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The Peer Effects of Residents' Carbon Emission Behavior: An Empirical Analysis in China

Congxian He [1,2], Ruiqing Shi [3] and Huwei Wen [4,*]

[1] Soviet Area Revitalization Institute, Jiangxi Normal University, Nanchang 330022, China; 005693@jxnu.edu.cn
[2] Research Base for Revitalization and Development of Old Revolutionary Base Areas of Jiangxi Province, Jiangxi Normal University, Nanchang 330032, China
[3] School of Marxism, Jiangxi Normal University, Nanchang 330022, China; 202340100495@jxnu.edu.cn
[4] School of Economics and Management, Nanchang University, Nanchang 330031, China
* Correspondence: wenhuwei@ncu.edu.cn

Abstract: The responsible low-carbon behavior of household residents is a crucial factor for the purpose of achieving carbon neutrality in the economy and society. Based on the peer effects theory, this study constructs a fixed-effects model to empirically analyze the existence, heterogeneity, and action mechanism of peer effects in household carbon emission behavior, which uses panel data from the China Household Finance Survey (CHFS). The results indicate that peer effects have a significantly positive impact on residents' carbon emission behavior, and the results are verified by the robustness test in various ways. Further mechanism tests show that peer effects influence carbon emission behavior through methods including the learning imitation mechanism and competitive imitation mechanism. In addition, we find that peer effects have different impacts on residents' carbon emission behavior in varying regions, income levels, education levels, and ages groups. This study aims to embed residents' carbon emission behavior into the strong relationship between surrounding groups, raise consumers low-carbon awareness through publicity, guidance, and group interaction, form a low-carbon atmosphere for the whole society, and contribute to the realization of Sustainable Development Goals.

Keywords: residents; carbon emission behavior; peer effects; China

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1. Introduction

Green development, energy conservation, emission reduction, and environmental regulation have become hot issues around the world because of the increasingly prominent global problems such as the greenhouse effect and environmental pollution [1,2]. Over the decades, the governance of climate change has mostly focused on the field of production, believing that the greenhouse effect caused by carbon emissions was mainly the result of production activities, and once ignored and underestimated the ecological and environmental impact of residents' carbon emission behavior. With the rapid growth of people's income, consumer demand and consumption power have increased significantly. Global warming is inseparable from residents' activities. Residents' carbon emission behavior not only directly increase the pressure on the ecological environment, but also send signals to the production field to affect the carbon emission at the production end, which indirectly harm the ecological environment.

Residents' activities, as the second largest energy consumption sector, has become an important source of carbon emissions. In 2015, the United Nations Sustainable Development Goals [3] clearly proposed to ensure sustainable consumption and production patterns, requiring the systematic participation and cooperation of all actors in the whole production and consumption supply chain process, and emphasizing that consumers accept sustainable consumption and lifestyles. According to the estimation of the United Nations Environment Program (2020) [4], residents' carbon emissions currently account for

about two-thirds of the total global carbon emissions. It can be seen that the low-carbon transformation of residents' activities will become an inevitable choice to realize green and low-carbon economic development. Some scholars have empirically analyzed residents' carbon emission behavior from a theoretical perspective [5], and a green lifestyle should be encouraged [6].

Low-carbon emissions are an inherent requirement for high-quality economic development. Promoting carbon emission reduction from the consumption side and realizing green economic development has become a key topic in current world development. Some scholars have studied sustainable development from the perspective of economic development and energy consumption and believe that economic growth and the ecological footprint present a bi-directional causality relationship [7–9]. In addition, some scholars believe that residents' lifestyles directly affect residents' carbon emissions. In this study, we enumerate some of our views on the factors affecting carbon emissions, as shown in Table 1.

Table 1. An analysis of the literature on the influencing factors of carbon emissions.

Influencing Factors	Viewpoint	Authors
Economic development and energy consumption	Economic growth and the ecological footprint showed a bi-directional causality relationship.	Destek and Sarkodie, 2019 [8]
	Environmental sustainability is the main concern of modern society, and the relationship among financial development, energy consumption, and carbon dioxide emission dynamics was analyzed.	Sheraz et al., 2021 [9]
	Examined the relationship between energy production, CO_2 emissions, and economic growth in Iran.	Ahmad and Du, 2017 [7]
Lifestyle of residents	People spend most of their life in buildings, and in order to meet occupational activities and thermal comfort, they have a large demand for energy consumption.	Fumo et al., 2015 [10]
	Analyzed the environmental impact of household consumption products and services in terms of greenhouse gas emissions.	Ivanova et al., 2016 [11]
Green and low-carbon behavior	Environmental pollution perception, publicity activities, and government incentives will stimulate residents' green behavior.	Zhang et al., 2019 [12]
	Reforming residents' behavior could effectively slow down climate change.	Guo et al., 2018 [13]
	Calculate the carbon footprint of residents' online consumption, and encourage residents to adopt a low-carbon lifestyle.	Long et al., 2023 [6]

Some authors believe that residents' behavior has triggered a large number of economic activities in the consumption of products and services [14]. Some of the literature has analyzed and tested many factors that affect residents' economic activities and believe that different consumer groups, income levels, precautionary savings, future risk predictions, credit constraints, e-commerce development levels, and public support policies will have different impacts on residents' behavior [6,15–18]. As the main body of social life, the strengthening of social interaction makes residents' decision-making behavior vulnerable to the influence of others, and the decisions among residents also show more and more obvious synchronicity.

Humans beings are social animals, so the behavior of surrounding groups will have an impact on their actions. William (1987) formally proposed the peer effects mechanism, also known as neighborhood effects in his book. In the sense of economics, peer effects means that when people make decisions in the face of market choices, they will be influenced by people with similar economic and social status. Some scholars focus on peer effects in the financial field. For example, corporate capital structure and financing decisions [19], dividend policy [20], corporate investment decisions [21], and other corporate financial decision-making behavior are significantly affected by peers. On this basis, from the perspective of interactions between individuals and society, many scholars have broadened the

research horizon to the influence of group behavior and the surrounding environment on individual residents; to be specific, they examined the interaction effects of group behavior on individuals in areas such as household consumption, personal health, employment, and adolescent growth. Scholars generally believe that peer effects exist in total household consumption expenditure, education expenditure, and favor expenditure [22–24]. To sum up, scholars have analyzed the existence of peer effects from different perspectives and basically recognized peer effects have some level of influence on residents' behavior. In the field of energy consumption, some empirical studies have found that social interaction can promote the diffusion of public low-carbon behavior and new energy technologies [25]. However, few empirical studies could be conducted from the perspective of peer effects.

