

# Digital Economy and Urban Carbon Emissions in China: An Empirical Study Based on The Spatial Dubin Model

Jie Lv

Business School, Hunan University of Science and Technology, Xiangtan Hunan 411201, China

**Abstract:** Starting from the Chinese city level, combined with the panel data of 281 cities in China from 2011 to 2019, this paper empirically examines the spatial impact of digital economy development on urban carbon emissions, and the results show that there is a significant spatial dependence and spatial spillover effect between digital economy and urban carbon emissions, and the region-wide inspection finds that the digital economy shows a significant promotion effect on local carbon emission levels, while the adjacent effect of digital economy shows "U" shaped characteristics. There is a "U" shaped relationship between the digital economy and the carbon emissions of the region, and the "U" relationship between the digital economy and the carbon emissions of neighboring areas is only within a specific distance. This paper grasps the general laws of digital economy development and urban carbon emissions from the medium and micro scales, and provides policy suggestions for solving the carbon emission reduction problems faced by high-quality development.

**Keywords:** Digital economy, Carbon emissions, Space Doberman model, City level.

## 1. Introduction

While the industrial revolution accelerated the development of the global economy and society, the excessive exploitation and utilization of fossil energy brought severe harm to the global environment, and a series of climate problems such as greenhouse effect and extreme weather seriously threatened the human living environment. In order to promote economic and social development and unswervingly promote the path of sustainable development, General Secretary Xi Jinping delivered an important speech at the general debate of the 75th session of the United Nations General Assembly in September 2020, saying that China's carbon dioxide emissions strive to peak carbon dioxide before 2030 and achieve carbon neutrality before 2060, which not only demonstrates the responsibility of major countries, but also provides guidance for the green and low-carbon process of energy dependence and development. At the same time, the world is in a new stage of development, breakthroughs and innovations in information technology have triggered the continuous expansion of digital scale, promoted the digital transformation of industries, driven society into the era of digital development, and the development of digital economy has brought new vitality and possibilities to promote economic transformation. In 2020, the scale of China's digital economy reached US\$5.4 trillion, ranking second in the world, an increase of 9.6% over 2019. Under the background of carbon peak and carbon neutrality, the deep integration of digital economy and green development has become an inevitable requirement and important support for achieving low-carbon emission reduction and promoting high-quality economic development. It can be seen that from the level of Chinese cities, exploring the mechanism of digital economy affecting urban carbon emissions, helping to accelerate the process of digital industrialization and industrial digitalization, and improving the effectiveness of carbon emission governance are the proper meanings of vigorously promoting the construction of ecological civilization and high-quality economic development in the journey of the new era, and are also an important topic on the way to building a

modern socialist power.

## 2. Literature Review

### 2.1. Digital economy

Domestic and foreign scholars have carried out rich research on the digital economy, and the focus of debate is mainly on the impact of the digital economy. On the one hand, most of the existing literature links the digital economy with high-quality development. Yang Wenpu (2021) believe that the digital economy helps the high-quality and efficient development of society by driving consumption levels. Ding Zhifan (2020) and other scholars explored the realization of booster effect from the micro, meso and macro levels. On this basis, Ren Baoping (2020) further pointed out that there is an indirect promotion mechanism for the innovation of quality, efficiency and power, which can accelerate the digital economy and promote social development, and put forward targeted suggestions from these three perspectives. Based on provincial panel data from 2010 to 2018, Zheng Jialin and Xu Wenhua (2021) believe that the in-depth integration and application of the digital economy in industrial structure and technological innovation are conducive to the high-quality and efficient development of society. On the other hand, some scholars pay special attention to the role of the digital economy in promoting innovation ability. With information technology as the carrier, the digital economy can deeply integrate the emerging elements of digital information and knowledge with traditional production factors, creating greater innovation space for traditional industries and driving the upgrading of regional own knowledge (Liang Qi et al., 2021). The innovative use of new generation technology in enterprises can not only shorten the production supply chain, reduce configuration time and resource consumption, improve operational efficiency, save enterprise costs, but also stimulate enterprise innovation ability. At the same time, the digital economy development innovation network sales platform closely connects the consumer, industrial and innovative needs, and solves the problem of information segmentation between supply and demand (Wen Jun et al.,

2019).

