Exploring the relationship between Globalization, Financial Development and Carbon Emissions

-- an empirical research based on China

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Abstract

In response to global warming, China has voluntarily proposed two goals of "carbon neutrality" and "carbon peaking". While ensuring financial development and leading globalization, realizing carbon reduction transformation is an opportunity and a challenge for China. This paper selects panel data from 2000 to 2019 in specific years from 30 provinces in China. First, this paper examines the temporal evolution and geographic characteristics of carbon emissions, financial development levels, and economic globalization in China's provinces by drawing heat maps. Then, this paper uses the spatial Durbin model to measure and analyze the spatial spillover effect between China's carbon emissions and financial development.

The conclusion concluded but not limited to : 1. China's overall carbon emissions are still growing, but the growth rate has slowed down significantly. The financial development of various provinces and cities continued to grow, but mainly in key cities. Trade openness increased overall but was stronger in the South. Carbon emissions, financial development and trade openness show a clear and ambiguous north-south polarization. 2. Financial development and population directly promote the intensity of local carbon emissions, but reduce carbon emissions in neignbours areas, so there is an overall inhibitory effect. 3. The direct, indirect and overall effect of scientific and technological development is to alleviate carbon emissions, which will become the key to China's realization of the "dual carbon" goal.

Keywords：Carbon Emission Intensity, Economic Globalization, Financial Development, Carbon Peaking, Carbon Neutrality, Spatial Spillover Effect

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1. Introduction

The greenhouse effect has become the most serious and urgent environmental problem faced by mankind, which is also the reason why the "Paris Agreement" was signed by all countries in the world. However, several studies have shown that even if all countries implement the nationally determined emission reduction contributions submitted by the parties in the environmental agreement, the average world temperature rise may be higher and cannot meet the requirements of the original temperature control target. Therefore, to further strengthen the response to the climate crisis and make more excellent contributions to the global carbon reduction process, China first proposed a long-term plan for China to achieve a "carbon peak" by 2030 at the meeting of "2014 China-US Joint Declaration on Climate Change." In the face of increasingly serious environmental problems and growing emissions, on September 22, 2020, China once again proposed the "dual carbon" goal ,which represented that striving to achieve a "carbon peak" by 2030, ans achieve carbon neutrality by 2060. These goals are ambitious. On the one hand, it shows China's ardent concern for environmental protection. On the other hand, the pressure of international public opinion on the external environment and the green trade fortress has brought severe tests to China's development.

The advantages of globalization are undoubtedly obvious. It promotes market opening, cooperation, and investment between different countries and stimulates China's economic development from multiple perspectives, providing developing countries with space for technological, political, and cultural development. However, straightforward financial growth has primarily undermined the sustainable use of China's natural resources. Restricted by the energy consumption structure, China's leading economic development is mainly based on coal, supplemented by oil and natural gas. Coupled with a large population, it will inevitably consume and generate a more considerable amount of carbon dioxide emissions. The high proportion of carbon emissions from coal consumption needs to be offset by a higher proportion of clean energy, which (further development of clean energy) is currently highly lacking in China. Constrained by its unique population, industrial structure, and resource constraints, China is a great challenge to complete the two carbon reduction goals. China, as a developing country, lags far behind in science and technology, innovation, and new energy, making it more difficult to promote emission reduction plans. How to achieve stable and sustained economic growth while accomplishing carbon reduction goals is an urgent consideration for China.[1]

There are many papers studying on the connection between globalization, trade openness, economic growth, financial development, carbon emissions, and several disputes have continued. So far, no unified conclusion has been achieved.

There are two main viewpoints: First, globalization and financial development can help decrease the release of carbon emissions; that is, economic growth brought about by globalization can improve resource utilization efficiency by promoting technological progress, thereby making imports and exports cleaner. The second is to

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[1] 莫姝，王婷．金融发展对碳排放强度影响的空间效应研究.
Mo, S., & Wang, T. (2022). A study on the spatial effect of financial development on carbon emission intensity.

oppose globalization, that is, to believe that foreign trade and financial development negatively affect the country's environment that surpasses its economic development. I will discuss these two viewpoints in detail in the second part.

To summarize, the extant research on the relationship involving globalization and carbon dioxide emissions illustrates there are still considerable discrepancies. Additionally, only a few scholars have made a corresponding empirical analysis based on the actual situation in China, and those data sourced from previous years are not fashionable enough. This paper explores the relationship between globalization (mainly referring to trade openness), financial development, and carbon emissions in the context of empirical research in China. In addition to the negative and positive linear relationship, is there a separate mathematical link between financial development and carbon emissions that varies depending on the combined impact of various variables and circumstances? Do carbon emissions have a spatial spillover effect, and how is it manifested? Can these findings in this paper help predict the success of China's carbon reduction goals? Is it possible to reasonably predict the evolution of carbon emissions and financial development in the next half century? Can China achieve a win-win outcome of financial development and carbon reduction? This article will attempt to address these issues. This paper will first examine the spatiotemporal characteristics of carbon emissions and financial development in different regions by constructing a heat map using data from 2000 to 2019 in China's 30 provinces and cities. Then, using the Spatial Durbin Model (SDM) in the geographical spillover model, examine the spatial influence of financial development on carbon emissions from one year before the financial crisis to 12 years after the financial crisis. The significance and value of studying this topic is that this paper can fill in the gaps in the existing research and further reveal the relationship between these factors; it can also provide the Chinese government with constructive policy suggestions.

Chapter 2 examines the current literature on the argument over the link between globalization, trade openness, financial development, and carbon emissions after the introduction. In addition, I will outline China's existing carbon policy and explore the drivers of China's carbon emissions. Chapter 3 provides a brief explanation of the variables and data sources used in this article. This chapter also clarifies how some crucial variables are measured to avoid misunderstandings. In addition, I constructed the spatial Doberman model used in this article. In Chapter 4, I will describe the key findings, which include a spatialtemporal study of financial development and carbon emissions, as well as model-measured spillovers. In order to make better predictions, this paper uses the research results of similar topics to conduct a horizontal comparison and analysis. Finally, it is the conclusion and policy recommendations of this paper.

2.Literature Review

2.1 Globalization and Carbon Emissions

With the deepening of globalization, foreign scholars began to reflect on globalization, financial trade, and economic growth on environmental change in promoting their financial development and came to different conclusions.

The first view is that the trade openness brought about by economic globalization will increase carbon emissions. Stretesky and Lynch (2009) used data on per capita carbon emissions and exports for 169 countries from 1989 to 2003 and found that global exports and per capita carbon dioxide emissions were positively correlated. Using data from 63 developed and developing countries, Managi (2004) showed that further trade liberalization would increase carbon dioxide emissions. Over time, China joined the push for globalization, and the reform and opening-up policy also led to more and more foreign investment flowing into China. The strong development of enterprises and production has caused the level of carbon emissions to increase sharply at this moment. Consequently, several Chinese academics have begun to investigate the correlation between financial globalization and carbon emissions. A study by Ang (2009) using time series data from 1953 to 2006 found that higher trade openness and higher income both increase CO2 emissions. Niu and Hu (2011)[2] studied data over the period from 1995 to 2007 and observed a positive correlation between foreign

[2] 牛海霞，胡佳雨.FDI 与我国二氧化碳排放相关性实证研究[J]. 国际贸易问题，2011(5) :100 - 109
Niu, H., & Hu, J. (2011). An empirical study on the correlation between FDI and my country’s carbon dioxide emissions. *International Trade Issues*, *5*, 100–109.

direct investment and my country's carbon emissions. Consequently, carbon dioxide emissions per capita would rise by about 0.09 percent for each 1 percent increase in foreign direct investment. (Niu & Hu, 2011)

Similarly, Fu et al. (2012) [3]obtained same conclusions. Their research shows that the entry of FDI increases China's CO2 emissions, and they conclude that foreign trade is not conducive to China's CO2 reduction goals. The second view is that globalization and trade openness will reduce CO2 emissions. In Cole's (2004) study, which examined the relationship between trade and pollution, no positive relationship was found between 'dirty' trade and pollution. Instead, Cole supports that trade openness can contribute to environmental improvements through increased competitiveness and efficient use of resources. Zhang et al. (2020) also think so. Their research found that globalization of production could make China's exports cleaner. Specifically, not only China but also all developing countries. As long as China and other developing countries focus on producing and developing their own clean energy, the process of globalization will not only bring about higher carbon emissions but will also reduce the carbon intensity of all countries' exports through the global production network to obtain green exports cycle.

[3] 傅京燕，裴前丽. 中国对外贸易对碳排放量的影响及其驱动 因素的实证分析[J]. 财贸经济，2012(5) : 75 - 81 Fu, J., & Pei, Q. (2012). Empirical analysis of the impact of China’s foreign trade on carbon emissions and its driving factors. *Finance and Trade Economics, 5*, 75–81.

2.2 Financial Development and Carbon Emissions

Recently, foreign scholars have used different methods to analyze carbon emission intensity and its motives. Most studies have proved that financial development is an important cause of carbon emission growth. Shahbaz et al. (2016) explored the causal association among carbon dioxide emissions and economic development in eleven countries during 1972 and 2013. According to the findings, Bangladesh's and Egypt's fast economic expansion in recent years is the primary cause of the rise in carbon emissions.

