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Can Digital Economy Promote Green Development in Chinese Cities?

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Abstract: "In the 14th Five-Year Plan, it is proposed to "accelerate digital development and build a digital China" and "promote comprehensive green transformation of economic and social development". At present, China is in the critical transition period of moving towards a new stage of high-quality development, and the pursuit of green development has become the main goal of economic development planning by the state and governments at all levels. The emergence of big data has brought new vitality to economic development, profoundly affecting various fields of economy and society such as production, circulation and distribution, and has become an important grip to promote green development. From the perspective of the construction of big data comprehensive pilot zone, we explore the theoretical mechanism and the role of big data and green development in order to provide a reference for big data-enabled green development.

The text uses Differences-in-Differences to study the impact of national-level big data comprehensive pilot zone pilot policies on the level of urban green development using 269 prefecture-level and above cities across China as research samples from 2011-2019. The study finds that the digital economy has a catalytic effect on urban green development. Meanwhile, the combination of big data and real economy should be promoted, the training of big data talents should be focused, the open sharing of data should be promoted, the regulatory and rule of law system should be improved, and the attention to the development of digital economy should be enhanced to empower green development.

Keywords: *Digital Economy: National-level Big Data Comprehensive Test Area: Green Development: Differences-in-Differences*

I. INTRODUCTION

The construction of a Digital China and green development are important components of achieving high-quality economic development. The 14th Five-Year Plan proposes to "accelerate digital development and build a Digital China" and "promote the comprehensive green transformation of economic and social development". Currently, China is in a crucial transition period towards a new stage of high - quality development. The pursuit of green development has become the primary goal of economic development planning at the national and local levels. The emergence of big data has brought new vitality to economic development, deeply influencing various fields of the economic and social sectors such as production, circulation, and distribution, and has become an important driving force for promoting green development. Therefore, from the perspective of the construction of big data comprehensive pilot zones, this paper explores the theoretical mechanism and the path of action between big data and green development, aiming to provide a reference for using big data to empower green development.

Since the concept of green development was proposed, the academic community has carried out multi - angle analyses and interpretations of the connotation (Zhu Dajian, 2012; Hu Angang and Zhou Shaojie, 2014; Zhu Dongbo, 2020), measurement (Gao Ying, 2019; Zhang Xu et al., 2020; Xu Xiaoguang et al., 2021), and influencing factors of green development. Among them, the research on the realization path and influencing factors of green development has received increasing attention from researchers recently. Existing research has discussed the realization conditions of green development from two major categories: economic transformation and environmental factors.As an important driving force for current economic transformation, the digital economy is bound to have an impact on the realization of regional green development. However, current empirical research on evaluating the role of the digital economy in urban green development based on the pilot policies of national big data comprehensive pilot zones is extremely scarce. Most of the existing relevant literature only explains it from a theoretical perspective or analyzes sub - topics of green development such as the impact of Internet development on technological progress, improvement of total factor productivity, and industrial structure upgrading, providing the possibility for this paper to make marginal contributions.

II. THEORETICAL BASIS AND RESEARCH HYPOTHESES

A. Theoretical Basis

2.1.1 Sustainable Development Theory

The sustainable development theory originated from environmental issues. However, it does not only focus on environmental protection. Instead, it comprehensively considers multiple aspects such as population, environment, economy, and social development. It is a comprehensive economic and social development strategy that has great guiding significance for China's green development. The sustainable development theory specifically includes three aspects: economic, social, and ecological sustainable development.

2.1.2 Green Development Theory

With the rapid development of the economy, a series of problems such as environmental pollution, tight resource constraints, and ecological degradation have emerged one after another. The contradiction between environmental protection and economic development has become prominent, and thus the green development theory came into being. The green development theory draws on the ideas of Marx's ecological civilization theory and is an important theoretical innovation that combines Marx's ecological civilization theory with China's development reality.

2.1.3 Environmental Kuznets Curve

In 1993, Panayotou borrowed the inverted U - shaped curve defined by Kuznets in 1955 between per capita income and income inequality and first named the relationship between environmental quality and per capita income the Environmental Kuznets Curve (EKC). The EKC reveals that environmental quality begins to deteriorate with the increase of income and improves with the increase of income after the income level rises to a certain extent, that is, there is an inverted U - shaped relationship between environmental quality and income. After the Environmental Kuznets Curve was proposed, the theoretical discussion on the relationship between environmental quality and income has continued to deepen, enriching the theoretical explanation of the EKC.

