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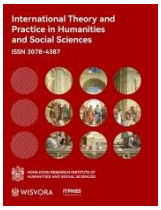

Quantitative Study on the Relationship between Digital Economy Development and Household Carbon Emission in Shanghai Municipality

Yuyang Liu, Yan Hao,Shi Jinghan,Liu Yutong

Shanghai Lixin University of Accounting and Finance

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Corresponding Author

Yuyang Liu

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Abstract

With the booming development of the Internet, its impact on household consumption patterns and carbon emission behaviors has received increasing attention. This study quantitatively analyzes the relationship between the development of Internet and household carbon emissions using data from the 2010-2020 China Family Panel Studies (CFPS) in Shanghai. It is found that the development of Internet significantly contributes to the upgrading of household consumption structure, especially the increase of developmental and Hedonic Consumption, while the proportion of Subsistence Consumption gradually decreases. Household income is a key factor influencing the upgrading of the consumption structure, the application of digital technology has had a profound impact on household consumption behavior, and the green consumption trend has gradually become a new trend in household consumption. This study also explores the heterogeneous impacts of the Internet on household carbon emissions and proposes corresponding policy recommendations to promote the green development of the Internet and the low-carbon transition of household consumption. The findings provide new perspectives for understanding the environmental impacts of the Internet and have important theoretical and practical implications for the formulation of environmentally friendly policies.

1. Research Background

In the context of the digital era, the booming Internet is profoundly changing economic structures and household lifestyles. Shanghai, as one of China's economic centers, has experienced particularly rapid growth in the Internet, which has had a significant impact on household consumption patterns and carbon emission behaviors. In this context, studying the relationship between the Internet and household carbon emissions not only helps to understand how the Internet indirectly acts on carbon emissions by influencing household consumption structure and behavior, but also is of great significance for formulating effective environmental policies and promoting green and sustainable development.

With the spread of Internet technology, mobile payments and digital finance, household consumption has tended to become digitalized, a change that has not only improved consumption

efficiency but also facilitated the diversification of consumption choices. However, digital lifestyles may also bring new environmental challenges, such as increased packaging waste and rising carbon emissions from logistics. Therefore, an in-depth analysis of the impact of the Internet on household carbon emissions can provide a scientific basis for the government to formulate relevant policies, such as optimizing the structure of income distribution, promoting digital technological innovation, adjusting the industrial structure, fostering regional cooperation, and raising the awareness of low-carbon consumption among households, in order to achieve a win-win situation for both economic development and environmental protection.

In addition, this paper reveals the decisive role of household income in upgrading the consumption structure and the rise of the green consumption trend, which suggests that raising the level of household income and guiding the green transformation of household consumption play an important role in promoting sustainable socio-economic development. This study can provide policymakers with empirical data to support the green development of the Internet and promote the low-carbon transformation of household consumption patterns, so as to provide strategic recommendations for realizing the "dual-carbon" goal and high-quality economic development.

2. Literature Review

Literature 1: Factors of household carbon emissions

Zhao et al. (2021) analyzed the impact of Internet dependence on household carbon emissions, pointing out that it may slow down consumption upgrading. Chen and Hu (2022) explored the impact of population aging on household carbon emissions and its relationship with household income. Hua and Shi (2023) suggest that Internet use promotes indirect household carbon emissions, especially in enjoyment and developmental consumption.

Existing literature has studied the impact of household size, income, consumption structure and environmental awareness on carbon emissions, but the relationship between consumption structure and carbon emissions and the role of other factors such as the Internet have been insufficiently explored. In this paper, we will utilize data from the Chinese Household Tracking Survey to investigate the heterogeneous effects of the Internet on household carbon emissions under different factors.There are relatively few studies discussing the impact of Internet use on household carbon emissions, and to fill the research gap, this paper will use the Internet as an entry point for research.