Using panel data from 1993 to 2016, Zhou (2018) [4]investigated the two-way dynamic link between financial development and carbon emissions in 23 nations and regions (developed and developing countries). The results show that for developed countries and regions, carbon emission intensity has a stronger effect on financial development. Munir et al. (2020) explored the relation among both carbon dioxide emissions and economic level (GDP) in various key Southeast Asian nations from 1980 to the present, and they found that energy conservation leads to slower growth, especially for economies that are particularly energy-dependent (Philippines and Singapore). In addition to this, Malaysia, the Philippines, and Thailand – which have not yet reached the income inflection point suggested by the EKC (Environmental Kuznets Curve) – are supported by the conclusions of the analysis of the EKC. For these countries,

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[4] 周莹莹. (2018). 金融发展对碳排放的影响——以 23 个国家与地区为例. 求索(5), 9.
Zhou, Y. (2018). The Impact of Financial Development on Carbon Emissions: Taking 23 Countries and Regions as Examples. Seek, 5(9).

economic growth is expected to affect the environment adversely. In addition, there is another view that financial development can help scientific and technological progress, promote the use of green energy in various countries, and improve the utilization rate of original resources, improve production efficiency, to meet the energy saving and emission reduction objectives. Consequently, financial growth is a significant role in lowering carbon emissions. Tamazian et al. (2008) utilized data from 1992 to 2004 to confirm that the liberalization and openness of financial development are essential factors in reducing carbon emissions. In addition, for developing nations, an increase in economic growth has a greater, more profound, and longer-lasting influence on carbon emissions. (Zhou, 2018) Acheampong (2019) found that from 1980 to 2015, financial developments represented by broad money have suppressed the growth of carbon emissions in countries such as Australia and Brazil. Chinese scholar Gu et al. (2012)[5] constructed a P-VAR model and concluded that the deepening and concentration of financial development could help reduce emissions. Zhang, Li, et al. (2020) developed static and dynamic geographic panel models and discovered that both models demonstrated that an increase in the degree of financial advancement would lower carbon dioxide emissions per capita consumption. [6]

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[5] 顾洪梅 ，何彬 ．我国省域金融发展与碳排放研究 [J].中国人口、资源与环境,2012,22(8):22-27. Gu, H., & He, B. (2012). Research on my country's Provincial Financial Development and Carbon Emissions. *China Population, Resources and Environment*, *22*(8), 22–27.

[6] 张忠杰，李真真，李宪慧. 金融发展,城镇化对人均能源消费碳排放的影响[J]. 统计与决策, 2020(8):5. Zhang, Z., Li, Z., & Li, H. (2020). The impact of financial development and urbanization on carbon emissions per capita

2.3 Drivers of China's carbon emissions

Han et al. (2017) [7]compared the carbon emission intensity and its drivers in ten major countries worldwide from 1960 to 2014. The findings indicate that per capita GDP is a key factor influencing carbon dioxide emissions in various countries, which represents the country's degree of economic growth and the material prosperity of its citizens. (Han et al., 2017) The regression coefficients of GDP are all positive, indicating that the increase in GDP significantly contributed to the increase in carbon emissions. Which indicated that as the economy develops and GDP increases, carbon emissions will increase. Especially for China and India, the huge population technology and the characteristics of developing countries make the increase of GDP per capita have a greater result on changes in carbon emissions. China's per capita production capacity has been increasing in recent years. The ongoing growth of China's economy, coupled with the acceleration of industrialization and urbanization, would ultimately result in a substantial increase in energy consumption and, therefore, carbon dioxide emissions. Shum and Ma et al. (2021) introduced the Lasso model to their study to compare carbon emissions data for 284 cities in China over a 12-year period after the millennium. Like the results of Han et al., they found that GDP

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energy consumption. *Statistics and Decision-Making*, *8*(5).

[7] 韩梦瑶，刘卫东，唐志鹏,等. 世界主要国家碳排放影响因素分析——基于变系数面板模型[J]. 资源科学, 2017, 39(12):10.
Han, M., Liu, W., Tang, Z., & Zhou, G. (2017). Analysis of the influencing factors of carbon emissions in major countries in the world—based on a variable coefficient panel model. *Resources Science*, *39*(12), 10.

growth, per capita spending power and total energy demand were responsible for the sharp spike in China's carbon dioxide emissions. This shows that the driving force of China's carbon emissions is mainly derived from economic growth. Huo et al. (2022) calculated the carbon emissions and GDP of the "low carbon policy" pilot cities in 2013. Through empirical research by scholars, the results indicated that the pilot cities will reduce carbon emissions by 2.72% per year, while the related GDP loss is about 1.19 trillion yuan. (Huo et al., 2022) In addition, household and living consumption are also the main driving factors for increasing carbon emissions. Liu and Qu et al. (2016) [8]studied the per capita living carbon emissions of 30 provinces on the Chinese mainland. The statistics indicate that China's per capita carbon emissions are increasing annually, which illustrates those higher incomes and more room for disposable income increase the carbon footprint. In Yuan et al. (2019), they found that the drivers of higher carbon emissions in coastal cities mainly come from income and population size. Therefore, the increase in China's carbon emissions is a consequence of economic expansion.

The industrial structure is another critical factor affecting carbon emissions. However, for countries at different development stages, the proportion of industrial added value varies. China's economy has expanded enormously since the introduction of the reform and opening-up program. Meanwhile, China's industrial structure is

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[8] 刘莉娜，曲建升，黄雨生,等. 中国居民生活碳排放的区域差异及影响因素分析[J]. 自然资源学报.
Liu, L., Qu, J., & Huang, Y. (2016). Analysis of regional differences and influencing factors of Chinese residents' living carbon emissions. *Journal of Natural Resources, 8*(14).

constantly adjusting to adapt to the ever-changing economic environment. The second industry grew gradually, the third industry developed swiftly, and the first industry progressed slowly after the reform and opening. In 1952, the composition of China's three industries was 51%, 21% and 28% respectively; before the reform and opening in 1978, the composition of China's three industries was 28%, 48% and 24% respectively; in 2013, after 30 years China's three industrial components are 9%, 44% and 47% respectively. (China Industry Report, 2018) From 1952 to 2013, the secondary and tertiary industries developed rapidly. This change is not only an objective reflection of the continuous upgrading of the consumption structure, but also the result of the continuous advancement of the industrial structure adjustment policy. After 1978, the share of the secondary industry in GDP has remained stable between 40% and 50%, with little change. The first industry fell from 28% in 1978 to 10% in 2013, while the third industry doubled in more than two decades. China's industrial dependence is still on heavy industry and high energy-consuming industries, resulting in a high proportion, even exceeding the proportion of the entire light industry recently. The fast expansion of energy-intensive businesses will inevitably result in a constant rise in energy consumption and, therefore, a substantial increase in long-term carbon emissions. Lu and Qiu (2013) dissected China's carbon emissions from 1994 to 2008, assessed the influence of China's six largest sectors on the country's carbon emission trends, and investigated the link between industrial structure and carbon emissions. After a temporary drop, the data indicate that China's total CO2 emissions have resumed an increase trend since 1995. This is mostly due to the restructuring of China's industrial structure.

Meanwhile, Cheng et al. (2013) [9]observed much higher carbon emissions than the south for the highly energy-dependent northwest, northeast, and mid-west provinces. Over time, carbon emission agglomeration tends to increase significantly because northern China mainly adopts a high-consumption and high-polluting energy consumption structure dominated by coal. There is a significant zonal high carbon emission accumulation feature compared with the eastern coastal areas, which have gradually begun the industrial transformation. China's energy characteristics of "sufficient coal, less oil, and lack of gas" determine the coal-based energy consumption structure. In China's main energy consumption structure, coal accounts for around three-quarters of the country's total energy output. In 2030, it is anticipated that the share of non-fossil energy will be further optimized, while coal use would decline to about 50 percent. However, the coal-dominated energy consumption system remains difficult to alter. We can see solid or weak decoupling in China's coastal provinces and cities. However, central industrial provinces and cities, such as Heilongjiang, Hebei, and other places, may show relatively large negative decoupling because these regions are more dependent on coal consumption. (Yuan, 2019) In

[9] 程叶青，王哲野，张守志,等．中国能源消费碳排放强度及其影响因素的空间计量[J]. Journal of Geographical Sciences, 2014, 68(10):1418-1431.
Cheng, Y., Wang, Z., & Zhang, S. (2014). Spatial measurement of carbon emission intensity of China’s energy consumption and its influencing factors. *Journal of Geographical Sciences*, *68*(10), 1418–1431.

conclusion, the industrial structure and energy consumption structure are the key determinants of China's carbon emissions. The industrial sector contributes the most to the increase in carbon emissions, followed by the transportation sector. In the study report by Luo and Zeng (2021)[10], a combination of the LMDI model and Granger causality test was used to examine possible markers influencing Shanghai's CO2 emissions from 1995 to 2017. It was found that the number of motor vehicles is also an absolute driver of urban carbon dioxide emissions.

2.4 China's current carbon reduction targets

China's urbanization and industrialization have rapidly doubled energy demand, driven by only half a century. In 2006 alone, to supply power to China, which is increasingly in demand, the increase in new power generation capacity exceeded 100 gigawatts, which is enough for the entire UK power system. (Wang & Chen, 2015) According to statistics, China's energy consumption and carbon emissions rank second in the world, behind only the United States. By 2025, China's carbon dioxide emissions are projected to be the highest in the world. (Chen, 2021) Consequently, the Chinese government's voluntary commitment to combating climate change is a key contributor to reducing carbon emissions in China and around the globe.

[10] 鲁万波，仇婷婷，杜磊．中国不同经济增长阶段碳排放影响因素研究[J]．经济研究, 2013(4):13.
Lu, W., Qiu, T., & Du, L. (2013). A Study on Influencing Factors of Carbon Emissions in Different Stages of China’s Economic Growth. *Economic Research*, *4*(13).