This paper takes residents' carbon emission behavior as the research object, uses data from the China Household Finance Survey (CHFS) conducted in 2011, 2013, and 2019 to study peer effects from the perspective of social interaction among community residents. We find that peer effects significantly exist in residents' carbon emission behavior. After the robustness test, the results are still significant; there are peer effects in residents' carbon emission behavior. In addition, travel mode and household head's education level are included in the regression equation as proxy variables of lifestyle and social status pursuit, respectively, to test the mechanism of peer effects. The results show that peer effects affect residents' carbon emission behavior through the learning imitation mechanism and competitive imitation mechanism. Further tests show that the peer effects of carbon emission behavior is heterogeneous in different regions and residents' personal characteristics, and peer effects are more obvious among urban residents, middle- and low-income families, residents with a low education level, and elderly residents. We put residents' behavior under the framework of peer effects, deeply discuss the relationship between residents' carbon emission behavior, and the influence of surrounding groups. We aim to reveal how group interaction affects residents' carbon emission behavior, so as to provide a strategic reference for different actors such as the government, social groups, and enterprises, effectively guide and standardize residents behavior, create a positive social learning environment, and improve residents' green lifestyle awareness. Promoting the actual effect of low-carbon emission reduction, which is of great significance to attaining the long-term goal of sustainable development.

Compared to the existing literature, this thesis raises four notable contributions. First, this paper draws on the consumer lifestyle and the input–output theory to scientifically measure the scale of residents' carbon emissions, which offers a new point for the study of carbon emission. Second, based on the sustainable development and the peer effects theory, the direct impact of peer effects on residents' carbon emission behavior is demonstrated from a social group perspective in our study. Recently, some scholars have explored the influencing factors of carbon emissions from the aspects of economic development, personal behavior, and consumption habits [26–28]. Social interaction has a profound impact on individual behavior, but most scholars have ignored the effect of observational and imitation learning of social groups on their own behavior. Third, based on the social learning theory [29] and Maslow's demand theory [30], the paper has analyzed the influencing mechanism of carbon emission behavior from two aspects including the learning imitation mechanism and competitive imitation mechanism, namely, lifestyle choices and the pursuit of social status, which relates to the scientific nature of peer effects' impact on carbon emission behavior and expands the research framework of carbon emission behavior. Fourth, the scheme of enhancing the awareness of green behavior and promoting carbon emission reduction is put forward including the aspects of government departments, enterprise production, social publicity, and individual residents, based on research showing that low-carbon activities are embedded in the strong relationship with surrounding groups, from the perspective of the demonstration effect of surrounding groups. It has implications for promoting low-carbon emissions and the realization of Sustainable Development Goals.

The following is the article structure. Section 2 introduces theoretical and research hypotheses. Section 3 documents the data and empirical analysis. Section 4 explains the

results of the impact of peer effects on residents' carbon emission behavior. Section 5 provides the research conclusions and corresponding policy recommendations. Based on the above, Figure 1 presents the framework of this study.

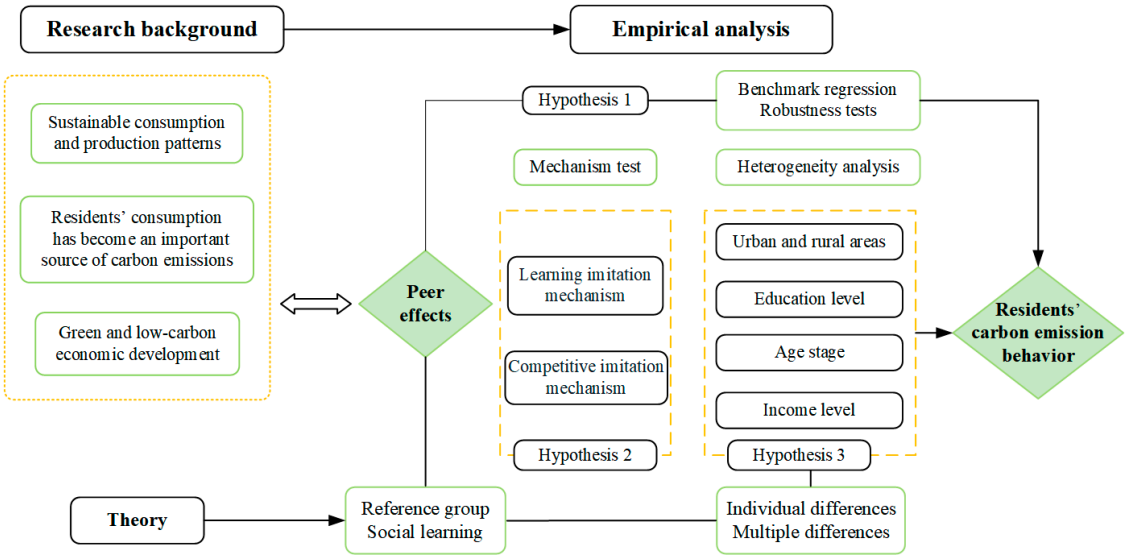


Figure 1. The framework of this study.

2. Theoretical Analysis and Research Hypotheses

Social interaction effect means that personal preferences, anticipation, and constraints are immediately affected by others, and individual behavior is affected by the presence of others [31]. When individuals exchange information with each other, the process of alliance will unfold over time and space, resulting in a kind of social interaction [32]. Based on the social interaction theory, individual behavioral decisions will be affected by neighborhood groups and surrounding people, which is called peer effects. Residents can obtain instrumental support from economic resources embedded in peer relations, and then make utility-maximizing choices for their economic decisions and behavior. The higher the individual social interaction is, the stronger the impact that peer effects have. Human behavior in important economic fields is usually influenced by surrounding groups, and environmental factors or others' behavior are often more evident than personality characteristics [33,34]. In recent years, some scholars have concentrated on the influence of peer effects on residents, such as in movie choice, fast food consumption, and weight gain [35–37]. There is interdependence and a learning demonstration effect between the behavior of individuals and surrounding groups, and the neighborhood environment may affect individual decisions and results [38]. Therefore, we believe that individuals living in different social groups are bound to be affected by group norms and pressure when taking actions, and that residents' carbon emission behavior will have a herd effect. Consequently, this paper puts forward the following hypothesis.

