The Impact of Internet Development on Green Economic Growth: Evidence from China

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Abstract. In the context of "Carbon Peaking and Carbon Neutrality", digital technologies, such as Internet, is now playing an increasingly prominent role in the economic and social development, serving as an engine in the green transformation and growth of the economy. Based on a two-way fixed effect model (TWFEM), this study researches the impact of Internet development (ID) on green economic growth (GEG), utilizing panel data for 30 Chinese provinces from 2006 to 2020. This study draws the following five main conclusions. Firstly, ID has a significant contribution to GEG in China. Secondly, compared to the central and western regions of China, the impact of ID on GEG is stronger in the east. Thirdly, the positive impact of ID on GEG was stronger after the 18th National Congress of the Communist Party of China (NCCPC) in 2012. Fourthly, ID promotes China's GEG mainly through promoting economic growth and improving pollution control. Fifthly, government intervention weakens the impact mechanism, while market development enhances it. After a series of robustness tests, the above findings remain valid, boosting important implications for furthering the coordinated development of the digital and green economies.

Keywords: Internet; Digital Economy; Green Economy; Two-way Fixed Effect; Moderating Effect; China.

1. Introduction

Facing the crisis of severe climate, the twenty-sixth session of the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) called on countries to refresh their nationally owned contributions (NDCs) and low-emission development strategies for a long term. The concept of Carbon Neutrality is taking shape globally, with the end of the traditional industrial age and the start of a new age of economic development (Mealy and Teytelboym, 2022). As the second largest economy and the largest carbon emitter around the world, China has fundamentally changed economic development philosophy to an intensive development approach of "High efficiency, Low energy consumption and Low emissions", and has set the goals of " Carbon Peaking by 2030 and Carbon Neutrality by 2060". Environmental protection is no longer a weight on economic development, but a driver of high-quality economic development (Luo et al., 2023). The shift from the old to the new implies a reshaping of the content and approach of economic development, and the concept of green economy development will be integrated into all areas of socio-economic development, contributing to smooth transformation and high-quality development. Green economy is a new economic development model, which is based on circular development green development and low-carbon development of industrial economy, with the direction of achieving economic development, social progress and protecting the environment, with the goal of improving human well-being and guiding the reform of human society from "Industrial Civilization" to "Ecological Civilization", with sustainable development that is environment-friendly and resource-saving in proportion to economic growth. Economic and social development must be coordinated with the construction of the ecological environment, and the common prosperity of all mankind must be achieved through sustainable development worldwide.

In recent years, digital technology has continued to integrate with all aspects of the economy and society, becoming an important engine for promoting China's consumption upgrade and economic structural transformation (Yuqing et al., 2012). In particular, Internet access has been upgraded from narrowband dial-up at the kilobit rate (Kb) level to broadband access at the 100-megabit bit rate (Mb) level, marked by light-to-home and fiber-to-the-table access. Meanwhile, the mobile Internet has developed rapidly, along with the promulgation of smart mobile terminals represented by smartphones and the upgrade of access technology represented by 5G mobile communication technology. With the emergence of various applications based on mobile Internet (Mourtzis, 2021), the "Internet +" has gradually changed the way the traditional real economy develops, making the concept of the Internet not only limited to the purely technical sphere, but gradually expanding to the sphere of social organization. ID of China has surpassed the global average and has achieved great results.

Much evidence shows that the deep embedding and application innovation of the digital economy, represented by artificial intelligence, Internet and big data in the energy, resource, industrial and environmental sectors, has injected new momentum to drive the green conversion of the economy (Wang et al., 2022). (1) Digital technology promotes the green transformation of the economy by making industrial enterprises turn to low-carbon production. The digital economy enables the decline of energy consumption throughout the life cycle of key carbon-emitting industries and sectors, unleashing the carbon reduction potential of digital technology. (2) Digital technology promotes green economic transformation by improving energy efficiency. It can efficiently grant businesses with smart green production and energy management, driving green process and service innovation to achieve a two-fold improvement in production efficiency and energy use efficiency. (3) Digital technology promotes green economic transformation through more efficient environmental governance. Through the commution of information and data resources among government, enterprises and the public, the digital economy can build a scientific and sustainable environmental and ecological system, bringing into the integrated utility of data, effectively monitoring environmental pollution and related governance, and ensuring the timeliness and efficiency of environmental governance measures (Yi et al., 2022).

However, little attention has been paid by scholars to the impact of Internet in the digital economy on the green economic development (GED). In China, where Internet is rapidly developing, can the development of the Internet itself and its application at all levels of society become a new engine for GED, and what are the mechanisms of its influence? This paper detects the impact of ID on China's GEG, utilizing data on indicators related to ID and GED in 30 Chinese provinces from 2006 to 2020, and then further investigates regional heterogeneity and temporal heterogeneity. Thus, the contributions of this study are as follows. Firstly, this paper constructs an evaluation index system (EIS) for China's ID and EIS for China's GED, and using the entropy value method (EVM) (Wang et al., 2022), comprehensively calculates China's ID index and GED index. Secondly, using TWFEM, the paper explores the impact of ID on China's GEG in a dimensional manner. Thirdly, the paper conducts a moderating effect analysis to explore the role of the government and the market in this mechanism.

The rest of the paper is structured as follows. Section 2 is the literature review and theoretical analysis. Section 3 is the empirical design. Section 4 presents the results and discussion of the empirical study. Section 5 draws conclusions and offers policy suggestions.

2. Literature Review

2.1 Overview of ID

With the rapid development of digital technology, the importance of Internet infrastructure construction and the concept of "Internet+" is increasing in the economy and society. Characterized with practical, inexpensive, functional and flexible feathers, the Internet has been developing at a rapid pace since its inception. China's Internet service market is developing rapidly, the network infrastructure is being strengthened and the external development environment of the Internet industry is being optimized (Yuqing et al., 2012).