In 2001, during China's tenth five-year plan announced, China first proposed the goal of reducing pollutant emissions, mainly targeting the production of SO2 and COD emissions. In 2005, the Chinese government proposed a 15-year carbon reduction plan in phases in the twelfth and thirteenth FYPs. Key elements of the policy include reducing carbon intensity levels by 40 percent; raising the proportion of non-fossil fuel energy sources, expanding the forest area by 40 million hectares, etc (Liu et al., 2022). The Chinese government's plan to use an "iron fist" shows its firmness and inevitability in achieving carbon reduction goals. When the provincial government announced stricter energy-saving plans in a town in Hebei province, some agencies even went so far as to cut power to meet their goals. The city of Wenzhou in Zhejiang province also withdrew from a mandatory policy requiring manufacturers to operate on a "ten days closed, five days open" for the remainder of 2010. (Wang & Chen, 2015) The effect of this is noticeable. By 2020, the carbon intensity has dropped by 48.4%, and the carbon emission reduction target has been exceeded. (Liu et al., 2022) At the UN climate summit in 2020, China formally proposed the "30·60" dual carbon goal, aims to reach the peak of CO2 emissions by 2030 and reach carbon neutrality by 2060.[11]

"Double Carbon" is the Chinese acronym for the two goals of "carbon peak" and "carbon neutrality". "Carbon peaking" is when carbon emissions reach a certain peak,

[11] 王志轩. 碳达峰,碳中和目标实现路径与政策框架研究[J]. 电力科技与环保, 2021.
Wang, Z. (2021). Research on the path and policy framework to achieve carbon peak and carbon neutrality. *Electric Power Technology and Environmental Protection*.

and then from there, emissions will no longer rise, but will gradually decline. (Wang, 2021) "Carbon neutrality" means that humans use various measures such as afforestation, energy conservation, and emission reduction to offset the greenhouse gasses emitted by humans to maintain their own lives and production and ultimately achieve "zero emissions" of carbon dioxide. (Chen, 2021) The Central Economic Work Conference held in December 2020 clearly stated that "carbon peaking" should be regarded as one of the essential work contents from 2021 to 2025 (the fourteenth FYP).

This chapter offers a detailed assessment and analysis of the extant literature. Overall, the literature has several empirically based debates on the link between economic globalization (including trade openness), financial growth, and carbon emissions. However, the results are still inconclusive; some scholars believe there is a positive relationship, and some believe there is a negative relationship between the two. This paper starts from this debate to fill in the literature gaps and examine again the relationship between globalization (opening of trade and the economic growth brought about by globalization) and carbon emissions. Since this paper mainly focuses on China's carbon emissions, it is first necessary to have a general concept of China's national conditions, industrial structure and consumption characteristics. Second, it is vital to comprehend the driving force behind China's carbon emissions with the use of published materials. According to the research conclusions of existing domestic and foreign literature on the driving forces of carbon emissions in various countries, China's carbon emissions are primarily driven by economic growth, long-term dependent industries, and domestic carbon emissions resulting from population and consumption.

In addition, for readers who are not familiar with China's carbon emission policy, the literature review also briefly describes the evolution process of China's carbon reduction policy, current gains, and future goals to help readers better understand the background of this article.

3. Explanatory variables, data sources and measures

3.1 Calculation of Total Carbon Emissions and Carbon Emission Intensity (CEI)

According to IPCC (2007), the following is the formula for computing carbon emissions:

$$CE_{energy} = \sum_{i=1}^{8} CE_i = \sum_{i=1}^{8} E_i \times NCV_i \times CEF_i \times COF_i \times \frac{44}{12}$$

Among them, CEenergy represents the total emissions from fossil fuel i in the region. Ei represents the burning amount of fossil fuel i . NCVi stands for mean low calorific value. CEFi represents the energy calorific value per unit of carbon content. As mentioned by Liu and Song (2020) in their study, we assume that the energy is fully burned and the short-term efficiency is constant, so the carbon emission factor is constant. COFi represents the rate of carbon oxidation. It refers to the ratio of the mass after carbon is completely oxidized to CO2 and before it is a standard quantity, which can be replaced by 1 by default and is constant. 44/12 represents the conversion rate. i symbolizes the energy type, which consists of eight categories, including coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil, and natural gas. Table 1 contains the names, average low calorific value, carbon content of the items, carbon oxidation rate, and carbon emission factor of eight fossil fuels. In some studies, it is often considered that there are 9 types, so i=9 is used to include the formula, but it will not affect the comparison of the results.

Carbon emission intensity represents the overall carbon emission generated for each unit of growth in gross national product (GDP). The intensity of a country's carbon emissions, known as Carbon emission intensity (CEI) may be used to determine the link between a country's economic level and its carbon emissions. China has not yet confirmed a fixed formula for calculating CEI so it will use the more commonly used internationally.

The CEI formula is generated as follows, while carbon intensity is computed as the ratio between the growth in total carbon emissions and the rise in GDP.

$$CEI_{it} = (CE_{energy})_{it} \div GDP_{it}$$

where t is time in years. i is a region or city. CEI_{it} represents the intensity of a region i's carbon emissions in year t. (CE_{energy})it is the total carbon emission of a region i in year t, GDP_{it} is the total GDP of a region i in year t.

All energy consumption will use standard units (ten thousand tons of ordinary coal), and then be converted into carbon emissions and carbon emission intensity through calculation formulas. [12]

Table 1: The coefficients of carbon emissions for different fossil fuels.

[12] 杨晓军，陈浩．全球化、城镇化与二氧化碳排放[J]．城市问题, 2013(12):9.
Yang, X., & Chen, H. (2013). Globalization, Urbanization and Carbon Dioxide Emissions. *Urban Issues*, *12*(9).

Fossil Fuel	Average Low Calorific Value (kJ/kg)	Carbon Content (kgC/GJ)	The Rate of Carbon Oxidation	Carbon Emissions Coefficients (tC/t)
Coal	20,908	25.8	0.913	0.4925
Coke	28,435	29.2	0.928	0.7705
Crude oil	41,816	20.0	0.979	0.8187
Fuel oil	41,816	21.2	0.985	0.8691
Gasoline	43,070	18.9	0.980	0.7977
Kerosene	43,070	19.5	0.986	0.8281
Diesel	42,652	21.1	0.985	0.8691
Natural gas	38,931(kJ/m^3)	15.3	0.990	0.5896 (tC/m^3)

Note. Source From "Financial Leverage, Economic Growth and Environmental Degradation: Evidence from 30 Provinces in China." By Zhao, M., Yang, R., & Li, Y. 2020, *International Journal of Environmental Research and Public Health*, *17*(3), 831. Copyright 2020 by Zhao, M., Yang, R., & Li, Y.

3.2 Financial Development

Financial development is a wide notion, making it difficult to quantify. However, the evaluation of financial development is very useful for evaluating the effectiveness of a country's financial system, fostering economic growth, and eliminating poverty. (Financial Development, 2016) Therefore, to date, standard quantitative indicators are often used in empirical work to calculate financial development, include the ratios of assets to GDP, current liabilities to GDP, and deposits to GDP. Ito and Kawa, 2018) Moreover, in the incomparable Chinese financial markets, loans are closely related to corporate activities, so the level of loans is a good proxy for China's financial development. (Zhang, 2011) In addition, these data (loans, deposits, and assets) are relatively easy to obtain for any country. Although there is still debate on whether it can represent a country's level of financial development, this is not the core content of what this article wants to figure out. Given the commonality and generality of this formula, this paper will use the ratio of bank loan and financial institutions' loans to GDP to represent financial development.

3.3 Economic Globalization

This paper selects two economic indices: trade openness and foreign capital dependence, to measure the level of China's participation in globalization. The measure of trade openness adopts the most common calculation method: the total import and export of each province and city divided by the total end of year GDP of the province and city. The degree of foreign capital dependence is measured by dividing the foreign direct investment in each province and city by the provincial and city GDP. Each province's total imports and exports are derived from the "regional total import and export value" (100 million yuan) in the "China Financial Data" released by the EPS data platform. And then, according to the GDP (100 million yuan) of each province and city, trade openness is obtained. (Unit: %). The FDI of each province and city is the actual use of foreign direct investment (100 million yuan). Then according to the GDP data of each province and city (100 million yuan), the foreign capital dependence degree (unit: %) is obtained. The data comes from "China's Macroeconomic Data" and "China's Financial Data" released by the EPS data platform.

3.4 Control variables

This paper's primary explanatory variable is carbon emission intensity (CEI), and the explanatory variable is financial development (FIN). The specific measurement methods of the two have been explained above. The ratio of a region's total carbon emissions to its gross regional product is used to calculate its carbon emissions intensity (CEI). There are many ways to measure financial development. It is very meaningful to measure financial development, which is helpful to the growth of the world economy, poverty reduction and common prosperity for all human beings in all regions. Because the concept of financial development is too broad, it is difficult to measure in practice. So far, countries have different long-standing criteria to quantify "financial development", such as the ratio of bank to financial institution credit to GDP, current liabilities to GDP, or existing deposits to GDP. Of course, these are relatively rough estimation methods, which are only used for measurement reference and cannot fully represent the level of financial performance of a country. In the paper by Ito and Kawai (2018), they argue that the use of loans and GDP to measure the level of financial development is too broad to capture subtle gaps in financial market development, nor to reflect other types of financial tools such as stocks, bonds and The role of insurance in financial development cannot reflect the diversity of the entire financial market. However, since the index model constructed by Ito and Kawai covers too many elements and data of the financial market, the calculation is too complicated, so I will not introduce it. In this article, to create following models and draw conclusive findings, I will continue to rely on the most conventional method for measuring financial development: the ratio of bank loans and financial institution credit to GDP.

Other control variables for this paper are as follows.

