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Exploring the Spatial Effects of the Digitization on Urban Green Growth: Evidence from Chinese Cities

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Abstract: Against the backdrop of increasingly prominent contradictions between resource-environmental constraints and economic development globally, the unsustainable nature of extensive growth models has become evident. How to achieve urban green transformation stands as a critical issue requiring urgent resolution to promote high-standard economic growth. This study adopts a spatial interdependence perspective, examining 277 Chinese cities to systematically explore digital empowerment in fostering ecological urban economic expansion and its regional heterogeneity. It further delves into the underlying mechanisms through which digital economic growth influences greening. The research reveals: Firstly, digital deepening in cities effectively promotes domestic environmental economic development, and enables neighbouring regions to capture digital dividends, driving deep integration and synergy between digitization and environmental progression—the spatial spillover effect of the digitization in enhancing the level of ecological economic development in cities has been confirmed. Secondly, the effect of the digitization on regional green development exhibits differentiated characteristics, with a significant 'digital divide' impact persisting across different regions. Thirdly, the digitization boosts the potential for environmental trajectory in urban economies through two primary pathways: promoting green technological innovation and optimising industrial structures. In light of these findings, these empirical results call for targeted interventions, providing scientific evidence and practical guidance for better advancing green development in urban economies and achieving sustainable development goals.

Keywords: Digital Economy; Urban Economic Green Trajectory; Spatial Percolation Effect; Spatial Durbin Approach; Spatial Lag Model

1. Introduction

As the preeminent emerging economy, China is weathering a transition from torrid growth to premium progression. However, the GDP-centered growth model has given rise to large-scale expansion, exerting mounting strain upon the Eco-friendly fabric. Pursuant to the "carbon peaking and carbon neutrality" strategy, we proposed the establishment of a architecture for efficient resource utilization and environmental protection development, marking significant milestone toward achieving great-quality transformation. The conventional growth model predicated on factor inputs and capital stock has become unsustainable. As a result of the maturation of information systems and the fortification of the cyber infrastructure and infrastructure, the digitization—characterized by unprecedented technological infusion and resource integration capabilities—has gradually become a pivotal catalyst of green economic transformation. By optimizing information transmission, facilitating data sharing, and reducing market transaction costs, the tech-driven economy revamps resource allocation patterns and efficiency, providing strong enabling conditions for green development and fostering a paradigm shift in production patterns and economic structures.

At the new stage of development, how to utilize the potential of the digital economy to achieve co-beneficial growth between economic enlargement and ecological protection, and approaches to balance the tension harmonizing fiscal growth and ecological saving, has emerged as research question. Does the digitization contribute to the green progression of China's urban economies? Does the green benefit it generates exhibit distinct spatial effects?

Conducting theoretical and empirical research on these questions will aid in understanding the current state of green development in China and the influence of the digitization on its level of green development, thereby providing insights for promoting green collaborative development across regions.

2. Theoretical Underpinnings and Testable Propositions

2.1 Digitalization and Eco-Economic Growth: A Spatial Nexus Perspective

Leveraging advanced instruments such as big data and cloud computing, digitization has experienced rapid development. Its multifaceted integration across all sectors of socio-economic development has charted a course towards green development. The digitalization's influence on regenerative progression is not singular but multifaceted and complex. At the micro level, the deploying digital enablers—notably 5G, the Internet of Things, and AI, digital control systems, and data pricing algorithms—in production processes has shifted production methods from traditional manual control to intelligent control. Enterprises can now make timely and effective adjustments based on real-time production status, significantly enhancing production efficiency [1]. The full deployment of tech-driven technologies enhances the matching between demand and supply sides of the economy, cultivates more sophisticated market pricing mechanisms, and thereby achieving green buildup at a greater steady-state level. From a holistic perspective, the digitization optimisms the synergy between new production factors, for instance, labour, capital, data, and , etc. ,and to develop dual-driven engines by factors and novelty. This cultivates greater resource utilization efficiency, continuously raises green total factor productivity, and thus drives green buildup. This reasoning leads to the following conjecture:

H1: The progression of the digitization facilitates the environmental progression of the city-level economic milieu.

