

The Impact of E-Commerce on Rural Energy Carbon Emissions: Income Effects and Regional Heterogeneity

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Abstract: *Drawing on provincial panel data from 2007 to 2020, this study empirically examines the impact of e-commerce development on carbon emissions from rural household energy consumption and identifies the underlying mechanism through the income effect. The results show that e-commerce development significantly increases both the aggregate scale and per capita level of rural household energy-related carbon emissions. This promotional effect declines over time and is more pronounced in eastern and northern regions than in central, western, and southern regions. Mechanism analysis reveals that income growth induced by e-commerce is the primary driver: it elevates emissions through expanded consumption scale and upgraded consumption structure, while simultaneously reducing emissions by facilitating cleaner energy transitions. These findings extend the environmental impact literature on e-commerce and offer practical implications for rural carbon emission management.*

Keywords: E-commerce; Rural household energy consumption; Carbon emissions; Income effect; Regional heterogeneity; Panel data.

1. Introduction

Under the realistic constraints of the “dual carbon” goal, it is crucial to clarify the realistic path of energy conservation and emission reduction. However, the current attention to energy conservation and emission reduction generally focuses on urban and industrial sectors, while ignoring the energy consumption issues in rural areas. As a traditional agricultural country, rural energy issues are related to national economy and people’s livelihood, and effective rural energy supply is an important guarantee for the production and life of rural residents. Along with the progressive transformation of rural energy consumption from traditional non-commercial energy to commercial energy, strengthening rural energy management has become an important part of implementing the goal of energy conservation and emission reduction (Shi Qinghua et al., 2014). At the same time, the implementation of the rural revitalization strategy has put forward higher requirements for rural environmental governance. Therefore, the research on rural energy consumption issues has important practical significance.

The promotion of the energy conservation and emission reduction goal needs to be led by the transformation of the economic development model. The development of digital economy represented by e-commerce is the most dynamic economic field at present. The development of e-commerce can rely on the modern logistics system and online services such as online transactions, B2C services, and electronic payments to promote the transformation of traditional operation and management models, and then have a profound impact on residents’ production and life, which is mainly reflected in many aspects such as rural residents’ consumption and employment. However, few studies have further focused on the impact of e-commerce development on rural household energy carbon emissions. Theoretically, household energy carbon emissions can be mainly divided into direct energy consumption carbon emissions such as heating and cooking, and indirect energy consumption carbon emissions such as consumption. On the one hand, the development of

e-commerce can affect residents’ consumption patterns, and affect the scale and structure of residents’ consumption by expanding product acquisition channels and improving personalized product service capabilities. On the other hand, it can change residents’ energy use choices by affecting their incomes. Therefore, it can be expected that the development of e-commerce can have a profound impact on rural household energy consumption carbon emissions.

Unfortunately, despite the fact that the real-world proposition of e-commerce development in rural areas has attracted much attention from the academic community, few studies have incorporated e-commerce development and rural energy consumption carbon emissions, especially carbon emissions from household energy consumption, into a unified analytical framework. Based on this, this paper attempts to answer the question of “how exactly does e-commerce development affect rural household energy consumption carbon emissions?”. The innovative work of this paper mainly includes two parts: First, it verifies the quantitative relationship between e-commerce development and rural household energy consumption carbon emissions, that is, empirically tests whether there is a causal relationship between the two. Based on the provincial-level panel data from 2011 to 2020, this paper measures the provincial-level rural e-commerce development and the scale of rural household energy consumption carbon emissions, and then constructs a panel fixed-effect model for empirical investigation. The study finds that e-commerce development significantly promotes the expansion of the scale of rural energy consumption carbon emissions; Second, it normatively explains the internal mechanism of e-commerce development’s impact on rural household carbon emissions. Based on the income growth effect brought by e-commerce development, this paper conducts a mechanism analysis from the dimensions of consumption scale, consumption structure, and energy use choice. The study finds that e-commerce development can promote the income increase of rural residents, and then increase household energy consumption carbon emissions by promoting the expansion of consumption scale and the upgrading of consumption structure. At the same time, it can

reduce rural household energy carbon emissions by promoting the cleaning of energy use choices.