Many scholars have explored the development of the Internet and its significance. Mourtzis (2021) estimated that 5G Internet communication technologies will increase global manufacturing GDP by

4% by 2030 (Mourtzis, 2021). The digital economy has stimulated the dynamism and creativity of markets, facilitated the reform of traditional industrial sectors, and promoted the growth of new industries. Hedberg (2021) argued that digitalization can contribute to the development of a circular economy through improved information transfer and better business models. Yang (2022) pointed out that the digital economy facilitates development of the regional economy. The integration of the digital economy with traditional industries can facilitate innovation in regional industries by promoting innovation in artificial intelligence, mobile services and cloud services (Yang et al., 2022).

In summary, the Internet has become a key driver of high-quality growth and coordinated regional development in China. The Internet is playing a more and more significant role in stimulating development of economy, facilitating social progress and improving quality of people's life. There is a need for greater cooperation between the government, international organizations, enterprises and civil society to increase investment in basic research on Internet-related technologies to achieve leapfrog development of the Internet (de Souza et al., 2022). The government should strengthen the training of top Internet talents and promote the digitization of national policies.

2.2 Studies on the Relationship between the Internet and Green Development

The information and communication technology revolution represented by the Internet is an important driving force for the realization of green economy. Regarding the relationship between Internet and green development, existing research focuses on three aspects: environmental governance efficiency, industrial green productivity, and urban green development. (1) Through the spatial DURBIN model and quantum regression model, Yang (2021) analyzed that ID could curb environmental pollution in China by improving the efficiency of environmental governance and technological innovation. Li (2022) researched that the digital economy, of which Internet is an important component, is significant for carbon emission decline. After a non-linear analysis combining the spatial DURBIN model and the panel threshold model, Li (2022) concluded that the digital economy has an overturned U-shaped relationship with carbon emissions. The impact of the digital economy on carbon emissions in the long term is also greater than the impact in the short term (Li and Wang, 2022). (2) Based on the spatial Durbin model, Yu (2022) argued that ID can meaningfully make a contribution to the improvement of industrial green total factor productivity by improving industrial structure and technological innovation, thus increasing industrial green productivity (Yu, 2022). (3) Through an improved DEA model, namely the super-EBM-non-ideal model, Wang et al. (2022) explored that ID can promote urban green innovation efficiency mainly by promoting producer service agglomeration for financial development and reducing resource dependency (Wang and Shao, 2023). Luo (2023) also supported the conclusion that ID can significantly improve urban green innovation efficiency. The Internet can promote urban development. Regional heterogeneity in the promotion effect was analyzed, present only in Northeast and East China in China (Luo et al., 2023).

Government and market occupy an important place in China's economic and social development; thus, it is necessary to investigate the role of government intervention and market development in China's economic and social development. Kou (2022) systematically tested the impact of different scales of Internet infrastructure on carbon emissions, both in terms of government intervention and market segmentation. Under the assumption of local government intervention, internet infrastructure has a disincentive effect on carbon intensity. In addition, local government intervention suppresses negative externalities that are specific to the environment. The impact of the internet on carbon emissions under local government intervention is N-shaped. Connected infrastructure under market segmentation dampens carbon emissions and does not exhibit a nonlinear characteristic of carbon emission intensity (Kou and Xu, 2022).

In summary, ID has a catalytic effect on green development, with government and market playing an important role in this mechanism. There is regional heterogeneity in this influence mechanism in China.

2.3 Literature Gaps

Although some researches have made initial studies of Internet and green development, there are still two research gaps. Firstly, existing research on the assessment of the green economy is not comprehensive enough and lacks uniform indicators. Second, the green economy usually consists of multiple sub-indicators, and a large amount of the existing studies focus on the relationship between the Internet and a particular sub-indicator, while few scholars have studied the impact of ID on the green economic system.

3. Research Design

3.1 Model Establishment

In order to scientifically examine the impact of ID on GEG, taking into account both time-fixed effects and regional-fixed effects, this study selects TWFEM (Chai et al., 2022). It adjusts for residual correlations across different provinces in different periods, and control for individual characteristics that do not vary with time and temporal characteristics that do not vary with province. The basic measurement model in this paper is shown in the following equation.

$$Greco_{it} = \alpha_0 + \beta Int_{it} + \sum \gamma X_{it} + \mu_i + v_t + \varepsilon_{it} \tag{1}$$

Where: $Greco$ is China GED Index, t represents year, i represents province. Int represents the China ID Index. Other factors that may have impacts on GEG are defined as control variables and are bid by environmental governance (Er), government intervention (Gov), infrastructure development (Inf), R&D investment intensity (Rd), urbanization level (Urb) and GDP per capita (Gdp).

In addition, α_0 is a constant term, β is a parameter to be measured, μ_i denotes a provincial effect, v_t represents a time effect, and ε_{it} denotes an individual and time varying disturbance term.

3.2 Variables

To measure the level of China's ID and GED, this paper constructs EIS for ID of China and EIS for GED of China. The indicators selected in this document are dynamic in nature, meaning that they can measure alterations in the same indicator at different points in time and have practical meaning over time. At the same time, the selected indicators are quantifiable, authentic and reliable.

After determining EIS of China's ID and EIS of China's GED, this paper applies EVM to assign objective values to the indicators (Zhang et al., 2022), and determines the weights according to the degree of variation of each indicator or the interrelationship between the indicators. In information theory, entropy is a measure of irregularity in a system. The greater the variability in the value of an indicator, the lower the information entropy, the more information the indicator provides, and the greater the weight of the indicator. Conversely, the smaller the variability in the value of an indicator, the greater the entropy of information, the less information the indicator provides, and the smaller the weight of the indicator. The precise steps are as follows.