Hypothesis 1. *There are peer effects in residents' carbon emission behavior.*

There are two perspectives explaining the peer effects mechanism. The first is the learning imitation mechanism, which refers to the subtle way in which surrounding groups change an individual's behavioral attitudes or values, thereby influencing their lifestyle through the individual's attitudes, self-identity, and perceived behavioral control [39,40]—a concept encapsulated in the adage "keep company with the red and you become reddened; keep company with the black and you become blackened." The second is the competitive imitation mechanism. According to social behavior theory, people adjust their behavior by imitating their peers in order to showcase their social identity, self-image, and reputa-

tion [41]. When they sense an increase in inequality, they have a strong motivation to imitate and follow others, driven by a compulsion to elevate their social status, thus establishing the dominant mechanism of social status seeking [42]. Based on the above analysis, this paper considers two potential mechanisms of the peer effects on residents' carbon emission behavior, the learning imitation mechanism and competitive imitation mechanism.

Social learning theory posits that due to a lack of financial resources, professional expertise, confidence, or complete information, the behavior of others can serve as signals of public goods quality [29,43]. Information from peers, as well as behavioral decision-making, plays a significant role in shaping individuals' perceptions, expectations, and ultimately their modes of behavior [44]. Individuals' preferences and beliefs are continually influenced by their surrounding environment and group behavioral norms, leading to active or passive adjustments in their lifestyle choices, such as transportation modes and dietary habits [41,45]. Social normative beliefs motivate individuals to adopt behaviors that are widely accepted by their peer groups [46], thereby learning the lifestyles of those around them, which facilitates the acquisition of group identity.

Maslow's hierarchy of needs theory explicitly talks about respect needs. Social status is defined as the respect, admiration, and voluntary subjection given by others, and people's mental and physical health seem to hinge on the status granted by others. Social status is an important motivation for human behavior, and residents' behavior is often due to a desire to show their status and identity. Education level, cultural recreation, and tourism are all related to class and status issues to some extent [47]. People manage and pursue status by participating in activities, strive to show social value, choose a social environment that can provide higher status, and react powerfully when they feel their status is threatened. In order to improve their social status, residents may irrationally imitate the behavior of neighboring individuals, which causes peer effects to have an impact on residents' carbon emission behavior. Hence, we proposes the following hypotheses.

Hypothesis 2a. *Peer effects will affect residents' carbon emission behavior through the learning imitation mechanism.*

Hypothesis 2b. *Peer effects will affect residents' carbon emission behavior through the competitive imitation mechanism.*

In terms of the above analysis, Figure 2 depicts the mechanisms of peer effects on residents' carbon emission behavior.

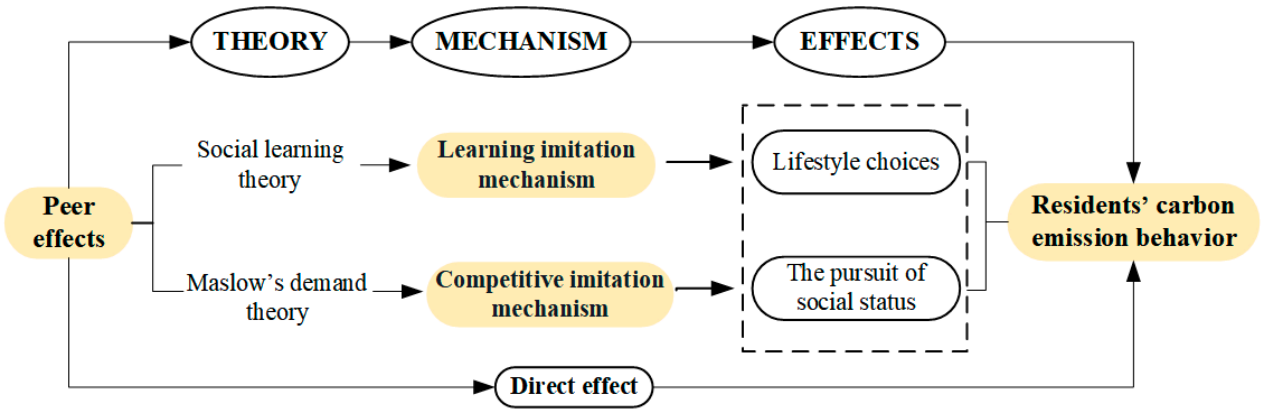


Figure 2. The mechanisms of peer effects on residents' carbon emission behavior.

The theory of individual differences was first proposed by Karl Hovland in 1946 and revised by De Fler in 1970. Based on the stimulus–response model in psychology, the theory of individual differences expounds the recipient, and believes that audience members are the key factors that affect their attention to the media and their behavior towards the issues

and other matters discussed by the media. From the perspective of behaviorism, individual differences in psychological or cognitive structure will lead to differences in their respective personal qualities and mental systems. Michalos proposed the Multiple Discrepancies Theory (MDT) in 1985. He believed that discrepancies, satisfaction, and behavior in health, family, work, housing, and other aspects were directly or indirectly affected by age, gender, education, race, and so on. Through empirical analyses, some authors in the literature have argued that household income, personal preference, social status, region, and other factors will lead to the significant heterogeneity of residents' behavior [22,42,48–50]. Regional economic development, policy orientation, social culture, resource allocation, and other living environments are different to some extent; in particular, urban and rural living environments are significantly different [26]. Education level is influenced by acquired knowledge, affecting individuals' cognitive ability, information acquisition ability, values, and decision-making processes, which in turn influences their behavioral choice in a group [51]. Individuals of different ages have significant discrepancies in physiological maturity, psychological development stage, social experience, etc., which determine their behavioral tendencies and response patterns in group interactions. Income level directly affects individuals' lifestyle, consumption habits, social status, etc., and individuals are more sensitive to changes in income levels. Relative income difference affects the influence of peer effects in different income groups [52].

The above aspects shape different group behavior patterns and psychological characteristics, revealing the complexity and diversity of peer group effects. This paper holds that residents with different characteristics have different levels of acceptance and responses to surrounding information. Therefore, peer effects have different impacts on residents' carbon emission behavior based on different characteristics. Residents with different household incomes, living areas, ages, and education levels have different psychology and behavior, so there are group differences in the level, structure, characteristics, and other aspects of carbon emissions. Hence, we put forward the following hypothesis.