2.2 Digitization's Spatial Footprint on Environmental Progression

As early as the 1990s, Cairncross [2] argued that the rise of communication technologies and the digital economy had weakened the constraints of geographic distance. The networked nature of the digital economy enables it to transcend spatial boundaries, generating significant spatial spillover effects. On one hand, the digital economy, relying on efficient information transmission mechanisms, strengthens interregional economic linkages and factor interactions [3]. The digital network system enhances the mobility and allocation efficiency of production factors, breaks the geographical dependence of traditional industrial clusters, and facilitates industrial chain coordination and transaction cost reduction. This, in turn, improves both resource allocation efficiency and energy utilization, advancing urban green transformation. On the other hand, neighboring regions often share similar geographic and ecological characteristics, allowing the digital economy to not only stimulate local green technological progress but also generate positive spatial spillovers through geographic connections. The perversion of tech-driven enablers and low-carbon initiatives strengthens regional linkages and raises overall ecological efficiency.

H2: The bearing of the datafication digital empowerm on city-level ecological economic progression exhibits spatial spillover effects.

2.3 Mechanism Analysis of the Digitization's Significance for Environmental Economic Progression

Structural re-alignment serves as the fundamental pathway for energy saving and releases reduction, while tech-based advancement serves as the key driver thereof.

Amidst escalating resource and ecological constraints, tech-based advancement has crystallized into the paramount impetus for growth and the fundamental approach to structural remaking, further propelling the economy's low-carbon transition. Firstly, the innovative buildup of tech-driven technologies continuously stimulates the renewal of frontier technology industries. Policy support across regions further alleviates corporate financing constraints, attracting substantial high-quality human capital. This provides enterprises with the financial, material, and talent foundations for low-carbon tech-based novelty. Secondly, as a clean and efficient new economic model, the digital empowerm possesses direct-energy optimization and release diminution effects. Low-carbon tech-based novelty can effectively facilitate comprehensive low-carbon remaking

across the economy and society, thereby propelling the low-carbon advancement of urban economies. Finally, the tech-based spillovers from low-carbon renovation provide fresh impetus for pre-existing industries to advance toward low-carbon and smarter operations, helping to pioneer new manufacturing buildup patterns centred on resource recycling and reduced pollution releases.

Manufacturing restructuring remains a crucial pathway for China's low-carbon buildup, effectively boosting pollutant release reductions while driving a positive shift in growth drivers. In agriculture, the use of sensing, remote sensing, and Internet of Things technologies enables the automated collection and intelligent monitoring of crop growth data, alongside ecological condition surveillance and early warning systems. Additionally, the widespread implementation of internet technologies raises the online sharing of diverse rural materials, reducing physical disparities between municipalities and hinterlands. This promotes the free movement of various rural materials between metropolitan and agrarian regions offline, accelerating the cultivation and buildup of new industries and business patterns in rural areas. It leads the remaking and upgrading of the rural sector, significantly enhancing the ecological benefits of rural buildup. In industry, bolstered by tech-driven technologies, manufacturing internet platforms enable comprehensive integration of data across product design, procurement, production, assembly, supply, sales, and services. This promotes efficient coordination and high-speed operation throughout the entire manufacturing value chain, helping to mitigate extensive growth patterns and drive manufacturing restructuring towards technology-intensive and ecologically friendly patterns. Consequently, this promotes energy conservation, efficiency gains, and effective resource utilisation. Within the service sector, the proliferation of the digital empowerm further mitigates information asymmetry arising from temporal and spatial misalignment inherent in pre-existing economic patterns. On the demand side, the rapid proliferation of tech-based artifacts including fifth-generation networks and visualized infrastructures markedly raises enterprises' capacity to adapt to consumers' diverse and flexible demands, substantially improving service efficiency and customer experience. On the supply side, big data analytics systems provide robust scientific decision-making support for business operations, enabling enterprises to accurately identify and match consumer needs. This effectively eliminates low-end, inefficient supply within traditional business models, accelerating the restructuring of the service sector and thereby elevating the level of green development in modern services.