1.represented as the regional GDP to total population ratio at the end of the year. It can quantify regional economic development more precisely. 2. Population (PO):

The province's total population was collected at the end of the year. Using it can help studies better see whether the population would siginificantly affect carbon emissions or o not. Population will attract skilled individuals, which may be beneficial to the region's efforts to generate new energy, cut carbon emissions, safeguard the sector, and alter the mode of production.   3. Industrial Structure (IS): As indicated in the literature study, the industrial structure is the primary driver of China's carbon emissions. Most of the carbon increments originate from China's chemical energy industry. Therefore, we will study the secondary industry and use the percentage between the secondary industry and regional GDP to measure the industrial structure. 4. Foreign Direct Investment (FDI): Expressed in terms of regional FDI and regional GDP. Foreign direct investment is an essential factor in measuring regional economic development and financial development. FDI can promote regional economic development, employment, technological development, and the entry of new talents. If FDI brings projects, resources, and technologies to reduce carbon emissions, it will directly affect the carbon intensity of the place. 5. Technological level (TE): Like the meaning of FDI, technological development can optimize the existing industrial structure and production model and bring new energy technology, thereby limiting and reducing the level of CO2 in certain region. In the existing literature, the number of patents is often used to represent technological development. 6.Trade Openness (TO) : The total import and export value of each province or city, divided by the provincial and municipal GDP, which represents the unit of percentage.

Table 2 summarizes all the variables appearing in this paper with their symbols, interpretations, and units.

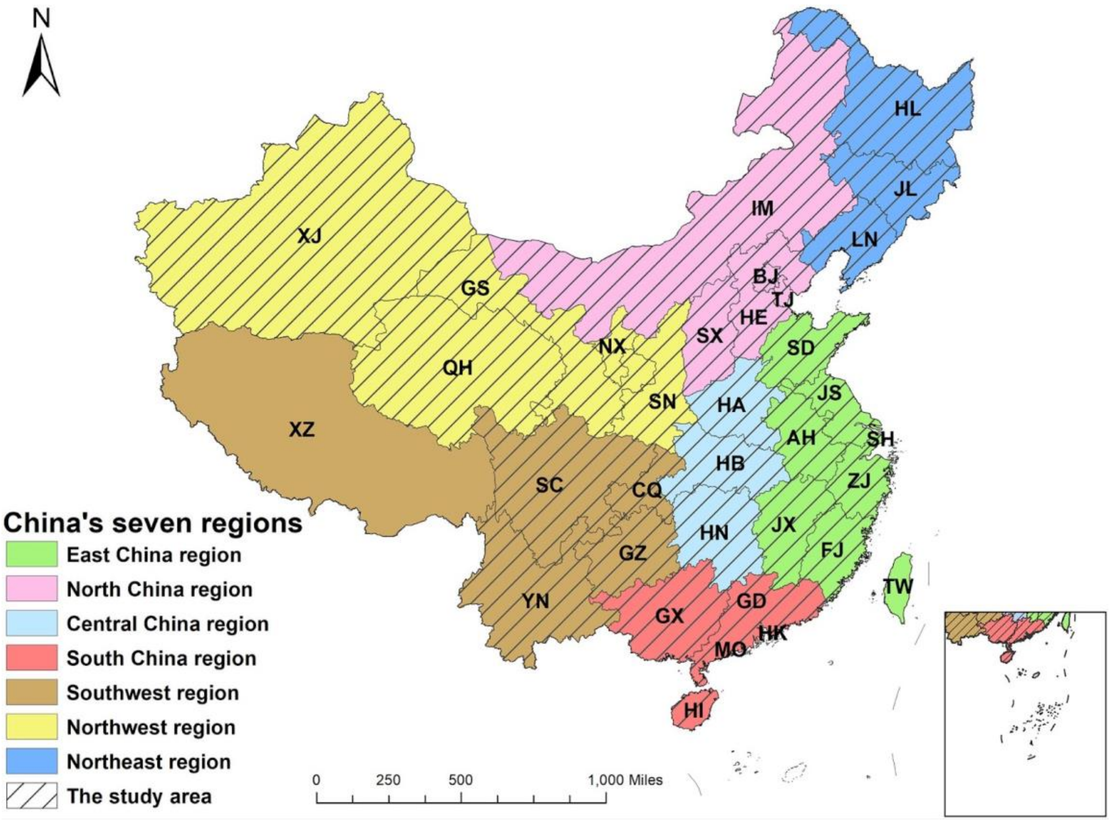
Table 2 : Lists of Variables, Symbols, Description and Units of measurement

Variables	Symbol	Description	Units
Carbon Emission Intensity	CEI	Carbon Emission/GDP (in a province)	Ton/10 thousand Yuan
Financial Development	FIN	Loans/GDP (in a province)	10 thousand Yuan/10 thousand Yuan
Trade Openess	TO	Total import & export / GDP (in a province)	%
Economic Growth	PGDP	GDP per capita, per province	CNY(Yuan)
Population	PO	Total population in a province	10 thousand
Industrial Structure	IS	GDP of the secondary industry/ GDP (in a province)	%
Foreign Direct Investment	FDI	foreign direct investment/GDP (in a province)	%
Technology Development	TE	Patent Applications in the province	Pieces

3.5 Data sources

This section selects official data from 30 out of China's 34 provinces and cities, and explores the time progress of carbon emissions and financial development levels in the twelve years after 2007, in province of China. Due to the poor availability and difficulty of collecting some data, China Tibet, China Taiwan, China Hong Kong, and China Macau are not included here. The China EPS data platform and the China Statistical Yearbook published by the National Bureau of Statistics of China are the key data sources. These yearbooks and reports are publicly released by the government and can be found on Chinese websites as electronic files. Figure 1 is from Liu and Song (2020). The map shows 34 provinces and cities in China, of which the shaded areas are the 30 provinces that will be studied in this paper. The non-shaded regions represent the four regions that cannot be included in the computation owing to insufficient data.

Figure 1. 34 provinces in China (30 out of 34, of which are shaded and covered in this study).



Note. Source From : "Financial development and carbon emissions in China since the recent world financial crisis: Evidence from a spatial-temporal analysis and a spatial Durbin model. " By Liu, H., & Song, Y. (2020). *Science of the Total Environment*, *715*, 136771. Copyright 2020 by Liu, H., & Song, Y. (2020).

3.6 Building a Spatial Econometric Model

Inspired by the studies of Fan and Liu et al. (2006), Wang and Wu et al. (2013), Li and Liu (2015), Zhang and Zhao (2019), Liu and Song (2020), I discovered that in the current literature, the STIRPAT model is used by the majority of the approaches employed to examine the influencing elements of carbon emissions in this study (full name: Stochastic Impacts by Regression on Population, Affluence, and Technology). York et al. (2003) presented the STIRPAT model, which was improved and further developed from their previous model IPAT. The classic IPAT model proves that environmental impact (EI) is closely linked to population (PO), affluence (A) and technology level (TE). (Yang & Chen, 2013) To avoid the limitations brought by the old model, York et al. (2003) designed a new STIRPAT model. This is an extensible and random environmental impact assessment model. It evaluates the relationship between the three independent variables of population, property, and technology and the dependent variable. It mainly describes population growth, technology, and changes in wealth. how it affects the environment. (York et al., 2003)

In addition, geographical analysis is essential since this research focuses on the link and effects of financial development on carbon emissions (Wang, et al., 2021). Numerous researchers have paid attention to and identified the geographical spillover impact of carbon emissions in previous studies. Then, there are several types of spatial panel analysis based on various geographical dependencies, such as spatial error model (SEM), spatial lag model (SLM), and spatial Durbin model (SDM). (Wang et al., 2021) These three models are based on a formula, the main difference is that they each use different items as independent variables to calculate the results, so the formulas can be transformed into each other. ((Liu & Song, 2020) Inspired by the exploration of factors such as environment and consumption by Marbuch (2017), Yan and Lei et al. (2017), Wang (2021) , this research choose to use the spatial Durbin model in order to quantify the geographical spillover effect between carbon emissions and economic growth.

According to the variables introduced in Section 3.3, according to the existing STIRPAT model, a basic model formula can be obtained as follows:

$$InCl = \beta_0 + \beta_1 InFIN + \beta_2 InPGDP + \beta_3 InPO + \beta_4 InIS + \beta_5 InFDI + \beta_6 InTE + \epsilon$$

From this, the spatial Durbin model is constructed as follows.

$$InCl_{it} = \beta_0 + \beta_1 InFIN_{it} + \beta_2 InPGDP_{it} + \beta_3 InPO_{it} + \beta_4 InIS_{it} + \beta_5 InFDI_{it} + \beta_6 InTE_{it}$$
$$+ p\, WInCl_{it} + \theta_1 WInFIN_{it} + \theta_2 WInPGDP_{it} + \theta_3 WInPO_{it} + \theta_4 WInIS_{it} + \theta_5 WInFDI_{it} + \theta_6 WInTE_{it} + \epsilon_{it}$$

