finance, and further accelerate the dissemination and service expansion of digital inclusive finance (Chang et al., 2023). The development of big data has enabled financial institutions to break the geographical restrictions of business outlets and achieve wide coverage of services, so that even enterprises located in remote regions can enjoy high-quality financial

services (Guo et al., 2020). The establishment of national BDPZs realizes the in-depth integration and precise analysis of information between financial institutions and financing targets, opening up a diversified, convenient and efficient financing channel for financial demanders, which is conducive to promoting the emergence of the digital finance industry and improving the accessibility and universality of financial services (Zhang et al., 2019). In general, the establishment of BDPZs can quickly integrate the relevant information of financing targets and financial institutions, and open up new channels of financing for financial demanders (Zhang and Li, 2024). This not only reduces the cost consumption of information search and matching between capital suppliers and demanders, but also facilitates information sharing (Wang et al, 2020), reduces information asymmetry, promotes the flourishing of digital finance industries, and accelerates the development of digital inclusive finance (Zhang and Li, 2024).

In the digital era, with the help of the new generation of information technology represented by big data, blockchain, cloud computing, 5G, and artificial intelligence, digital inclusive finance has broken the geographical limitation and information asymmetry of traditional finance (Sun et al., 2024), dramatically improved the popularity and accessibility of financial services, and made funds flow more efficiently, accurately and quickly to strategic emerging industries. This not only injects vitality into strategic emerging industries and stimulates the innovation vitality of industrial enterprises, but also facilitates the R&D, application and promotion of new technologies, pushes forward the optimization and upgrading of industrial structures, and promotes the formation and development of NQP. In addition, as an innovative force of the modern financial system, digital inclusive finance effectively promotes scientific and technological innovation, accelerates the transformation and application of scientific and technological achievements, promotes the optimization and upgrading of industrial structures, and lays the foundation for the development of NQP by optimizing the allocation of financial resources. Relying on a new generation of information technology such as cloud computing, artificial intelligence, big data, 5G, blockchain, digital inclusive finance realizes the efficient and intelligent evaluation of green projects, greatly expands the channels for enterprises to obtain information, effectively alleviates the problem of information asymmetry existing in the financial market, and provides more efficient and convenient financial support for the development of green industries (Huang and Li, 2017), promotes the rapid development of green industries, injects new vitality and momentum for the comprehensive progress of the economy and society, and lays the foundation for the green development of NQP. Based on the above analysis, the following hypotheses are proposed.

Hypotheses 2: The establishment of national BDPZs promotes the development of NQP by accelerating the development of digital inclusive finance.

3.3. The mediating role of green technology innovation

The establishment of BDPZs has made the application of data elements more extensive, enriched the channels for knowledge acquisition and dissemination, and continuously enhanced dissemination efficiency, and accordingly increased the stock of social knowledge, which is conducive to the role of innovation elements such as talent, capital, and high-tech enterprises, thereby elevating the level of green technological innovation (Wei et al., 2022). Meanwhile, the BDPZs have successfully attracted the inflow of high-tech talents with a high level of professional qualities and advanced technical capabilities, which favorably facilitates the agglomeration of digital talents, meets the urgent demand for digital talents within the pilot zones, provides robust talent support for their sustainable development, and stimulates the vitality of R&D and innovation, thus laying the foundation for green technological innovation (Song et al., 2024).

General Secretary Xi Jinping pointed out that “green development is the underpinning of high-quality development, NQP is inherently green productive forces, representing an advanced form of productive forces that align with the new development philosophy.” Green technological innovation can effectively improve the means of labor, adjust the relations of production, optimize resource allocation, drive industrial transformation and upgrading, boost total factor productivity, and facilitate the formation and development of NQP. In addition, green technology innovation can enhance the efficiency of resource utilization, promote the efficient and recycled use of resources through technological iteration and upgrading, cultivate a new model of green and low-carbon development (Xu and Chen, 2024), facilitate the green transformation of traditional productive forces, realize the profound transformation of productive forces, and ultimately promote the development of NQP. Based on the above analysis, we propose the following hypotheses.

Hypotheses 3: The establishment of BDPZs can drive the development of NQP by accelerating green technological innovation.

