Carbon Emission Reduction Effect of Information Technology: Stata Analysis Based on City Panal Model

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Abstract—Application of Information Technology such as big data, Internet, blockchain and cloud computing provides more possibilities for the low carbon economy. This paper scientifically estimates the carbon emission of 275 cities from 2011 to 2018 in China, builds a city panal model and studies the impact of Information Technology on carbon emissions with Stata software analysis, which verifies the emission reduction effect of Information Technology. Mechanism analysis shows that Information Technology curb the intensity of carbon emission by alleviating credit constraints and reducing the energy consumption intensity.

Keywords-Information Technology; carbon emission reduction; Stata Analysis; City Panal Model

1 INTRODUCTION

Suppressing global warming and reducing carbon emissions has become the consensus of the whole world in the 21st century. A global climate governance pattern after 2020 been formed in Paris Agreement, which guides and constrains all countries to make full efforts to fulfill the responsibilities of carbon emission reduction and seek practical and feasible ways. In 2020, China made a commitment of ‘30.60’ emissions peak and carbon neutrality to the whole world, which means it is necessary to promote energy conservation and emission reduction while realizing economic development.

On the one hand, as a considerable engine and driving force of the new economy era, the Information Technology industry only shares a small percentage of the carbon footprint nowadays, however, along with the optimization and upgrading of China's industrial structure, the rapid development of the Information Technology industry may have a significant impact on the carbon emission pattern, and the surge in electricity consumption and carbon emissions are the "hidden levers" of the rapid development of the Information Technology industry. Research shows that, without controlling, the global ICT industry's greenhouse gases emission may increase from 1%-1.6% in 2007 to over 14% by 2040. On the other hand, with the development of Information Technology and the application of high-tech communication technology, labor, transportation, logistics, information and other resources can be allocated effectivly, which reduces the transaction cost of enterprises, promotes the continuous flow of factor resources to enterprises with lower energy consumption and pollution, eliminating those enterprises which tends to b dirty and thirsty, and allocating rationally among industries, thus reducing the pollution emissions of the whole region [1]. In addition, the use of Information Technology has greatly reduced the information asymmetry in business activities. Using of big

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data enables us to grip the market demand and preference along the route in time, rationally distribute the production factors such as talents and capital, reduce unnecessary resource loss and reduce pollution emissions. Under this background, this paper adopts city panel data mode, uses Stata software to analysis the relationship between national Information Technology and carbon emissions. Possible marginal contribution of this paper are as follows: First, it enriches the research on influencing factors of carbon emission reduction. Second, it broadens the research on the environmental effects of Information Technology development. Thirdly, the channel mechanism of Information Technology of carbon emission reduction is discussed, which enriches the theoretical research on the functional paths of carbon emission reduction.

2 MODEL AND DATA

2.1 Model Setting

Refers to STIRPAT model proposed by Dietz and Rosa (1997) [2] as the basis of research:

$$I = aP^b A^c T^d u \tag{1}$$

I, P, A, T is the environment, population, economic development level and technical level respectively.

According to the above analysis, the basic city panal regression model of this paper is set as follows:

$$Y_{it} = \alpha_0 + \alpha_1 IT_{it} + X_{it} + u_i + v_t + \varepsilon_{it} \tag{2}$$

Y is the interpreted variable, this paper is the carbon emission intensity, i and t represent cities and years respectively, IT is the level of Information Technology, X are a series of control variables, u, v and ε are the urban fixed effect, time fixed effect and random disturbance terms respectively.

2.2 Varible

The interpreted variables: carbon emission intensity (GCO2) = total carbon emission (CO2)/GDP, in which carbon emission refers to the calculation method of Wu Jianxin and Guo Zhiyong (2016) [3], and the carbon emission level of each city is calculated in accordance with the energy consumption of electricity, natural gas, liquefied petroleum gas, etc.

$$CO_2 = C_n + C_p + C_e = kE_n + \gamma E_p + \phi(\eta \times E_e) \tag{3}$$

C_n、C_p、C_e is the carbon emissions of natural gas, liquefied petroleum gas and electric power respectively, $E_n$andE_p、$E_e$are the consumption of natural gas, liquefied petroleum gas and electric power respectively of the city, η is the proportion of coal-fired power generation in the total power generation, k, r and Φ are the carbon emission coefficients of natural gas, liquefied petroleum gas and coal-fired power respectively.

Explanatory variables: Information Technology development level, Internet penetration rate: Internet users per 10,000 persons, the data comes from the China City Statistical Yearbook.