On this basis, we therefore put forth the following contentions.

H3a: The digitization indirectly fosters green development by enhancing environmental industrial invention.

H3b: Advancing industrial metamorphosis subsequently fosters green development in urban economies.

3. Variable Selection and Empirical Specification

3.1 Determination of Relevant Factors

3.1.1 Dependent factors

Urban Eco-Environmental Economic Progression Level. The level of urban eco-efficient fiscal progression is measured by environmental total factor productivity. Following the methods of Oh [4] and Tone [5], this analysis mobilizes a super-efficiency SBM configuration with environmentally detrimental residuals and the Global Malmquist–Luenberger index to calculate city-measurel green total factor performance.

3.1.2 Independent variable

In constructing the digitization index system, this research draws on the work of Huang [6] and Zhao Tao. The selected indicators include: total volume of telecommunication services, mobile phone penetration rate, internet user penetration rate, computer service employment magnitude and software industry, together with the Digital Inclusive Finance Metric compiled by the digital finance research unit at Peking University. After standardization, the indicators are integrated through dimension reduction technique to obtain a comprehensive digital fiscal indicator.

To facilitate cross-year comparisons between indicators, data is standardised using 2012 as the base period:

$$S_{i,t} = \frac{X_{i,t} - X_{\min 0}}{X_{\max 0} - X_{\min 0}} \quad (1)$$

t represents the year, i denotes the city, $X_{i,t}$ indicates the raw data for a given

metric, $X_{\min 0}$ and $X_{\max 0}$ denote the inferior and superior bounds of the raw data for that indicator in the base period, respectively, $S_{i,t}$ represents the standardised data for that indicator.

3.1.3 Control variables

To conduct a more comprehensive analysis of the disorganization's contribution to cities low-carbon economic progression, this paper draws upon research by Hu [7], Yang [8] et al. and selects the adjustment variables: First, Science and Technology Investment (Sti). This is denoted by the share of technological innovation fiscal expenditure within total fiscal outlays. Second, Foreign Investment Intensity. This is expressed as the presence of Foreign-Invested Enterprises in the industrial enterprise segment above designated size. Third, monetary progression measure, derived from the share of outstanding credit extended by financial institutions at the end of the fiscal year in relation to GDP. Fourth, environmental regulation intensity (ER), characterised by the comprehensive utilisation rate of general industrial solid waste. Fifth, economic development level (Ecl), represented by the logarithm of per capital GDP.

3.1.4 Mediating variables

Drawing upon the methodology of Qi, Shao Zhou et al. (2018), the number of green patents applied for per hundred individuals within each city during the year under consideration was employed to characterise green technological innovation.

This study utilises the degree of industrial structure upgrading to represent industrial structure advancement. The upgrading of industrial structure reveals the process by which industrial forms evolve from lower to higher stages, specifically the extent of transition from from the agrarian sector to the industrial and service sectors.

3.2 Model Specification

3.2.1 Benchmark econometric formulation

To examine whether the digitization affects green economic development, the following benchmark regression model is established:

$$Incd_{i,t}=\alpha_0+\beta_1 Dei_{i,t}+\gamma_h \sum Con_{i,h}+\sigma_i+\mu_t+\varepsilon_i \quad (2)$$

Under this setup, i denotes the region, t denotes year. Incd represents the degree of green economic development associated with city i for the t-th year; Dei is the measure of digital economy development; Con denotes the set of control variables; σ_i and μ_t represent individual and time fixed effects, respectively; and ε_i is the random disturbance term.