Literature 2: Impact of Internet usage on household carbon emissions

Research on the Internet's impact on carbon emissions has focused on network technology, data analytics, and digital financial services. Li and Zhang (2021) point out that advances in network technology significantly reduce China's carbon emission intensity, while Zhu et al. (2023) find that the development of the Internet improves carbon productivity. Sun et al. (2023) show that big data has a dampening effect on carbon emissions at the county level, indicating that big data technology helps reduce greenhouse gas emissions. The impact of information and communication technology (ICT) on the economy also indirectly affects climate change, Ahmed and Le (2020) showed that ICT improves environmental quality by reducing emissions.Liu et al. (2022) confirmed that there is a positive correlation between ICT and CO_2 emissions. Wang (2022) explores the complex impact of digital finance on carbon emissions in manufacturing, while Wang and Fan (2022) find that digital financial inclusion significantly reduces carbon emissions.Du et al. (2024) show that although the Internet increases carbon emissions from direct household consumption, indirect carbon emissions are reduced by expanding the scale of consumption and reducing energy intensity.

Combined with the above literature, it can be seen that the Internet shows potential for promoting environmental sustainability, but more in-depth research is needed to reveal its complexities and inform policy development.

Literature 3: The mediating role of consumption upgrading in the impact of Internet usage on carbon emissions

Combined with the analyses in the existing literature, the important mediating effect of consumption upgrading in achieving emission reductions can be clearly seen. Specifically, consumption upgrading not only directly affects consumers' purchasing choices and consumption patterns, but also plays a key intermediary role in emission reduction by promoting the demand for green products and driving technological innovation in enterprises.Wang et al. (2022) find that digital financial development boosts household carbon emissions, but residents' environmental awareness moderates this effect.Zhang and Wei (2023) argue that the Internet promotes the low-carbon transition of household consumption, especially in the South and low-carbon electricity cities.Yang et al. (2023) analyzed the contribution of the Internet to household consumption upgrading, especially in regions with high levels of digital innovation factors. Li (2023) points out that the Internet has a significant contribution to the consumption of different household types, mainly through improving income and financial literacy. Li et al. (2024) find that digital capabilities promote consumption through higher income levels and lower volatility, although they do not change households' marginal propensity to consume.

In summary, The Internet presents both challenges and opportunities in the context of carbon emissions reduction. While it has the potential to drive efficiencies and promote sustainability, careful management and policy making are crucial to mitigating the negative impacts associated with increased digital consumption. Continued research is needed to navigate the complexities of this evolving landscape.Besides,the Internet has a significant impact on household consumption from increased ease of payment and improved environmental awareness. However, there are differences in impacts across regions and household types, and the market for the elderly and the low-carbon effect require further research. The specific impact mechanisms of digital capabilities are unclear and need to be explored in depth in different social-economic contexts. This paper will comprehensively analyze the relationship between digital transformation on household consumption and the environment in the context of the Sustainable Development Goals, and provide recommendations for policy making.

3. Methods and Data

In this paper, we construct the following model: $Y_{it} = \propto + \beta_1 Internet_i + \lambda Z_{it} + \gamma t + \epsilon_{it}$ (1)

Where Y_{it} denotes the low carbon transition in i-household consumption, including per capita carbon emissions ($preCO_2$) and carbon intensity of consumption ($intensity\_\_CO_2$); $Internet_i$ denotes whether or not the Internet is used, with use of the Internet as 1 and no use of the Internet as 0; Z_{it}represents a series of control variables related to household consumption, including individual-level and household-level control variables; γ is a time FE; ε represents a random disturbance term. Z_t represents a series of control variables related to household consumption, both at the individual level and at the household level, γ is a time FE, and ε_{it} represents a random disturbance term.