4. Model Construction and Variable Descriptions

4.1. Model construction

To deeply investigate the specific impact of BDPZs on NQP, this research employs the DID method to identify the causal relationship between them. This paper uses the pilot policy of national BDPZs as a quasi-natural experiment, drawing on the methodologies of Sun et al. (2023) and Wang et al. (2023) to construct the following model:

$$NQP_{it} = \beta_0 + \beta_1 BDPZs_{it} + \alpha X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

In the model, i represents the city and t represents the year. NQP is the dependent variable, representing new quality productivity. BDPZs is the independent variable, representing the policy dummy variable of national big data pilot zones, if a city becomes a pilot zone of national BDPZs in a certain year, the value of this city in that year and subsequent years is 1; otherwise, the value is 0. X_{it} denotes a set of control variables at the city level that may affect NQP, μ_i and γ_t represents the city fixed effect and the time fixed effect respectively, ε_{it} is the random disturbance term. The estimated coefficient β_1 is the core of our concern in this paper. It profoundly reflects the impact of the establishment of BDPZs on NQP, that is, the average treatment effect. If $\beta_1>0$, it indicates that the BDPZs can significantly enhance NQP. Conversely, BDPZs has an adverse effect on NQP.

4.2. Variable Description and Data Source

4.2.1. Dependent variable

New Quality Productivity (NQP). This paper draws on existing research (Lu and Wang, 2024; Lu and Guo, 2024), and constructs an indicator evaluation system for NQP from three dimensions: innovative productivity, green productivity, and digital productivity (as presented in Table 1).

Table 1. Indicator Evaluation System for NQP

Primary Indicators	Secondary Indicators	Indicator Description	Affect
Innovative Productivity	Innovative Input Level	Financial Expenditure on Science, Technology and Education / General Public Budget Expenditure	+
	Innovative Outputs	Number of Granted Invention Patents	+
	Innovation Resources	Number of Full-Time Faculty in General Higher Education	+
		Number of Students Enrolled in General Higher Education	+
	Technical Production	Original Density of Robot Installation	+
Green Productivity	Energy Intensity	Energy Consumption / GDP	-
	Exhaust Gas Emission	Industrial Sulfur Dioxide Emissions / GDP	-
	Wastewater Treatment	Centralized Treatment Rate of Wastewater Treatment Plants	+
Digital Productivity	Internet Penetration Rate	Number of Broadband Internet Access Subscribers	+
	Telecommunication Services Communication	Total Volume of Telecommunication Services	+
	Mobile Phone Penetration Rate	Number of Mobile Phone Users at Year-End	+
	Digital Technology	Number of Patent Applications in the Digital Economy	+

4.2.2. Independent variable

National big data pilot zones (BDPZs). In 2016, the National Development and Reform Commission and other departments approved the establishment of national BDPZs in 10 provinces and cities, including Chongqing and Henan. If a city is established as a pilot zone of national BDPZs in 2016, the city will take the value of 1 in 2016 and subsequent years, otherwise it will take the value of 0.

4.2.3. Mediating Variable

Digital inclusive finance (index), referring to the research of Chang et al. (2023), the total index of urban digital inclusive finance in the "Peking University Digital Inclusive Finance Index (2012-2022)" is used to measure the development status of digital inclusive finance; Green technological innovation (LnGIP), based on Jiang and Huang (2024), uses the natural logarithm of the number of patent applications for green inventions in a city plus one to represent urban green technological innovation.

4.2.4. Control variable

To reduce the potential impact of omitted variables on the estimation results, this paper draws on methodological approaches from existing research (Lang et al., 2024; Wei et al., 2024) and selects a series of control variables to be included in the equation: ①Economic Development Level (LnGDP): To mitigate the influence of extreme values and the problem of heteroscedasticity, this variable is represented by the natural logarithm of per capita GDP; ② Industrial Structure (Str): Measured by the ratio of tertiary industry value-added to secondary industry value-added; ③ Social Consumption Level (LnCom): Calculated as the ratio of total retail sales of consumer goods to GDP; ④ Financial Development Level (Fin): Represented by the ratio of total loans from financial institutions to GDP; ⑤ Government Intervention Intensity (Gov): Measured by the proportion of fiscal expenditure in GDP.