(1) Build the original matrix. Build the original matrix of indicators: With m years and n indicators, a matrix of m rows and n columns can be built. Let any data in the matrix be x_{ij}, indicating the actual value of indicator j in year i.

(2) Data standardization. The specific method is:

Positive index:

$$y_{ij} = [x_{ij} - \min(x_{1j}, x_{2j}, ..., x_{nj})] / [x_{\max}(x_{1j}, x_{2j}, ..., x_{nj}) - \min(x_{1j}, x_{2j}, ..., x_{nj})] * 100 \tag{2}$$

Negative index:

$$y_{ij} = [\max(x_{1j}, x_{2j}, ..., x_{nj}) - x_{ij}] / [x_{\max}(x_{1j}, x_{2j}, ..., x_{nj}) - \min(x_{1j}, x_{2j}, ..., x_{nj})] * 100 \tag{3}$$

(3) Calculate the entropy value e_j of the indicator j:

$$e_j = -k * \sum_{i=1}^{m} [p_{ij} * \ln(p_{ij})]$$
$$k = 1/\ln m, p_{ij} = y_{ij} / \sum_{i=1}^{m} y_{ij} \tag{4}$$

(4) Calculation of the weight w_j of the indicator j .

$$w_j = (1-e_j) / \sum_{j=1}^{n} (1-e_j) \tag{5}$$

(5) Calculate the development index u_i of the variables in EIS:

$$u_i = \sum_{j=1}^{n} (y_{ij} * w_j) \tag{6}$$

3.2.1 Explained Variable - GED Index

In this paper, thirteen indicators, namely per capita fiscal revenue, per capita GDP, share of tertiary industry, share of secondary industry, per capita fixed asset investment, energy intensity, electricity intensity, per capita water resources, per capita arable land area, industrial wastewater emissions, smoke (dust) emissions, industrial SO2 emissions, and industrial solid waste generation, are selected into three dimensions to construct EIS for GED in China.

Under the EM, the weights of the indicators in the system are shown in Table 1.

Table 1. GED evaluation index system

Dimension	Indicator	Unit of measurement	Type	Weight
Economic growth	Per capita fiscal revenue	Yuan	Positive	9.44
	Per capita GDP	Yuan	Positive	9.48
	Share of tertiary industry	%	Positive	9.09
	Share of secondary industry	%	Positive	7.24
	Per capita fixed asset investment	10,000 Yuan/person	Positive	12.57
Resource utilization	Energy intensity	Ton of standard coal /10,000 Yuan	Negative	3.77
	Electricity intensity	kWh/Yuan	Negative	3.32
	Per capita water resources	Cubic meter/person	Positive	8.03
	Per capita arable land area	Mu/person	Positive	10.42
Pollution control level	Industrial wastewater emissions	10,000 Tons	Negative	7.44
	Smoke (dust) emissions	10,000 Tons	Negative	3.65
	Industrial SO_2 emissions	Ton	Negative	9.56
	Industrial solid waste generation	10,000 Tons	Negative	6.00

Note: The total weight is set at 100.

Finally, this paper measures GED Index ($Greco$) in China as the explanatory variable, according to the weights of each indicator.

3.2.2 Explanatory Variable - ID Index

Table 2. ID evaluation index system

Dimension	Indicator	Unit of measurement	Type
Number of Internet users	10,000 persons	Positive	8.85
Penetration rate of Internet users	%	Positive	13.34
Number of domain names	10,000	Positive	7.89
Number of websites	10,000	Positive	4.80
Length of long-distance fiber-optic cable lines	Kilometer	Positive	6.64
Number of Internet broadband access ports	10,000	Positive	12.95
Proportion of IPv4 addresses	%	Positive	11.61
Average number of bytes per web page	KB	Positive	8.13
Volume of express delivery services	10,000	Positive	4.12
Per capita GDP	Yuan	Positive	10.51

Per capita disposable income of urban residents	Yuan	Positive	11.15

Note: The total weight is set at 100.

In this paper, eleven indicators, namely number of Internet users, penetration rate of Internet users, number of domain names, number of websites, length of long-distance fiber-optic cable lines, number of Internet broadband access ports, proportion of IPv4 addresses, average number of bytes per web page, volume of express delivery services, per capita GDP and per capita disposable income of urban residents are selected to construct EIS for evaluating ID in China.

Under the EVM, the weights of each indicator in the system are shown in Table 2.

Finally, this paper measures ID Index (Int) in China as the explanatory variable, according to the weights of each indicator.

3.2.3 Control Variables

In the study, as described earlier, six control variables are included in TWFEM. The ratio of industrial pollution control investment to industrial value added represents environmental control (Er). The ratio of government fiscal expenditure to year-end GDP for each province represents government intervention (Gov). The ratio of total road and rail mileage to total area of each province represents infrastructure development (Inf). Internal expenditure on R&D investment as a percentage of provincial year-end GDP represents R&D input intensity (Rd). The ratio of urban population by province represents urbanization level (Urb). GDP per capita at the end of the year for each province represents GDP per capita (Gdp).

3.2.4 Moderating Variables

For the moderating effects analysis in the paper, two moderating variables were selected. The ratio of government fiscal expenditure to the year-end GDP of each province represents government intervention (Gov). The Fan Gang Market Index represents market development (Mkt).