Hypothesis 3. *Peer effects have a heterogeneous influence on residents' carbon emission behavior based on different characteristics such as area, education level, age stage, and income level.*

3. Research Design

3.1. Sample and Data

This paper mainly studies peer effects in carbon emission behavior among Chinese residents. The basic data for the construction of the index of residents' carbon emissions come from the China Household Finance Survey (CHFS) [53] conducted in 2011, 2013, and 2019. The CHFS is a nationally representative large-scale sample survey conducted by the China Household Finance Survey and Research Center of Southwestern University of Finance and Economics which has been published every two years since 2011. The survey covers individuals, households, and regions, reflecting demographic traits, assets and liabilities, insurance and protection, and spending and income, providing data support for academic research and public policy analysis. In terms of the items of consumption expenditure, the questionnaire includes 20 items of residents' consumption expenditure, like clothing, food, housing, transportation, education, medical care, visiting relatives, and traveling, which can provide a more comprehensive understanding of residents' carbon emissions. This study also involves the calculation of energy consumption and gross domestic product (GDP) by specific industry. The original data for energy consumption by specific industry are from the China Statistical Yearbook [54], and the original data for GDP output value by specific industry are from input–output table data. Based on the availability of data and questionnaire content, we selected consumption data and individual and household characteristics variables for 2011, 2013, and 2019, combined into three tables. First, the heads of households with missing data were screened out and deleted, then the corresponding variables were assigned, and finally we obtained the relevant data of 35,726 valid interviewed households.

3.2. Variable Selection

Residents' carbon emissions mainly generates greenhouse gases containing carbon dioxide, methane, nitrous oxide, etc. According to the National Oceanic and Atmospheric Administration's (NOAA) Annual Greenhouse Gas Index (AGGI), the warming effect of long-lived greenhouse gases on the climate increased by 49 percent from 1990 to 2022, with CO_2 accounting for about 78 percent of the increase [55]. Because carbon dioxide is the most important greenhouse gas in the atmosphere and emissions of other greenhouse gases are relatively small, residents' carbon emission behavior is chosen as the research object.

Explained variable (res_CO_2): To attribute all emissions that occur during production and distribution to the final consumers of goods and services [56], the explained variable is residents' carbon emissions. According to China's national economic classification, residents' consumption includes eight categories, such as food, clothing, residential, and so on. We matched eight categories of residents' consumption expenditure with the corresponding industrial production sectors according to the Classification of National Economy Industries, released by the National Bureau of Statistics of China in 2017, as shown in Table 2.

Table 2. Categories of residents' consumption and related industries involved.

Category	Product	Industries
Food	Food, beverage, tobacco and alcohol, catering services	Agriculture, forestry, animal husbandry, and fishery; agricultural and sideline products processing industry; food manufacturing; wine, beverage, and refined tea manufacturing
Clothing	Clothing, footwear	Textile industry; textile and garment industry; leather, fur, feathers, and other manufacturing
Residential	Rental housing rent, housing maintenance, repair and management, water and other, self-owned housing conversion rent	Production and supply of electricity and heat; water production and supply industry; production and supply of gas; building industry
Daily necessities and services	Furniture and interior decoration, household utensils, textiles and commodities, personal nursing materials, home services	Wood processing and bamboo, rattan, brown, grass products; furniture manufacturing; rubber and plastic products industry; non-metallic mineral products industry; metal products industry; electrical machinery and equipment manufacturing
Transportation and communications	Transportation, correspondence	Automobile manufacturing; transportation equipment manufacturing industry; electronic equipment manufacturing; transportation, warehousing, and postal services
Education and entertainment	Education, culture, recreation	Paper and paper products industry; printing and recording media reproduction; manufacturing of cultural, educational, industrial, sports, and entertainment products; instrumentation manufacturing industry
Health care	Medical equipment and drugs, medical services	Pharmaceutical industry
Other supplies and services	Other supplies, other services	Other manufacturing industries; wholesale and retail trade; accommodation and catering

Some scholars have used the consumer lifestyle approach (CLA) and the input–output approach to link various consumer activities to economic activity, energy use, and carbon dioxide emissions [27,57]. Based on the research of Tong and Zhou (2019) [58], we deduced the calculation formula of household carbon emissions. According to the energy consumption scale of different industries published in the Statistical Yearbook of China and the carbon emission coefficient released by the Intergovernmental Panel on Climate Change (IPCC), the scale of carbon emissions by different industries across the country was calculated. The formula is shown in (1).

$$CE_{it} = CEP_{it} \times CEC \quad (1)$$

Here, i represents the industry and t indicates the time. CE_{it} (ton carbon) presents the carbon emissions scale of industry i in year t, CEP_{it} (ton standard coal) represents the energy consumption of industry i in year t, and CEC (ton of carbon / ton of standard coal

equivalent) represents the carbon emission index of energy consumed by different industries. We adopts the *CEC* (0.69) recommended by the Energy Information Administration of the United States Department of Energy to calculate.

According to the GDP by specific industry in the input–output table, the carbon emission per unit GDP by specific industry is calculated. Then, classify and calculate the types of industries involved in each type of consumption to gain all types of residents' carbon emissions. The formula is shown in (2).

$$CI_{jt} = \sum_{i=1}^{n} (CE_{it}/GDP_{it}) \quad (2)$$

Here, j represents the type of consumption, and n presents the industries covered by each consumption type; that is, the j consumption type includes n industries, which are presented in Table 2. CI_{jt} (ton/CNY) describes the carbon emission intensity of the j type of residents' consumption in year t, GDP_{it} (CNY) represents the GDP scale of industry i in year t.

By applying CPI deflator to the data, the effect of price changes on economic indicators can be eliminated, so that a more accurate actual situation can be obtained. Using 2011 as the base period, we recalculated the data of the explained variable and core explanatory variable for 2013 and 2019 based on the CPI index.

The residents' consumption value is multiplied by the carbon emission intensity to obtain the carbon emissions generated by various types of residents' consumption. Then, calculate the sum of carbon emissions from all types of consumption, and the urban carbon emission levels is included in the model calculation, and the total carbon emissions of individuals is finally obtained. The formula is shown in (3).

$$res_CO_{2ht} = \sum_{j=1}^{8} \left(CI_{jt} \times Consumption_{jt} \times rate \right) \quad (3)$$

Here, h represents the household. $Consumption_{jt}$ represents the amount of type j consumption expenditure in year t, and $rate$ represents the proportion of carbon emission intensity of the city in which household h is located to the national average level in year t.