3.2.2 Spatial econometric model

To further analyze how the digitization affects urban green economic development, this study adopts a nested spatial model (GNS) following the approaches of Chen [9] and Han [10]:

$$Gtfp_{i,t}=\alpha+\rho \sum_{j=1,j\neq i}^{N} W_{ij}\, Incd_{i,t}+X_{it}\beta+\sum_{j=1}^{N} W_{ij}\, X_{ijt}\theta+\sigma_i+\mu_t+\varepsilon_i \quad (3)$$

$$\varepsilon_i=\varphi \sum_{j=1,j\neq i}^{N} W_{ij}\, \varepsilon_{jt}+\mu_{it} \quad (4)$$

Here, $Incd_{i,t}$ denotes the level of green development, X_{it} represents the digital economy level and other control variables, α is a constant term, and ρ and ϕ denote the spatial autoregressive and spatial autocorrelation coefficients, respectively. W_{ij} is the spatial weight matrix.

3.3 Data Sources

After excluding cities with severe data deficiencies, this study selects 277 prefecture-level and higher-rank cities across China from 2012 to 2022, constructing a balanced panel dataset containing 3,047 city–year observations. The primary data sources include: China Urban Statistical Yearbook; Statistical Yearbooks of individual prefecture-level cities; Institute of Digital Finance, Peking University; China Patent Database.

4. Empirical Analysis

4.1 Benchmark Regression Analysis

Table 1. Results of the Benchmark Regression

	(1)	(2)
	Ged	Ged
Dei	0.010***	0.008**
	(0.004)	(0.004)
L.Ged		-0.166**
		(0.077)
_cons	0.968***	1.106***
	(0.086)	(0.139)
N	3047.000	2770.000
R^2	0.131	0.163

As is illustrated in Table 1, the findings of the benchmark regression demonstrate that after controlling for individual fixed effects, the impact magnitude of the digitization variable is 0.010 and positive with statistical significance at the 1% threshold, suggestive of the fact that the

progression of the digitization significantly promotes green economic growth. In Column (2), after introducing the one-period lag of green economic development as an additional explanatory variable, the positive effect of the digital economy remains robust and statistically significant. Taken together, the digital economy variable maintains a positive and significant relationship with urban green economic development at the 5% significance level or higher across all model specifications. These findings suggest that the advancement of the tech-driven economy substantially accelerates the low-carbon remaking of urban economies, thereby validating Hypothesis H1.

4.2 Spatial Correlation Test

To scrutinize the spatial ramifications of the digitization on verdant economic trajectory, this study first employs the Moran's I measure to assess the spatial correlation between the predominant parametric variable—the digitization (De)—and the dependent variable, low-carbon economic buildup(Ged).The results, presented in Table 2, indicate that under both the geographical weight matrix and the economic weight matrix, the global Moran's I auto-correlation metrics for verdant fiscal progression and the tech-driven economy are markedly positive. This finding suggests that both variables exhibit significant positive spatial correlation and spatial clustering characteristics, thereby confirming the necessity of incorporating a spatial econometric model in the analysis.

Table 2. Moran's I Index

Year	Ged				Dei			
	Economic Matrix		Geographical Matrix		Economic Matrix		Geographical Matrix	
	Moran's I	z	Moran's I	z	Moran's I	z	Moran's I	z
2012	0.012***	1.537	0.005***	1.604	0.420***	11.194	0.294***	12.479
2013	0.012**	1.258	0.031*	1.490	0.432***	11.535	0.304***	12.863
2014	0.128***	2.868	0.166***	7.606	0.420***	11.202	0.315***	13.335
2015	0.041*	1.437	0.053***	2.408	0.421***	11.253	0.274***	11.640
2016	0.098***	3.278	0.099***	4.319	0.403***	10.772	0.308***	13.058
2017	0.144***	4.848	0.063***	2.875	0.414***	11.046	0.287***	12.187
2018	0.139***	4.826	0.159***	7.205	0.418***	11.148	0.291***	12.335
2019	0.032*	1.180	0.006***	1.921	0.414***	11.044	0.293***	12.417
2020	0.092***	3.504	0.028***	1.516	0.415***	11.075	0.282***	11.976
2021	0.220***	7.470	0.080***	3.629	0.424***	11.321	0.298***	12.644
2022	0.210***	7.119	0.076***	3.449	0.418***	11.164	0.298***	12.652