3.3 Data

Market development data are based on the Fan Gang Market Index. Considering the availability, validity and consistency of the rest of the data, the study selects the panel data of 30 Chinese provinces, autonomous regions and cities (excluding Hong Kong, Macao, Taiwan and Tibet) from 2006 to 2020. All the above data are obtained from China Energy Statistical Yearbook, China Statistical Yearbook, China Science and Technology Statistical Yearbook, China Environment Yearbook, China Urban Statistical Yearbook, China High Technology Statistical Yearbook, China Marketization Index Report by Province. Where there are missing data for some cities, this paper fills in the gaps by consulting the statistical yearbooks of each province and city and by using interpolation.

Table 3. Descriptive statistics of variables

Variable	Sample size	Mean	Standard deviation	Minimum	Maximum
$Greco$	450	0.445	0.083	0.267	0.66
Int	450	0.212	0.125	0.017	0.691
Er	450	0.004	0.003	0	0.028
Gov	450	0.231	0.101	0.083	0.645
Inf	450	0.913	0.502	0.068	2.223
Rd	450	0.015	0.011	0.002	0.064
Urb	450	0.558	0.137	0.275	0.896
Gdp	450	46289.83	28033.32	5787	164889
Mkt	270	6.153	1.795	2.33	10

In order to decrease the absolute value of the data, compress the scale of the variables, make the data smoother, weaken different effects of differences between different intervals in the entire value domain of the data, and reduce the covariance and heteroskedasticity of the model, one control variable GDP per capita (Gdp) is logarithmically treated in this paper and is denoted as $\ln Gdp$. The remaining five control variables (environmental governance, government intervention, infrastructure development, R&D input intensity, urbanization level), the explained variable (GED Index), the explanatory variable (ID index) and moderating variables (market development, government intervention) are kept at their original values without logarithmic treatment.

The descriptive statistics of the data are shown in Table 3.

4. Empirical Results and Discussion

4.1 Baseline Estimation

Based on TWFEM, the study conducts stepwise regressions and Table 4 reports the stepwise regression results of ID Index and GED Index. As results in Column1,2,3 and 4 show, the RCs for the ID Index (Int) are all significantly positive as the control variables are gradually introduced. The development of Internet has a significant contribution to the level of GED in China.

Table 4. Baseline estimation results

	$Greco$ (1)	$Greco$ (2)	$Greco$ (3)	$Greco$ (4)
Int	0.317^{***} (10.54)	0.242^{***} (7.52)	0.258^{***} (7.11)	0.259^{***} (7.80)
Er		0.679 (1.62)	0.595 (1.43)	0.871^{**} (2.29)
Gov		-0.176^{***} (-5.40)	-0.122^{***} (-3.37)	-0.008 (-0.24)
Inf			0.041^{**} (3.16)	0.004 (0.31)
Rd			0.033 (0.06)	2.083^{***} (4.05)
Urb				0.080^{*} (1.70)
$\ln Gdp$				0.067^{***} (7.29)
Constant term	0.336^{***} (88.28)	0.366^{***} (50.20)	0.325^{***} (23.28)	-0.381^{***} (-4.52)
Province FE	Control	Control	Control	Control
Year FE	Control	Control	Control	Control
R^2	0.921	0.927	0.929	0.941
N	450	450	450	450

Note: Corresponding standard errors of robustness t-values are given in square brackets under the coefficients; *, **, *** denote 10%, 5% and 1% significance levels separately.

In Column 4, (1) The control variable environmental governance (Er) is significantly positive at the 5% SL, which shows that environmental governance affects GEG positively. National governance of environmental pollution is of great practical significance in achieving sustainable economic development and overall harmony in human society. (2) The control variable government intervention (Gov) is not statistically significant, which indicates that government intervention is not important in GEG. The government's governance model or policies does not fit properly into the GED model.

(3) The control variable infrastructure development (Inf) is not statistically significant, indicating that infrastructure development is not important in GEG. Infrastructure construction needs to establish a sound investment and financing system, as well as strengthen the capacity of independent innovation in core technologies to improve economic efficiency (Huang and Tian, 2023). (4) The control variable R&D input intensity (Rd) is statistically significantly positive at the 1% level, which indicates that technological development has a positive impact on GEG. Technological innovation can inject new impetus into economic development, enhance competitiveness for enterprise development, and stimulate cohesion for green development (Ma and Zhu, 2022). (5) The control variable urbanization level (Urb) is statistically significantly positive at the 10% level, which shows that urbanization development affects GEG positively. An increase in urbanization rate can further the development of economies of scale and increase national awareness of environmental protection (Dong et al., 2023). (6) The control variable GDP per capita (Gdp) is statistically significantly positive at the 1% level, which shows that an increase in the level of economic development is crucial in green economy.

4.2 Heterogeneity Analysis

4.2.1 Regional Heterogeneity

As the level of economic development changes considerably across different regions of China, the level of digital technology and GED exist differences (Wang et al., 2023). The impact of ID on GEG may be heterogeneous. To analyze the impact of ID on GEG across different levels of development, this paper divides 30 provinces, autonomous regions and cities (excluding Hong Kong, Macao, Taiwan and Tibet) of China into the east, central regions and the west.

To verify the regional heterogeneity effect of ID, based on TWFEM, the study adds Eastern region dummy variable ($East$), Central region dummy variable (Mid) and the interaction terms between these two dummy variables and the ID Index $Int * East$ and $Int * Mid$ respectively. This paper re-estimates them using the original data, with the corresponding regression results covered in Column 1 and Column 2 of Table 5.

In Column 1, no control variables are introduced in the study. In Column 2, after the introduction of control variables in this paper, RC of the explanatory variable ID Index (Int) is significantly positive. RC of the interaction term is significantly positive; RC of the interaction term is 0.025, which is not significant in terms of statistical significance. Economically, in the west, every 1 unit increase in the ID Index significantly leads to 0.317 unit increase in the corresponding GED Index. In the east, compared to the west, 1 unit increase in the ID Index significantly leads to a more 0.048 unit increase in the corresponding GED Index. In the central region, the contribution of ID to GEG is almost the same as that in the western region.