2. Literature Review

First, it is the measurement research on carbon emissions from energy consumption. In fact, there are numerous studies related to the measurement of carbon emissions from energy consumption. However, most of these studies generally focus on carbon emission measurement at the national, provincial or city levels. Some studies even focus on carbon emission measurement at the county and household levels. For example, at the national level, Cheng Yeqing et al. (2013) estimated the scale of carbon emissions from China's energy consumption based on the quantity of different types of energy consumption, while Adekoya et al. (2021) estimated the total carbon emissions from energy consumption in 126 countries and regions based on global energy consumption data. At the provincial level, Zhao Xuemin and Bian Tengrui (2015) took Shaanxi Province as the research object and characterized the dynamic evolution of its carbon emissions from energy consumption based on the total energy consumption. Li Zhiguo et al. (2021) estimated the carbon emissions from energy consumption in 30 provinces across the country according to inter-provincial energy consumption data. At the city level, Li Zhiguo and Wang Jie (2021) estimated the scale of carbon emissions from primary energy consumption in cities based on the energy consumption data published in the China City Statistical Yearbook. Based on the same analysis idea, Li Zhiguo et al. (2022) measured the carbon emissions of 274 prefecture-level cities and above in the country. At the industry level, Li Zhiguo et al. (2021) measured industry carbon emissions based on industrial sub-sector energy consumption data and estimated the productivity level including non-desirable outputs at the industry level according to the obtained carbon emission data. At the household level, Zhang Xin et al. (2011) measured the direct and indirect carbon emissions from household energy consumption using the carbon emission coefficient method. On this basis, Wang Jun et al. (2022) investigated the consumption carbon emissions at the household level based on the household consumption characteristics published in the China Family Panel Studies data. However, research on carbon emissions from rural energy consumption is relatively scarce, and it generally focuses on the indirect energy consumption of rural households. The measurement of carbon emissions from rural residential energy consumption is relatively lacking. Therefore, comprehensive research focusing on carbon emissions from rural residential energy consumption is particularly important.

Second, it is the analysis of the influencing factors of carbon emissions from energy consumption. Methods such as the logarithmic mean Divisia index (LMDI) method, the STIRPAT decomposition method, the EKC hypothesis, and the Granger causality test method have been widely used in the analysis of the influencing factors of carbon emissions (Xu Guangyue and Song Deyong, 2010). At the same time, spatial econometric methods that incorporate spatial spillover effects have also become common tools for analyzing the influencing factors of carbon emissions (Zheng Changde and Liu Shuai, 2011; Tong Xin et al., 2014; Hu Zongyi and Liu Yiwen, 2015). Research shows that the total carbon emissions,

carbon intensity, and regional emission reduction work are jointly affected by multiple factors. On the one hand, the total industrial energy consumption, total domestic energy consumption, energy use structure, and energy use efficiency have a direct decisive effect on carbon emissions (Wang Huogen and Teng Yuhua, 2013; Shao et al., 2016; Yang Hao and Zhang Zhang Zhang Ling, 2018). On the other hand, factors such as the level of economic development, technological innovation level, and industrial structure can indirectly affect carbon emissions through energy consumption (Li Zhixue et al., 2019). Lu Wanbo et al. (2013) found through a stage-based division of economic growth that the important influencing factors of carbon emissions vary in different stages, showing a characteristic of changing from economic aggregate and industrial structure to energy intensity and energy structure; Peng Shuijun et al. (2015) found through the decomposition of carbon emissions at the production and consumption ends that the continuous growth of domestic consumption scale and the change of factor input structure are the main reasons for the increase in carbon emissions; Wang Ya'nan and Zhao Tao (2017) used the geographically weighted regression method (GWR) to compare and analyze the influencing factors of carbon emissions in each province and found that the driving factors for the increase in carbon emissions vary among provinces. Among them, the promotion of urbanization has a significant impact on the increase in carbon emissions in the eastern region and a weaker impact on the central and western regions; Wang Shaojian et al. (2018) pointed out that the industrial-led industrial structure and the rapid expansion of investment scale are the main reasons for the increase in urban carbon emissions, while population density, technical efficiency, and opening up to the outside world help to inhibit urban carbon emissions; Chen Zhanming et al. (2018) found based on an extended STIRPAT model that population size, industrial structure, and heating demand are the main reasons for the increase in urban carbon emissions, while the impact of urbanization promotion tends to weaken. With the booming development of the digital economy, the impact of the digital economy on carbon emissions from energy consumption has become a hot topic widely concerned by the academic community. However, relevant research mainly focuses on the impact of digital technology application, industrial digitalization, and digital industrialization on carbon emissions under the background of digital economy development. There is little research directly discussing the impact of the transformation of the operation and management mode of the digital economy as a new economic form on carbon emissions from energy consumption. Among them, e-commerce, as an important part of the development of the digital economy, its impact on carbon emissions from energy consumption is also generally ignored.