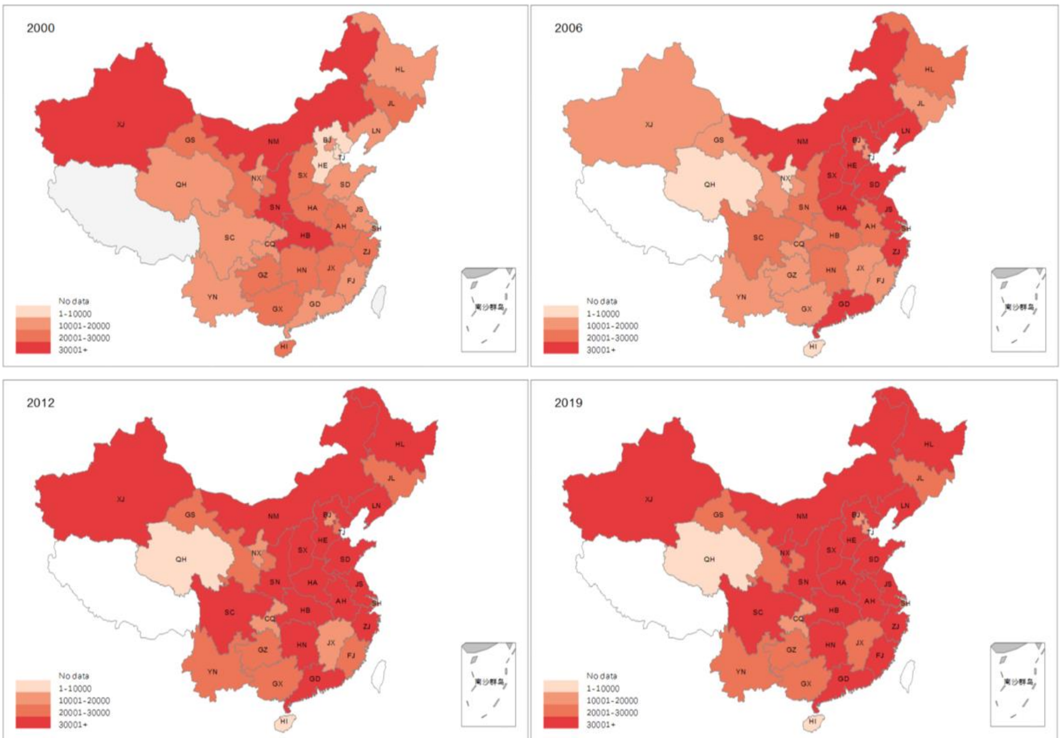
where is the independent variable coefficient and it is the random error, i represents the region, respectively from i = 1,2, 3,....30, t represents the time, from 2007, 2008...2019. The specific explanation of the variables such as CI, FIN, PGDP, PO, IS, FDI and TE can be found in Table 2.

4. Results and Discussion

4.1 Time evolution of China's provincial carbon emissions

Through the data provided by the EPS database, I have obtained carbon emission data reports for 30 out of 34 provinces in China from 2000 to 2019. The figure below is a map-like image drawn by EXCEL - provincial carbon emissions heat map. Carbon emissions are divided into five levels, represented by different colors. Darker locations represent higher carbon emissions. The abbreviations of Chinese provinces are marked in different locations (you can check the distribution of 34 provinces in China and the research area of this paper in Section 3.4/figure.1), such as Beijing (BJ), Shanghai (SH), Guangzhou (GZ), Shenzhen (SZ) and so on. For a more concise comparison, I have selected four of the years, 2000, 2006, 2012, and 2019.

Figure 2 . Geographically distribution of China's provincial carbon emissions in selected years



Based on the regional distribution of carbon intensity in the chosen years, it is possible to make certain conclusions.

First, in 2000, the carbon emissions in the most extensive range were mainly in northern and central China, such as Xinjiang, Inner Mongolia, Shaanxi, and Hubei. Meanwhile, the lowest carbon emissions are in Tianjin and Hebei. By 2006, significant carbon emission reductions had been achieved in large parts of the country, especially in western China. This may be attributed to the successive announcements of environmental protection and energy policies in 2004-2006.In 2004, China issued its first medium- and long-term energy development plan, which was also China's strategic focus on energy reduction and economic development at that time. (Liu & Song, 2020) In 2005, China launched a new industrial policy system starting from energy conservation and consumption reduction, mainly to eliminate outdated enterprises and production capacity projects. We saw a shift in areas with high carbon emissions in the same year, gradually from the west to the northeastern coastal provinces. From 2006 to 2012, high-level carbon emissions increased rapidly, and the whole of China entered a large-scale increase in carbon emissions. Since only five intervals are set, areas over 30,000 (CO_2, 10,000 tons) appear dark. Judging from the actual data, the cities with significant carbon emissions are Inner Mongolia, Shandong, and Hebei. The city with the most significant carbon emissions is Shandong, which has reached 120,000 (carbon dioxide, 10,000 tons). This may have a strong connection to the industrial structure.

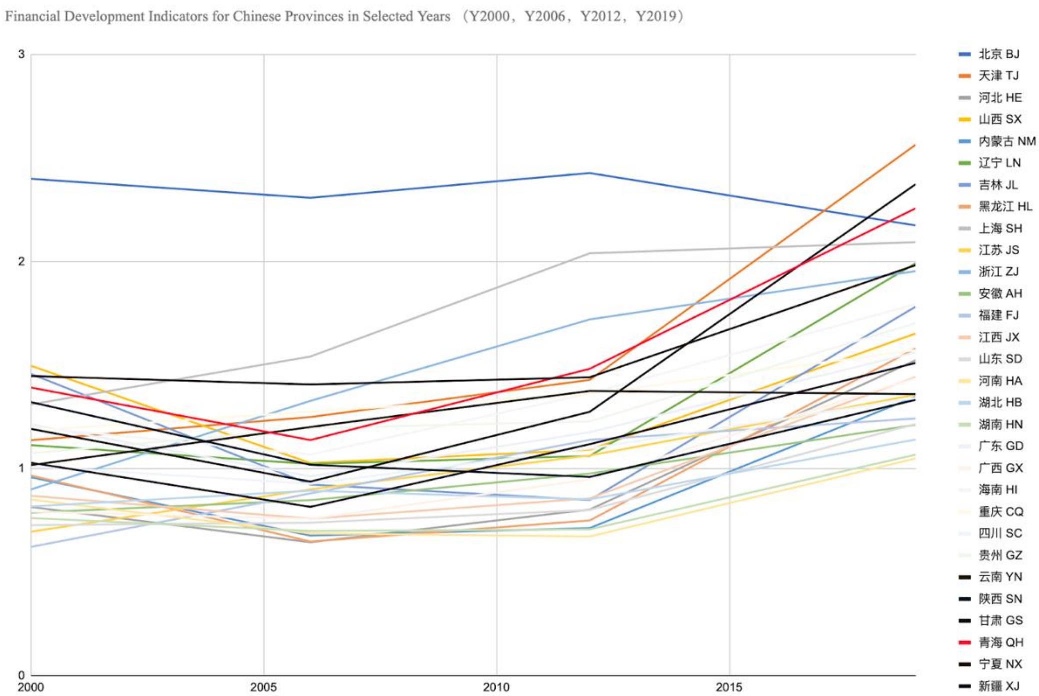
The cities mentioned earlier with highly high carbon emissions are located in China's northern and northwestern regions, and these provinces mainly develop energy-intensive industries. By 2019, it can be seen that one or two cities have entered the ranks of high carbon emission cities (30000+ CO2). Since only five intervals were set, areas with more than 30,000 (carbon dioxide, 10,000 tons) were all dark, and new results were found after viewing the specific data. From 2012 to 2019, many cities achieved carbon emission reductions to varying degrees, such as Jilin, Heilongjiang, Shanghai, Henan, Hunan, Hubei, Yunnan, Guizhou, Sichuan, and Chongqing. This demonstrates that the Chinese government's low-carbon transition policies implemented in the three major areas (Beijing-Tianjin-Hebei, the Yangtze River Delta, and the Greater Bay Area) are the most effective at reaching the Yangtze River Delta's low-carbon objective. In addition, from the specific data, although the carbon emissions of other cities are still gradually increasing, the growth rate has slowed down significantly. Northern China, including Shanxi, Shandong, and Inner Mongolia, is home to the regions with the largest carbon emissions. Restricted by the industrial structure, these regions mainly develop energy-intensive industries.

On the whole, from 2000 to 2019, carbon emissions first decreased and then increased globally. Meanwhile, northern area of China exhibits significantly higher carbon emissions than southern China. We have observed that more than one-third of the provinces in China have significantly reduced carbon emissions to some extent. Furthermore, while carbon emissions in the rest of China's provinces are still rising, the rate of growth has slowed.

4.2 Results of China's Provincial Financial Development Indicators

From the China EPS database, I obtained the GDP of each province in China and the loan volume of banks and financial institutions and calculated the financial development indicators through Excel. The method used in this paper to measure financial development has been described above. Figure 3 shows a line graph plotted indicators of China's provincial financial development for certain years (2000, 2006, 2012, 2019).

Figure 3 . China's provincial financial development indicators in selected years



Since 2000, the overall level of financial development in most of China's provinces has been unsatisfactory. This may be because, after the Asian financial crisis in 1997, the growth of China's economy, investment, and consumption slowed down, exports fell sharply, the influential market demand was insufficient, and deflation occurred. In addition, after the millennium, China has carried out a series of financial reforms and joined several international financial organizations, which may also bring more significant capital market risks. Only southern China's coastal cities, including Shanghai (SH) and Zhejiang (ZJ), have attained early financial growth.

Since 2006, financial development in most of China's provinces has stagnated, possibly due to the premonition of the 2008 financial crisis. In addition to the Shanghai (SH) mentioned above and Zhejiang (ZJ), cities that can still achieve more excellent financial development include Qinghai (QH), Gansu (GS), and Liaoning (LN). This is because in addition to a series of economic stimulus plans promulgated in response to the financial crisis, China also implemented the western development policy for the western region of China. After 2012, rapid financial development began across the country. Thanks to the western development policy, cities such as Liaoning (LN), Gansu (GS), and Qinghai (QH) are among the top 30 provinces in terms of financial development growth rates.Moreover, the economic differences between regions are gradually narrowing. Coastal cities in East and South China have also experienced significant financial development. It is worth noting that the financial development of Beijing (BJ) and Shanghai (SH) has been slow or even decreased since 2012.