4.3 Spatial Effect Analysis

This investigation applies three spatial econometric parametrization—the Spatial Durbin parametrization, the Spatial Autoregressive parametrization, and the Spatial Error parametrization—to estimate the relationships among the selected variables. As shown in Table 3, whether using the geographical spatial weight matrix or the economic weight matrix, the estimated coefficients of the digital economy variable remain significantly positive across all three models. Furthermore, both the rho (ρ) and lambda (λ) values are statistically significant at the 1% level, indicating that the level of digital economy development in one city exerts a significant positive transmission r contagion on the verdant fiscal development of neighboring cities. These results confirm the existence of strong spatial interdependence and diffusion effects in the process of verdant economic transformation driven by the digitization.

This study sequentially conducts the Lagrange Multiplier (LM) test, Likelihood Ratio (LR) test, and Hausman test to establish the optimal model specification. The results, as shown in Table 4, indicate that the Spatial Durbin Model (SDM) exhibits the best overall goodness of fit. Under both the geographical and economic weight matrix settings, the SDM cannot be simplified into either the Spatial Error Model (SEM) or the Spatial Lag Model (SLM).Based on these diagnostic tests, this study ultimately selects the two-way fixed-effects Spatial Durbin Model (SDM) for the quantitative substantiation.. The corresponding regression results are presented in Table 5.

As shown in Table 5, the results in Columns (1) and (2) demonstrate that regardless of the model specification or the choice of weight matrix, the coefficient of the digitization remains positive with significance at the 5% level or higher. This finding indicates that the progression of the

digitization significantly promotes urban green economic development, thereby validating Hypothesis H1. With the widespread adoption of digital technologies, intelligent services, and network infrastructure, both the efficiency and speed of resource allocation have improved substantially, making the digitization a key driving force behind urban green transformation. Furthermore, in Columns (3) and (4), the spatial lag terms of the digital economy are both positive and significant under the geographical and economic weight matrices, suggesting that the development of the digital economy in one city can enhance the level of green development in surrounding regions, exhibiting a notable spatial spillover effect. Compared with geographical proximity, economic linkages play a stronger role in promoting green development, as the spillover effects are more pronounced under the economic weight matrix. By leveraging its high degree of technological penetration, the digital economy breaks through information barriers and strengthens regional economic and social connectivity through digitalization, fostering coordinated and synergistic green development across regions through "point-to-area diffusion."

Table 3. Results of SDM, SAR, and SEM Models

	Geographical Weight Matrix			Economic Weight Matrix		
	(1)SDM	(2)SAR	(3)SEM	(1)SDM	(2)SAR	(3)SEM
Dei	0.007***	0.004***	0.005***	0.005***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Sti	0.199***	-0.022	0.053	-0.056	-0.061	-0.066
	(0.068)	(0.058)	(0.064)	(0.059)	(0.058)	(0.058)
Foi	0.114***	0.006	0.032**	-0.000	0.007	0.007
	(0.018)	(0.012)	(0.014)	(0.012)	(0.012)	(0.012)
Fid	0.000	0.005***	0.004**	0.005***	0.005***	0.005***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
ER	0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ecl	0.014***	0.013***	0.013***	0.010**	0.015***	0.016***
	(0.003)	(0.003)	(0.003)	(0.005)	(0.002)	(0.002)
rho	0.350***	0.351***		0.056***	0.065***	
	(0.045)	(0.044)		(0.019)	(0.018)	
lambda			0.439***			0.060***
			(0.045)			(0.019)
sigma2_e	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N	3047	3047	3047	3047	3047	3047