4.2.5. Data Sources and Descriptive Statistics

Considering data availability and regional specificity, this paper excludes some cities with serious missing data, and finally selects the panel data of 284 cities in China from 2014 to 2022. For individual missing values that still exist, the interpolation method is used to complete them. The research data mainly come from "China Energy Statistical Yearbook", "China Statistical Yearbook", "China Urban Counting Yearbook", "Chinese Research Data Services Platform", provincial statistical yearbooks, and provincial and municipal statistical bureaus. The descriptive statistics of the research variables in this paper are presented in Table 2.

Table 2. Descriptive Statistics

Variable type	Variable symbol	Sample size	Mean	Standard deviation	Minimum value	Maximum value
Dependent variables	NQP	2556	0.0711	0.0757	0.0164	0.7407
Independent variable	BDPZs	2556	0.1835	0.3871	0	1
Mediating variables	Index	2556	227.8159	50.8560	105.6100	361.0663
	LnGIP	2556	4.4348	1.6788	0	10.0835
Control variables	LnGDP	2556	10.8765	0.5264	9.2273	12.4565
	Fin	2556	1.1680	0.6527	0.1180	9.6221
	Str	2556	1.1995	0.6354	0.2616	5.6503
	Com	2556	0.3970	0.1121	0.00003	0.9958
	Gov	2556	0.2099	0.1035	0.0439	0.9155

5. Empirical Analysis

5.1. Benchmark regression results

Regardless of whether control variables and fixed effects are included, the coefficient of BDPZs remain positive and statistically significant at the 5% confidence level. This indicates that the establishment of BDPZs contributes to enhancing the level of NQP. According to the estimation results in column (4), after the establishment of national BDPZs, the level of NQP will increase significantly by 0.0085 within the pilot zones, and hypothesis 1 is verified.

Table 3. Benchmark regression results

Variables	NQP (1)	NQP (2)	NQP (3)	NQP (4)
BDPZs	0.0371***	0.0085**	0.0241***	0.0085**
	(0.0140)	(0.0037)	(0.0090)	(0.0036)
LnGDP			0.0554***	-0.0069*
			(0.0110)	(0.0042)
Fin			0.0268***	0.0038*
			(0.0076)	(0.0021)
Str			0.0298*	0.0020
			(0.0172)	(0.0020)
Com			0.0821***	-0.0010
			(0.0217)	(0.0054)
Gov			-0.0911*	-0.0680***
			(0.0496)	(0.0199)
Constant	0.0643***	0.0696***	-0.6164***	0.1521***
	(0.0037)	(0.0007)	(0.1286)	(0.0477)
Year-fixed effect	NO	YES	NO	YES
City-fixed effect	NO	YES	NO	YES
R^2	0.0360	0.9778	0.4478	0.9784
Adj.R^2	0.0356	0.9749	0.4465	0.9756
N	2556	2556	2556	2556

Note: The figures in parentheses are robust standard errors clustered at the city level; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. The same applies below.

5.2. Robustness test

5.2.1. Parallel trend test

When conducting baseline regression analysis using the DID method, it is essential to satisfy the assumption of parallel trends. That is, before the establishment of BDPZs, the levels of NQP in the treatment group and the control group should exhibit similar changing trends, and there will be no systematic differences over time. This ensures the rationality of using the control group as the "counterfactual" control group for the treatment group. This paper draws on the research of Wang et al. (2023), and Yan et al. (2024) to construct the following model:

$$NQP_{it} = \alpha_1 + \alpha_2 pre\_2 + \alpha_3 pre\_1 + \alpha_4 \text{current} + \alpha_5 \text{post\_1} + \alpha_6 \text{post\_2} + \alpha_7 \text{post\_3} + \alpha_8 \text{post\_4} + \alpha_9 \text{post\_5} + \alpha_{10} \text{post\_6} + \beta_1 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (2)$$