Figure 4 shows that from 2000 to 2019, most regions in China achieved relatively significant financial growth. Especially in the northwest region, they are mainly represented by Qinghai (QH) and Gansu (GS). At the same time, the coastal cities in East and South China have also experienced a great degree of financial development, mainly represented by Liaoning (LN), Jilin (JL) and Heilongjiang. The other central provinces in China have not seen much change in financial development but are still growing steadily.

In 2006, financial development fell into a low ebb; except for Beijing (BJ), the financial indexes of all other regions declined. Soon, however, such a financial crisis was immediately broken. In 2012, most parts of China returned to financial levels similar to those in 2000, and the eastern coastal areas also achieved substantial growth. By 2019, all country regions have entered the ranks of vigorous financial growth. In contrast, the northwest, eastern regions, and key provinces (Beijing, Shanghai, and Guangdong) have higher financial development than other provinces.

Figure 4 . Geographically distribution of China's provincial financial development in selected years

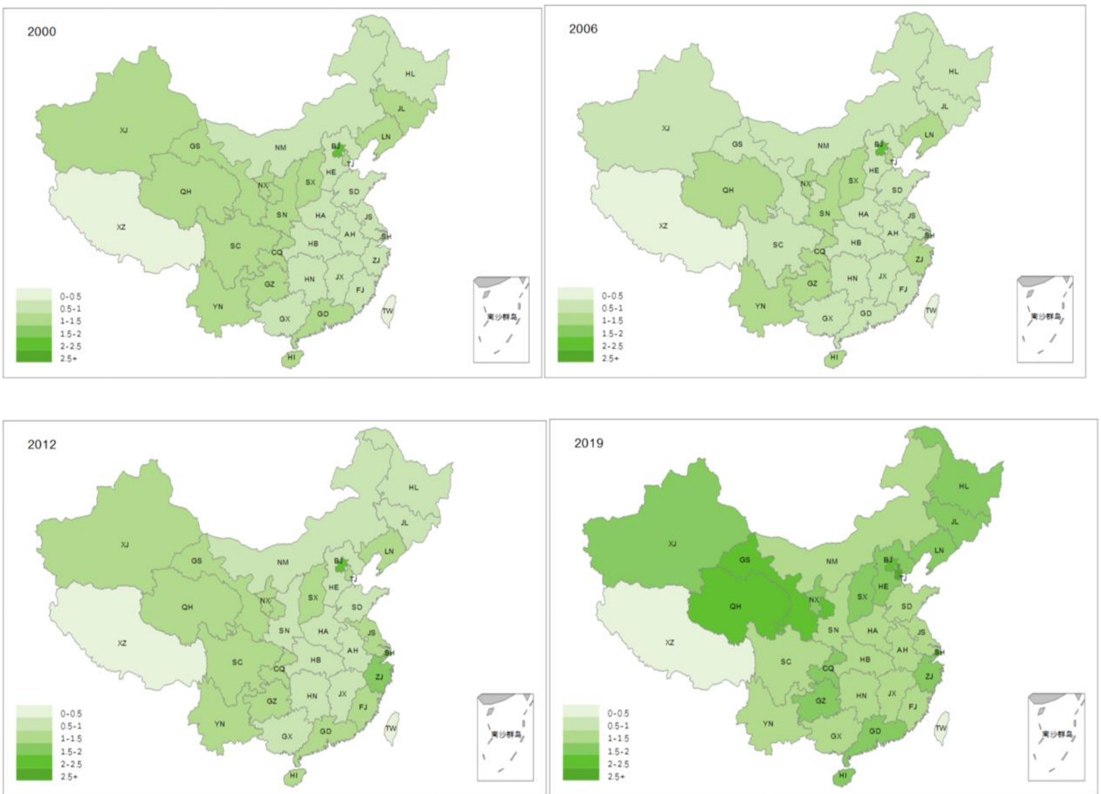


Figure 3 shows that from 2000 to 2019, the level of financial development in all Chinese provinces has grown significantly. Thanks to policies, some northwestern cities such as Liaoning (LN) and Qinghai (QH) have even achieved doubled financial development. The financial development of critical provinces, such as Beijing (BJ), Shanghai (SH), and Tianjin (TJ), typically exceeds those of other locations. The financial development levels of all provinces are spatially interrelated and have their characteristics. Figure 4 shows that from 2000 to 2019, most of China experienced very large financial growth. While financial levels were lower in 2006, such situations were quickly filled and surpassed. At the same time, it can be seen that the northwest (Qinghai and Gansu), eastern coastal areas (Heilongjiang, Jilin, Liaoning, Zhejiang) and important provinces (Beijing, Shanghai, Guangdong) have higher financial development than other provinces. The financial development levels of all provinces are spatially interrelated and have different characteristics

4.3 Results of economic globalization at the provincial level in China

I collected the GDP of each province in China and the total import and export volume of each province and city and the amount of foreign investment in each province and city from the China EPS database, then calculated the degree of trade openness and foreign capital dependence . The method used in this paper to measure trade openness and foreign capital dependence has been described above. Figure 5 shows the heat map of China's provincial trade openness (Figure 5) and China's provincial foreign investment dependence heat map (Figure 6).

Figure 5. Geographically distribution of China's provincial trade openness in selected years

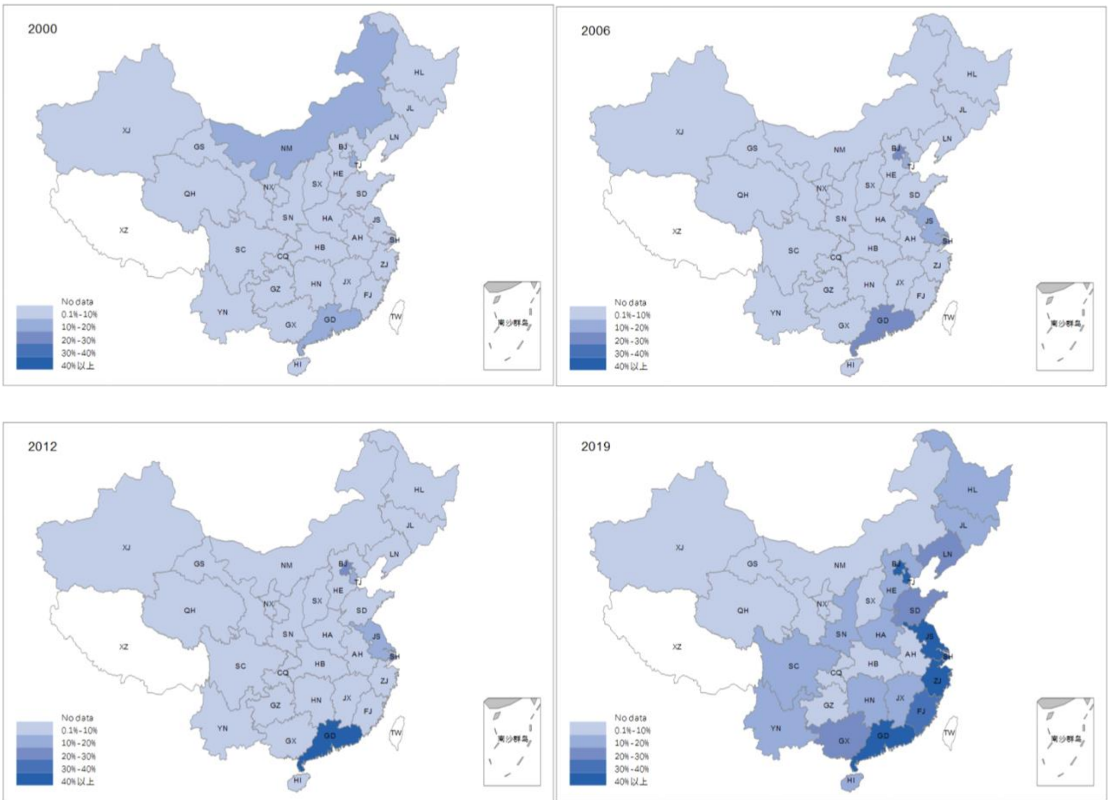
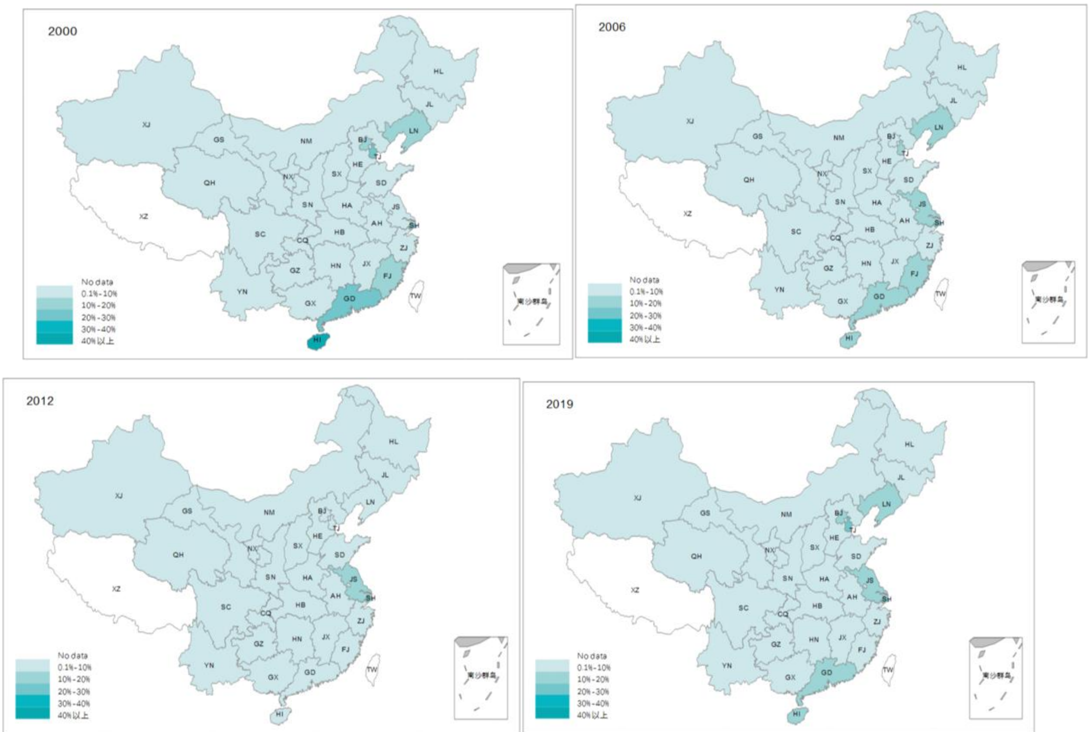