2.1.4 Digital Governance Theory

The digital governance theory is a framework for guiding management organizations and public policies. It attempts to introduce data science and technical methods to re - define the traditional technical and governance structures of policy - making. The core hypothesis of this theory is that big data technology and computing power can speed up the decision - making process, improve the efficiency of solving complex problems, and make policies more intelligent and effective. The digital governance theory includes using advanced technologies to collect a large amount of real - time data, using algorithms to analyze them, and applying the results to policy and decision - making. It also supports social science research to better understand the impacts of affairs development and optimize policies based on feedback. Different from other policy - making technologies and methods, the digital governance theory emphasizes timely feedback and provides executable improvement suggestions according to the changing environment.

B. Hypothesis Development

In recent years, the concept of green development has gradually become an important guiding ideology for regional economic development. However, the realization of the green transformation of the economy still faces many constraints, such as a rough economic development model, a heavy - industry - oriented industrial structure, and insufficient development momentum of new economic drivers. With the accelerated development of the digital economy, digital technology has been deeply integrated into all aspects of economic development, having a profound impact on the social and economic growth mechanism. As a new economic form, the digital economy not only directly provides new impetus for green economic growth but also has an indirect impact on urban green development through channels such as improving information interaction efficiency, innovation levels, and strengthening regional connections. The specific mechanisms are as follows.

First, the development of the digital economy has improved the efficiency of information interaction. From a market perspective, improved information interaction efficiency means reduced information asymmetry. The development of the digital economy can optimize product matching and transactions. Digital technology builds digital economy platforms to aggregate fragmented demand and supply information, greatly reducing the search costs of enterprises and users, fully mobilizing demand and supply, and improving the efficiency of social resource allocation (Xiao Xu and Qi Yudong, 2019). This, in turn, improves the operating efficiency of the regional economy and realizes urban green development. From a regulatory perspective, the development of digital technology has promoted the openness of industry information and broadened the channels for environmental supervision. Information technology has broken through the traditional regulatory channels, transforming the traditional vertical regulatory form dominated by the government into a multi - dimensional regulatory form involving the government, the public, and society. The public has become one of the main forces in supervision, greatly enhancing the intensity of environmental supervision, strengthening the environmental protection responsibility awareness of enterprises, and forcing the industry to transform towards green development.

Second, the digital economy has improved the level of innovation. Technological progress is the key mechanism for the green transformation and upgrading of the regional economy (Fang Min et al., 2019). The characteristic of the digital economy that accelerates information flow enables faster and lower - cost knowledge spillovers and knowledge interactions in the innovation network. Relying on digital and information technology, enterprise entities can more conveniently obtain knowledge and information, quickly master and accumulate emerging knowledge and skills, and thus obtain external information, increase innovation knowledge reserves, promote technological upgrading, and achieve the green transformation of industries. In addition, due to the introduction of digital technology, learning and communication activities among technical departments have become more convenient. On the one hand, communication stimulates the collision of innovation inspirations, making innovation occur more quickly. On the other hand, the smooth information channels and the uncompressed information dissemination channels can better help both supply and demand sides understand innovation demands and reduce useless innovation.

Finally, the digital economy has strengthened the interaction and cooperation among regions. Industrial agglomeration and inter - regional circulation and interaction are conducive to improving the efficiency of regional resource utilization, forming a circular economic system, reducing pollutant emissions (Wang Yanhua et al., 2019), and thus promoting the green transformation of the region (Wei Lili and Hou Yuqi, 2021). In reality, on the one hand, limited by spatial isolation, it requires high costs to form a well - functioning industrial agglomeration pattern. On the other hand, the competition effect among neighboring regions leads to poor inter - regional cooperation, so the positive externalities of industrial agglomeration and regional cooperation cannot be fully exerted. With the development of the digital economy and digital technology, spatial isolation is no longer an obstacle to regional cooperation. Long - distance cooperation among cities has become more convenient. Cooperative forms such as "enclave economy" have been given new meanings in the digital age. Cooperation is no longer limited by the negative impact of "neighboring government competition." Regions can use digital technology to establish industrial interactions through virtual information platforms. Some non - physical industries can even form cloud - based industrial clusters, which can effectively improve economic operation efficiency and contribute to urban green development.