In this model, pre_i and post_i are a series of dummy variables that take the value of 1 if the treatment group is in year i before (after) becoming a pilot zone; otherwise, they take the value of 0. This study draws on the methodology of Yue et al. (2024), takes the first year of the policy implementation (2016) as the reference period and plots the results of the parallel trends test of national BDPZs pilot policy within a 90% confidence interval, as shown in Figure 1. The estimated coefficients near zero and all are statistically insignificant before the establishment of BDPZs in 2016. This indicates that there are no significant differences in NQP between pilot and non-pilot cities before the policy implementation, thereby satisfying the parallel trends assumption. Starting from the second year of the implementation of BDPZs policy, the estimated coefficients are all positive and all pass at least the 10% significance level test. As time goes by, the policy effect continues to strengthen, and the estimated coefficients of the establishment of BDPZs on NQP are gradually significant, which demonstrates that the establishment of BDPZs promotes the enhancement of NQP levels.

5.2.2. Placebo test

To prevent omitted variables from interfering with the estimation results, this study draws on the methodologies of Sun et al. (2023), and Zhang et al. (2025) to conduct a placebo test. This test is used to determine whether the impact of the establishment of BDPZs on the level of NQP is caused by other random factors. The specific method is as follows: Based on the big data pilot zone implementation status across 284 cities, we randomly select 120 cities as the pseudo-treatment group and assign the remaining cities to the control group. By repeating this regression procedure 1000 times, we obtain 1000 "pseudo" estimated coefficients of BDPZs policy. The distribution of coefficients is plotted, and the kernel density and p-value changes of the coefficients corresponding to 1000 regressions are obtained, as shown in Figure 2. The coefficient values of the randomly generated "pseudo" national BDPZs are distributed around zero. The kernel density of the estimated coefficients and the distribution of the p-values show a normal distribution, and both are smaller than the benchmark regression coefficient of 0.0085 (vertical line), which is in line with the expectations of the placebo test. Most of the p-values are far from zero, and only a few fall within the 10% significance level (horizontal line), this pattern demonstrates that the observed results are not coincidental, further confirming that the establishment of BDPZs significantly enhances NQP levels, thereby validating the robustness of our benchmark regression results.