3.1 Data sources and description of variables

The data in this paper mainly comes from the biannual China Family Tracking Survey (CFPS). The 2010 baseline survey covered 16,000 households in 121 cities and 162 counties in 25 provinces, and the data includes food expenditure, clothing expenditure, housing expenditure, household equipment and supplies expenditure, transport and communication expenditure, culture, education and recreation expenditure, healthcare expenditure, and other expenditure, which is highly representative of the research on the issue of low-carbon transition in household consumption. This data is very representative for studying the issue of low-carbon transition in household consumption. Because the team's practice site is located in Shanghai, and household visits and research have been carried out on households participating in CFPS in Shanghai, this paper selects Shanghai as the research object, aiming to explore the impact of the Internet on household carbon emissions in Shanghai, and because the CFPS2020 data does not involve consumption, this paper mainly uses the individual database of the CFPS in 2010-2018 Since the CFPS2020 data does not cover consumption, this paper mainly uses the individual database and household database of the CFPS from 2010-2018, and adopts the 2011-2019 China Energy Statistical Yearbook, China Statistical Yearbook, China Industrial Statistical Yearbook, and the 2006 IPCC Greenhouse Gas Emission Inventory Guidelines to calculate the carbon emission coefficients of the eight types of consumption. In addition, the carbon emission intensity of Shanghai is calculated from the carbon emissions of cities in the China Carbon Emission Databases (CEADs). Before the empirical analysis, this paper firstly deletes the samples with missing and unidentifiable key variables; secondly, the household financial respondent is regarded as the head of the household as the representative sample of the household, and deletes the sample of the head of the household whose age is less than 16 years old; thirdly, matches the individual database with the household database, screens out the individual characteristic variables, and calculates the household-related variables; lastly, combines the data from 2010 -2018, deletes the samples that could not be counted consecutively during the sample period, resulting in a balanced panel data of 598 samples.

Table 1 Relevant variables and descriptive analyses

Variables			Variable Meaning	Sample Value	Avg.	S.D.
DV	Carbon emissions per capita consumption	*pre_*CO_2	Carbon emissions from per capita household consumption	598	2395.513	3866.668
	carbon intensity	*intensity_*CO_2	Carbon emissions per unit of consumption	598	0.192	5.521
IV	Internet usage	Internet	use=1，unuse=0	598	0.180	0.384
CV	Individual level	*gender*	Male = 1, Female = 0	598	0.579	0.494
		health	1-7 Increased health status in descending order	598	5.544	1.173
		education	educational attainment	598	8.835	3.563
	Family level	*familysize*	Family size	598	9.324	1.027
		foster	Share of population under 16 and over 65	598	3.924	1.733
		lnpincom	Logarithmic net	598	0.257	0.274

			household income per capita			
Mechanism variables	Consumer Perceptions of Environmental Stress	*cognize*	Magnitude of environmental problems	396	4.911	2.151
	consumer preference	*preference*	Income elasticity of demand for green consumer goods	598	0.711	0.176
	Product Green Technology Innovation	*technology*	Number of green patents per 1,000 people	598	0.157	0.292

1. Explained variables

The low-carbon transition in household consumption includes carbon emissions per capita (pre_CO_2) and carbon intensity of consumption (intensity_CO_2). The low-carbon transition in household consumption refers to the reduction of carbon emissions from consumption and the shift from high-carbon to low-carbon products, which is manifested in the reduction of per capita carbon emissions and the decrease of carbon intensity of consumption. If the impact of the Internet on both per capita consumption carbon emissions and carbon intensity is significantly negative, it means that the Internet not only realises a low-carbon transition in household consumption, but also that the carbon emissions generated by consumption growth are lower than those reduced by the greening of the consumption structure, which is the optimal effect of the Internet in driving a low-carbon transition in household consumption; if the impact of the Internet on per capita consumption carbon emissions is significantly positive or insignificant, but on household carbon intensity is significantly negative, the Internet is the best effect of the Internet in driving a low-carbon transition in household consumption. If the impact of the Internet on per capita consumption carbon emissions is significantly positive or insignificant, but the impact on household carbon intensity is significantly negative, it means that the household has realised a low-carbon transition in consumption, but the carbon emissions generated by the increase in consumption exceed the carbon emissions reduced by the adjustment of the consumption product; if the impact of the Internet on per capita consumption carbon emissions is significantly negative, but the impact on household carbon intensity is significantly positive, it means that the household has not realised a low-carbon transition in consumption, but rather has reduced its consumption expenditure. As this paper uses micro data to study the relationship between the Internet and the low-carbon transition of household consumption, referring to Tong and Zhou (2022), the Consumer Lifestyle Approach (CLA) is used and urban productivity is incorporated into the model to calculate the household carbon emissions, and the specific calculation formula is as follows:

$$CO_{2i} = \sum_{j=1}^{8} CI_j \times Pce_j \times ratio_c \quad (2)$$

Where , CO_{2i} is the total carbon emission of i household consumption, CI_j is the carbon emission coefficient of jth category consumption, Pce_j is the expenditure of jth category consumption fee, and $ratio_c$ is the ratio of Shanghai's emission intensity to the national average.