This suggests that there is a regional heterogeneous effect of ID on GEG. In the east, central regions and the west of China, ID contributes to GEG. Among them, the positive impact of ID on GEG is most significant in the east. Possible reasons for the difference are as follows: the eastern region is strategically located, rich in resources and has more educated workforce(Hammad et al., 2023), stronger technological capabilities and more supportive policies, resulting in a higher level of economic development and more senior digital technologies. Therefore, in the east of China, Internet contributes more to green economy.

4.2.2 Temporal Heterogeneity

In November 2012, the 18th NCCPC was held, incorporating the building of ecological civilization into the overall design of China's "Five-in-One" and making "beautiful China" the ambitious goal of ecological civilization construction for the first time. Therefore, there may be a heterogeneous effect of ID on GEG around 2012. To analyze the impact of ID on GEG in different time periods, this paper divides the period from 2006 to 2020 into two time periods: 2006 to 2012, 2013 to 2020.

To verify the time-heterogeneity effect of ID, based on TWFEM, this paper adds a dummy variable (Int) for the time period 2006 to 2012 and an interaction term between this dummy variable and the

ID Index $Int*Before$. This paper re-estimates it using the original data, with the corresponding regression results reported in Column 3 and Column 4 of Table 5.

In Column 3, no control variables are introduced in this paper. In Column 4, after the introduction of control variables, RC of the explanatory variable ID Index (Int) is significantly positive. RC of the interaction term $Int*Before$ is significantly negative. In terms of economic significance, after the 18th NCCPC (2013-2020), every 1 unit increase in the ID Index significantly leads to 0.229 unit increase in the corresponding GED Index. Compared to the period after the 18th NCCPC (2013-2020), in the period prior to the 18th NCCPC (2006-2012), every 1 unit increase in the ID Index significantly leads to less 0.061 unit increase in the corresponding GED Index.

This suggests that there is a temporal heterogeneity effect of ID on GEG. In all time periods, ID has a boosting effect on GEG. In particular, the positive effect of ID on GEG is more pronounced after the 18th NCCPC (2013-2020). Possible reasons for this are as follows: after the 18th NCCPC in 2012, the development of circular economy has been more effective and resource use efficiency has improved significantly. Moreover, investment in environmental pollution control has expanded and significant progress has been made in green and low-carbon development, transforming and upgrading the economy.

Table 5. Heterogeneity analysis (regional, temporal) results

	$Greco$ (1)	$Greco$ (2)	$Greco$ (3)	$Greco$ (4)
Int	0.423^{***} (9.19)	0.203^{***} (4.28)	0.345^{***} (9.66)	0.229^{***} (6.30)
$Int*East$	-0.075^{**} (-2.95)	0.048^{*} (1.65)		
$Int*Mid$	-0.012 (-0.44)	0.025 (1.00)		
$Int*Before$			0.452 (1.46)	-0.061^{*} (-1.94)
Er		0.887^{**} (2.33)		0.942^{**} (2.47)
Gov		-0.002 (-0.07)		-0.001 (-0.28)
Inf		0.001 (0.08)		0.005 (0.38)
Rd		1.984^{***} (3.83)		1.961^{***} (3.80)
Urb		0.107^{**} (2.14)		0.120^{**} (2.34)
$\ln Gdp$		0.073^{***} (7.41)		0.067^{***} (7.32)
Constant term	0.332^{***} (83.80)	-0.442^{***} (-4.78)	0.331^{***} (65.70)	-0.394^{***} (-4.68)
Province FE	Control	Control	Control	Control
Year FE	Control	Control	Control	Control
R^2	0.923	0.942	0.922	0.942
N	450	450	450	450

Note: Corresponding standard errors of robustness t-values are given in square brackets under the coefficients; *, **, *** denote 10%, 5% and 1% significance levels separately.

4.3 Sub-dimensional Mechanism Analysis

To further research the influence mechanism of ID on GEG, the study divides EIS of China's GED into three dimensions: economic growth, resource utilization rate and pollution control level. Similarly, after determining the economic growth EIS, resource utilization EIS, and pollution control level EIS, this paper utilizes EVM to objectively assign values to the indicators under each EIS and obtains the Economic Growth Index (Eco_grow), Resource Utilization Index (Res_use), and Pollution Control Index (P_gov) after measurement. As shown in Table 6.

Table 6. Sub-dimensional index system

Economic Growth Evaluation Index System			
Indicator	Unit of measurement	Type	Weight
Per capita fiscal revenue	Yuan	Positive	19.74
Per capita GDP	Yuan	Positive	19.82
Share of tertiary industry	%	Positive	19.01
Share of secondary industry	%	Positive	15.15
Per capita fixed asset investment	10,000 Yuan/person	Positive	26.28
Resource Utilization Evaluation Index System			
Indicator	Unit of measurement	Type	Weight
Energy intensity	Ton of standard coal /10,000 Yuan	Negative	14.77
Electricity intensity	kWh/Yuan	Negative	13.00
Per capita water resources	Cubic meter/person	Positive	31.45
Per capita arable land area	Mu/person	Positive	40.79
Pollution Control Level Evaluation Index System			
Indicator	Unit of measurement	Type	Weight
Industrial wastewater emissions	10,000 Tons	Negative	27.91
Smoke (dust) emissions	10,000 Tons	Negative	13.71
Industrial SO_2 emissions	Ton	Negative	35.88
Industrial solid waste generation	10,000 Tons	Negative	22.51

Note: The total weights of each system are set to 100.