Based on this, the hypothesis of this paper is proposed:

H1: The digital economy can promote the green development of Chinese cities.

III. RESEARCH DESIGN

A. Model Setting

Since the pilot projects of national big data comprehensive pilot zones were implemented in various cities in 2015 and 2016, a multi - period difference - in - differences model should be selected. Referring to the methods of predecessors (Beck et al., 2010), a multi - period difference - in - differences model is used to conduct research, and the econometric model is set as follows:

$$GEE_{it} = \beta_0 + \beta_1 DID + \beta_2 GDP_{it} + \beta_3 POP_{it} + \beta_4 Gsize_{it} + \beta_5 Edu_{it} + Year + \varepsilon$$

This paper uses panel data. The subscripts i and t represent cities and years respectively. The explained variable GEEit is the green development level of city i in year t. DID is the key explanatory variable reflecting whether a city is a national big data comprehensive pilot zone. It is assigned a value of 1 when a city is in the pilot year and subsequent years, and 0 otherwise.

What this paper cares about is the coefficient β1 of DID, which measures the impact of the national big data comprehensive pilot zone on high - quality economic development.

B. Variable Explanation

3.2.1 Explained Variable

Referring to the practices of previous scholars (Liu Jia et al., 2021), this paper selects 2 first - level indicators of "three - waste" emissions and waste treatment, and 6 second - level indicators including industrial wastewater emissions, industrial sulfur dioxide emissions, industrial smoke (dust) emissions, the comprehensive utilization rate of general industrial solid waste, the centralized treatment rate of sewage treatment plants, and the harmless treatment rate of domestic waste to construct an evaluation index system for urban green development in China. The entropy method is used to comprehensively evaluate the urban green development index in China, as shown in Table 1. The data for constructing the index system are sourced from the "China City Statistical Yearbook" and CNRDS over the years.

3.2.2 Explanatory Variable

The construction policy of the national big data pilot zone is the explanatory variable of this paper. This paper regards the national big data pilot zone policy as a quasi - natural experiment. When a city is in the pilot year and subsequent years, it is assigned a value of 1, and 0 otherwise.

3.2.3 Control Variables

The control variables selected are per capita GDP (per capita regional GDP), the total population at the end of the year POP, government size Gsize (the number of employees in public management and social organizations in each region), higher education Edu (the number of regular institutions of higher education), and year fixed effects Year (natural years from 2012 - 2019).

C. Descriptive Statistics

According to the integrity of data, a total of 269 cities are selected as the research objects. 82 cities located in the provinces and cities of the national big data comprehensive pilot zones are used as the experimental group samples, and the other cities are used as the control group samples. The descriptive statistics of each variable are shown in Table 2.

Table 1 Green Development Evaluation Index System

Classification Index	Secondary Index	Specific Index	Unit of Measurement	Index Attribute		
				Positive	Moderate	Negative
Green Development	Three - waste Emissions	Industrial wastewater emissions / Industrial output value	ton/10,000 yuan			√
		Industrial sulfur dioxide emissions / Industrial output value	ton/10,000 yuan			√
		Industrial smoke (dust) emissions / Industrial output value	ton/10,000 yuan			√
	Waste Treatment	Comprehensive utilization rate of general industrial solid waste	%	√		
		Centralized treatment rate of sewage treatment plants	%	√		
		Harmless treatment rate of domestic waste	%	√		

Table 2 Descriptive Statistical Results of Variables

Variable	Obs	Mean	Std.dev.	Min	Max
GEE	2, 325	0.0000989	0.0000196	0.0000281	0.0001357
DID	2,325	0.1316129	0.3381422	0	1
GDP	2, 325	52885.76	34068.62	6916	467749
POP	2, 325	456.4647	313.8958	30	3416
Gsize	2, 325	5.347006	4.248867	0.17	50.24
Edu	2, 325	8.91914	14.91293	1	93

IV. EMPIRICAL RESULT ANALYSIS

A. Correlation Coefficient Analysis

The results of the correlation coefficients of each variable are shown in Table 3.

