Influence Mechanism of County Scale and Structure on the Household Carbon Emissions and its Planning Strategies

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Abstract. In order to achieve China's national contribution goal of 60% to 65% reduction in CO2 intensity per unit of GDP from 2005-2030 at the climate conference in Paris, China needs to make more efforts in low carbon development. The county is an important level for China's urban-rural carbon and oxygen planning, and it still has a large potential for carbon emission reduction. This study mainly explores the influence mechanism of county scale and structure on household carbon emissions. First of all, I build a county scale and structural factor index system, and analyse the impact mechanism on this basis. Secondly, I select 10% of the county-level administrative units, and empirically analyse the relationship between factor indicators and the household carbon emissions in terms of population, economy and land use. Finally, based on the results of the empirical analysis, the impact mechanism is re-discussed, and the corresponding county planning strategy is proposed accordingly. The results of this study and policy recommendations have guiding significance for promoting institutional arrangements for low-carbon development in counties.

1. Introduction
Since the 1970s, people have realized that the high energy consumption caused by industrial civilization is a crisis for the human settlements. Achieving the goal of low carbon in cities is the key to solving climate problems. Researchers have systematically explored the scale of cities, spatial structural elements and their impact mechanisms that affect urban carbon emissions. Dietz et al.'s STIRPAT model provides a method for decomposing the elements of human activity and analysing its causal relationship to environmental impact [1]. Based on the STIRPAT model, studies by Birdsell and Lonnren K et al. show that the growth of urban population size and the growth of greenhouse gas emissions are synchronized [2]. Alametal conducted an empirical study of the relationship between urban size and carbon emissions in Pakistan, and found that the growth of carbon emission levels and the improvement of urbanization levels are related [3]. Another classic model for carbon emission drivers is Kaya's identity. Luciano Charlita analysed the factors of Ireland's 1970-2009 CO2 emissions and other scholars applied similar methods to Ireland, South Korea, Mexico and other regions. The results show that the growth of urban economic activities and permanent population are the most important factors of affecting the increase of carbon emissions. Wu Junkui studied the impact of urban scale and spatial structure elements on carbon emissions and the mechanism of action, and found that compact urban structure can significantly reduce urban carbon emissions [4]. Wang Guixin's research shows that the disorderly expansion of urban scale leads to low urban space utilization efficiency, affects urban carbon emissions, and provides a policy path for low-carbon urban development [5]. In summary, the population, economic and land use scale elements have different mechanisms for carbon emissions, but their impact mechanism at the county scale and the perspective of household carbon...
emissions needs to be further studied.
Therefore, this study analyses of the impact mechanism of county household carbon emissions, establishes the county scale structure index system, and analyses the impact of scale structure factors on carbon emissions based on the previous research results, combined with the particularity of China’s county towns, The impact mechanism and related characteristics of different indicators are obtained, and corresponding planning and control recommendations are proposed accordingly.

2. the Influence Mechanism of Scale and Structure Elements on Household Carbon Emissions

The concept of urban carbon emissions refers to the general term for CO2 emissions generated by energy consumption during urban industrial production, residential life and transportation. Household carbon emissions are an important dimension of urban carbon emissions. The city scale is an indicator to measure the size of the city. It mainly includes three aspects: urban economic scale, population size and space scale. The impact mechanism of household carbon emissions can still be divided into the above three key factors.

From the perspective of demographic factors, the impact mechanism of population size factors on household carbon emissions is mainly reflected in the total amount and population structure: 1) the growth of total population directly leads to the growth of household carbon emissions; 2) the growth of population size brings about structural changes in population. It also has a positive or negative impact on carbon emissions. Studies have shown that the impact of urbanization on carbon emissions presents an inverted U-shaped curve \[6\], but at the current level of development, most cities in China have not yet reached the inflection point \[7\]. The geographical distribution pattern of population also has an impact on carbon emissions. Urban carbon emissions are generally more than suburban arable land, and population movement between urban and rural areas has a significant impact on urban ecology \[8\].

In terms of economic factors, the city is the product of agglomeration economies. From the perspective of urban residents, the difference in economic development and wealth level leads to differences in household living methods such as consumption levels, and occupational residence patterns, which in turn leads to differences in carbon emission levels \[9\].