Figure 5 shows that the trade openness of various provinces and cities in China shows a very large gap. The southeastern coastal provinces and cities have become the regions with the strongest trade openness in the country. In 2000, except in Inner Mongolia (NM) and Guangdong (GD), there was little difference in trade openness among Chinese provinces and cities. After 2000, the trade openness of Inner Mongolia (NM) decreased and maintained a certain level of stagnation. It shows that the region's GDP and total imports and exports have not improved much. The regions with higher trade openness are Guangdong, Beijing, Jiangsu and Shanghai. In 2012, Guangdong (GD) achieved growth again, becoming the first region in the country to enter the trade level of 40%. In 2019, southern coastal cities such as Fujian, Zhejiang, Shanghai, Jiangsu, and northern coastal cities had achieved a greater degree of trade openness than Shandong, Liaoning, and Tianjin. This may be because these areas are coastal, so they have a better geographical advantage in trade. In contrast, Northwest's trade openness is lower and has not shown an upward trend in 19 years.

The heat map of China's provincial-level foreign capital dependence is shown in Figure 6. Foreign direct investment in China's provinces and cities has maintained a consistent trend from 2000 to 2019. In 2000 and 2006, we can see that Guangdong, Fujian, Shanghai, Jiangsu and Liaoning had higher foreign capital dependence than the national average. By 2012, the foreign capital dependence of China's provinces and cities was very similar, except for Shanghai and Zhejiang, which retained a slightly higher level. In 2019, foreign direct investment in China's provinces and cities rebounded to a level comparable to that of 2006. The foreign capital dependence of other provinces has not changed significantly.

Figure 6. Geographically distribution of China's provincial foreign capital dependence in selected years



As shown in Figure 5, the trade openness of China's provinces and cities has increased over the past 19 years. The eastern seaboard has the highest trade openness, while the Northwest has the lowest. Figure 6 shows that the change in foreign capital dependence of Chinese provinces and cities from 2000 to 2019 is very insignificant. Except for some southern and eastern coastal cities whose foreign capital dependence is higher than the national average, almost no significant increase or decrease has been observed in other regions.

Combining the four points of China's provincial carbon emissions, China's provincial financial development index, China's provincial trade openness, and China's provincial foreign investment dependence, several conclusions can be drawn: From 2000 to 2019, Northwest China, where carbon emissions have been at a high level The financial development level of the cities is also higher than the national average level, but the trade openness and foreign capital dependence of these cities are relatively low. This may be because the secondary industry that drives carbon emissions does not participate in import and export but rather plays a role in supplying the needs of local industries. The regions with the highest trade openness are China's eastern and southern coasts, and these provinces also have higher-than-average carbon emissions. However, the gap in financial development is not significant. For example, the financial level of Jiangsu and Fujian provinces is average, but the carbon emission and trade openness are very high. This may show a non-linear relationship that is not directly common among the three factors of carbon emissions, trade openness, and financial development. Finally, in general, the foreign investment dependence of Chinese provinces has not changed much. From this point of view, the rapid growth of high carbon emissions in the past 19 years may not be directly related to foreign direct investment but is caused by a combination of factors.

4.4 Spillover results of spatial Durbin templates

Table 3 demonstrates that the coefficient of direct influence of financial development is 0.409, which passes the 1% significance threshold. Moreover, the spillover coefficient is -0.973, which is statistically significant at the 5% level. The total coefficient of impact was -0.564, which was statistically significant at the 10% level. This collection of statistics indicates that in a certain location, every 1 percent rise in financial development would directly result in a 0.409% increase in local carbon emissions. This demonstrates that economic growth has a direct influence on carbon emission intensity. In addition, stronger financial development will spur growth in local carbon intensity. From the literature background, this may be because financial development can bring more capital inflows, population inflows, etc., thereby enhancing the economic vitality of the region, the income and consumption expenditure of the local population. In addition, the research indicates that financial development is a significant contributor to carbon emissions and may enhance output, hence increasing carbon emissions. However, Table 3 does not indicate the reduction of carbon emissions, indicating that the changes in the industrial structure brought about by financial development are minimal or not. Neighboring provinces gain the spillover effect of financial development, reducing carbon intensity by 0.973%. Speculation may be because, due to the improvement of financial development in a particular province, some enterprises will expand the production scale, which also drives people from other provinces in the region to work, produce and consume. This caused those provinces (where they came from, or their home province) to lose some level of production and consumption, resulting in a significant and immediate reduction in energy and carbon emissions in the region. The flow of financial resources between provinces, cities, and regions also helps renew the original industry and achieves a certain degree of emission reduction effect. Overall, carbon emissions development reduced the region's carbon emissions levels by 0.564%. The financial development of a province and city does not generally increase carbon emissions but suppresses the national carbon emission intensity.

The results regarding technology development (TE) are observed from Table 3. The direct effect coefficient of technological development is -0.932, which meets the significance level of 1%. The scientific and technical development impact coefficient is -1.49, which is statistically significant at the 1% level.   This shows that technological development has the effect of curbing carbon emissions. At the same time, for adjacent areas, technological development can also reduce carbon emissions. This shows that the development of high-tech can improve the existing high-energy-consuming, high-pollution industrial operation mode. The development of new and clean energy is the key to China's future carbon reduction.

In terms of the regional population (PO), industrial structure (IS), and foreign direct investment (FDI), a significance of at least 5% is observed. In terms of direct effects, they will all contribute to the growth of carbon emissions in the region to varying degrees. This shows that, from the current situation in China, neither labor inflow nor capital inflow has helped reduce carbon emissions. It may be because there is no reasonable allocation of funds and labor in the local area. One possible reason is that the local government failed to allocate capital and labor rationally and instead used it to promote production and consumption, resulting in an increase in carbon emissions instead of a decrease. Optimizing the economic and industrial structure is the key to minimizing carbon emissions, according to this perspective. Otherwise, no amount of labor and capital will only flow to the opposite environmental protection.

Table 3. Direct Effects, Spatial Spillover Effects, and Total Effects

Independent variable	Direct effect coefficient	Indirect effect coefficient	Total effect coefficient
lnFD	0.1603**	–0.6407***	–0.4804***
lnP	0.0683*	–0.3055***	–0.2372***
lnPGDP	–0.0203	–0.1853	–0.2056
lnIS	–0.2598**	0.3967*	0.1369
lnFDI	0.0323	0.1089*	0.1412**
lnEI	1.1222***	0.1934	1.3156***

Note: *, **, *** represent the 10%,5%, and 1% significant levels, respectively, and the standard errors are shown in brackets.

4.5 Horizontal comparison and prediction

Table 4 shows the results of spatial spillovers between China's provincial carbon intensity and financial development, population, GDP, energy intensity, industrial structure, and foreign investment calculated by Liu and Song (2020) using the spatial Durbin model. By looking at their research, I hope that it is possible to reasonably predict the evolution of spatial effects of China's carbon emissions and financial development, population, GDP, and other factors in the future. The following variables are covered in Liu and Song (2020): regional financial development (FD), provincial population (P), provincial GDP per capita (PGDP), provincial secondary industry structure (IS), provincial Foreign Direct Investment (FDI), Energy Intensity (EI). The calculation and definition of variables are the same as in this article, which is beneficial for the horizontal comparison of this paragraph in this article. They will not cause a deviation in understanding.

As shown in Figure 4, financial development will directly increase the local carbon emission intensity (significant at 5%). However, the spillover effect on the surrounding areas reduces the carbon emission intensity at the overall level. The same effect was shown on provincial population growth. The secondary industry and foreign direct investment have brought spillover effects to surrounding areas, leading to an increase in the carbon intensity of surrounding provinces. However, secondary industries directly reduce local carbon intensity. The first possibility is that due to the development of the regional economy, the space for production activities is insufficient, and it is gradually transferred to the surrounding areas. The second possibility is that the shift in the production center due to the increase in output is also indicative of the robust growth of the secondary industry (the carbon emission reduction brought about by the industrial transformation has not yet been realized), so the overall benefits are still positively correlated.

Table 4. Direct Effects, Indirect Effects, and Total Effects (Liu & Song, 2020)

Independent variable	Direct effect coefficient	Indirect effect coefficient	Total effect coefficient
lnFD	0.1603**	–0.6407***	–0.4804***
lnP	0.0683*	–0.3055***	–0.2372***
lnPGDP	–0.0203	–0.1853	–0.2056
lnIS	–0.2598**	0.3967*	0.1369
lnFDI	0.0323	0.1089*	0.1412**
lnEI	1.1222***	0.1934	1.3156***

Note. *, **, *** represent the 10%,5%, and 1% significant levels.
Source From : "Financial development and carbon emissions in China since the recent world financial crisis: Evidence from a spatial-temporal analysis and a spatial Durbin model. " By Liu, H., & Song, Y. (2020). *Science of the Total Environment*, *715*, 136771. Copyright 2020 by Liu, H., & Song, Y. (2020).