The formula for calculating carbon emissions per capita consumption is as follows:

$$\text{pre\_}CO_{2i} = \frac{CO_{2i}}{\text{familisize}_i} \quad (3)$$

The formula for calculating the carbon intensity of consumption is as follows:

$$\text{intersity\_}CO_{2i} = \frac{CO_{2i}}{\text{consume}_i} \quad (4)$$

Where, pre CO_2 is the carbon emissions generated by per capita consumption of household i, i.e. per capita consumption carbon emissions, familysize, is the population size of household i; intensity CO_{2i} is the carbon emissions generated by per unit of consumption of household i, i.e. the carbon intensity of consumption, and $consumption_i$ is the total consumption of the ith household.

2. Core explanatory variables

Network infrastructure development is one of the key indicators of the development of the Internet. At the same time, only households that use the Internet can receive digital dividends.

3. Control variables

This paper focuses on controlling for factors that may have an impact on the low-carbon transition in household consumption, both at the individual level and at the household level. Household headship characteristics such as gender, health and education are important factor(s) that influence residents' consumption. Gender difference affects the demand for low-carbon products from the psychological level, health condition affects the low-carbon transformation of consumption by influencing the consumption structure of residents, and the years of education of the head of the household affects the acceptance of low-carbon technology and the level of environmental protection awareness, which in turn affects the low-carbon transformation of consumption. Based on the environmental STIRPAT model, controlling for household population size, population structure and per capita wealth, population size is measured by the total household population (family size), population structure is measured by the ratio of people under 16 and over 65 years old (foster), and per capita wealth is measured by the logarithm of the total per capita income of the household (Inpincom). According to the scale effect, the larger the household size, the smaller the marginal carbon emission growth, the more favourable to carbon emission reduction. Tong, Yufen and Zhou (2022) argue that household ageing is conducive to curbing household carbon emissions because the main household, in which the elderly and the young live together, is more "energy efficient and environmentally friendly". According to the absolute income hypothesis, income is a key variable affecting consumption and an important factor in determining consumption structure, which has a significant impact on the low-carbon transition of household consumption.

4. Mechanism variables

This paper uses consumer environmental stress perception, consumer low carbon preference and product green technology innovation as mechanism variables. Drawing on Wang et al. (2023), the perceived severity of environmental problems as perceived by households was chosen to measure individual environmental stress perceptions. Income elasticity of demand for green consumer goods was used as a proxy variable for consumer low-carbon preferences, drawing on He et al.'s (2023) measure of consumer preferences. Product green technology innovation is measured by the number of green invention patent applications per 10,000 people in Shanghai, drawing on the approach of Dong and Wang (2021).

4. Results and Discussion

4.1 Benchmark regression

Table 2 shows the impact of the Internet on per capita consumption carbon emissions and carbon intensity. From the results, the Internet reduces per capita household consumption carbon emissions and significantly reduces carbon intensity. The results of the regression of control variables are basically consistent with previous scholars' studies.

Table 2 the impact of the Internet on per capita consumption carbon emissions and carbon intensity

Variables	(1)	(2)
	pre_CO₂	*intensity_CO₂*
Internet	-0.0377*	-0.1045***

	(0.0218)	(0.0108)
gender	-0.0470***	-0.0150**
	(0.0143)	(0.0058)
health	0.0237***	0.0094***
	(0.0058)	(0.0026)
education	0.0276***	0.0027***
	(0.0023)	(0.0009)
familysize	0.2326***	0.0135***
	(0.0094)	(0.0036)
lnpincom	-0.0887***	0.0071***
	(0.0053)	(0.0019)
foster	-0.1286***	-0.0963***
	(0.0266)	(0.0124)
_cons	4.4685***	-2.5006***
	(0.1684)	(0.0594)
time FE	Y	Y
N	598	598
R^2	0.4292	0.7873

Note: Due to the large difference between the data of *pre*_CO_2 and intensity CO_2,we use logging variables to make the data smoother. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Robust standard errors are in parentheses. Same as below.

