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A study of the effects of regional competition and digital financial inclusion on urban carbon emissions

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Abstract: *Based on the panel data of 204 cities in China from 2014 to 2020, this paper applies a benchmark regression model to explore the impact of developing digital financial inclusion index on carbon emissions under regional competition and the difference in impact. The results of the study show that the development of digital financial inclusion can effectively promote the reduction of carbon emissions, the development of digital financial inclusion under moderate regional competition helps to reduce carbon emissions, while the development of digital financial inclusion under excessive regional competition will increase carbon emissions. These findings help policymakers better understand the role of digital inclusive finance in promoting green and low-carbon development, and formulate policies and measures accordingly.*

Keywords: *digital financial inclusion; carbon emissions; regional competition*

1. Introduction

The issue of carbon emissions has become one of the key factors affecting the community of human destiny. Carbon emissions not only exacerbate global warming and the frequency of extreme weather events, but also have far-reaching impacts on biodiversity, ecosystem stability and human socio-economic development. The continuous growth of urban economy is accompanied by an increase in energy consumption and greenhouse gas emissions, which makes it even more urgent to address climate change and low-carbon transformation of the economy[1] . Therefore, how to effectively reduce and control carbon emissions has become a major issue common to all countries around the world.

With the transformation of traditional finance and the arrival of the big data era, digital inclusive finance is playing an increasingly important role in carbon emission reduction. Financial development, including digital inclusive finance, has a significant impact on changes in carbon dioxide emissions, and digital finance has a significant inhibitory effect on carbon emissions, providing a way to promote social change[2-4]. Existing studies have explored the relationship between digital inclusive finance and carbon emissions, and found that there is an inverted U-shaped relationship between the development of digital inclusive finance and carbon emissions[5] , i.e., it may lead to an increase in carbon emissions at the initial stage, while it helps to reduce carbon emissions when it matures. However, there are fewer studies on the effect of digital inclusive finance on carbon emissions under regional competition. So what will be the effect of digital inclusive finance on carbon emissions in the context of regional competition? So in this paper, when studying the effect of digital inclusive finance on total carbon emissions, empirically study how digital inclusive finance affects carbon emissions under the background of regional competition.

2. Literature review

2.1 Study on the impact of digital financial inclusion on carbon emissions

In the context of environmental issues in the era of digital financial inclusion, Sohail et al.[6] discuss the linear relationship between human capital and carbon dioxide emissions, emphasising the importance of considering financial inclusion in the carbon emissions discussion. The relationship between digital financial inclusion and agricultural carbon emissions has been studied and has attracted attention in the context of technological innovation in agriculture[7] . It has been shown that digital inclusive finance can contribute to an increase in total factor carbon productivity in cities[8] . Yin and Yikun[9] examined the impact of the development of digital finance on carbon emissions, particularly in

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the manufacturing sector, and emphasised the need to consider the role of digital financial services in emission reduction efforts. Wang et al.[10] analysed the impact of digital inclusive finance on carbon emissions from the three dimensions of digital inclusive finance, and the results show that the breadth of coverage and depth of use of digital inclusive finance have a positive correlation.

2.2 Study of the dynamics of economic development in the context of regional competition

Competition among local governments can motivate local governments to promote economic growth and attract business investment by providing better infrastructure, tax incentives, and other measures, thus promoting economic growth in the region[11] . Shen Liang and Liu Hao[12] believe that local governments, in order to increase their fiscal revenues, may enhance the quality of their own fiscal revenues by improving the efficiency of tax collection and optimising the tax structure, which can help to improve the overall development of the local economy. However, inter-regional competition may also exacerbate regional imbalances. If inter-regional competition is overly concentrated in certain areas, it may lead to an unbalanced distribution of resources and exacerbate the imbalance of regional development, especially in regions with a lower level of development that may face greater challenges[13] . In the context of regional competition, environmental protection and sustainable development are receiving increasing attention, and reducing carbon emissions is a necessary concern for environmental protection and sustainable development.