Based on TWFEM, the study measures the impact of ID on indicators of different dimensions in the green economy indicator system. Table 7 reports the regression results of ID Index with Economic Growth Index, Resource Utilization Index and Pollution Control Level Index respectively. (1) In Column 1, after the introduction of control variables, RC of the explanatory variable ID Index (Int) is 0.200 and is significant at the 1% SL. (2) In Column 2, after the introduction of control variables, RC of the explanatory variable ID Index (Int) is -0.071, which is not statistically significant. (3) In Column 3, after the introduction of control variables, RC of the explanatory variable ID Index (Int) is 0.681 and is significant at the 1% SL.

This suggests that ID contributes significantly to GEG primarily through the promotion of economic growth and improved pollution control. ID has no significant effect on the improvement of resource utilization. Possible reasons for this are as follows: (1) The integration of Internet and manufacturing industries raises the value added of industries (Hao et al., 2023). The Internet cultivates and develops new dynamics to deepen supply-side reform. It enhances supply capacity through mining and analysis, promotes efficient coupling and precise matching between the supply side and the demand side, and accelerates the upgrading of industrial structures. What's more, it promotes the healthy and benign development of the sharing economy, cultivates new growth points and forms new dynamics in the sharing economy. The Internet creates new industries, new business models and new employment opportunities. Thus, the Internet empowers new dynamics of economic growth. (2) ID has no significant impact on the increase of resource utilization (Geng et al., 2017). The propaganda role of the Internet is not strong enough and the national awareness of green consumption needs to be raised. Based on the Internet the mobility, timeliness and balance of information sharing on resource consumption are not strong enough. (3) Under the "Internet+" model, various governance bodies such as government departments, civil society groups, social enterprises and the public are able to scientifically collect, process, integrate and analyze environmental pollution management information data. Therefore, ID can significantly improve the real-time and accuracy of pollution management.

Table 7. Sub-dimensional mechanism analysis results

	Eco_grow	Res_use	P_gov
Int	0.200*** (3.73)	-0.071 (-1.64)	0.681*** (7.45)
Er	1.845** (3.00)	-0.414 (-0.83)	0.360 (0.34)
Gov	0.023 (0.41)	0.140*** (3.01)	-0.208** (-2.13)
Inf	-0.007 (-0.36)	-0.032* (-1.91)	0.058* (1.68)
Rd	4.810*** (5.79)	-1.670** (-2.51)	0.814 (0.58)
Urb	-0.380*** (-5.00)	-0.044 (-0.71)	1.023*** (7.92)
$\ln Gdp$	0.197*** (13.21)	0.046*** (3.82)	-0.146*** (-5.75)
Constant term	-1.628*** (-11.93)	-0.102 (-0.92)	1.589*** (6.84)
Province FE	Control	Control	Control
Year FE	Control	Control	Control
R^2	0.931	0.577	0.708
N	450	450	450

Note: Corresponding standard errors of robustness t-values are given in square brackets under the coefficients; *, **, *** denote 10%, 5% and 1% significance levels separately.

4.4 Moderating Effects Analysis

In the basic economic system of China at this stage, the market plays a leading role and the government plays a macro-regulatory role(Wang et al., 2023), which combine with each other to facilitate the rapid development of China's economy. Therefore, government intervention and market development may be potential moderating variables in the mechanism of the impact of ID on GED (Li et al., 2021). To analyze the impact mechanism of ID on GED, this paper conducts a moderating effect analysis to explore whether the impact of ID on GED varies with government intervention and market development.

To verify moderating effects of government intervention and market development separately, based on TWFEM, the study constructs interaction terms $Int*Gov$, $Int*Mkt$, between government intervention (Gov), market development (Mkt) and ID Index (Mkt) respectively, and re-estimates them using the original data. The corresponding regression results are reported in Table 8.

In Column 1, no control variables are introduced. In Column 2, after the introduction of the control variables, RC of the interaction term $Int*Gov$ is negative and significant at the 10% SL. In terms of economic significance, government intervention weakens the positive impact of ID on GEG and has a dampening effect. (2) In Column 3, no control variables are introduced in this paper. In Column 4, after the introduction of the control variables, RC of the interaction term $Int*Mkt$ is positive and significant at the 10% SL. In terms of economic significance, market development enhances the positive impact of ID on GEG and has a catalytic effect.

This suggests that government intervention and market development are the moderating variables in the mechanism of the impact of ID on GED. There is a suppressive moderating effect of government intervention and a facilitating moderating effect of market development. Possible reasons for this are as follows: (1) Prior to the introduction of the sense of green development, government policies favored the crude growth model of "High Input, High Energy Consumption and High Emissions" to fulfil the objective of rapid economic development in the short term (Deng et al., 2022). As a result, inappropriate government intervention has undermined the positive impact of ID on GEG. In the age of "Carbon Peaking and Carbon Neutrality", the government needs to change its intervention to an intensive development model of "High Efficiency, Low Energy Consumption and Low Emissions" in order to achieve a green transformation of economic development. (2) Markets can flexibly reflect changes in market supply and demand, transmit information about market supply and demand, and achieve rational allocation of resources (Kemp-Benedict, 2018). The market uses market competition and interest leverage to mobilize market players, promote the advancement of business management, labor productivity and technology and make the effective use of resources come true. As the results of labor productivity improvement vary among market players, resources flow to the more efficient enterprises through market regulation (Chowdhury et al., 2022). Thus, market development improves the virtue of resource distribution, promotes economic efficiency and enhances the positive impact of ID on GEG.