Core explanatory variable (*peer_comm*): We analyze the peer effects in the community in which the residents live, and take the same community as a group. The core explanatory variable is the peer effects, which is expressed by the mean value of residents' carbon emissions in the same community. The interview locations of the CHFS data provide a favorable location space for this study, being specific to the levels of district, county, and community with a certain geographical region and population, and the interaction of residents in the same community are relatively frequent. In [59], the authors believe that geographical proximity can be used as an important criterion for constructing reference groups, residents living in the same area can be considered as a reference group, and the average value of the neighborhood, community, and overall economy can be used to represent the peer effects. In this paper, families living in the same community are defined as a group, and the peer effect index is adopted for the calculation. The peer effects are the average carbon emissions of other families within the range of community c except family h. The calculation formula is shown in (4).

$$peer_comm_{ht} = \frac{\sum_{N}^{c} res_CO_{2ht} - res_CO_{2ht}^{c}}{N_{ct} - 1} \quad (4)$$

where $re_CO_{2ht}^{c}$ (ton) represents the residents' carbon emission scale of household h in community c in year t, $\sum_{N}^{c} res_CO_{2ht}$ represents the total residents' carbon emission of community c in year t, N_{ct} represents the number of household samples in the investigated community c in year t, and $peer_comm_{ht}$ (ton) represents the peer effects in relation to the average carbon emission scale of other households in community c except household h in year t.

Control variables: Some scholars believe that demographic factors (age, family size, education level, income, etc.) also influence low-carbon behavior [60]. Based on the

data characteristics of the CHFS, this paper controls for the influence of household head characteristics and family characteristics. The characteristics of the household head include age, marriage, health status, risk investment attitude, whether there is a credit card, etc. Family characteristics include total family income, family size, ownership of the house, place of residence, etc.

Mechanism variables: Our study uses the mode of transportation for residents to travel and the education level of household heads as the mechanism variables, and assigns the corresponding mechanism variables. Peer information and behavioral decisions play an important role in shaping individual behavior patterns [44], and we choose the residents' transportation mode as the proxy variable of the learning imitation mechanism to measure the influence of peer effects. Indicators of educational attainment affect a family's social status [61], and in this paper, the educational attainment of household heads is selected as the mechanism variable of the competitive imitation mechanism to reflect whether the peer effects impact carbon emission behavior through residents' social orientation. Table 3 reflects the descriptive statistics of variables and their assignment.

Table 3. Variable assignment and descriptive statistics results.

	Name of Variable	Symbol	Definition	Mean Value	Standard Deviation
Explained variable	Household carbon emission	res_CO_2	Take the logarithm of household carbon emissions for the past 12 months	9.224	1.086
Core explanatory variable	Peer effects	*peer_comm*	The logarithm of other households' carbon emissions in the same community is taken	9.556	0.758
Individual-level control variable	Age of household head	*age*	Age of head of household, take the logarithm	3.847	0.266
	Head of household marital status	*marriage*	Single individuals are assigned 1, and other individuals are assigned 2	1.892	0.310
	Physical status of household head	*health*	Unhealthy is assigned 1, and healthy is assigned 2	1.740	0.438
	Attitudes to risk	*invest*	Robust investment risk attitude is assigned 1, and positive attitude is assigned 2	1.275	0.446
	Have a credit card or not	*credit_card*	Do not have a credit card is assigned 1, and have a credit card is assigned 2	1.146	0.353
Household-level control variable	Household size	*people*	Total household size	3.303	1.317
	Relative income	*re_income*	The ratio of individual household income to the highest income household in the community	0.333	0.294
	Have owner-occupied housing or not	*house*	Do not have owner-occupied housing is assigned 1, and have owner-occupied housing is assigned 2	1.915	0.280
	Household in town or rural area	*town_rural*	Household in rural area is assigned 1, and household in town is assigned 2	1.568	0.495
Mechanism variable	Head of household education level	*education*	Primary schools and below are assigned 1, middle schools are assigned 2, high schools and secondary schools are assigned 3, and junior colleges and above are assigned 4	2.625	1.065
	The transportation mode of residents	*transportation*	Walking and cycling are assigned 1; electric cars, motorcycles, public transportation are assigned 2; and taxi and private car are assigned 3	1.899	0.710

3.3. Empirical Model

In order to verify the relevant hypotheses of this study, the following benchmark regression model is established to verify the impact of peer effects on carbon emission behavior among Chinese residents. The specific model is as follows:

$$lnres_CO_{2ht} = \alpha_0 + \alpha_1 lnpeer_comm_{ht} + \alpha_2 X_{ht} + U_k + V_t + \varepsilon_{ht} \quad (5)$$

The explained variable res_CO_{2ht} is the carbon emissions of resident h in year t. The explanatory variable $peer_comm_{ht}$ is the mean value of other residents' carbon emissions in the same community in year t, which represent the peer effects. X_{ht} is the control variables such as the personal characteristics and family characteristics of resident h. In the model, α_0, α_1, and α_2 are the coefficients to be evaluated, among which α_0 is the constant term, α_1

is the core estimation parameter concerned by this paper, which measures the impact of peer effects on carbon emission. If the coefficient α_1 is obviously larger than 0, the peer effects affect the carbon emission behavior positively. And province fixed effects (U_k) and year fixed effects (V_t) are controlled in the model. ε_{ht} is the random disturbance term.

This paper designs the following mechanism model to test the influence path of peer effects on carbon emission behavior as follows:

$$Mediation_h = \beta_0 + \beta_1 lnpeer_comm_{ht} + \beta_2 X_{ht} + U_k + V_t + \varepsilon_{ht} \quad (6)$$

where $Mediation_h$ represents the mechanism variables of the influence of peer effects on residents' carbon emission behavior, and β_1 is the coefficients to be estimated to measure the impact of mechanism. Other variables have the same meaning as those in Formula (5).

4. Analysis of Results

4.1. Benchmark Regression Results

The benchmark regression results of the peer effects on carbon emission behavior are shown in Table 4. The explained variable is residents' carbon emissions (res_CO_2), and the mean value of other residents' carbon emissions in the same community (peer_comm) is introduced as the core explanatory variable. In columns (1) and (2), only the explanatory variable (*peer_comm*) is put into the regression equation. In columns (3)–(6), the personal and household characteristics variables are added for benchmark regression. Regions and years are fixed in columns (2), (4), and (6). In columns (1)–(6), the peer effects are significantly positive with a stable coefficient. Column (6) is selected to represent the final regression results. The coefficient of the core explanatory variable (peer_comm) is 0.264, which significant at the statistical level of 1%, indicating that there are remarkable peer effects on residents' carbon emissions. For every 1 percentage point increase in the mean value of other residents' carbon emissions in the same community, the individual carbon emission will increase by 0.264 percentage points. Thus, Hypothesis 1 is confirmed.