3. Theoretical analyses and research hypotheses

3.1 Analysis of the impact of digital financial inclusion on carbon emissions

The positive impact of digital inclusive finance on carbon emissions has been highly recognised by academia. On the one hand, by providing financial support, digital inclusive finance can encourage enterprises to invest in research and development (R&D) and technological innovation, and technological progress can improve productivity and reduce energy consumption and carbon emissions. In particular, digital inclusive finance in low-carbon technologies and green industries can promote the development of low-carbon economy and green finance[14] ,provide broader coverage of financial services. For example, by supporting investments in green projects and clean energy technologies, which in turn can help reduce carbon emissions. On the other hand, promoting digital inclusive finance can improve the efficiency and marketability of financial services[15] , which can reduce transaction and time costs. This can help promote economic growth and job creation, thus indirectly reducing carbon emissions. This is because economic growth is usually accompanied by increased energy demand and rising carbon emissions, but by improving the efficiency of financial services, unnecessary energy waste can be reduced. Therefore, this paper proposes the following research hypotheses:

H1: All other things being equal, the development of digital financial inclusion helps to reduce carbon emissions.

3.2 Analysing the impact of digital financial inclusion on carbon emissions in the context of regional competition

It has been shown that competition between regions tends to drive rapid economic growth, which is usually accompanied by an increase in energy consumption, especially fossil energy consumption, and is a direct cause of increased carbon emissions[16] , while moderate local government competition can improve regional carbon emission problems[17] . On the one hand, in the context of regional competition, in order to attract more investment and enhance competitiveness, some regions may overdevelop digital finance, leading to the waste of digital financial resources and the reduction of the efficiency of energy use. Such overdevelopment may lead to unnecessary energy consumption and carbon emissions. On the other hand, the promotion of digital financial inclusion under regional competition may exacerbate inequalities between regions. Such inequalities may lead to greater challenges in controlling carbon emissions in some less developed regions. Under the pressure of regional competition, some local governments may lower their environmental standards in order to attract investment and deregulate the environmental requirements of digital finance companies. This may lead to the approval and implementation of some highly polluting and energy-consuming digital finance projects, which in turn increase carbon emissions. For this reason, this paper proposes the following research hypotheses:

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H2: The development of digital inclusive finance under moderate regional competition will help reduce carbon emissions, while the development of digital inclusive finance under excessive regional competition will increase carbon emissions.

4. Variable setting, data and model selection

4.1 Variable setting and data description

4.1.1 Total carbon emissions and their data measurement

The carbon emission data of 204 prefecture-level cities in China are selected as the explanatory variables, and the latest scope 1, scope 2 and scope 3 accounting is adopted with reference to Cong et al.[18] , and the specific calculation criteria are as follows:

Total carbon emissions = Scope 1 emissions + Scope 2 emissions + Scope 3 emissions. Where Scope 1 emissions = emissions from transport and buildings + emissions from industrial processes + emissions from agriculture, forestry and land-use change + emissions from waste disposal activities, and Scope 2 emissions = emissions from purchased electricity + emissions from heating and cooling, with carbon emissions expressed in tonnes of carbon dioxide.

4.1.2 Core explanatory variables

Depth of use of digital financial inclusion index (*df*):Promoting digital financial inclusion can lead to changes in the depth of use of the digital financial inclusion index[19] . In this paper, the depth of use of digital inclusive finance in the Peking University China Digital Inclusive Finance Index is selected as an explanatory variable.

Regional Competition (*rc*): Because the fierce competition among regional governments to attract foreign investment is considered a key means for local governments to obtain diversified development resources to promote the development of the region, many domestic and foreign scholars prefer to use foreign direct investment (FDI) as an important indicator to measure the level of competition among local governments[20-21] . Based on this, this study chooses the amount of FDI actually used by each region in the current year as a proxy variable for regional competition. Referring to Xiao Ye et al.[22] , the unit of investment amount is converted to RMB based on the annual average exchange rate of RMB to USD in the annual report released by the State Administration of Foreign Exchange (SAFE). For cities with serious missing data, this study chooses to exclude them.