The impact of land use scale on carbon emissions is reflected in the land use intensity, that is, the total amount of land used; on the other hand, it is reflected in the land use efficiency, that is, the compactness of the land. Existing studies have shown that the spread of urban construction land will affect the choice of commuting distance and the mode of transportation.

Based on the above analysis, it is proposed to construct a scale structure factor index system that affects the carbon emissions of residents. It is divided into three dimensions: population, economy and land use. They all include two-dimensional indicators: aggregate and structural indicators. This research will conduct a correlation test on the indicator system and household carbon emission to clarify the impact mechanism of each element.

| Table 1. Selection of scale structure indicators |
|-----------------------------------------------|
| **Dimension** | **Aggregate indicator** | **Structural index** |
| Population | Urban population size (UPS) | Urbanization level (UL) |
| | Proportion of county district population (PCDP) | Proportion of county district population (PCDCL) |
| | Urban population density (UPD) | Location quotient of population density (LQPD) |
| Economic | Secondary and tertiary industry GDP(ST-GDP) | Per capita secondary industry and tertiary industry GDP(PER-GDP) |
| | Proportion of secondary and tertiary industry GDP (PRO-GDP) | |
| Land use | Construction land scale (CLS) | Proportion of county district construction land (PCDCL) |
| | | Location quotient of population density (LQPD) |
3. Research methods and data acquisition

3.1 Sample selection method
Firstly, this paper selects 2015 as the time point of research. According to the situation of China's administrative divisions in the year, the sample population of 1896 county and county-level municipal administrative units was determined. Secondly, this paper divides the samples of all counties into three groups and applies the K-means clustering method of SPSS to select experimental sample. The cluster mainly considers the two aspects of development scale and development level. The population size represents the development scale of the county, and the GDP per capita GDP represents the development level of the county. Finally, the samples with missing data were excluded, and the sample size of this study was selected according to 10% of all county-level sample populations, and 190 samples were obtained as the research object.

3.2 Measurement methods and data acquisition
In general, the household carbon emissions can be divided into five aspects: cooking, lighting, electrical appliances, building warming and transportation. The first four categories can be collectively referred to as residential building carbon emissions. Expressed by the formula:

\[ C_{\text{Resident}} = C_{\text{House}} + C_{\text{Traffic}} \]

(1) The carbon emissions of residential buildings can be divided into three aspects: electricity, gas, and energy consumption. Data were obtained from the 2015 annual statistical yearbooks of provinces, prefecture-level cities and counties. The process of converting energy consumption data into carbon emissions first converts various energy consumption into standard coal equivalents. Further, according to the emission factor provided by the IPCC 2006 greenhouse gas emission inventory, it is further converted into carbon emissions. The formula can be expressed as:

\[ C_{\text{House}} = C_{\text{gas}} + C_{\text{electric}} = p_g * E_{\text{gas}} + p_e * E_{\text{electric}} \]

Where \( C_{\text{House}} \) represents the total carbon emissions of the building, \( C_{\text{gas}} \) represents the total carbon emissions, \( C_{\text{electric}} \) represents the total carbon emissions, \( p_g \) and \( p_e \) represent the carbon and electricity carbon emission coefficients, respectively, and \( E_{\text{gas}} \) and \( E_{\text{electric}} \) represent the total energy consumption of gas and electricity.

(2) Residents travel carbon emissions are a very important part of residents' carbon emissions. No direct energy consumption data can be obtained. According to the existing research, the private car ownership can be converted into energy consumption. It is converted into carbon emissions based on the carbon emission factor provided by the IPCC. According to estimates, Chinese private cars travel an average of 15,000 kilometers per year, averaging 8.6 liters of gasoline per 100 kilometers \(^{[10]}\). The formula is expressed as:

\[ C_{\text{Traffic}} = PCV * AAM * AFC \]

In the formula, \( C_{\text{Traffic}} \) represents the total amount of carbon emissions from transportation, \( PCV \) represents the number of private cars, \( AAM \) is the average mileage, and \( AFC \) is the average fuel consumption. The data on the number of private car ownership comes from the annual Statistical Bulletin of each city and county.