Control variables: economic development level(lngdp), which uses logarithmic value of per capita GDP to control the possible influence of economic development level; the ratio of dependence on foreign trade(open) is expressed by the proportion of total import and export trade to GDP of that year. The role of government (lnfis) is expressed by the logarithmic value of fiscal expenditure. The level of foreign direct investment(lnfdi) is expressed by the logarithmic value of the actual utilization of foreign direct investment in each city.

The data in this paper comes from 275 prefecture-level cities in China from 2011 to 2018 (excluding Linzhi, Tongren, and other cities which are serious lack of relevant data), with a total sample size of 2,200. The data used in this paper come from China Energy Statistics Yearbook, China Statistics Yearbook, China City Statistical Yearbook, China Environmental Statistics Yearbook, National Research Network Database, China Economic Network Database, etc., and missing values have beeen supplemented by interpolation.

3 EMPIRICAL RESULTS AND ANALYSIS

3.1 Basic Regression

By using Stata software, the results estimated by the city panel fixed effect model in this paper are shown in column (1)-(5) of Table 1. It can be seen that when other factors are not controlled, the basic regression result is at the 0.05 significance level, estimated coefficient is -0.072. After adding a series of control variables, the coefficient is -0.0661, which is still significantly negative, there was no significant disparity, which shows that the estimation results are robust, and the development of the Information Technology is indeed conducive to reducing the carbon emission intensity of cities.

Table 1 Basic Regression

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	GCO2	**GCO2**	**GCO2**	**GCO2**	**GCO2**
IT	-0.0772** (0.0349)	-0.0767*** (0.0351)	-0.0790*** (0.0358)	-0.0782*** (0.0356)	-0.0661*** (0.0310)
df		3.355*** (1.165)	3.385*** (1.153)	3.396*** (1.146)	3.503*** (1.146)
lnfdi			0.0283** (0.0271)	0.0297* (0.0272)	0.0388** (0.0272)
lnfis				-0.0549 (0.0470)	-0.0100 (0.0416)
lnpgdp					-0.526*** (0.199)
_cons	0.483*** (0.0231)	0.372*** (0.0477)	0.0970 (0.264)	0.820 (0.662)	5.595*** (2.142)

N	2200	2200	2200	2200	2200
R2	0.297	0.311	0.312	0.312	0.327
city fixed effect	YES	YES	YES	YES	YES
year fixed effect	YES	YES	YES	YES	YES

Note: Standard errors in parentheses, *, * * and * * * are significant at 10%, 5% and 1% respectively

3.2 Robustness Test

1) Sample problem: General literatures regard provincial capitals, sub-provincial cities and municipalities directly under the central Government as central cities, which are quite different from other normal prefecture-level cities in economic scale, population and administrative level. This paper deletes these data and regresses the samples of ordinary prefecture-level cities.

2) Data winsorization: In order to avoid the influence of possible outliers on regression results, the data have been winsorized at 1% level to eliminate the interference of outliers.

3) Eliminate macro-systematic differences: Eliminate the influence of macro-systematic differences by controlling the joint fixed effect of "province-year" and clustering standard errors to the provincial and year level.

The results are shown in Table 2, in the case of only retaining the samples of ordinary prefecture-level cities, removing data outliers, excluding macroscopic systematic differences, the development of the Information Technology has a significant inhibitory effect on carbon emissions.

Table 2 Robustness and Endogenous Problems

variable	**Robustness test**			**Endogenous treatment**
	(1) Exclude macro	**(2) Reject**	**(3)**	**(4)**
	Systematic difference	**Central city sample**	**winsorization**	**instrumental variable**
IT	-0.0661*** (0.0309)	-0.1161*** (0.0569)	-0.0605*** (0.0237)	
In 1984. Per capita post and telecommunications data				-0.1033*** (0.0349)
control variables	YES	YES	YES	YES
city fixed effect	YES	YES	YES	YES
year fixed effect	YES	YES	YES	YES

Kleibergen-Paap rk LM statistic				39.595 [0.000]
Kleibergen-Paap Wald rk F statistic				60.643 {11.59}
N	2200	2200	2200	2200
R2	0.34	0.24	0.27	0.28

Note: the p values are shown in brackets, inside the curly braces for Stock - Yogo threshold at the 10% level

3.3 Endogenous Problem

In order to solve the endogenous problems, this paper uses instrumental variables to test. Refer to Huang Qunhui et al. (2019)[4], this paper uses the product of 1984 post income data per capita of cities and national Internet users as instrumental variables, the estimated results are shown in Table 2. Kleibergen-Paap rk LM test result is significant at 1% level, rejecting the original assumption of insufficient identification of instrumental variables, and Kleibergen-Paap Wald rk F statistic is biggerr than the critical value of Stock-Yogo test at 10% level, rejecting the original assumption of weak identification of instrumental variables. These The results of the second stage in column (4) show that after controlling the endogenous problem, the estimation coefficient is basically consistent with the basic regression result above.