4.1.3 Control variables

Considering the robustness of the results, this paper considers other factors that may affect carbon emissions, respectively, the following indicators: ① government intervention (*gv*); ② road freight transport (*hv*); ③ Level of economic development (*pg*); ④ Science and technology innovation level (*stl*); ⑤ Total Energy Consumption (*tec*).Data were also standardised for all control variables.

4.2 Modelling

In order to investigate how the digital inclusion index affects carbon emissions in the context of regional competition, this paper constructs the following model:

$$cb_{it} = \alpha_0 + \alpha_1 df_{it} + \alpha_2 rc_{it} + \alpha_3 rc_{it} \times df_{it} + \alpha_4 X_{it} + u_{it} + \varepsilon_{it} \quad (1)$$

where i represents the prefecture-level city, and t represents the year; cb_{it} is the explanatory variable, representing carbon dioxide emissions; df_{it} is the explanatory variable, representing digital financial inclusion index, and rc_{it} represents regional competition; $rc_{it} \times df_{it}$ denotes the cross-multiplier of regional competition and digital financial inclusion; X_{it} denotes a set of control variables that may have an impact on carbon emissions, namely government intervention (gv_{it}), road freight volume (hv_{it}), level of economic development (pg_{it}), level of science, technology and innovation ($st1_{it}$), total energy consumption (tec_{it}); u_{it} represents individual city fixed effects to control for city characteristics that do not change over time; ε_{it} is a random disturbance term.

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4.3 Descriptive statistical analyses

In this paper, panel data of a total of 204 cities in China from 2014 to 2020 are selected for empirical analysis, and the data are obtained from China Statistical Yearbook, National Bureau of Statistics, China Urban Statistical Yearbook, EPS China City Database, CNRDS Database, and Peking University Digital Inclusive Finance Index. For the missing data the linear interpolation hair is used to make up the data description as shown in the table. From the table 1, it can be found that the mean value of carbon emissions is 4903.01, and the standard deviation is 10149.89, which indicates that the carbon emissions of each prefecture-level city have a large degree of dispersion; moreover, the maximum value of carbon emissions is 108,560.80, and the minimum value is 706.30, which indicates that there is a significant imbalance in the carbon emissions of cities in various regions of China.

Table1:Description of variable data

Variable	Obs	Mean	Std. Dev.	Min	Max
cb	1,435	4903.01	10149.89	706.30	108560.80
df	1,435	211.38	52.35	84.31	349.75
rc	1,435	81.72	172.74	0.01	2047.53
df1	1,435	234.65	57.09	95.38	435.84
df2	1,435	413.88	99.96	186.99	774.49
df3	1,435	171.11	63.67	13.02	373.37
df4	1,435	148.21	31.78	35.96	200.64
gv	1,435	0.23	0.13	0.00	1.00
hv	1,435	0.12	0.11	0.00	1.00
pg	1,435	0.24	0.17	0.00	1.00
stl	1,435	0.10	0.10	0.00	1.00
tec	1,435	0.08	0.11	0.00	1.00

5. Empirical findings

(1) Impact of digital financial inclusion on carbon emissions in the context of regional competition

Table 2 demonstrates the regression results for the benchmark model, including fixed and random effects. As can be seen in Table 2, the Hausman test rejects the original hypothesis at the 1% significance level for both regression analyses without and with control variables. This result indicates that the fixed effects model has more explanatory power than the random effects model.