Third, it is the analysis of the economic effects of the development of e-commerce. The many positive impacts of the development of e-commerce in the economic field have been widely confirmed. Research has found that the development of e-commerce helps to boost economic vitality, promote employment and innovation among residents, attract external investment, and drive innovation and balanced development. The role of the development of e-commerce in the environmental field has also been a hot topic of concern among many scholars. Then, what is the impact of the

development of e-commerce on environmental quality? Cao et al. (2021), based on a quasi-natural experiment of the construction of national e-commerce demonstration cities, found that the development of e-commerce is beneficial to the green transformation of the economy, which is mainly due to the reduction in transaction costs and the upgrading of the industrial structure driven by the development of e-commerce. This research finding is basically consistent with that of Liu Naiquan et al. (2021). Jin Huan et al. (2022) mainly focused on the impact of the development of e-commerce on the green innovation of enterprises. Their empirical results showed that the development of e-commerce can significantly promote the improvement of the level of green innovation. Further, a few studies directly discussed the correlation between the development of e-commerce and carbon emissions. For example, Wang et al. (2023) and Dong et al. (2023), by means of a quasi-natural experiment of the construction of national e-commerce demonstration cities, used a difference model to examine the impact of the development of e-commerce on the total urban carbon emissions and per capita carbon emissions. The research confirmed that the development of e-commerce has a positive and significant emission reduction effect, and this conclusion has also been corroborated by the research of Biao et al. (2023). It is worth noting that the above studies on the emission reduction effect of the development of e-commerce generally focus on the urban level, while the rural areas, as an important part of energy consumption carbon emissions, have rarely been studied.

To sum up, the existing research on how e-commerce affects rural energy consumption carbon emissions is relatively scarce. Not to mention the rural household energy consumption carbon emissions that this paper focuses on, its internal mechanism of action also needs to be further discussed in depth. Based on the above research deficiencies, this paper measures the rural household energy consumption carbon emissions, and then conducts an empirical investigation and mechanism analysis of the correlation characteristics between the two.

3. Research Design

3.1 Research Methods

Given that there are relatively many influencing factors for rural household energy consumption carbon emissions, the key to improving the accuracy of estimation results is to eliminate irrelevant variables or minimize omitted variables as much as possible. This paper mainly uses the Lasso (Least Absolute Shrinkage and Selection Operator) method (hereinafter referred to as "Lasso") to identify the impact of e-commerce development on rural household energy consumption carbon emissions. The advantage of this method is that it can impose constraint conditions on the traditional least squares method to eliminate the multicollinearity problem among influencing factors as much as possible, so as to more accurately identify the influencing factors of rural household energy consumption. The specific mathematical form of the adaptive Lasso model constructed in this paper is as follows:

Assume that the explained variable Y and the explanatory variables X satisfy the functional relationship $Y = \beta X + \varepsilon$,

where ε represents the random disturbance term), then the estimate of β is defined as:

$$\hat{\beta}_{LASSO} = \operatorname{argmin}_{\beta} \sum_{i=1}^N (y_i - \beta x_i)^2 + \lambda \sum_{q=1}^Z |\beta_q|$$

Among them, λ represents the constraint parameter, and the estimated value of $\hat{\beta}$ is closely related to λ . By setting $\lambda = \sum \hat{\beta}$, different degrees of compression can be imposed on the regression coefficient $\hat{\beta}$ by adjusting the constraint conditions. In extreme cases, if the estimated coefficient of the explanatory variable X_i is compressed to 0, it means that the impact of this variable on rural household energy carbon emissions is not significant and is thus eliminated. Further, based on the constraint condition λ , the generalized cross-validation statistic GCV can be constructed, that is:

$$GCV(\lambda) = \frac{|Y - X\hat{\beta}_{\lambda}|^2}{(1 - e(\lambda)/N)^2}$$

Combined with the research of Wu Yilin and Li Xian (2018), the λ that makes the generalized cross-validation statistic GCV take the minimum value is the optimal one. Further, Zou (2006) sets different weights for the constraint parameters of different $\hat{\beta}$ to make $\hat{\beta}$ meet the asymptotic normality requirement, that is, the adaptive Lasso model, and its corresponding form is as follows:

$$\hat{\beta}_{LASSO} = \operatorname{argmin}_{\beta} \sum_{i=1}^N (y_i - \beta x_i)^2 + \lambda \sum_{q=1}^Z \omega_q |\beta_q|$$

Among them, ω_q represents the weight corresponding to the estimated parameter, $\omega_q = (|\beta_{q \cdot (OLS)}|)^{-\gamma}$, $\beta_{q \cdot (OLS)}$ is the least squares estimator of β_q , and γ is an adjustable parameter. Combining the extended Bayesian information criterion (EBIC) and the Akaike information criterion (AIC), etc., the adaptive Lasso model can obtain the optimal regression coefficient $\hat{\beta}$.

3.2 Data Sources and Indicator Explanation

1) Indicator Explanation. E-commerce Development (EB). Based on the basic measurement indicator system proposed by the China Internet Research and Development Center, the Ministry of Commerce of China and Alibaba Research Institute characterized e-commerce development by e-commerce transaction volume. Referring to the research of Zhang Hengshuo et al. (2022), this paper uses the ratio of online retail sales to total household consumption to describe the level of e-commerce development.