4.2 Robustness Check

1.PSM-DID

Although this paper controls for variables related to the individual and household levels and controls for urban dummy variables, there are large differences between individuals, which may still result in biased estimation results, so 1:5 proximity matching is adopted for the experimental and control groups, and PSM-DID is used to conduct robustness tests. From the first 2 columns of the test results in Table 3, it can be seen that the Internet significantly suppresses the per capita household consumption carbon emissions and also reduces the carbon intensity, indicating that the Internet has a certain positive effect on the low-carbon transition of household consumption. From the estimation results of the difference terms, the level of significance of household per capita consumption carbon emissions increases significantly after matching, and the absolute value of the estimated coefficients becomes larger, which indicates that the Internet has a more obvious effect on household per capita consumption carbon emission reduction after narrowing down the differences between individuals, and the obtained results remain robust.

2.Substitution of variables

In order to avoid the estimation bias caused by the selection of variables, household carbon emission (CO_2) is used to replace the household per capita consumption carbon emission (*pre*_CO_2), and the intensity of carbon intensity without considering the energy efficiency of Shanghai city (intensity_ CO_2 _ 1) is used to replace the intensity of carbon intensity with the consideration of the energy efficiency of Shanghai city (intensity_CO_2). From columns (3) and (4) of Table 3, it can be seen that the Internet promotes a low-carbon transition in household consumption. Consistent with the results of the benchmark regression, the results are robust.

Table 3 Robustness test results

Variables	PSM-DID		Replacement of explanatory variables		Substitution of explanatory variables	
	(1)	(2)	(3)	(4)	(5)	(6)
	pre_CO2	*intensity_CO2*	*CO2*	*intensity_CO2_1*	*pre_CO2*	*intensity_CO2*
Internet	-0.0559** (0.0240)	-0.0976*** (0.0115)	-1.6966*** (0.3819)	-0.0061*** (0.0014)	-	-
digita1	-	-	-	-	-0.0791 (0.0478)	-0.1519*** (0.0216)
control variable	Y	Y	Y	Y	Y	Y
time FE	Y	Y	Y	Y	Y	Y
N	598	598	598	598	598	598
R^2	0.4271	0.7940	0.166	0.248	0.4162	0.7879

4.3 Mechanism analysis

According to theoretical analyses, the Internet can promote the low-carbon transformation of household consumption on the demand side by raising consumers' awareness of environmental pressure and changing consumer preferences, and on the supply side by promoting the innovation of green technology in products to help the low-carbon transformation of household consumption. The next three paths are analysed from the above two aspects. First, the development of the Internet guides the low-carbon transformation of household consumption by raising consumers' awareness of environmental pressure. The regression results presented in column (1) of Table 4 show that the Internet has a positive effect on improving consumers' perception of environmental pressure, and Gifford and Nilsson (2014) point out that environmental perception is the most favourable predictor of environmentally friendly behaviors, while the development of the Internet, especially the Internet, effectively improves consumers' perception of environmental pressure. The Internet, with Internet technology at its core, has changed the mainstream way of information dissemination and accelerated the speed of information dissemination. Consumers can learn low-carbon knowledge and environmental protection knowledge through the Internet to spontaneously form an awareness of environmental protection, which improves the level of consumers' awareness of environmental issues and increases the likelihood of environmentally friendly behaviours. In this way, the Internet is conducive to raising consumers' awareness of environmental pressures and promoting the low-carbon transformation of household consumption.

Second, the Internet drives a low-carbon transition in household consumption by changing consumer preferences. The results in column (2) of Table 4 show that the Internet can drive the shift of consumer preferences to low-carbon and promote the low-carbon transformation of household consumption. The development of the Internet has led to the dissemination of new consumption concepts to residents through the Internet, reshaping their consumption awareness at the psychological level, changing their consumption preferences, and adjusting their consumption behaviours from the demand side. Therefore, the low-carbonisation of consumer preferences is the influence mechanism of the Internet in promoting the low-carbon transformation of household consumption.