Table2: Estimated results of the baseline model

variant	(1) Fixed effects	(2) Random effects	(1) Fixed effects	(2) Random effects
df	-5.442149*** (0.008)	-6.040044*** (0.006)	-6.657401** (0.016)	-16.32123*** (0.000)
rc	-26.90039*** (0.000)	-19.50108*** (0.000)	-27.45014*** (0.000)	-15.13287*** (0.000)
rc×df	0.1232355*** (0.000)	0.1297131*** (0.000)	0.1253807*** (0.000)	0.107584*** (0.000)
gv			2383.163 (0.217)	2529.718 (0.210)
hv			-2473.268*** (0.413)	3256.108 (0.215)
pg			3875.8* (0.089)	294.6524 (0.886)
stl			-4587.182* (0.052)	-7304.12*** (0.002)
tec			-1925.061 (0.602)	26541.29*** (0.000)
_cons	5905.568*** (0.000)	5300.28*** (0.000)	5569.899*** (0.000)	5154.747*** (0.000)
N	1428	1428	1428	1428
Hausman test	160.46***		194.04***	

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As can be seen from the first column of Table 2, the coefficient of the depth of use of the digital financial inclusion index (*df*) without the inclusion of control variables is -5.442149 and is significantly negative at the 1% level of significance, indicating that the development of digital financial inclusion can reduce carbon emissions. The estimated coefficient of the cross-multiplier term (*rc* × *df*) of regional competition and depth of use of digital financial inclusion index is 0.1232355 and is significantly positive at the 1% level of significance, indicating that the interaction of regional competition and the development of digital financial inclusion weakens the positive effect of the digital financial inclusion index in reducing carbon emissions. Combining the regression coefficients of the depth of use of the digital financial inclusion index (*df*) with the estimated coefficients of the cross-multiplier term of regional competition and the depth of use of the digital financial inclusion index (*rc*×*df*), the effect of the development of digital financial inclusion under regional competition on carbon emissions is estimated to be "-5.442149+0.1232355rc "When the level of regional competition is below this threshold, i.e., *rc is* less than 44.16, regional competition combined with the development of digital financial inclusion has a significant impact on the reduction of carbon emissions. The combination of regional competition and the development of digital financial inclusion has a positive impact on the reduction of carbon emissions, implying that the development of digital financial inclusion in the context of moderate regional competition contributes to the reduction of carbon emissions. However, when the level of regional competition exceeds this critical value, i.e., *rc* is greater than 44.16, the combination of regional competition and the development of digital financial inclusion has a negative impact on carbon emissions, indicating that the development of digital financial inclusion in an overly competitive regional environment leads to an increase in carbon emissions. This estimation remains unchanged even after the introduction of control variables.

The results of the above analyses strongly support research hypothesis 1, which states that the development of digital inclusive finance can effectively contribute to the reduction of carbon emissions when all other conditions remain unchanged. In addition, research hypothesis 2 is also verified, that is, promoting the development of digital inclusive finance under moderate regional competition has a positive impact on reducing carbon emissions; however, when regional competition is excessive, the development of digital inclusive finance may lead to an increase in carbon emissions.

6. Conclusions and recommendations

6.1 Main findings of the paper

In order to examine the impact of developing digital financial inclusion index on carbon emissions under regional competition, this paper empirically investigates the carbon emissions of 204 Chinese cities from 2014 to 2020, and categorises the digital financial inclusion index to study the differences in the impact effect on carbon emissions. The study finds that (1) the development of digital inclusive finance can effectively contribute to the reduction of carbon emissions while other conditions remain unchanged; (2) the estimated coefficients of *rc*×*df* in the baseline regression are significantly positive, indicating that in a moderately competitive regional environment, the promotion of digital inclusive finance has a positive effect on the reduction of carbon emissions for the whole society; when regional competition is excessive, the development of digital inclusive finance leads to an increase in carbon emissions for the whole society's carbon emissions.

6.2 Policy recommendations

The impact of digital inclusive finance on carbon emissions is a complex topic that involves various aspects such as financial technology, environmental protection and economic development. Based on the above research, relevant policy recommendations are given: (1) The government should formulate a series of incentive policies to encourage financial institutions to actively develop digital inclusive finance, especially financial products and services that contribute to carbon emission reduction. For example, it can provide policy support such as tax incentives and loan preferences for financial institutions participating in carbon emission reduction projects. (2) In order to reduce carbon emissions more effectively, we should formulate targeted promotional strategies. During the promotion process, the interaction between digital inclusive finance and regional competition should be closely monitored, and the strategy should be timely adjusted and optimised according to the actual development.

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