## 2.2. Carbon emissions

There are some differences between domestic and foreign scholars on the influencing factors of carbon emissions. In terms of the role of industrial structure on regional carbon emissions, Zhang Keyu et al. (2017) constructed the energy structure consumption matrix and carbon emission structure matrix of the industry based on the input-output table, and believed that more than half of the secondary industry sectors, especially energy and metal processing industries, should have a lower production scale to achieve green and low-carbon development requirements. Wang Shaojian et al. (2021) found that industrial development can affect carbon emissions through three aspects: economic scale, industrial structure and technology. In terms of the role of technological innovation, Luna et al. (2019) conducted research from a spatial perspective and concluded that the change of new low-carbon technologies has a significant inhibitory effect on carbon emissions, but only has an impact on the local area, and has no significant effect on the surrounding areas. Starting from innovative cities, Zhang Hua and Fengchao (2021) found that innovative city construction can mobilize multiple factors and strengthen policy support, stimulate urban innovation potential, reduce urban carbon emissions through multiple ways, and improve overall benefits. In terms of the role of financial development on regional carbon emissions, Hu Jinyan and Wang Mengqing (2018) believe that financial development and carbon emission intensity show an evolution trend of first increasing and then decreasing. He Yunxin et al. (2020) found that traditional finance plays a negative role, while emerging finance and carbon emissions show a link between first increase and then decrease. Chen Xiao and Xue Yinglan (2021) study the impact of inclusive financial development on carbon emissions, arguing that the development of inclusive finance can slow down the rising trend of carbon emissions and show a curbing effect on most provinces. In terms of the role of environmental regulation, Zhang Hua and Wei Xiaoping (2014) found that environmental regulation will initially positively affect carbon emissions, and then show a negative effect after reaching a certain extent, and the overall situation will change from a "green paradox" to a development model of "forced emission reduction". However, the "reverse emission reduction effect" produced by China's current regulatory measures is not significant. Yuan Weipeng et al. (2021) believe that it is related to the high-quality and efficient development of society by first decreasing and then increasing, and the vertical control mode can achieve high-quality, low-carbon and win-win development of the economy through transmission paths such as technological innovation, industrial optimization and adjustment, and resource allocation efficiency.

## 2.3. Digital economy and carbon emissions

The digital economy, with information technology as the core, provides new impetus for environmental intelligent management, has been popularized and deeply integrated into the research of energy consumption and environmental protection, which is helpful to solve the problems of environmental carrying capacity decline and scarcity (Rehman et al., 2021), and has great potential to improve the ecological environment (Alam and Murad, 2020). The impact of digital economy on carbon emissions is mostly analyzed

through the impact of digital economy on energy supply and demand. From the perspective of energy supply, digital technology can ensure the safe and efficient operation of energy systems (Chen, 2020) and reduce environmental hazards. Innovation in technological level can accelerate the comprehensive use of renewable energy, and the use of digital technology can greatly shorten the R&D cycle of clean energy, and improve R&D efficiency through accurate simulation of natural and geographical conditions (Allam and Jones, 2021). The digital economy can also help governments control total energy supply through energy pricing and cross-subsidization to adjust the energy mix and stabilize carbon emission levels. From the perspective of energy demand, the application of digital technology in transportation, entertainment, communication and other system fields can effectively reduce energy consumption, improve energy efficiency, and promote the low-carbon transformation of the whole society (Li et al., 2021). The digital economy reduces the demand for energy by promoting the dematerialization of public daily activities and communication, especially the application of digital technology in smart cars, electrical appliances, etc., effectively transforming the energy consumption structure and promoting energy-saving and low-carbon development (Aydin et al., 2018). In addition, some scholars analyze the relationship between digital economy and carbon emissions from the perspective of spatial and regional characteristics. Li et al. (2021) based on the expanded SPIRPAT model, conducted an empirical analysis of the impact of energy structure and digital economy on carbon emissions in 30 provinces in China from 2011 to 2017 through panel data, and found that the energy structure dominated by coal will increase carbon emissions, and the impact on resource-based provinces is more prominent. The energy structure is a necessary support for achieving low carbon, and this impact is only more significant in non-resource-based provinces and East China.