Table 8. Moderating effects analysis results (government intervention, market development)

	Greco (1)	*Greco* (2)	*Greco* (3)	*Greco* (4)
Int	0.331^{***} (11.56)	0.360^{***} (9.58)	-0.215^{**} (-2.54)	-0.286^{***} (-3.62)
*Int * Gov*	-0.689^{***} (-6.71)	-0.782^{***} (-5.20)		
*Int * Mkt*			0.031^{***} (5.68)	0.041^{***} (6.67)
Er		0.758^{**} (2.05)		0.449 (1.20)
Gov		0.185^{***} (3.65)		0.0005 (0.01)
Inf		0.0002 (0.02)		-0.046^{**} (-2.07)
Rd		1.655^{***} (3.28)		2.374^{**} (3.10)
Urb		0.046 (1.00)		0.142^{*} (1.90)
ln *Gdp*		0.075^{***} (8.30)		0.105^{***} (7.17)
Constant term	0.341^{***} (92.12)	-0.467^{***} (-5.60)	0.383^{***} (53.49)	-0.731^{***} (-5.32)
Province FE	Control	Control	Control	Control
Year FE	Control	Control	Control	Control
R^2	0.929	0.945	0.884	0.916
N	450	450	270	270

Note: Corresponding standard errors of robustness t-values are given in square brackets under the coefficients; *, **, *** denote 10%, 5% and 1% significance levels separately.

4.5 Robustness Tests

Implicit in the above regression analysis is the underlying assumption that ID is an exogenous variable. Although this paper uses methods such as TWFEM to reduce measurement error, there is still a risk of endogeneity bias due to omitted variables and reverse causality in the estimation of the model (Chai et al., 2022). To avoid endogeneity problems caused by the reverse causality of "the higher the GED index, the higher the ID index". To further validate the reliability of the study results and to examine the stability of the model, the following two methods are used for robustness tests.

(1) Lagging explanatory variables. The promotion of ID on GED takes some time and there is a lag. In this paper, the ID Index is treated with one and two periods lags respectively. The results after re-regression are reported in Table 9. In Column 1, RC of the one-period lagged ID Index is positive and significant at the 1% SL. In Column 2, RC of ID Index with a two-period lag is positive and significant at the 1% SL. The test results indicate that the promotion effect of ID on GED remains significant and the regression analysis results are robust and consistent.

(2) Instrumental variables method. This paper utilizes the one-period lagged ID Index as an instrumental variable for the ID Index and applies two-stage least squares estimation to correct for the endogeneity problem of the model. On the one hand, the level of ID in period t+1 is similar to the level of ID in period t, thus satisfying the correlation condition. On the other hand, the level of ID in period t+1 does not directly affect the level of GED in period t. Thud, there is some exogeneity. The results of the estimation of the instrumental variables in column 3 of Table 9 below show that ID still affects GED positively after the consideration of endogeneity of ID. This indicates that the results of the above regression analysis are robust and consistent.

Table 9. Robustness tests results

	Greco (1)	*Greco* (2)	*Greco* (3)	*Greco* (4)
Int	0.246^{***} (6.80)	0.279^{***} (7.10)	0.293^{***} (7.00)	0.332^{***} (9.06)
Er	0.886^{**} (2.14)	1.152^{***} (2.74)	0.921^{***} (2.82)	1.151^{***} (3.01)
Gov	-0.010 (-0.27)	0.024 (0.56)	0.003 (0.09)	-0.013 (-0.37)
Inf	-0.009 (-0.71)	-0.014 (-1.03)	-0.003 (-0.19)	-0.030^{**} (-2.03)
Rd	2.537^{***} (4.68)	2.723^{***} (4.88)	2.162^{***} (3.70)	1.183^{*} (1.95)
Urb	0.118^{**} (2.34)	0.155^{***} (2.95)	0.119^{**} (2.42)	0.108 (1.60)
ln *Gdp*	0.074^{***} (7.34)	0.087^{***} (7.97)	0.066^{***} (6.03)	0.079^{***} (7.65)
Constant term	-0.457^{***} (-4.80)	-0.614^{***} (-5.67)	-0.518^{***} (-4.26)	-0.478^{***} (-5.27)
Province FE	Control	Control	Control	Control
Year FE	Control	Control	Control	Control
Cragg-Donald Wald F			789.209	
R^2	0.935	0.932	0.969	0.944
N	420	390	420	390

Note: Corresponding standard errors of robustness t-values are given in square brackets under the coefficients; *, **, *** denote 10%, 5% and 1% significance levels separately.

In this paper, further robustness tests are conducted by excluding the samples of municipalities directly under the central government.

(3) Sample replacement. Since municipalities directly under the central government in China have greater economic specificity compared to prefecture-level cities, this paper re-runs the regression after excluding the samples of four municipalities directly under the central government in China (Tianjin, Beijing, Shanghai and Chongqing). The regression results are shown in Column 4 of Table 9 below. RC for the explanatory variable ID Index is positive and significant at the 1% SL. The test results indicate that the contribution of ID to GED remains significant and the results of the regression analysis are robust and consistent.

5. Conclusion and Policy Implications

5.1 Conclusion

Internet has been fully integrated into all areas of economic and social development of China and has profoundly influenced the lifestyles and consumption habits of its citizens (Yang et al., 2022). Especially in the age of the "Carbon Peaking and Carbon Neutrality", the Internet has become increasingly important for the GED in China.

The study empirically tests the impact of ID on GEG utilizing data from 30 Chinese provinces from 2006 to 2020. There are five following conclusions. First, the development of Internet contributes to the growth of green economy in China significantly. This finding still holds under multiple robustness tests, which has strong policy implications for China to achieve "Carbon Peaking and Carbon Neutrality" goal. Second, regional heterogeneity analysis represents that the positive impact of ID on GED is found in the eastern, central and western China. Among them, the positive impact of ID on GEG is most significant in the eastern region. Third, the analysis of temporal heterogeneity shows that the positive impact of ID on GEG is stronger after the convening of the 18th NCCPC in 2012. Fourth, the sub-dimensional mechanism analysis shows that ID mainly contributes to GEG through promoting economic growth and improving pollution control (Dunlap, 2023), but the role of resource utilization enhancement is smaller. Fifth, the analysis of the moderating effect shows that government intervention weakens the positive impact of ID on GEG, while market development enhances the positive impact of ID on GEG.