3.4 Mechanism Analysis

With the development and the popularization of big data and other Information Technologies, the problem of information asymmetry among economic entities has been greatly alleviated, which conduce to alleviating the financing constraints of low-carbon enterprises [5], reducing financing costs. The application of Information Technology has effectively improved the utilization efficiency of coal, promoted the continuous decline of new energy development and utilization costs, and increased the energy consumption per unit GDP.

Table 3. Mechanism Test

	(1)	**(2)**	**(3)**	**(4)**
	Finance	**GCO2**	**Genergy**	**GCO2**
IT	0.0207** (0.00801)	-0.0605** (0.0318)	-0.0122** (0.00570)	-0.00343 (0.00408)
Finance		-0.271** (0.126)		
Genergy				5.699*** (0.118)

_cons	15.76*** (0.319)	3.779 (2.528)	0.820** (0.357)	0.921*** (0.312)
control variables	YES	YES	YES	YES
N	2200	2200	2200	2200
R2	0.818	0.331	0.378	0.985
city fixed effects	YES	YES	YES	YES
year fixed effects	YES	YES	YES	YES

Refers to Baron et al. [6] for the idea of mediating effect test, this paper adopts the mediation effect model method to analyze the channels for Information Technology development to curb carbon emission. Energy consumption per unit GDP is used to represent energy intensity (Genergy), and the logarithmic value of financial institutional loan balance is used to represent the level of financial development (Finance). Table 3 summarizes the results of the mediation effect test. The regression results of column (1) Finance are significantly positive at the level of 1%, indicating that the development of Information Technology has a significant role in promoting the development of urban finance. The coefficient of carbon emission intensity of column (2) is -0.0625, which is less than the benchmark regression coefficient mentioned above, indicating that financial development plays an intermediary role in it. Similarly, the development of Information Technology has significantly reduced the energy consumption intensity, while the coefficient of column (4) is not significant.

3.5 Heterogeneity Analysis

Resource endowment and geographical location are the basis of economic activities and environmental pollution. In view of this, this paper will examine the impact of Information Technology development on low-carbon emission reduction from the perspectives of these two aspects. In this paper, 275 sample cities are divided into 111 resource-based cities and 164 non resource cities according to The State Council's classification. Geographically, it is can be divided into four regions: East, Middle, West and Northeast. The regression results are shown in Table 4. It can be found that the development of the Information Technology will significantly reduce the carbon emissions of non-resource-based cities, but the impact on resource-based cities is not significant. From the perspective of location, emission reduction effect is more significant in the Middle and West

Table 4 Heterogeneity Analysis

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	resources GCO2	**Non-resource** GCO2	**East** GCO2	**Middle** GCO2	**West** GCO2	**Northeast** GCO2
IT	-0.120 (0.0776)	-0.0604*** (0.0294)	-0.0103 (0.0155)	-0.134** (0.0608)	-0.153*** (0.0629)	-0.0842 (0.0835)

_cons	6.207** (2.570)	10.66*** (3.900)	0.757 (2.151)	16.17** (7.696)	8.942** (4.104)	1.689 (3.036)
N	880	13	680	624	632	264
R2	0.505	0.353	0.551	0.490	0.332	0.675
control variables	YES	YES	YES	YES	YES	YES
city fixed effects	YES	YES	YES	YES	YES	YES
year fixed effects	YES	YES	YES	YES	YES	YES

4 CONCLUSION

Climate change caused by carbon emissions is one of the greatest threats to human existence presently. How to establish a long-term mechanism of carbon emission reduction based on present conditions is the key to economic development under the goal of "double carbon". Based on city panal model, this paper discusses the impact of Information Technology on carbon emssion by Stata analysis. The results show that the Information Technology can effectively curb the carbon emission intensity of cities, the conclusion is still robust after a series of tests. Financial development and energy consumption intensity reduction are the effective channels for the Information Technology development to curb the carbon emission, and its emission reduction effect is remarkable in the Middle and Western regions and non-resource-based cities.

According to the above analysis, implications can be drawn as follows: promote the application and development of the Information Technology, promote the transformation of high energy-consuming industries and the development of low-carbon industries, and deepen the financial reform. The realization of carbon emission reduction requires the joint participation of low-carbon industries, the Information Technology and financial markets. Secondly, support backward areas and balance inter-regional development, cities have different geographical locations and resource endowments, so appropriate emission reduction paths should be formulated accordingly.

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