## 3. Methodology

### 3.1. Model settings

In this paper, the spatial Dubin model is selected as the basic model to carry out empirical research, and then the spatial impact of digital economy on urban carbon emissions is examined. Build the following spatial Doberman model:

$$CE_{it} = \alpha_0 + \rho \sum_{j=1}^n w_{ij} CE_{jt} + \alpha_1 DIG_{it} + \alpha_2 DIG_{it}^2 + \alpha_3 Z_{it} + \beta_1 \sum_{j=1}^n w_{ij} Dig_{jt} + \beta_2 \sum_{j=1}^n w_{ij} DIG_{jt}^2 + \beta_3 \sum_{j=1}^n w_{ij} Z_{jt} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where  $i$  represents the region,  $t$  represents the year,  $CE$  represents the level of urban carbon emissions,  $DIG$  represents the level of the digital economy, and  $Z$  represents a series of control variables;  $\rho$  indicates the coefficient to be estimated of the spatial lag of the explanatory variable, which is the coefficient to be estimated for each variable, and  $\alpha_i$  represents the coefficient to be estimated for the spatial interaction term of the variable,  $w_{ij}$  represents a spatial weight matrix, and the adjacency matrix is selected as the spatial weight matrix for spatial econometric regression analysis.

### 3.2. Variable selection

Explained variable: Urban carbon emission level. Detailed fuel classification estimates will be used to measure carbon emissions in conjunction with relevant parameters published by Chinese officials. China's fossil energy that produces carbon dioxide during use mainly includes carbon, oil, natural gas and electricity, of which carbon includes coal and coke, and oil includes crude oil, gasoline, kerosene, diesel and pigment oil. In order to ensure that the calculated CO<sub>2</sub> emissions are closer to the true value, the consumption of the above nine energy sources is taken into account.

Explanatory variable: level of digital economy development. Referring to domestic and foreign research on digital economy, drawing on the comprehensive index construction ideas of Zhao Tao et al. (2020), Xu Weixiang et al. (2022), etc., and starting from the aspects of digital infrastructure, digital industry development, digital innovation capabilities and digital inclusive finance, the evaluation index system of digital economy development level is constructed. (1) At the level of digital infrastructure, this paper starts from two indicators: broadband Internet foundation and mobile Internet foundation. (2) The development of digital industry is the core of the development of digital economy, and this paper measures the development of e-commerce industry, the foundation of information industry and the output of telecommunications industry. (3) Digital innovation capability is the key to the development of digital economy, and this paper measures it from the support of digital innovation factors, the output level of digital innovation and the penetration of digital high and new technologies. (4) Finance is the hub of resource allocation and an important driving force for the development of the real economy, and digital inclusive finance is an essential component of digital life, which is mainly measured from the breadth of coverage, depth of use and degree of digitalization

of digital inclusive finance.

Control variables: (1) Environmental pollution index : Existing studies generally use industrial wastewater discharge, industrial sulfur dioxide emission and industrial solid waste discharge to measure the environmental pollution status of an area, but due to the lack of solid waste discharge data at the city level, industrial wastewater discharge, industrial sulfur dioxide emission and industrial smoke (dust) emission are selected to measure. (2) Population size : The number of permanent urban residents is selected to measure. Studies have shown that CO<sub>2</sub> emissions from the household sector should not be underestimated, and population size is an important aspect of increasing carbon emissions through energy consumption at the household level. (3) Industrial structure : It is expressed as the proportion of tertiary industry output value to GDP in prefecture-level cities. The development and expansion of the tertiary industry play an important role in promoting urban economic growth, improving innovation performance, and promoting environmental protection, and are of great significance for curbing urban carbon emissions. (4) Urbanization level : measured by the proportion of urban population in the total population. The process of urbanization will lead to a large demand for energy consumption, which may lead to a corresponding increase in carbon emissions.