5.2 Policy Implications

Based on the findings of the study, the following policy implications are proposed in order to better utilize the benefits of Internet to facilitate GED in China.

Firstly, all provinces of China should take measures to promote Internet, further advance the level of ID, and facilitate the establishment of a strong network and digital technology country (Zhang et al., 2021). (1) Promote the development of Internet technologies to a deeper level. Strengthen investment in basic research on Internet-related technologies, continue to promote fundamental research on Internet technologies, and consolidate the existing Internet technology foundation. Use technologies such as 5G, IPv6, artificial intelligence, blockchain and big data to build a new framework for ID, enhance technological innovation capabilities and accelerate breakthroughs in key technologies for ID. (2) Strengthen the integration of the Internet with the real economy. Based on ensuring more extensive coverage of wireless networks, build a new concept of Internet ideas and advance the application of Internet by enterprises (Adhikari and Bisi, 2020). Facilitate the upgrading of Internet-related industries and the development of their associated industries. Accelerate technological innovation, business innovation and business model innovation, enhance the transformation of digital innovation towards market orientation, and accelerate the formation of a cluster of Internet industries with international competitive advantages. Strengthen the stability of Internet-related industrial chains and the competitiveness of supply chains. (3) Pay attention to regional coordination and narrow the digital divide between regions. Each region should take into account its own characteristics and development trends to formulate ID strategies, break the limits of the ID divide and achieve balanced development of the Internet across regions (Ren et al., 2022). Large cities should make full use of the Internet effect to promote the diffusion of large-scale Internet technologies and industries in small and medium-sized cities, forming a new pattern of intra- and inter-regional ID and accelerating inter-regional connectivity.

Secondly, all actors in economy and society of China should pay attention to the "coordinated development of the Internet and GED" and give full play to the role of the Internet in facilitating the green economy, so as to help achieve the goal of "Carbon Peaking by 2030 and Carbon Neutrality by 2060". (1) Make full use of Internet to improve efficiency(Shang et al., 2023). Technological innovation is essential to improve the efficiency of environmental regulation. In the respect of ID, research and development of low-carbon technologies should be strengthened according to the characteristics and needs of environmental governance, in order to improve the efficiency of comprehensive energy use, reduce carbon emissions, improve carbon performance, and enhance the efficiency of environmental governance (Li et al., 2022). (2) Make full use of Internet to enhance the comprehensive strength and green transformation of the real economy. To achieve a coordinated symbiosis between the digital transformation of the real economy and green development, China should accelerate the cultivation of new business models based on Internet technology, accelerate green technology innovation, promote low-carbon technological innovation in resource-based industries, continuously release the vitality of Internet construction to empower the green conversion of the real economy, and build a supporting mechanism for Internet-driven GED (Liu et al., 2023). (3) Make full use of Internet to promote inter-regional collaboration. The central and the west of China are relatively lagging behind in terms of green development. In the process of promoting the development of the regional green economy, it is necessary to establish cooperation and exchange platforms by guiding leading enterprises in the industry to use Internet technology. Moreover, it is also good to encourage capable enterprises to build cooperation parks in the central and western regions, and provide relaxed policy support for such enterprises for a certain number of years to optimize the institutional environment (Nechifor et al, 2020), drive low-carbon technological innovation in industries in the central and western regions, promote industrial upgrading, and achieve green and intelligent industrial and economic development.

Thirdly, in order to promote the positive impact of ID on the green economy, the government should adjust its economic development goals and related policies, while making full use of the market(Chen et al., 2022). (1) The government can use a combination of soft and hard constraint policies when setting policy targets (Pan et al., 2023). On the one hand, in order to avoid excessive investment and pollution emissions caused by excessively hard constraint targets, the government can leave room for economic growth development targets and promote the conversion of the economic development model to a green and efficient direction. On the other hand, when formulating policies related to environmental protection, the government should adopt hard constraint targets (Hao et al., 2023) and resolutely reduce pollution emissions. With a two-way promotion effect, the government can fully stimulate the coordinated effect of efficient economic development and green development, and take advantage of Internet to promote the GED. In short, the government should use Internet and other digital technologies as a basis to consider a multi-goal combination model of green and low-carbon, economic growth, coordination and sharing, as well as other high-quality development. (2) The market can optimize resource allocation, further the deep integration and innovative application of Internet with economic entities (Ren et al., 2021). On top of that, it gives rise to industries, new technologies and business models related to the low-carbon sector. The government should take into account the importance of market development in economy and society of China, and allow sufficient policy space for the market to play a facilitating role in the "positive impact of ID on GEG".

5.3 Limitations

Although the study explores the impact of ID on GEG in China and makes certain innovations and policy recommendations, it still has some limitations. Firstly, this paper chooses provincial-level panel data for its empirical analysis. If prefectural and municipal data had been utilized for the analysis, the results would have been more precise than the data in this paper. Secondly, the lower indicators that make up the EIS of GED flow not only upstream and downstream of the industry and between industry chains but also between regions, so the GED of each region is related to the GED of other regions. This implies that there may be spatial spillover effects on the GED. However, this paper does not consider the spatial factor. Thirdly, the EIS of GED constructed in this paper may be incomplete and the analysis of the influence mechanism is partial. In the future, these problems can be solved. Finally, the findings of the study can be applied to other regions of the world to provide useful guidance for the achievement of global carbon neutrality.

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