Table 4 also shows that the impact of age and physical health on residents' carbon emissions is significantly negative, and the impact of the other control variables is positive. In terms of individual factors, the physical health status negatively affects the carbon emissions. Poorer households are likely to spend more on things like health care, which in turn will increase carbon emissions [62,63]. Residents' carbon emissions decrease as age increases. The elderly have a lower income after retirement, their future income expectations are less optimistic than those of the young, and their consumption habits are conservative, so they have lower carbon emissions. Households with non-single heads will have a stronger pursuit of a happy life and tend to have higher daily consumption and higher carbon emissions than those with single heads. Residents tend to have a positive and optimistic attitude towards investment risks, indicating that they believe that the consumer market trend is positive, and tend to increase their consumption, resulting in higher carbon emissions. The regression results also show that having a credit card actively influences carbon emissions, the reason being that credit cards give consumers more power to spend [64]. Credit card-based consumption can easily stimulate residents' impulsive, herd, and show-off consumption, because the type of consumption only brings about a reduction in numbers, which weakens the psychological stimulation of consumers and produces a psychological perception bias.

In terms of household factors, both the absolute and the relative income theory emphasize the positive impact of income on residents' consumption expenditure [24], so households with higher incomes emit more carbon. The larger the household population size, the higher the consumption expenditure, and the higher the carbon emissions will be. The lack of self-owned housing has a crowding-out effect on other types of household consumption. In order to purchase housing, residents inhibit other consumption desires, and thus, saving towards a property increases the demand for housing purchases, so their carbon emissions are relatively low. Residents living in urban areas have higher carbon

emissions than those living in rural areas, which may be due to the degree of consumption in urban areas being higher than that in rural areas.

Table 4. Empirical results of benchmark regression.

Variables	*res_CO₂*					
	(1)	(2)	(3)	(4)	(5)	(6)
peer_comm	0.816 ***	0.262 ***	0.712 ***	0.266 ***	0.758 ***	0.264 ***
	(0.006)	(0.045)	(0.006)	(0.044)	(0.006)	(0.042)
age			−0.791 ***	−1.014 ***	−0.619 ***	−0.878 ***
			(0.018)	(0.146)	(0.018)	(0.128)
marriage			0.461 ***	0.366 ***	0.187 ***	0.167 *
			(0.014)	(0.085)	(0.014)	(0.081)
health			0.121 ***	−0.045	0.097 ***	−0.062 *
			(0.010)	(0.030)	(0.010)	(0.031)
invest			0.087 ***	0.008	0.061 ***	0.005
			(0.010)	(0.025)	(0.010)	(0.023)
credit_card			0.406 ***	0.232 ***	0.334 ***	0.171 ***
			(0.013)	(0.040)	(0.013)	(0.039)
people					0.116 ***	0.133 ***
					(0.004)	(0.012)
re_income					0.766 ***	0.316 ***
					(0.015)	(0.041)
house					0.065 ***	0.121 **
					(0.015)	(0.045)
town_rural					0.023 **	0.102
					(0.010)	(0.144)
Constant	1.429 ***	6.260 ***	3.806 ***	9.113 ***	2.578 ***	8.139 ***
	(0.060)	(0.413)	(0.102)	(0.660)	(0.099)	(0.632)
Year FE	No	Yes	No	Yes	No	Yes
Region FE	No	Yes	No	Yes	No	Yes
N	35,726	35,726	35,726	35,726	35,726	35,726
*R*2	0.120	0.163	0.136	0.197	0.170	0.250

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Moreover, we found that marriage has a stronger impact than people or total income. Income and people tend to have a single effect, while marriage has more to consider. Marriage is a closer relationship between the sexes, and the influence of behavior between the two parties is more obvious, so economic cooperation and resource sharing brought about by it may change the level and structure of household consumption. Marital status and patterns are not only a matter of individual or family quality of life, but they become an important window into social structure and mobility, involving the economic support and input, consumption decisions, and socio-economic status of both families.

4.2. Robustness Tests

To ensure the reliability and accuracy of the benchmark regression results, this study will provide the following four ideas for robustness testing.

4.2.1. Model Replacement

When data processing is carried out in this paper, the value of some missing values of the samples is assigned to 0, which may mean the original benchmark regression model cannot be consistently estimated. In this study, a panel Tobit model is used to replace the benchmark regression model, and then the regression is carried out again. Column (1) of Table 5 shows that the influence of peer effects on carbon emission behavior is remarkable. For a 1 percentage point increase in the mean value of other residents' carbon emissions in

the same community, the individual carbon emission level will increase by 0.762%. This result is unanimous with the benchmark regression results above.

Table 5. Results of the robustness tests.

	Tobit Model (1)	Variables Replacement (2)		Random Sampling (3)	Winsorization Test (4)
peer_comm	0.762 ***	0.230 ***		0.281 ***	0.264 ***
	(0.006)	(0.033)		(0.060)	(0.042)
peer_city			0.419 ***		
			(0.060)		
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes
N	35,726	35,648	35,726	21,423	35,726
*R*2	0.225	0.114	0.250	0.244	0.250

Note: Standard errors in parentheses; *** $p < 0.01$.

4.2.2. Explained Variable and Core Explanatory Variable Replacement

In order to avoid an estimation bias caused by the selection of variables, this study uses the carbon emission of food consumption ($food_CO_2$), which accounts for a significant proportion of residents' carbon emissions, to replace the explained variable (res_CO_2). According to the results in column (2) of Table 5, for a 1% increase in the mean value of other residents' food consumption carbon emissions in the same community, the individual food consumption carbon emissions will increase by 0.230%. The mean value of other residents' carbon emissions in the same city (*peer_city*) is used to replace the community peer effects (*peer_city*), and the results are shown in column (3) of Table 5. The coefficient of the core explanatory variable (*peer_city*) is 0.419, which is significant at the statistical level of 1%, indicating that peer effects strongly influence carbon emissions. Despite the change in research variables, the impact of peer effects on residents' carbon emission behavior is significantly positive, which is consistent with the previous estimation conclusions.

4.2.3. Random Sampling Simulation

This paper draws 60% of the data randomly from the overall sample and then tests peer effects' impact on carbon emissions, and the results are illustrated in column (4) of Table 5. The influence of peer effects on residents' carbon emission behavior is notably positive. For a 1% increase in the average carbon emission of other residents in the same community, individual carbon emissions will increase by 0.281%. It is verified that peer effects exist in residents' carbon emission behavior.