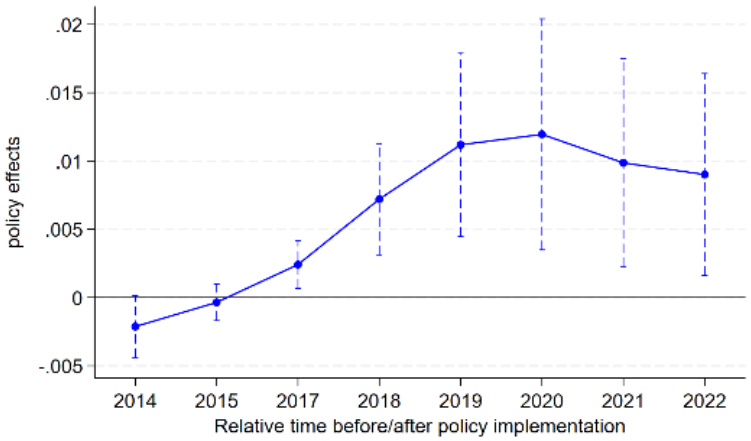

Figure 1. Parallel trend test

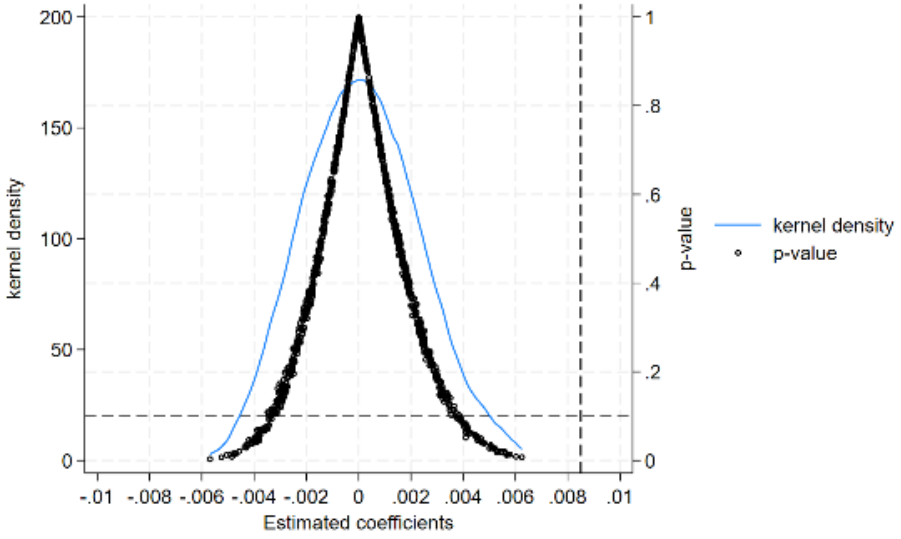

Figure 2. Placebo test

5.2.3. PSM-DID test

To eliminate the interference of different economic characteristics at the urban level on the estimation results and reduce the estimation bias. This study draws on the approaches of Hou et al. (2023), Pan and Cao (2024), and uses the Propensity Score Matching Difference-in-Differences (PSM-DID) method to re-estimate the impact of the establishment of BDPZs on NQP, so as to ensure the robustness of the conclusions of this paper. This study employs nearest neighbor matching and kernel matching methods, uses the control variables as matching variables for matching to ensure a more reasonable comparison between the treatment group and the control group. On this basis, Equation (1) is applied to conduct regression analysis on the matched data, re-examining the policy effects of national BDPZs on NQP. The regression results are presented in Table 4. Column (1) shows the estimation results of the nearest neighbor matching. From column (1), we can see that the coefficient of national BDPZs is 0.0073, which is statistically significant at the 5% level, indicating that the establishment of BDPZs significantly enhances the development of NQP. Column (2) displays the estimation results of the kernel matching, the coefficient of BDPZs is 0.008 and statistically significant at the 5% level, which once again verifies the robustness of the regression results.

5.2.4. Exclude outliers

Taking into account the possible existence of extreme outliers in the sample, to ensure the robustness of the benchmark regression results and effectively prevent individual outliers or extreme outliers from interfering with the regression results, this paper conducts a winsorization treatment at the top and bottom 1% for all continuous variables in the sample. Equation (1) is applied to regress the processed data, and the obtained regression results are presented in column (3) of Table 4. After excluding the influence of possible individual outliers or extreme outliers, the estimated coefficient of BDPZs is 0.0041, which is statistically significant at the 10% confidence level. This indicates that the establishment of BDPZs promotes the enhancement of NQP, and once again verifies the robustness of our conclusions.

5.2.5. Adjust the study sample time

Considering the potential impact of the COVID-19 pandemic outbreak in 2020 on the development of NQP, this study excludes samples from 2020, 2021, and 2022 to ensure that our research findings are not influenced by external uncontrollable factors. The study period is narrowed to 2014-2019, and regression analysis is re-conducted with the adjusted sample. The results are presented in column (4) of Table 4. After adjusting the time period, the regression coefficient of BDPZs is 0.0064, which is statistically significant at the 5% level. This demonstrates that the establishment of BDPZs facilitates the enhancement of NQP, further confirming the robustness of the benchmark

regression results.

Table 3. Robustness test

Variables	NQP nearest neighbor matching PSM-DID (1)	NQP kernel matching PSM-DID (2)	NQP Exclude outliers (3)	NQP Adjust the research sample time (4)
BDPZs	0.0073** (0.0036)	0.0080** (0.0036)	0.0041* (0.0024)	0.0064** (0.0025)
Control variables	YES	YES	YES	YES
Constant	0.1590** (0.0614)	0.1621*** (0.0474)	0.0984*** (0.0377)	-0.0007 (0.0347)
Year-fixed effect	YES	YES	YES	YES
City-fixed effect	YES	YES	YES	YES
R^2	0.9787	0.9790	0.9852	0.9862
Adj.R^2	0.9747	0.9762	0.9833	0.9833
N	1816	2511	2556	1704

5.3. Mechanism analysis

From the previous theoretical analysis, BDPZs can promote the enhancement of NQP levels through digital financial inclusion and green technology innovation. To further verify the mechanism of the establishment of BDPZs on NQP, this study draws the research methodology of Sun et al. (2023) and constructs the following mediating mechanism test model.

$$mediator_{it} = \theta_0 + \theta_1 BDPZs_{it} + \theta_2 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (3)$$

$$NQP_{it} = \varphi_0 + \varphi_1 BDPZs_{it} + \varphi_2 Mediator + \varphi_3 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (4)$$

Among them: the Mediator is the mediating variable, representing digital inclusive finance and green technological innovation. The definitions of other variables remain consistent with those specified in Equation (1).