Table 4 Mechanism test results

Variables	(1)	(2)	(3)

	cognize	preference	technology
Internet	0.1727***	0.0400***	0.1083***
	(0.0647)	(0.0054)	(0.0071)
time FE	Y	Y	Y
N	598	598	598
R^2	0.2393	0.1073	0.7948

Finally, the Internet promotes a low-carbon transition in household consumption by increasing the level of green technological innovation in products. As can be seen in column (3) of Table 4, the Internet improves the level of green technological innovation. Theoretically, green technology innovation is an effective means to reduce carbon emission intensity and increase the supply of low-carbon products. For one thing, green technology innovation reduces carbon emissions in the production process of products, which is ultimately reflected in the reduction of implied carbon emissions at the consumption end. Secondly, green technology innovation can increase the supply of low-carbon products, thus leading residents to consume low-carbon behaviour.

Overall, the Internet raises consumer awareness of environmental pressures and low-carbon preferences from the demand side, and promotes green technological innovation in products from the supply side, together fuelling a low-carbon transition in household consumption.

4.4 Heterogeneity analysis

1. Analysis of household heterogeneity

The urban-rural dual structure has always been one of the prominent problems in China, and there are large differences in the level of economic development, infrastructure construction, and consumption concepts between urban and rural areas, and there is urban-rural heterogeneity in the impact of the Internet on the low-carbon transition of household consumption. Therefore, urban households are assigned a value of 1, and rural households are assigned a value of 0. The interaction term between the urban household dummy variable (urban) and the Internet dummy variable (Interenet) is used to verify the differential effect of the Internet on the low-carbon transition of household consumption caused by the different financial status of households. From the results reported in columns (1) and (2) of Table 5, it can be seen that there is no obvious urban-rural difference in the impact of the Internet on household consumption "emission reduction", and the effect of "carbon reduction" on urban households is more obvious. Under the impact of the Internet, words such as "green", "healthy" and "low-carbon" are rapidly spreading and influencing consumers' consumption concepts, and urban households are more likely to accept the new concepts of low-carbon consumption and green consumption. As consumers in urban households are more likely to accept the new concepts of low-carbon and green consumption, they will translate them into consumption behaviour, thereby reducing the carbon intensity of urban household consumption.

Absolute Income Hypothesis suggests that consumption is determined by current income; however, the emergence of consumer borrowing and the rise of the concept of over consumption have led to a high incidence of household financial deficits. On the one hand, financial deficits may be the result of a change in the family's income, and residents will cut back on unnecessary expenditures in order to reduce carbon emissions from consumption, whereas spontaneous consumption, such as food, has a lower carbon content, so financial deficits may promote residents to "reduce emissions and reduce carbon emissions", but this kind of low-carbon transition of consumption to reduce one's own utility is not to be advocated. On the other hand, financial deficits may also be caused by residents' over consumption, which not only creates unnecessary waste, but also negatively affects the realisation of a low-carbon consumption transition. In this paper, households with financial deficits are assigned a value of 1, and households with financial surpluses are assigned a value of 0. The interaction term between the dummy variable for households with financial

deficits (deficit) and the dummy variable for the Internet (Interenet) is used to validate the differential effect of the Internet on the low-carbon transition of household consumption due to the different household financial status. From columns (3) and (4) of Table 5, it can be seen that the Internet inhibits the low-carbon transformation of consumption in families with financial deficits, indicating that families with financial deficits will lead to irrational consumption after being affected by the Internet, which is not conducive to the low-carbon transformation of family consumption, so moderate consumption is an important way to guide the transformation of family consumption into a low-carbon economy.