### 3.3. Data source

In this paper, the panel data of 281 prefecture-level cities and above in China from 2011 to 2019 were selected as the research sample. The data involved are mainly from the China Urban Statistical Yearbook, China Urban Construction Statistical Yearbook, China Regional Economic Statistical Yearbook and municipal statistical yearbooks of the corresponding years, and the descriptive statistical results of the relevant variables are shown in the Table 1.

**Table 1.** Descriptive statistics of variables

Variable	Observation	Mean	Standard deviation	Min	Max
<i>CE</i>	2529	0.089	0.150	0.002	2.286
<i>DIG</i>	2529	0.168	0.104	0.020	0.824
$\ln ER$	2529	-2.768	0.872	-8.102	5.002
$\ln POP$	2529	5.881	0.685	3.149	8.067
$\ln IND$	2529	3.685	0.242	2.664	4.425
$\ln URB$	2529	3.469	1.352	0	5.597

### 3.4. Spatial weight matrix

In this paper, four spatial weight matrices are used to process the spatial Dubin model: (1) spatial adjacency weight matrix, that is, the value is 1 when two cities are adjacent and 0 when the two cities are not adjacent or are the same region; (2) The spatial weight matrix of geographical distance, calculated by the latitude and longitude of the city center point; (3) The spatial weight matrix of economic distance, that is, the matrix is constructed based on the reciprocal of the per capita GDP gap between the two cities; (4) Economy-geography nested matrix, considering the influence of geographical factors and economic factors, the geographic distance spatial weight matrix and economic distance spatial weight matrix are nested to construct the matrix. The adjacency matrix is also used for spatial autocorrelation testing. In addition, in order to analyze the spatial impact

effect of digital economy on urban carbon emissions under different spatial distance thresholds, construct a spatial weight matrix with different spatial distance thresholds, use SDM model for continuous regression, analyze the spatial spillover effect of digital economy in multi-distance economic circles, and in order to analyze the geographical boundary of spatial spillover effect, according to relevant research (Yuan Yijun and Gao Kang, 2020), the weight matrix of different spatial thresholds is constructed as follows:

$$w_{ij} = \begin{cases} 1/d_{ij}, & d_{ij} \leq d \\ 0, & d_{ij} > d \end{cases} \quad (2)$$

$d_{ij}$  represents the geographic distance between cities, represents the upper limit of the spatial threshold, when the geographical distance between the two cities is less than the

spatial threshold, the weight is the reciprocal of the geographical distance, otherwise it is 0.

## 4. Empirical Results

### 4.1. Spatial autocorrelation test

Table 2 shows the global spatial autocorrelation test results of digital economy and urban carbon emissions calculated by stata17.0. From the data in the table, whether it is digital economy or urban carbon emissions, Moran's I value from

2011 to 2019 is positive, and has passed the 1% significance level test, which indicates that the digital economy development and carbon emissions of each city show significant positive spatial autocorrelation, indicating that the spatial distribution of the two is not random, but shows a certain spatial agglomeration characteristics, that is, the development of digital economy and cities with high urban carbon emission levels are agglomerated. The development of the digital economy and cities with low levels of urban carbon emissions are clustered with each other.

**Table 2.** Moran index value.

Year	DIG			CE		
	Moran's I	Z	P	Moran's I	Z	P
2011	0.680	16.919	0.000	0.170	4.589	0.000
2012	0.462	11.617	0.000	0.186	5.001	0.000
2013	0.420	10.620	0.000	0.196	5.249	0.000
2014	0.406	10.446	0.000	0.198	5.254	0.000
2015	0.376	9.493	0.000	0.197	5.270	0.000
2016	0.373	9.474	0.000	0.186	4.992	0.000
2017	0.357	9.078	0.000	0.179	4.753	0.000
2018	0.355	9.024	0.000	0.150	3.967	0.000
2019	0.313	7.964	0.000	0.141	2.221	0.013