Table 3: Results of Variable Correlation Coefficients

	GEE	DID	GDP	POP	Gsize	Edu
GEE	1.0000					
DID	0.0698***	1.0000				
	0.0008					
GDP	0.1172***	0.0631***	1.0000			
	0.0000	0.0023				
POP	0.1717***	0.1106***	-0.0211	1.0000		
	0.0000	0.0000	0.3100			
Gsize	0.0875***	0.1564***	0.2819***	0.7477***	1.0000	
	0.0000	0.0000	0.0000	0.0000		
Edu	0.1157***	0.0408**	0.4010***	0.5054***	0.7279***	1.0000
	0.0000	0.0494	0.0000	0.0000	0.0000	

Note: *, **, *** represent significance levels of 10%, 5%, and 1% respectively.

B. Benchmark Regression Results

This paper focuses on examining the impact of the national big data pilot zone policy on urban green development. Table 4 reports the benchmark regression results. Column (1) shows the impact of the digital economy on green development without adding control variables, and column (2) shows the impact of the digital economy on green development after adding control variables. The results show that the coefficients of DID are significantly positive at the 5% level, indicating that the national big data pilot zone policy significantly promotes urban green development, and Hypothesis 1 is verified. The reason may be that national big data pilot zones have complete digital infrastructure. Through digital simulation or data collection, they can adjust and optimize the production operation parameters of the industrial base period, reduce unnecessary energy consumption, lower production costs and environmental pollution, activate ecological value, and empower urban green development.

Table 4 Benchmark Regression Results

	(1)	(2)
	GEE	GEE
DID	0.000**	0.000**
	(2.29)	(2.38)
GDP		-0.000
		(-0.19)
POP		-0.000
		(-1.03)
Gsize		-0.000
		(-0.98)
Edu		0.000
		(0.97)
_cons	0.000***	0.000***
	(143.04)	(18.06)
Year	Yes	Yes
N	2325	2325
R^2	0.6023	0.5718

Note: *, **, *** represent significance levels of 10%, 5%, and 1% respectively.

C. Parallel trend test

A key assumption of using the DID model is to satisfy the parallel trend test. Therefore, a parallel trend test is performed in this paper, and the results are shown in Figure 1.

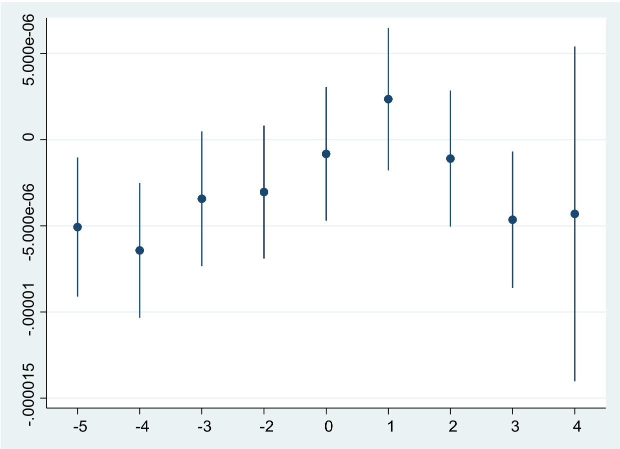

Figure 1: Parallel trend test

D. Robustness test

4.4.1 Replace the explanatory variable.

Taking industrial sulfur dioxide emissions as a proxy variable for urban green development, the regression results show that the DID coefficient is significantly negative at the 1% level, indicating that the big data pilot reduces industrial sulfur dioxide emissions and promotes urban green development, which proves that the results of this paper are robust, as shown in column (1) of Table 5.

4.4.2 Exclude municipalities directly under the central government.

Drawing on the practice of previous scholars (Li Zheng and Liu Fengshuo, 2020), the samples of the four municipalities directly under the central government were excluded, and the results showed that the DID coefficient was still significantly positive at the level of 5%, which proved that the research results of this paper were robust, as shown in Table 5 (2).

Table 5: Robustness test

	Replace the explanatory variable	Exclude municipalities directly under the central government
	(1)	(2)
	$lnSO_2$	GEE
DID	-0.388***	0.000**
	(-8.74)	(2.50)
_cons	10.962***	0.000***
	(57.90)	(18.29)
Control	Yes	Yes
Year	Yes	Yes
N	3406	2294
R^2	0.6078	0.5147

Note: *, **, *** represent significance levels of 10%, 5%, and 1% respectively.

CONCLUSIONS AND RECOMMENDATIONS

A. Research conclusions

Based on the panel data of 269 cities in China from 2011 to 2019, this paper empirically tests the impact of the construction of national big data pilot zones on the green development of Chinese cities by using the difference-in-difference model. The results show that, on average, the establishment of national big data pilot zones can promote urban green development, and the conclusion is still valid after a series of robustness tests such as replacing samples and variables.