5.3.1. The mediating effect of digital inclusive finance

According to the theoretical analysis, the establishment of BDPZs fosters the development of NQP by accelerating the advancement of digital inclusive finance. The results of the mechanism analysis are shown in columns (1) and (2) of Table 5. As can be seen from column (1), the impact of the establishment of BDPZs on digital inclusive finance is 3.794, which is significant at the 1% confidence level, indicating that the establishment of BDPZs effectively accelerates the development of digital inclusive finance. As shown in column (2), the coefficient of digital inclusive finance is 0.0006 and statistically significant at the 1% confidence level, indicating that the establishment of BDPZs elevates NQP levels by facilitating digital inclusive finance development. Hypothesis 2 is verified.

5.3.2. The mediating effect of green technological innovation

Theoretical analysis reveals that the establishment of BDPZs influences the development of NQP by accelerating the progress of green technological innovation. The mechanism analysis results are presented in columns (3) and (4) of Table 5. As shown in column (3), the estimated coefficient of BDPZs is 0.1685 and statistically significant at the 1% confidence level, indicating that the establishment of national BDPZs exerts a significant positive impact on the enhancement of green technology innovation levels. As shown in column (4), the coefficient of green technology innovation is 0.0015 and significant at 5% confidence level, indicating that the establishment of BDPZs can promote the improvement of the level of NQP by accelerating the development of green technology innovation. Hypothesis 3 is verified.

Table 5. Mechanism Analysis

Variables	Index (1)	NQP (2)	LnGIP (3)	NQP (4)
BDPZs	3.7940*** (0.9081)	0.0061* (0.0034)	0.1685*** (0.0576)	0.0082** (0.0036)
Index		0.0006*** (0.0001)		
LnGIP				0.0015** (0.0007)
Control variables	YES	YES	YES	YES
Constant	127.9906*** (23.4168)	0.0714* (0.0406)	2.1753* (1.3138)	0.1488*** (0.0470)
Year-fixed effect	YES	YES	YES	YES
City-fixed effect	YES	YES	YES	YES
R^2	0.9911	0.9800	0.9483	0.9785
Adj.R^2	0.9899	0.9774	0.9415	0.9756
N	2556	2556	2556	2556

5.4. Heterogeneity Analysis

5.4.1. Heterogeneity in City Administrative Levels

In the grand blueprint of national and regional economic development, cities at different administrative levels play distinctly different roles. Key cities (cities at the vice-provincial level and above) often serve as focal points and pioneering practitioners in the implementation of national or regional economic development strategies. These cities are not only larger in scale but also lead the country in terms of economic strength, human resources, digital infrastructure, industrial development, and other critical dimensions. Key cities are more likely to receive policy support and resource investment. They are able to allocate more resources to scientific and technological innovation, industrial upgrading, and improving people's livelihood, providing solid support for the cultivation and development of NQP. This paper divides the sample into key cities (cities at the vice-provincial level and above) and ordinary cities (prefecture-level cities) to empirically examine the impact of the establishment of BDPZs on the NQP of the city's administrative level heterogeneity, and the regression results are presented in columns (1) and (2) of Table 6. As indicated by columns (1) and (2), the establishment of BDPZs facilitates the enhancement of NQP in key cities. The underlying reasons may be attributed to the fact that key cities demonstrate stronger resource allocation capabilities and policy implementation capacity in the construction of national BDPZs. These cities are more likely to secure national policy support, financial investments, and preferential project allocations, enabling them to better leverage their inherent resources and advantages. Such conditions facilitate the attraction of high-tech enterprises and talent inflow, thereby promoting the concentration of digital professionals and meeting the urgent demand for digitally skilled personnel within pilot zones. This dynamic subsequently drives urban infrastructure development, industrial upgrading, and technological innovation, ultimately providing robust institutional support for the cultivation and advancement of NQP. Ordinary cities due to the lagging level of economic development, the insufficient agglomeration effect of digital technology talents, it is difficult for these cities to attract a large number of high-tech enterprises and emerging enterprises to settle in, resulting in the internal and external environment of BDPZs needs further to be improved, which leads to the establishment of BDPZs has not yet fully exerted its promoting effect on NQP.