4.2.4. Winsorization Test

The samples are treated with extreme values at the 1% and 99% quantiles; a value of 1% is used for the numbers less than 1%, and a value of 99% is used for the numbers greater than 99%. The results in column (5) of Table 5 show that after eliminating extreme values, the coefficient of peer effects on residents' carbon emission behavior is strikingly positive at the level of 1%. For a 1% increase in the average carbon emissions of other residents in same community, individual carbon emissions will increase by 0.264%.

4.3. Mechanism Test

4.3.1. Learning Imitation Mechanism

According the social learning theory, individual lifestyle and behavioral choices are significantly influenced by the behavior of surrounding peer groups, with changes in behavior being the result of repeated exposure to certain information [65]. Individuals living in the same community may exhibit similar behavioral habits and lifestyles due to shared environmental factors [45,66], tending to adhere to uniform, homogeneous behavioral standards to maintain their desired group identity and achieve conformity with their

peers [67]. Peer effects influence individual lifestyles, including the choice of transportation modes. Sherwin et al. (2014) [68] found that in the UK, the majority of new cyclists reported that their shift in transportation mode was influenced by others around them. Road traffic is a significant source of greenhouse gas emissions [69]. The transportation choices of a group can influence individual transportation mode selection, which in turn affects individual carbon emission behavior. Therefore, using transportation mode as a proxy for lifestyle choice facilitates a more rigorous examination of the mechanism through which peer effects influence residential carbon emission behavior. The results in Table 6 (2) indicate a significantly positive impact of peer effects on residents' transportation modes for daily living, suggesting that peer effects influence carbon emission behavior by altering individual lifestyles.

Table 6. Mechanism test results.

	Learning Imitation Mechanism		**Competitive Imitation Mechanism**	
	***res_CO*$_2$ (1)**	***transportation* (2)**	***res_CO*$_2$ (3)**	***education* (4)**
peer_comm	0.264 ***	0.057 **	0.264 ***	0.151 ***
	(0.042)	(0.024)	(0.042)	(0.051)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes
N	35,726	35,726	35,726	35,726
R2	0.250	0.054	0.250	0.343

Note: Standard errors in parentheses; ** $p < 0.05$, *** $p < 0.01$.

4.3.2. Competitive Imitation Mechanism

According to the previous theoretical analysis, residents have a strong motivation to imitate and follow others through the competitive imitation mechanism, and they are driven by a compulsion to elevate their social status. People with strong identity awareness are more driven by social status and interpersonal mediation [70]. Social status often depends on a family's ranking in relation to wealth distribution, education level, and other indicators. Against a social background such that the return mechanism of education is becoming more and more perfect, education has become a mechanism to obtain a social status beyond the constraints of one's family background. Blau and Duncan (1967) [71] proposed a social status acquisition model (B-D model), with attention being paid to the transcendent role of education as an intermediate variable in family background limiting children's social status. The pursuit of social status is related to education investment and consumption [61]. We choose education as a proxy variable for social status to analyze whether peer effects affect residents' carbon emission behavior through the pursuit of social status. The traditional cultural values of "he who excels in study can follow an official career" and the inter-generational relationship of nurture–support make Chinese families pay more attention to education, especially higher education, which is regarded as an important way to improve one's future social status. The results in column (4) of Table 6 explain that there is a positive relationship between education and residents' carbon emission behavior, indicating that individuals imitate others' decisions in a competitive group environment. In order to maintain competitiveness and improve social status, individuals tend to mimic the behavioral decisions of peers with more resources and higher social status, then increasing the investment in family education costs and the investment in themselves, which ultimately affects the carbon emission behavior.

4.4. Heterogeneity Analysis

The above regression results show that peer effects have a significantly positive influence on carbon emission behavior among Chinese residents, but the impact may be different for residents with different characteristics. In the same community, residents face relatively similar living environment and consumption needs, but individuals have

different role characteristics and psychologies, resulting in differences in their behavior and habits. In order to test the heterogeneity, this paper conducts the grouped regression of samples according to different urban and rural areas, age stage, education level, and income levels to verify the differences in peer effects in residents' carbon emission behavior with different characteristics.

4.4.1. Heterogeneity of Urban and Rural Areas

China's urban–rural dual economic structure induces substantial distinctions in the impact of economic development on the expenditure of urban and rural residents [72]. In this paper, the samples are regressed by groups of urban and rural areas. The results are shown in columns (1) and (2) of Table 7. The peer effects affect the carbon emission behavior of urban and rural residents in a significantly positive way, but the impact on the carbon emissions of rural residents is weaker than that of urban residents. This conclusion is similar to the research conclusions of many other scholars. Rural residents may have a weaker risk tolerance, and are more likely to restrain their consumption desire due to the deterioration of their health status and credit constraints [73]. The household saving rate of rural residents is higher than that of urban residents because they have problems such as slow income growth, a large regional gap, and an uncertain disposable income [74], and rural residents' willingness to consume is significantly weaker than that of urban residents. To sum up, because of the long-standing urban–rural dual pattern, under the joint influence of education, income, and other factors [75], the quality of life of rural residents is significantly lower than that of urban residents [18], thus restricting the consumption demand of rural residents, which weakens the influence of peer effects on rural residents' carbon emission behavior.

Table 7. Results of heterogeneity of region and education level.

	Urban and Rural Areas		**Education Level**			
	Rural (1)	**Urban (2)**	**Primary Schools and Below (3)**	**Middle Schools (4)**	**High and Secondary Schools (5)**	**Junior Colleges and Above (6)**
peer_comm	0.219 ***	0.303 ***	0.209 ***	0.233 ***	0.290 ***	0.246 ***
	(0.060)	(0.060)	(0.063)	(0.069)	(0.087)	(0.085)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
N	15,451	20,275	10,887	12,634	6601	5585
*R*2	0.221	0.312	0.196	0.224	0.303	0.436

Note: Standard errors in parentheses; *** $p < 0.01$.