### 4.2. Spatial measurement results

The relevant empirical results of the development of digital economy on the spatial impact of urban carbon emissions are shown in Table 3, according to the test results, it can be found that:(1) The development of the digital economy has shown a significant role in promoting the local carbon emission level, and it cannot effectively help the region achieve the carbon emission reduction target in the short term, but will increase the carbon emission volume. This may stem from the fact that China's digital economy is in the ascendant, and as a new engine of economic growth, it is more reflected in the ability

to break the physical barriers of traditional methods through technological means, thereby improving the production efficiency of various factors. However, for a "newborn", the emission reduction effect of the digital economy may not be able to offset its dependence on energy for the time being, in the process of digital industrialization, it is necessary to consume a lot of power resources, and China's current coal power proportion is high, the rise in electricity consumption means increased coal consumption, thereby increasing the generation of carbon emissions.(2) The impact of the development of the digital economy on the carbon emission

**Table 3.** The spatial impact of the digital economy on carbon emissions.

Variable	$w_1$	$w_2$	$w_3$	$w_4$
<i>DIG</i>	0.5590*** (0.0715)	0.4646** (0.5729)	0.4404** (1.0151)	0.4574** (1.0063)
<i>DIG</i> <sup>2</sup>	-0.6243** (0.1016)	-0.5095 (1.9069)	-0.7347* (4.4301)	-0.6420* (4.3968)
<i>wDIG</i>	-0.8844*** (0.1152)	-0.9224*** (5.2846)	-0.1041** (1.9516)	-0.0081 (8.2925)
<i>wDIG</i> <sup>2</sup>	0.7048* (0.2060)	0.3260 (0.0428)	0.3026 (0.0419)	-0.3147 (0.0416)
Control	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observation	2529	2529	2529	2529
<i>R</i> <sup>2</sup>	0.5024	0.5682	0.3845	0.4567

Note: (1) \*, \*\*, and \*\*\* denote the significance of a coefficient at 10%, 5%, and 1% levels, respectively. (2) The robustness standard error is shown in brackets.

level of neighboring areas is quite different from that of the local area. Different from the development of digital economy, which promotes local carbon emissions, the development of digital economy will inhibit the increase of carbon emissions from neighboring areas, and the neighboring effect of the digital economy shows the "U" shaped characteristic, that is, the overall development of the digital economy has the characteristics of "first suppressing and then rising" the

carbon emissions of neighboring areas. The reason is that in the short term, the development of the digital economy affects the resource trend of neighboring regions, and profit-seeking production factors tend to flow to areas with greater demand, so that the rapid development of the local economy and the high carbon emissions, while the carbon emissions of neighboring areas are declining due to the "seizure" of resources. However, in the long run, the level of local digital

economy development will gradually increase, the internal structure of the digital economy will continue to be optimized, more attention will be paid to technological innovation, and the demand for high-emission energy will weaken, but will attract "clean" resource elements, squeeze out excess high-emission energy, and increase the carbon emissions of neighboring areas.

### 4.3. Spatial effects of different urban economic circles

Under the global spatial weight matrix, the regression results show that the effect of local digital economy development on urban carbon emissions is similar under different spatial weight matrices, but the effect on neighboring carbon emissions is different under different spatial weight matrices. The reasons are: (1) The effect of the digital economy on the carbon emissions of neighboring cities needs to meet certain conditions. For example, the impact of the digital economy gradually fades as the distance between regions increases, which means that the carbon emission effect of the digital economy has a greater impact on the nearby regions. (2) There is a calculation error in the setting of the regional spatial distance weight matrix, and the

proximity of the impact of the development of the digital economy and the agglomeration of the regional economy may cause the results to be different in different distance ranges. In order to verify whether the conjecture is valid, this paper examines the spatial impact effect of the digital economy on carbon emissions in different distance urban economic circles, and the results are shown in Table 4. It can be seen that the relationship between the digital economy and the region's carbon emissions mainly shows a "U" trend. Further observing the data changes, the difference in carbon emission effects of digital economy development in different urban economic circles was examined, and the "U" shaped nonlinear relationship between digital economy and neighboring carbon emissions was shown in different urban economic circles within a distance range of 200-300km. However, the "U" shaped feature of the neighborhood effect is more reflected in the range of specific distances, and the "U" relationship between the digital economy and carbon emissions of neighboring areas weakens when the distance of the urban economic circle exceeds 300 kilometers, such as 500-800 km. The "U" shape feature of the adjacent land effect is more likely to be established in a specific local area, and obvious errors may occur if only the global test is carried out.