Table 5 Tests of Heterogeneity in Household Characteristics

Variables	Urban-rural heterogeneity		Financial heterogeneity		Age structure heterogeneity	
	(1)	(2)	(3)	(4)	(5)	(6)
	pre_CO_2	intensity_CO_2	pre_CO_2	intensity_CO_2	pre_CO_2	intensity_CO_2
Internet	-0.0567*	-0.591***	-0.3001***	-0.1456***	-0.0380*	-0.0813***
	(0.03400)	(0.0153)	(0.0214)	(0.0112)	(0.0225)	(0.0205)
urban×internet	0.0167	-0.0774***	-	-	-	-
	(0.0367)	(0.0160)				
deficit×internet	-	-	0.8099***	0.1263***	-	-
			(0.0309)	(0.0150)		
young×internet	-	-	-	-	0.0039	0.0115
					(0.0389)	(0.0294)
old×internet	-	-	-	-	-0.0724*	-0.0187
					(0.0391)	(0.0310)
control variable	Y	Y	Y	Y	Y	Y
time FE	Y	Y	Y	Y	Y	Y
N	598	598	598	598	598	598
R^2	0.4316	0.7890	0.4617	0.7887	0.4294	0.7058

Age structure is an important factor affecting household carbon emissions. According to the age structure, households are divided into young adult households, polygamous households and aging households, firstly, the polygamous households are assigned as 1, and the rest of the households are assigned as 0, secondly, the aging households are assigned as 1, and the rest of the households are assigned as 0. The interaction terms of the polygamous dummy variable (young) with the Internet dummy variable (Interenet), the aging dummy variable (old) with the Internet dummy variable (Interenet) are used to verify the differential effects of different age structures on the low-carbon transition of household consumption. Interenet) interaction terms to verify the differential effect of the Internet on the low-carbon transition of household consumption due to differences in age structure. From columns (5) and (6) of Table 5, it can be seen that the Internet promotes the low-carbon transition of consumption in young and old households, has no significant difference in the effect on polygamous households, and has a significant effect on reducing per capita consumption carbon emissions in old households, but has no significant difference in reducing the carbon intensity of consumption. As the impact of the Internet on per capita consumption carbon emissions is not only reflected in the carbon reduction effect of low-carbon consumption behaviors, but also by the impact of the Internet on the expansion of the consumption scale of the increase in emissions, the Internet significantly reduces the per capita consumption carbon emissions of the aging households may be due to the old people's ideological concepts of thrift and frugality constrain the consumption, therefore, the exertion of the Internet consumption dividend to stimulate the old people's demand for low-carbon

consumption to expand the The low-carbon consumption market for the elderly is not only conducive to economic development but also effective in achieving environmental goals.

2. Heterogeneity of consumption categories

It has been verified in the previous mechanism analysis that the Internet can promote household consumption carbon emission reduction through consumer preference decarbonisation on the demand side, and this paper constructs a consumption type heterogeneity analysis to explore the impact of the Internet on the carbon emissions of eight types of consumption respectively. Table 6 shows that the Internet significantly reduces the consumption carbon emissions of clothing, housing, transport and healthcare. From the estimated coefficients, the Internet has the most obvious carbon emission reduction effect on residential consumption, and the reduction effects on healthcare, transport and clothing are decreasing in order. The emission reduction effect on the consumption of household equipment and supplies is only significant at the 10% level, and the carbon emission reduction effect on the consumption of food and the consumption of culture, education and entertainment is not significant, and raises the carbon emission level of other consumption. The agriculture and service sectors have been regarded as low-carbon industries, so the low-carbon transformation of industry, construction and transport has been emphasised to the neglect of cleaner production in the agriculture and service sectors in achieving environmental goals. Excessive fertiliser application, agricultural film residue and diesel machinery production for harvesting have increased the implicit carbon in agricultural products, and the low-input, low-output development model of the service sector has not been conducive to the enhancement of energy efficiency, with the cost of and pressure for emission reduction rising year by year. The cost and pressure of emission reduction are increasing year by year. With the rise of digital technology, other consumption, especially online virtual consumption, has proliferated, accompanied by an increase in carbon emissions. It is thus clear that the low-carbon transformation of agriculture and services empowered by the Internet is an important path to promote carbon emission reduction in household consumption, and that the Internet guiding residents to consume rationally is a key way to realise the low-carbon transformation of household consumption.