4. Empirical research and analysis of results

4.1 Analysis of the relationship between population factors and household carbon emissions
(1) Empirical test results
The urban population size, urban population density, county population ratio and urbanization level are analysed by bivariate correlation with total household carbon emissions and per capita household carbon emissions, and the elasticity of each relevant indicator is obtained by fitting the scatter plot trend line. Trends, the results are shown in Table 2:
Table 2. Correlation analysis between population factors and household carbon emissions

|                      | UPS  | UPD  | PCDP | UL   |
|----------------------|------|------|------|------|
| Total household carbon emissions | Pearson correlation | .430** | - .020 | .209** | .142 |
|                      | Significant (two-tailed) | .000 | .782  | .004  | .053  |
| Per capita household carbon emissions | Pearson correlation | -.127 | -.145* | .409** | .035 |
|                      | Significant (two-tailed) | .083  | .050  | .000  | .633  |

(2) Analysis of the impact mechanism

At the county level, urban population size and total carbon emissions are positively correlated, while urban population density is negatively correlated with per capita carbon emissions. This shows that population growth will inevitably lead to an increase in total carbon emissions, but increasing population concentration will help reduce carbon intensity. According to the environmental Kuznets theory, the expansion of scale will lead to greater environmental impact in the early stage of urbanization. The proportion of the county district has a significant positive impact on the total carbon emissions and per capita carbon emissions. This indicates that the population of the county district has more pronounced promotion of carbon emissions than its town area population. This is because that there is more lighting and heating demand, and more car usage needs in the county districts.

Unlike the existing research, the level of urbanization is not related to the total household carbon emissions and per capita household carbon emissions. The urbanization level is an important variable affecting carbon emissions at the urban level but not at the county level. It may be due to the significant difference between the living standard in the county district and the county town. This indicator includes both types of population in the urban population calculation, so that the real impact of carbon Excessive estimates of the size of the population emitted result in inaccuracies. Conclusion of population factor analysis indicating that China's county is still in a state of extensive growth, and it has not reduced the overall environmental cost of the county due to population growth.

4.2 Research results on the impact of economic scale structure and household carbon emissions

(1) Empirical test results

The urban economic scale, the proportion of secondary and tertiary industry GDP, the per capita secondary and tertiary industry GDP, and the total household carbon emissions and per capita household carbon emissions were analysed by bivariate correlation. The results are shown in Table 3:

Table 3. Correlation analysis between economic factors and household carbon emissions

|                      | ST-GDP | PER-GDP | PRO-GDP |
|----------------------|--------|---------|---------|
| Total household carbon emissions | Pearson correlation | .544** | .179*  | -.043  |
|                      | Significant (two-tailed) | .000  | .014   | .557   |
| Per capita household carbon emissions | Pearson correlation | .155*  | .260** | -.026  |
|                      | Significant (two-tailed) | .035  | .000   | .728   |

(2) Analysis of the impact mechanism

The scale of urban economy has a significant correlation with the total amount of carbon emissions,
and has a general correlation with per capita carbon emissions. This shows that the economic scale as an important indicator to represent the level of county economic development has a significant relationship to the growth of household carbon emissions. The growth of China’s county economy has led to an increase in the population's ability to consume, but it has not formed environmental awareness and energy saving system. Therefore, county-wide extensive consumption growth will inevitably lead to an increase in the total carbon emissions.

Per capita secondary and tertiary industry GDP has a significant correlation with per capita carbon emissions, and has a general correlation with total carbon emissions. This shows that per capita secondary and tertiary industry GDP as a representative indicator of the living standard and consumption level of the residents promotes the growth of carbon emission intensity more than the total growth. This also shows that not only between urban and rural areas, but also between towns and cities, the expansion of income levels and living standards will lead to more energy consumption, and will promote the “high carbonization” of personal travel habits, which will result in more carbon emissions.