**Table 4.** Spatial effect re-examination.

Variable	$W_{200}$	$W_{300}$	$W_{500}$	$W_{800}$
<i>DIG</i>	0.7670*** (0.0468)	0.6646** (0.4587)	0.5517** (0.2678)	0.3574** (1.1392)
<i>DIG</i> <sup>2</sup>	-0.6783** (2.2863)	-0.3845** (1.5495)	-0.6945* (2.8342)	-0.5570* (3.3492)
<i>wDIG</i>	-1.2032** (3.8478)	-0.7564** (5.1878)	-0.3874** (4.2654)	-0.1047* (4.2925)
<i>wDIG</i> <sup>2</sup>	0.9043*** (0.7235)	0.3482** (0.8327)	0.6836 (0.8267)	0.3478 (0.9023)
Control	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observation	2529	2529	2529	2529
$R^2$	1.2846	1.0428	0.9372	0.7256

## 5. Conclusions and policy implications

### 5.1. Conclusions

Starting from the Chinese city level, combined with the panel data of 281 cities in China from 2011 to 2019, this paper empirically examines the spatial impact of digital economy on urban carbon emissions, and the results show that: (1) there is significant spatial dependence and spatial spillover effect between digital economy and urban carbon emissions, and the region-wide test finds that the digital economy shows a significant promotion effect on local carbon emission levels, while the adjacent effect of digital economy shows "U" shaped characteristics. (2) Examining the carbon emission effects of the digital economy in different urban economic circles, it is found that the inverted "U" shaped relationship between the digital economy and the carbon emissions of the region is inverted, and the "U" shaped relationship between the digital economy and the carbon emissions of neighboring areas is only established within a specific distance.

### 5.2. Policy implications

Based on the above conclusions, this paper puts forward

the following policy recommendations: (1) Promote development and increase quality, and promote digital empowerment and emission reduction. The digital economy is an important driving force for the country to achieve the "dual carbon" goal and comprehensively promote the low-carbon development of society. First of all, cities should vigorously increase the construction of digital infrastructure, actively guide the development of the digital information industry and the integration and penetration of the whole industry, and create a good development environment. Second, all regions should reduce the consumption of fossil resources by relying on new digital technologies such as big data and cloud computing, increase the development and utilization of new energy, rationally plan and adjust the regional energy structure, promote the transformation of the energy system to modernization, and build a low-consumption and efficient energy system. Finally, through digital communication, the government has increased its efforts to advocate green and low-carbon, form awareness of energy conservation and emission reduction in the whole society, and enhance the synergy between the public and the government in carbon emission reduction actions. (2)

Combine the characteristics of urban economic circles to build a coordinated development mechanism. On the one hand, all regions should rationally plan the process of social digitalization, strengthen exchanges and cooperation between regions, give full play to the advantages of regional digital economy in high-end factor allocation, knowledge spillover and technological innovation in neighboring regions, and promote the green and low-carbon transformation of all regions. On the other hand, reasonably control the siphon effect of regions with high digital economy levels, and support regions with low development levels in terms of policies, funds and technologies, such as building regionally linked energy Internet and energy big data platforms, innovating energy consumption, trading, supervision and financing methods, comprehensively creating "digital energy construction, smart energy construction" solutions, and jointly achieving the "dual carbon" goal.