Compared to the findings of this research (Table 3), it is evident that, throughout time, all variables have had varying degrees of direct or indirect influence on carbon intensity. Financial developments and demographic changes have brought higher direct effects and more substantial spillover effects. This shows the heterogeneity of financial development and population; that is, the carbon intensity of surrounding areas has been alleviated while bringing higher carbon emissions to the local area. Both have the effect of curbing carbon emissions. We reasonably guess that this is due to the agglomeration brought about by regional economic development. People leave their hometowns and flock to provinces with better development, resulting in considerable differences in carbon emission intensity between regions. So as time goes by, this situation is still intensifying.

From the perspective of industrial structure, I observed that the direct effect showed a negative correlation from 2016 to a positive correlation in 2019. At the same time, both the indirect effect and the overall effect have a certain degree of growth with the passage of time. This may be due to the re-development of local industries or the return of the old industrial structure, which affects the overall carbon emission intensity. These figures, which are corroborated by the section on the literature assessment, demonstrate that the strong expansion of the secondary sector is still the primary driving force of China's energy transition, and China is still dependent on these secondary industries (energy-intensive industries), so this has led to several The period of 2016-2019 has greatly contributed to the growth of carbon emissions. Foreign investment, over time, still has significant positive spillover effects and is increasing.

5. Conclusion

This paper seeks to investigate the link between globalization, financial development, and carbon emissions and to identify novel geographical spillover effects at the province level in China by empirical analysis of the aforementioned data. First, this research studies the dynamic evolution and spatial-temporal pattern of China's province financial growth and carbon emissions. From 2000 to 2019, the carbon emissions of Chinese provinces and cities increased steadily, although the rate of rise has decreased considerably in recent years. Financial development, in general, has proliferated, especially after 2012. Restricted by the industrial structure, the areas with higher carbon emissions are mainly located in China's northern and northwestern regions, where there are energy-intensive industries. However, the level of financial development in these high-emitting cities is not high. In contrast, China's southeastern coastal cities and western provinces have higher levels of financial development. From the standpoint of policy execution, the Yangtze River Delta area has made a pretty effective transition to a low-carbon economy, and carbon emissions have stayed low for a number of straight years. The financial development level of these cities is also among the best in the country. The carbon emissions of various provinces and cities in China show an insignificant bipolar characteristic, mainly higher in Northwest China and lower in North and South China. In financial development, this north-south polarization is more prominent. Although the overall financial development level has been dramatically improved, and the gap between provinces and cities is gradually narrowing, the economic status of the western and southern coastal cities is still much superior to that of other provinces.

This research also employs the geographical spillover effect model to evaluate the probable association between China's degree of financial growth and carbon emission intensity in the 12 years after 2007. The findings indicate that both economic growth and population have a direct influence on the carbon intensity of local provinces and cities. In general, however, both have a reasonably positive impact on carbon emission intensity, both in nearby regions and in the overall evaluation. In contrast, foreign direct investment and the structure of the secondary industry contribute to carbon emissions, both directly and indirectly. Technological development has significant adverse spatial spillover effects and will be the key to China's future carbon reduction goals.

6. Policy Recommendations and the Two-Carbon Goal

From the above conclusions, it can be seen that China has made practical efforts in carbon reduction and has also obtained a certain degree of harvest. With such a vast understanding of national economic development, the pace of increase in carbon emissions has moderated. However, in the face of rising carbon emissions, China faces enormous challenges to achieving the dual goals of "carbon neutrality" and "carbon peaking" by 2030 and 2060. What else can China do to achieve its carbon reduction plan while profiting from a growing economy?

Firstly, based on the established regional spillover effects of economic growth, it is evident that both financial development and population have a negative impact on China's carbon emissions. This decrease in emissions is a result of the movement of economic output across areas. Similar performance may also be seen in the geographic spillover effect of the secondary industrial structure. The government should reject the conventional "production first" philosophy and concentrate on altering the current industrial structure. Limited financial resources and talent should be used to reduce carbon emissions instead of driving production again. Promoting the shared sustainable growth of businesses and the environment is the first step in achieving a transition to a low-carbon economy.

Second, due to the observed regional polarization, carbon reduction policies should be tailored to local conditions and avoid imposing one policy on all regions. The financial development of southern coastal cities is fast, and the transition to carbon reduction is also relatively successful. While stabilizing the existing results, the experience and lessons should be passed on to other cities rapidly developing their economies to replicate the "success". Of course, no country is inseparable from production and manufacturing, especially China, which has a huge population base, vast geography, and a rise in manufacturing. A more stringent carbon reduction policy should be implemented in the northwest region, where carbon emissions remain high. By restricting the new production capacity of traditional industries, we can urge the transformation of the original traditional production methods as soon as possible and force these high-polluting and high-emission energy companies to speed up the transformation process. In order to better monitor these companies to join the ranks of emission reduction, the government can set up a "carbon disclosure" platform. To put it simply, it is to publicly disclose the information related to carbon emissions of enterprises to investors and the public in a proper, comprehensive, timely and sufficient manner and publish it on the government's information website or paper media. This information can not only facilitate government departments and financial institutions make a comprehensive assessment of climate risks and help the government implement effective supervision and policy formulation. For enterprises, the disclosure of their carbon information reduces the risk of carbon management and provides a basis for formulating low-carbon strategies and low-carbon management decisions. At the same time, it is also an important reference condition for investors to make investment decisions. In addition, carbon information disclosure is conducive to giving full play to the supervision power of the public.

At the same time, it can be seen from the spatial spillover effect of technology that the government should also focus on the development of clean energy and new energy and promote the progress and innovation of new technologies. For example, strengthening energy storage, developing smart grids, accelerating research and development, promoting new energy vehicles and hydrogen fuel cell vehicles, etc. This is the most powerful and reliable driver for achieving the "two-carbon" goal. Moreover, due to the huge amount of funds required for new energy and new technologies, it is recommended that China strengthen the financing for new energy and clean energy in the future to help accumulate sufficient development funds for the "dual carbon" goal. Research results show that to achieve "carbon peaking" in 2030, the annual capital demand is about 3.1-3.6 trillion yuan[13]. To achieve "carbon neutrality" by 2060, an additional investment of more than 139 trillion yuan will be required. However, the large funding gap and low local enthusiasm have always been key problems in China's realization of the "dual carbon" goal. In the future, China must thus continue to enhance the investment and financial structures and procedures associated with carbon emission reduction, increase capital sources and local financial input, and promote local "carbon peaking" and "carbon neutrality".

The literature assessment indicated that China's carbon emissions are mostly driven by its industrial structure, energy consumption per capita, and living consumption.

[13] 陈国英. "双碳"目标下我国碳排放政策的发展及展望[J]. 长江技术经济, 2021, 5(6):4.
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Adjustments may be made to the industrial structure in order to phase out fossil-based output. Living consumption can be achieved by reducing green travel and environmentally friendly packaging. So how can per capita energy consumption be reduced? The Chinese government should introduce laws and regulations to strictly limit the waste of resources and the crackdown on enterprises and individuals who use resources opportunistically. For example, housing in major provinces and cities in China is used as a tool for appreciation and profit. In the hands of companies and individuals with strong assets, many resources are wasted, and a bubble economy emerges. This is a potential threat to China, which is developing rapidly. It may not only lead to the collapse of the financial system but also is not good for social stability and harmony. In response to such problems, the Chinese government should take the initiative to intervene in the purchase policy, set up purchase restrictions, and strictly prohibit real estate speculation for huge profits. Turn housing issues into regular consumption that is fairer and more reasonable for all. Concurrently, promote green and low-carbon buildings, encourage young people to rent housing, etc., in order to redistribute scarce resources.

Again, in the table of spatial effects, it is observed that the direct, indirect and aggregate effects of foreign investment are all very high and increase over time. This means that foreign direct investment brings significant and persistently high carbon emissions. Therefore, it is suggested that the government improve the foreign investment access system in terms of foreign direct investment, and strictly prohibit the entry of industries with high carbon emissions, to prevent China from becoming a "paradise" for other countries to transfer pollution. In addition, the entry threshold for foreign investors needs to be raised again. The Chinese government should learn from and welcome companies that bring high-tech. For foreign companies that overlap with traditional industries, the Chinese government needs to measure their entry into the Chinese market. Necessity should not be rejected.

In addition, from a globalization viewpoint, China should work on reducing the negative environmental effect of trade in terms of trade openness. The Chinese government should introduce new structures and products that can reduce emissions, increase the original energy efficiency, and achieve a green internal cycle. At the same time, optimizing the structure of export commodities to limit high-energy-consumption and high-polluting products means that China's exports have become cleaner due to globalization.

Finally, globalization led by China should be the right path for the world to develop low-carbon trade together. China's voluntary "dual-carbon" goal enables China to face such an era full of opportunities and challenges. However, the completion of the goal must not rely on the transfer of responsibility but clear policy supervision and technological development in key areas. China may cut carbon emissions by emphasizing the creation of clean energy rather than exporting carbon-intensive goods, and globalization of manufacturing makes China's exports cleaner (Zhang et al., 2020). In addition, China's Belt and Road Initiative will increase trade and economic growth in most nations along the path, both now and in the future; nevertheless, it will also increase carbon emissions to some degree. (Hu et al., 2020)

China, as a proponent of the Belt and Road Initiative, should thus take the initiative to reduce emissions. Concurrently, China should promote the development of green energy and technology to assist other nations in mitigating rising carbon emissions while achieving trade liberalization and economic growth. All Belt and Road nations should also work together to construct a green Belt and Road and develop carbon reduction policies and objectives. (Hu et al., 2020) These efforts are not ephemeral and are of enormous relevance and service to the globe.

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