4.4.2. Heterogeneity of Education Level

Higher education is an important channel for Chinese families to achieve social status and inter-generational mobility. Education has a stronger role in the inter-generational transmission of cultural and economic status [76]. Peer influence is crucial to comprehending educational achievement, and peers are generally more important to individuals in a school environment [77]. As shown in (3)–(6) of Table 7, peer effects have significantly positive impacts on residents' carbon emission behavior, and their coefficients vary with the level of education. The impact of peer effects on carbon emissions becomes gradually stronger with the increase in education level below junior college, while the impact weakens with the improvement in education above junior college. For residents with a low education level, their motivation and demand for social status will be reflected through education. They hope to continuously improve their quality and skills, and have high demand for conspicuous consumption such as cultural and educational [51]. Therefore, the community residents will have the effect of imitating each other, and behaviors such as comparison and imitation will be more obvious. For the residents with a high education level, they have more diversified information, pay attention to making utility maximization

choices in education, and have a stronger awareness of low-carbon activities [78]. Peer effects have a weak impact on residents with a high education level, and play a small role in guiding the carbon emission behavior.

4.4.3. Heterogeneity of Age Stage

As shown in columns (1)–(3) of Table 8, the peer effects' impact on residents' carbon emission behavior of different age groups is apparently positive, indicating that no matter at what age stage, the social relationship between groups is strongly interactive, and the surrounding people can easily have an impact on individuals. The outcomes also reflect that with the increase in age, peer effects become stronger and stronger among different age groups. On the one hand, middle-aged and elderly people are limited in function and activities [79], and communities are long-term places for them to live. Young people have more time and energy to participate in group activities, activities in a wider range of regions, and access to information through more diverse channels. On the other hand, middle-aged and elderly people are retired and unemployed, have more opportunities to communicate with their peers, and are more influenced by the information exchange of surrounding groups compared with young people, which tends to refer to the choices of their peers due to herd mentality. Therefore, peer effects will be more obvious with age.

Table 8. Results of heterogeneity of age stage and income level.

	Age Stage			**Income Level**		
	≤44 (1)	**45–59 (2)**	**≥60 (3)**	**Low (4)**	**Medium (5)**	**High (6)**
peer_comm	0.233 **	0.253 ***	0.335 ***	0.187 **	0.190 *	0.161
	(0.099)	(0.056)	(0.085)	(0.079)	(0.096)	(0.112)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
N	13,343	15,580	6803	11,909	11,908	11,909
R2	0.378	0.175	0.198	0.199	0.209	0.268

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.4.4. Heterogeneity of Income Level

The relative income difference between neighbors has an impact on individual behavior [52]. In this paper, the income of all samples is classified according to low, medium, and high levels, and then three groups of samples are regressed, respectively. As shown in columns (4)–(6) of Table 8, the peer effects have an active impact on the carbon emissions of residents with different income levels, and the impact is significant for the residents with low and medium income, while it is not significant for residents with a high income. These results are the same as the findings of Ling et al. (2018) [22]. The residents with a low and medium income are still in the early stage of human capital accumulation, for which there are no obvious differences between the surrounding groups at the same level. In addition, for residents with a low and medium income, their consumption is sensitive to income changes [74]. They are more subject to budget constraints, making their consumption less selective and more sensitive to the perception of changes in the expenditure of the surrounding groups. The residents with a high income have more diversified consumption modes from which to choose, such as culture and entertainment, clothing, and other aspects. Therefore, the peer effects have a more notable influence on the carbon emission behavior of low- and medium-income residents.

5. Conclusions and Policy Implications

5.1. Research Conclusions

This study delves into the intriguing realm of peer effects on carbon emission behavior among Chinese residents, utilizing the 2011, 2013, and 2019 China Household Finance Survey (CHFS) data. Our findings illuminate the profound influence that social networks

exert on environmental behavior, revealing that an individual's carbon emission behavior is significantly influenced by the behavior of those in their immediate social circle.

Central to our exploration is the role of social norms and personal values in shaping environmental consciousness [80]. Our research applies the principles of social interaction and sustainable development theories, employing a robust fixed-effects model that integrates a variety of control variables. The results are striking, confirming the substantial impact of peer effects—neighbors and friends do indeed inspire one another towards more sustainable practices [81]. This conclusion is supported by a litany of robustness checks, including alternative regression models and variables, random sampling simulations, and Winsorization tests, each reinforcing the powerful effect of peer influences.

Building on the foundation of social learning and Maslow's hierarchy of needs, we propose and examine two distinct mechanisms through which peer effects operate: the learning imitation mechanism and the competitive imitation mechanism. These mechanisms highlight how lifestyle choices, self-identity, and aspirations for social esteem collectively drive carbon emission behavior within communities [52,70]. This insight is pivotal for stakeholders, from policymakers to marketers, offering a clearer understanding of consumer behavior in relation to environmental products and services.

Furthermore, we segment the population by demographic characteristics such as living area, income level, age stage, and education level. Our analysis reveals subtle differences in how peer effects manifest across different groups, with notable distinctions observed among urban dwellers, lower-income families, less educated individuals, and the elderly. This will help formulate more effective policies and targeted measures, utilize peer effects to guide residents to participate in low-carbon emission reduction, and promote the popularization of low-carbon lifestyles.

5.2. Policy Implications

In light of these insights, we suggest several policy interventions aimed at nurturing a low-carbon ethos among the populace. Governmental action could include fiscal incentives to lower the costs of green products and adjust taxation to reflect the environmental impact of consumer choices.

Businesses, on the other hand, should focus on aligning low-carbon principles with consumer insights to enhance the availability and appeal of sustainable products through improving the product energy-saving and green manufacturing standard system.

Additionally, leveraging the influential power of peer effects, governmental bodies can significantly amplify the impact of informational campaigns. By disseminating targeted information and fostering a bespoke low-carbon culture, these efforts can cultivate a community ethos that values sustainability. Initiatives like community posters, public service announcements, and the showcasing of model behavior can serve as powerful catalysts, encouraging individuals to embrace reduced carbon footprints as part of their daily lives.

To knit these efforts together, a holistic approach involves the participation of all societal segments to create a cohesive low-carbon lifestyle. This includes establishing codes of conduct for environmentally friendly behavior and creating guides that aid residents in making sustainable choices. By fostering an environment where green behavior is modeled and rewarded, we can ensure that sustainability becomes a shared community goal.

Finally, tapping into social identity and consumer psychology can further refine consumption patterns. For instance, elevating the economic standing of middle and lower-income families can expand their access to sustainable options, promoting more informed and deliberate consumption choices. Moreover, by introducing digital platforms like a "carbon ledger", the government can provide a comparative analysis of personal versus communal carbon contributions, reinforcing positive behavior through social benchmarks and peer comparisons.

In general, with the perspective of social interaction, our study further deepens the understanding of the theory of peer effects, enriches the application of peer effects in the field

of environmental behavior, offers actionable pathways for engaging communities in the vital endeavor of carbon reduction, and finally advance towards a more sustainable future.

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