## References

- [1] W. P. Yang, Digital economy promotes high-quality development: production efficiency improvement and consumption expansion, *Journal of Shanghai University of Finance and Economics*, Vol. 24 (2022) No. 01, p. 48-60.
- [2] Z. F. Ding, Research on the mechanism of digital economy driving high-quality economic development: A theoretical analysis framework, *Modern Economic Discussion*, Vol. 1 (2020) No. 01, p. 85-92.
- [3] B. P. Ren, The logic, mechanism and path of digital economy leading high-quality development, *Journal of Xi'an University of Finance and Economics*, Vol. 33(2020) No. 02, p. 5-9.
- [4] J. L. Zheng, W. H. Xu, Research on the Mechanism of Digital Economy in Promoting China's High-quality Economic Development—Based on the Analysis of Regional Heterogeneity, *Price Theory and Practice*, Vol. 01(2020) No. 08, p. 148-151.
- [5] Q. Liang, S. P. Xiao, M. X. Li, Development of Digital Economy, Spatial Spillover and Improvement of Regional Innovation Quality: On the Threshold Effect of Marketization, *Shanghai Economic Research*, Vol. 01(2021) No. 09, p. 44-56.
- [6] J. Wen, Z. J. Yan, Y. Cheng, Digital economy and the improvement of regional innovation ability, *Exploration of Economic Issues*, Vol. 01(2019) No. 11, p. 112-124.
- [7] J. Y. Zhang, M. Q. Liao, J. Yang, Analysis of China's industrial structure adjustment under the background of green and low carbon, *Chinese Export, Resources and Environment*, Vol. 01(2019) No. 11, p. 112-124.
- [8] S. J. Wang, S. S. Tian, Q. N. Cai, Driving factors and carbon transfer analysis of industrial carbon emissions in Guangdong Province under the background of industrial transfer, *Geographical Research*, Vol. 01(2019) No. 11, p. 112-124.
- [9] N. Lu, W. D. Wang, M. Wang, Breakthrough low-carbon technology innovation and carbon emissions: direct impact and spatial spillover, *Chinese Export, Resources and Environment*, Vol. 01(2019) No. 11, p. 112-124.
- [10] H. Zhang, C. Feng, Innovative low-carbon city: carbon emission performance evaluation of innovative city construction, *Southern Economy*, Vol. 01(2019) No. 11, p. 112-124.
- [11] J. D. Hu, China's financial development and carbon dioxide emissions—Based on provincial panel data from 1998 to 2015, *Shandong Social Sciences*, Vol. 01(2019) No. 11, p. 112-124.
- [12] Y. X. He, T. Xu, L. X. Zhong, The impact effect and path of financial development on carbon dioxide emissions, *Comparison of Economic and Social Systems*, Vol. 01(2019) No. 11, p. 112-124.
- [13] X. Chen, Y. L. Xue, Can the development of inclusive finance reduce China's carbon emissions?— Time series analysis based on LMDI decomposition method, *Research on financial issues*, Vol. 01(2019) No. 11, p. 112-124.
- [14] H. Zhang, X. P. Wei, Constraints and Relief of "Energy-Economy-Environment" System:Theory and Empirical Evidence, *Journal of Beijing Institute of Technology(Social Science Edition)*, Vol. 01(2019) No. 11, p. 112-124.
- [15] X. F. Zhang, X. Han, J. J. Wu, Environmental regulation and carbon emissions: "retrogressive effect" or "retrogressive effect", *Soft Science*, Vol. 01(2019) No. 11, p. 112-124.
- [16] W. P. Yuan, H. Sun, M. Yan, Can dual environmental regulations promote win-win development of high-quality economy and carbon emission reduction? *Journal of Yunnan University of Finance and Economics*, Vol. 01(2019) No. 11, p. 112-124.
- [17] A. Rehman et al. Estimating the connection of information technology, foreign direct investment, trade, renewable energy and economic progress in Pakistan: evidence from ARDL approach and cointegrating regression analysis, *Environmental Science and Pollution Research International*, Vol. 28(2021) No. 36, p. 50623-50635.
- [18] M. Alam, M. Wahid. The impacts of economic growth, trade openness and technological progress on renewable energy use in organization for economic co-operation and development countries, *Renewable Energy*, Vol. 01(2020) No. 145, p. 382-390.
- [19] J. D. Chen. County-level CO2 emissions and sequestration in China during 1997-2017.[J]. *Scientific data*, Vol. 07(2020) No. 1, p. 391-391.
- [20] Z. Allam, D. S. Jones, Future (post-COVID) digital, smart and sustainable cities in the wake of 6G: Digital twins, immersive realities and new urban economies, *Land Use Policy*, Vol. 01(2021) No. 101, p. 105201-.
- [21] Y. Li, Energy structure, digital economy, and carbon emissions: evidence from China, *Environmental Science and Pollution Research International*, Vol. 28(2021) No. 45, p. 64606-64629.