Table 6 Results of the test for heterogeneity of consumption categories

Variables	(1)	(2)	(3)	(4)
	pco2_food	*pco2_dress*	*pco2_daily*	*pco2_house*
Internet	-0.0057	-0.0125**	-0.1053*	-0.2878***
	(0.0099)	(0.0061)	(0.0582)	(0.0745)
time FE	Y	Y	Y	Y
N	598	598	598	598
R^2	0.3986	0.2112	0.0403	0.0686

Variables	(5)	(6)	(7)	(8)
	pco2_trco	pco2_eec	pco2_med	pco2_otehr
Internet	-0.0153**	-0.0055	-0.0238***	0.0090***
	(0.0068)	(0.0220)	(0.0087)	(0.0033)
time FE	Y	Y	Y	Y
N	598	598	598	598
R2	0.2184	0.1088	0.0518	0.0558

5.Conclusion and Suggestion

5.1 Conclusion

(1)The Internet usage and the low-carbon transition in household consumption

The rapid development of the Internet has provided a strong impetus for the low-carbon transformation of household consumption. With the popularity and application of the Internet, not only has the way of information dissemination undergone profound changes and the speed of dissemination increased dramatically, but at the same time the level of consumer awareness of environmental issues has increased significantly, which provides a good basis for prompting environmentally friendly behaviour. Specifically, the Internet actively promotes households' transition to low-carbon consumption through three main ways: raising consumers' awareness of environmental pressures, changing their consumption preferences, and promoting green technological innovation. This suggests that the Internet is not only a new engine of economic development, but also an important force in promoting sustainable consumption behaviour.

(2)Age structure and consumption patterns

The Internet stands out in promoting a low-carbon transition in the consumption of young adult households, while its impact on polygamous households is smoother. Meanwhile, for aging households, while the Internet significantly reduces their per capita consumption carbon emissions, its impact on overall carbon intensity is insignificant. This may be related to the deeply rooted concept of thrift and frugality among the elderly, which restricts their freedom of consumption to a certain extent. Therefore, making full use of the consumption dividend brought about by the Internet to stimulate the low-carbon consumption demand of the elderly group can not only expand this market, but also effectively contribute to the achievement of environmental goals and the sustainable development of the economy.

(3)Emission reduction effects of consumption categories

The impact of the Internet on carbon emissions reductions in different areas of consumption shows significant variability. For consumption types such as clothing, housing, transport and healthcare, the Internet significantly reduces the associated carbon emissions. In the case of household equipment and supplies, the reduction effect is only significant at the 10 per cent level, while food consumption and education, culture and entertainment consumption have insignificant carbon reduction effects, and in some cases even raise the level of carbon emissions of other consumption. This phenomenon underscores the importance of in-depth analysis of the heterogeneity between different consumption categories when designing measures for a low-carbon transition, and thus the need to target consumer choices and behaviours in order to achieve the overall carbon reduction target.

5.2 Suggestion

In order to achieve the goal of "double carbon" and high-quality economic development, the research analyze the impact of the Internet on household carbon emissions in Shanghai, and put forward the following policy recommendations:

(1)Promoting the Internet and technological innovation

The government need to strengthen urban technological innovation, increase investment in the Internet industry and scientific and technological research and development, cultivate low-carbon industries and related talents, improve standard and monitor mechanisms, and enhance the efficiency of carbon emissions.

(2)Optimization of urban industrial structure

With the help of the Internet, we will adjust the configuration of the industry, promote intelligent and low-carbon transformation, upgrade the digital infrastructure, and promote the development of productivity and the tertiary sector, while accelerating the reform of the energy structure.

(3) Promoting regional cooperation

Governments should strengthen regional cooperation and resource integration, optimise resource allocation, and establish a unified national market to enhance the digital economy and green development of the overall urban agglomeration.

(4) Policy support and consumption upgrade

Encourage families to adjust their consumption structure and raise awareness of low-carbon consumption, pay particular attention to the imbalance in development between rural and urban areas, improve the quality of life of residents through improved information networks and financial services, and promote green consumption.

(5) Comprehensive measures adapted to local conditions

The government should take into account local characteristics, cooperate with science and technology enterprises to develop green technologies, raise public awareness of low carbon, build a carbon emission monitoring system, and promote cross-sectoral cooperation and incentives to facilitate green living.

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