5.4.2. Heterogeneity of resource endowment

The construction of national BDPZs requires the support of relatively abundant digital technology talents, digital infrastructure, funds and other elements. China has a considerable number of cities dominated by resource-based industries such as coal and minerals, which have relatively singular industrial structures and show weaker receptivity toward new technologies and emerging industries. In contrast, non-resource-based cities demonstrate better development in digital economy, industries, and digital infrastructure, possessing advanced technologies and higher levels of digital infrastructure. Compared with non-resource-based cities, resource-based cities have limited space for development, the economic development process is prone to path dependence on the resource development model, and the development of big data is relatively slower and may not be as obvious as non-resource cities in promoting the development of NQP. This study divides the samples into resource-based cities and non-resource-based cities, and the regression results are presented in column (3) and column (4) of Table 6. As shown in Columns (3) and (4), the establishment of BDPZs contributes to enhancing the development of NQP in non-resource-based cities. The reason may be that non-resource-based cities have a relatively high level of digitalization, diversified industrial structures, strong scientific and technological innovation capabilities, and a large concentration of digital technology talents, they are better positioned to leverage the policy dividends generated by national BDPZs to foster the development of NQP.

Table 6. Heterogeneity analysis

Variables	Key cities (1)	Ordinary cities (2)	Non-resource-based(3)	Resource-based cities(4)
BDPZs	0.0421*** (0.0123)	0.0023 (0.0016)	0.0097* (0.0051)	0.0021 (0.0014)
Control variables	YES	YES	YES	YES
Constant	-0.5634 (0.4158)	0.0806*** (0.0278)	0.2190** (0.0878)	0.0412** (0.0164)
Year-fixed effect	YES	YES	YES	YES
City-fixed effect	YES	YES	YES	YES
R^2	0.9715	0.9740	0.9785	0.9631
Adj.R^2	0.9648	0.9706	0.9755	0.9578
N	171	2385	1530	1026

6. Conclusions and Suggestions

6.1. Conclusions

The study finds that: (1) The establishment of national BDPZs effectively empowers the development of NQP in pilot regions, and this conclusion remains valid after a series of robustness tests ; (2) Mechanism analysis reveals that the establishment of BDPZs facilitates the development of NQP by advancing the development of digital inclusive finance and facilitating green technological innovation; (3) Heterogeneity analysis demonstrates that the establishment of BDPZs contributes to enhancing the level of NQP in key cities and non-resource-based cities.

6.2. Suggestions

Based on the above research conclusions, this paper puts forward the following suggestions: (1) Each region should

align with their actual conditions, clarify the development goals and strategic positioning of BDPZs, actively promote the construction of national BDPZs, fully leverage their demonstration and leadership roles, comprehensively implement big data development strategies, and empower the advancement of NQP. The establishment of national Big Data Pilot Zones facilitates the formation and development of NQP by promoting the upgrading and optimization of digital infrastructure, giving full play to the agglomeration effect of data elements, unleashing the vitality of innovation, accelerating the development of big data industries, and nurturing digital application sectors. (2) The government should fully exert its guiding and coordinating role by implementing a series of policy measures to encourage financial institutions to increase investment in digital inclusive finance. Such efforts will promote the innovation and development of financial technology, effectively expand the coverage of financial services, enhance their inclusiveness and efficiency, and provide comprehensive support and services for nurturing and developing NQP. (3) The government and enterprises should jointly increase investment in the research and development of green technologies, support breakthroughs in key core technologies. Concurrently, efforts should be intensified in the cultivation and recruitment of talent in green technology innovation fields, establishing a multi-tiered and diversified talent development system to provide robust talent support for green technology innovation. (4) Each region should formulate corresponding development strategies and plans according to its own unique advantages and conditions, actively promote the construction of BDPZs, improve digital infrastructure, optimize industrial structure and layout, and develop NQP in light of local conditions.

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