Table 4. Results of Model Diagnostic Tests

year	**Ged**				**Dei**			
	Economic Matrix		Geographical Matrix		Economic Matrix		Geographical Matrix	
	Moran's I	z	Moran's I	z	Moran's I	z	Moran's I	z
2012	0.012***	1.537	0.005***	1.604	0.420***	11.194	0.294***	12.479
2013	0.012**	1.258	0.031*	1.490	0.432***	11.535	0.304***	12.863
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2020	0.092***	3.504	0.028***	1.516	0.415***	11.075	0.282***	11.976
2021	0.220***	7.470	0.080***	3.629	0.424***	11.321	0.298***	12.644
2022	0.210***	7.119	0.076***	3.449	0.418***	11.164	0.298***	12.652

Table 5. Estimates of the SDM

Geographical Matrix				Economic Matrix			
VAR	(1)Ged	VAR	(2)Ged	VAR	(3)Ged	VAR	(4)Ged
Dei	0.009**	W x	0.012	x	0.009**	W x	0.020***
	(0.004)		(0.015)		(0.004)		(0.006)
Sti	0.129	W x1	-0.344	x1	0.041	W x1	0.298**
	(0.096)		(0.333)		(0.095)		(0.125)
Foi	-0.081*	W x2	0.163*	x2	-0.008	W x2	-0.011
	(0.049)		(0.085)		(0.036)		(0.056)

Fid	-0.003	W x3	-0.013	x3	-0.002	W x3	-0.006
	(0.003)		(0.013)		(0.003)		(0.007)
ER	-0.000	W x4	0.000*	x4	-0.000	W x4	-0.000
	(0.000)		(0.000)		(0.000)		(0.000)
Ecl	0.022***	W x5	-0.045***	x5	0.011**	W x5	-0.029***
	(0.007)		(0.016)		(0.006)		(0.008)
rho	0.317***	N	3047	rho	0.028	N	3047
	(0.046)				(0.019)		(0.000)

4.4 Robustness Tests

To verify the reliability of the above conclusions, this study conducts robustness analyses from the following perspectives:

4.4.1 Replacement of spatial weight matrices

The model is re-estimated using both the adjacency matrix and a spatially nested matrix to replace the previously used geographical distance and economic distance matrices. In the adjacency matrix, an element is assigned a value of 1 if two cities are geographically adjacent, and 0 otherwise. In the spatially nested matrix, each element represents the standardized interaction of geographical and economic distances between two cities.

4.4.2 Replacement of the dependent variable

The dependent variable is replaced with green total factor productivity recalculated using the SBM-DDF method. As shown in Column (3) of Table 6, even after replacing the dependent variable, the development of the digital economy continues to significantly promote urban green economic development.

The robustness test results in Table 6 indicate that the coefficient of the digital economy remains significantly positive across all model specifications. This finding demonstrates that, with the steady development of the digital economy, urban green economic development has been substantially enhanced, confirming the robustness of the selected spatial econometric models.

Table 6. Robustness Test Results

	(1)	(2)	(3)Replace the explained variable	(4)
	Adjacency matrix	Spatially nested matrix	Geographical	Economic
Dei	0.012***	0.009**	0.004**	0.005***
	(0.004)	(0.004)	(2.26)	(3.06)
Sti	0.091	0.002	0.053	0.001
	(0.098)	(0.095)	(1.32)	(0.03)
Foi	-0.068	0.065	-0.030	0.001
	(0.051)	(0.042)	(-1.48)	(0.08)
Fid	-0.004	-0.002	-0.001	-0.001
	(0.003)	(0.003)	(-1.02)	(-0.99)
ER	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(-0.56)	(-1.06)
Ecl	0.014*	0.030***	0.009***	0.005**
	(0.007)	(0.007)	(3.07)	(2.11)
rho	0.280***	0.373***	0.551***	0.125***
	(0.022)	(0.029)	(16.61)	(6.92)
sigma2_e	0.002***	0.002***	0.000***	0.000***
	(0.000)	(0.000)	(38.85)	(38.91)