B. Policy recommendations

China's economic development has entered a stage of high-quality development, and it is necessary to actively play the role of big data to bring new vitality to economic development and promote the green transformation of economic and social development. Therefore, based on the above research conclusions, and considering the reality of China's big data development and green development, this paper puts forward the following policy recommendations.

5.2.1 Promote the integration of big data and the real economy, and cultivate new momentum for green development

Actively use big data to empower the real economy, promote the optimization and upgrading of the industrial structure, promote the emergence of new models and new business formats, and cultivate new momentum for green development. Based on the advanced experience in the construction of the big data comprehensive pilot zone, we will further strengthen policy support, actively promote the combination of big data and the real economy, enrich the application scenarios of big data technology in the real economy, cultivate new formats and industries, promote the upgrading of the industrial structure, and improve the efficiency of economic operation; Actively use big data technology to transform traditional industries, accelerate the transformation of traditional industries to networking and intelligence, promote the upgrading and quality improvement of traditional industries, actively build industrial Internet platforms, strengthen the application of industrial enterprises in industrial big data, form a green and low-carbon industrial system, improve the level of automation and greening, improve energy efficiency, and promote the improvement of enterprise production efficiency; Actively explore the innovative use of big data in various scenarios such as resource recycling, environmental governance, and green manufacturing, and effectively use big data to empower green development.

5.2.2 Focus on the Cultivation of Big Data Talents and Actively Introduce High - end Talents

Encourage universities and scientific research institutions to offer big data majors, especially those that highlight practicality and interdisciplinarity. Establish an education system at different levels, design professional training systems and courses, and promote the integration of industry and education to meet the market's demand for big data talents at different levels. Cultivate a group of compound big data professionals to provide sufficient talent reserves for the development of big data and effectively alleviate the shortage of big data talents. At the same time, attract high - level scientific and technological talents and big data talents by offering preferential conditions. Actively introduce high - end talents, build a high - quality talent team, further improve the talent grading evaluation system, scientifically design the talent introduction system, create a good innovation environment and talent ecosystem, so as to avoid brain drain and further attract more high - level talents, and enhance the regional human capital level.

5.2.3 Promote Data Openness and Sharing and Improve the Supervision and Legal System

Data is an important production factor and strategic resource, which is of great significance for promoting digital transformation. The openness and sharing of data are the foundation of the development of the digital economy and the key to the emergence of new industries, new business forms, and new models. We should actively promote the openness and sharing of data, standardize the issue of data ownership, promote the standardization of data factor circulation and transactions, formulate basic systems for data ownership confirmation, transactions, circulation, and other links, ensure the orderliness of data factor circulation, increase the effective supply of data factors, promote the market - oriented allocation reform of data factors, and form a good data ecosystem. At the same time, while promoting data openness and sharing, it is necessary to ensure data security. Establish a sound data supervision system and corresponding legal system, emphasize the traceability, supervision, and security of data factors, and accelerate the construction of the data factor market.

5.2.4 Strengthen the Attention to the Development of the Digital Economy and Empower Green Development

As an important part of China's new economic drivers, the digital economy plays a crucial role in promoting regional economic growth, driving economic structure transformation, and achieving regional green development. The government should follow the development trend, further increase investment in the infrastructure required for the development of the digital economy, and help the development of the regional digital economy by promoting the construction of new infrastructure such as artificial intelligence and 5G. All regions should continue to promote the implementation of policies such as "Digital China", give full play to the role of digital technology in the process of economic structure transformation and upgrading, promote the integration of traditional industries and digital technology, use digital technology to improve the production efficiency and resource utilization rate of traditional industries, reduce production costs and pollution emissions, and realize the digital, intelligent, and green development of traditional industries. All regions should encourage the vigorous development of the digital industry. The digital economy not only has high industrial value itself but also can provide intelligent assistance functions for other industries. Digital products are widely used in all links of industrial production. For example, by building an integrated big data platform covering production, transaction, circulation, and supervision of the whole industrial chain, it is possible to establish cloud - based industrial clusters across regions, industries, and departments, deeply optimize decision - making in production, management, operation, sales, and other links, and achieve a circular, efficient, and intensive economic development model.

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