There is no correlation between the proportion of secondary and tertiary industry GDP in the county to carbon emissions and per capita carbon emissions. This result indicates that the industrial development structure of the county has no positive or negative impact on the living environment, which is consistent with the low-level development of the county. The level of urbanization of industry is related to the level of high-end industry development. The high-level urbanization space of high efficiency, energy conservation and intensiveness has not been fully formed in the county of China.

4.3 Research results on the impact of land use size structure and household carbon emissions

(1) Empirical test results

The two-variable correlation analysis was carried out on the scale of urban construction land, the proportion of land used for construction of county district, the location density of county population, and the total carbon emissions and per capita carbon emissions. The results are shown in Table 4:

| Total household carbon emissions | Pearson correlation | CLS | PCDCCL | LQPDP |
|----------------------------------|---------------------|-----|--------|-------|
| Per household capita carbon emissions | Pearson correlation | -.014 | .312** | -.030 |
|                                   | Significant (two-tailed) | .849 | .000 | .682 |

As shown in the data table, the total amount of carbon emissions is significantly related to the scale of urban construction land use and proportion of county district at the level of 0.01. Per capita carbon emissions and proportion of county district are significantly correlated at the level of 0.01.

(2) Analysis of the impact mechanism

The proportion of county district construction land have a strong correlation with total carbon emissions and per capita carbon emissions. Compared with the total indicators, the land use structure characteristics are often more positive for county carbon emissions control. The planning mode of the scale of the county district area has a strong correlation effect on the development of low carbonization in the county.

The total amount of construction land has a strong correlation with the total amount of carbon emissions, indicating that the expansion of construction land is an increase in the size of the
population, the expansion of the economic aggregate in space, and a certain correlation with carbon emissions. At the county level, the expansion of construction land did not bring good environmental benefits, and the spread of land on a larger scale caused more carbon emissions. Expanded but not intensive space pattern in the county areas has caused a dramatic increase in the consumption of living energy, and due to the low concentration of population and economic factors, it has resulted in extensive growth and low-efficiency development models.

5. Management and control strategy of county scale structure elements based on reducing household carbon emissions

5.1 Development strategy of population factors
(1) Control the population size of county districts and towns. Empirical studies show that the expansion of county population will lead to accelerated growth of carbon emissions. This shows that the scale of an oversized county is not an energy-efficient urban development model. It should appropriately control the population size of the county, control the disorderly expansion of county towns.

(2) Moderately increase population density and reduce urban carbon emissions. Most counties in China adopt an extensive development model, and even residents’ living space exceeds the needs of residents. The occupancy rate in the residential areas in counties is low and the habitat pattern is more dispersed. Moderately increasing the density of population living and degree of population concentration will help reduce commuting energy consumption and improve the efficiency of public service applications, thereby reducing carbon emissions in urban life.

5.2 Development strategy of economic factors
(1) Transforming the energy consumption structure in the process of economic development. In order to realize the development of energy conservation and carbon control in the county, we should actively seek the transformation of the economic development model, increase the use of clean energy, and promote the use of more green and clean energy such as wind energy and hydropower in the industry.

(2) Advocating low-carbon consumption. At the county level, the economic level of counties and towns is much higher than that of non-urbanized areas. At the same time, the electricity, gas and other energy consumption of living needs are also greater, while residents travel more dependent on cars. The government should vigorously promote the lifestyle of low-carbon consumption in counties and improve the efficiency of living energy consumption.

5.3 Development strategy of land use factors
(1) Intensive construction land and strict ecological red line. Local governments should actively seek to allocate existing construction land and intensive urban space. On the other hand, strictly adhere to the ecological red line, actively cultivate the ecological environment and improve the greening level of counties and towns.

(2) Actively develop small and medium-sized cities and towns and strictly control the scale of the county districts. We should aim at the development of low-carbon cities, explore the potential of emission reduction in existing cities, strictly control the scale of county districts, and actively deploy small towns.

6. Summary
The research in this paper shows that the county's population, economy, and land use scale structure elements have different influences and mechanisms on residents’ carbon emissions. Based on this conclusion, the planning development strategy of the three element systems is proposed. It has guiding significance for the rational planning of county districts and towns in the future and the promotion of institutional arrangements and sustainable development of low-carbon development in the county.
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