5. Transmission Conduits of the Digital Fiscal Influences City Innovation

Hypothesis 3 posits that while the tech-driven economy drives manufacturing upgrading, it simultaneously promotes the low-carbon buildup of urban economies. Consequently, this study selects low-carbon tech-based renovation (Gti) and domains Structure Upgrading as inter-mediation vehicles to disentangle how digitization impinges upon the low-carbon buildup of urban economies. Empirical analysis was conducted using the mediation effect model constructed above. Mediation effects were tested via 1,000 bootstrap resampling iterations, with Sobel tests determining their statistical significance. The estimation estimates in Table 4 indicate that both mediating variables pass the Sobel test with statistical significance at the 1% level. This demonstrates that the digitization exerts a direct contributor to low-carbon financial progression. Furthermore, the advancement of the digitization further stimulates low-carbon technology renovation while simultaneously propelling manufacturing structure towards more rational and advanced directions. Thus, the tech-driven economy raises the potential for verdant city financial

progression by supporting ecological technology renovation and improving domains structure. Both hypotheses H3a and H3b are confirmed.

6. Concluding Elaborations and Policy Guidelines

This research covers the period from 2012 to 2022, examining 277 regional and greater-tier urban areas across China. It measures the digitization and levels of green advancement of these urban areas, systematically exploring the influence of the digitization on urban verdant economic growth and its heterogeneity from a spatial correlation perspective. Furthermore, it analyses the transmission channels through which China's digitization catalyzes green progression. The principal findings are summarized below.

First, the digitization exerts a salutary, promotional imprint on verdant economic development. Moreover, the progression of the digitization in each city not only directly promotes domestic verdant economic development but also enables neighbouring regions to reap digital dividends. This drives the deep integration and synergistic enhancement of the digital economy and green economic development, confirming the spatial spillover effect of the digital economy in elevating urban verdant fiscal progression degrees. Stability tests confirm the persuasiveness of this conclusion. Secondly, the footprint of the digitization on green economic development differs between different areas, with a persistent ‘digital divide’ effect observed in its influence on urban green development. Thirdly, the digitization strengthens the potential for verdant fiscal progression by fostering green engineering ingenuity and improving productive structures. In light of these findings, the following policy suggestions are put forth:

First, elevate the level of the urban digitization by consolidating infrastructure and research investment. Within the overarching system of the digitization driving renovation , increase capital allocation to the internet sector, particularly in 5G commercialization and big data model growth, and to further cement the ‘tech-driven dividend’ advantages it generates for low-carbon economic growth. Establish system to encourage and support tech-driven retooling of legacy sectors.

Secondly, strengthen the disorganization's enabling contribution to low-carbon growth. Local governments should align with the tech-driven trend, proactively plan for future frontier technology sectors, and foster the vigorous growth of information sectors. By facilitating the in-depth integration of information technologies with pre-existing domains, they should synergistic-ally advance both the tech-driven industrialization alongside the tech-driven restructuring of domains, thereby reducing urban pollution releases. Furthermore, addressing the ‘tech-driven divide’ effect in current urban low-carbon growth, efforts should explore collaborative mutual assistance mechanisms for regional tech-driven advancement. This includes strengthening inter-regional cooperation and support in tech-driven technologies, talent growth, and infrastructure construction. Additionally, institutional tools should be fully leveraged to guide the tech-driven economy and low-carbon growth, actively boosting smart city pilot initiatives and intellectual property systems.

Thirdly, market-oriented mechanisms must be refined. Urban areas should establish systematic low-carbon growth planning alongside regular monitoring and early-warning systems, enhancing institutional frameworks characterized by robust governmental leadership, active corporate participation, and effective market regulation to better stimulate societal engagement in low-carbon growth. Concurrently, ecological protection efforts should appropriately incorporate temporal continuity, evaluating the policy outcomes and ecological performance of preceding periods as crucial references for policy refinement and new work plans.

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