Carbon Emissions from Rural Energy Consumption (CC). Referring to the research of Li Qi et al. (2019), this paper measures the carbon emissions from rural energy consumption using 21 types of energy consumption based on the carbon emission coefficients published by the IPCC in 2006. The carbon emission coefficients for electricity and heat are based on the "China Regional Grid Baseline Emission Factors for Emission Reduction Projects in 2019". The specific carbon emission measurement model is as follows:

$$y = \sum AE \times NCV \times EF \times 0 \times 44/12$$

Among them, AE represents the energy consumption volume, and the specific energy consumption types include raw coal, electricity, natural gas, gasoline, diesel, briquette, lubricating

oil, liquefied petroleum gas, liquefied natural gas, heat, coke, coke oven gas, fuel oil, kerosene, petroleum asphalt, other washed coal, other gas, washed clean coal, refinery dry gas, petroleum coke and other petroleum products. NCV represents the average low calorific value, and EF and O represent the carbon content per unit calorific value and the carbon oxidation rate respectively.

Other influencing factors. Considering that there are many factors that may affect the carbon emissions from household energy consumption, this paper mainly selects control variables from the dimensions of rural economic development, population size, quality of life and basic living inputs, including: Economic Development (AGDP), represented by the total agricultural output value deflated with 2007 as the base period; Basic Living Input (LBIN), represented by the completed fixed-asset investment of rural residents deflated with 2007 as the base period; Energy Efficiency (EFFI), represented by the ratio of total rural energy consumption to total agricultural output value; Population Size (POP), represented by the proportion of the total rural population to the total local population; Population Aging (OLD), represented by the rural old-age dependency ratio; Quality of Life (CON), represented by the per capita consumption expenditure of rural residents; Consumption Structure (Stru), represented by the proportion of service consumption such as culture and entertainment, medical care and health in the total consumption expenditure of rural residents; Energy Price (Price), represented by the ex-factory price index with 2007 as the base period; Energy Structure (Estr), represented by the proportion of coal consumption in the total rural energy consumption.

2) Data source. This paper mainly selects the panel data of rural areas in 30 provinces of China from 2007 to 2020 (excluding Tibet and Hong Kong, Macao and Taiwan regions) as the research sample. Among them, the energy consumption data of rural areas mainly come from the China Energy Statistical Yearbook, the basic indicators of rural areas such as total population, per capita income, and total agricultural output value come from the China Statistical Yearbook, the indicators such as rural living fixed asset investment and energy price come from the China Rural Statistical Yearbook, and the rural old-age dependency ratio comes from the statistical yearbooks of each province. Relevant monetary indicators are deflated with 2007 as the base period.

4. Empirical Results Analysis

4.1 Benchmark Analysis

Table 1 reports the benchmark regression of the impact of e-commerce development on rural household energy consumption carbon emissions obtained from the adaptive Lasso model. For comparison, this paper also lists the estimation results obtained from the ordinary OLS method. It can be seen that the estimated coefficient of the impact of e-commerce development on rural household energy consumption carbon emissions is significantly positive, which means that e-commerce development will lead to an increase in the total amount of rural household energy consumption carbon emissions. The estimation results obtained from the

OLS method also support the above conclusion. It can be seen that while e-commerce development boosts rural economic development, it also brings new problems of rural household energy consumption carbon emissions. And how to alleviate the growth of rural household energy consumption carbon emissions induced by e-commerce development is an issue that cannot be ignored in the future development of rural e-commerce under the constraint of the “dual carbon” goal. From the estimation results of other control variables, the estimated coefficients of variables such as economic development, living infrastructure investment, population size, quality of life, energy use structure, and consumption structure are all significantly positive, while energy efficiency, population aging, and energy prices are significantly negatively correlated with household energy consumption carbon emissions. Further, to ensure the reliability of the estimation results, this paper also uses the per capita rural household energy consumption carbon emissions as a substitute indicator for robustness testing. The results show that e-commerce development can also significantly promote the per capita rural household energy consumption carbon emissions. It can be seen that the benchmark conclusions obtained above are relatively reliable.

Table 1: Benchmark Regression of the Impact of E-commerce Development on Rural Household Energy Consumption Carbon Emissions

	(1)	(2)	(3)
	Adaptive Lasso	Ordinary OLS	Robustness test
EB	0.0047*** (4.32)	0.0050*** (4.11)	0.1328*** (2.65)
AGDP	0.0468*** (12.09)	0.0501*** (10.26)	0.1548*** (6.88)
LBIN	0.1783** (2.20)	0.2005*** (2.14)	0.5238*** (4.93)
EFFI	-0.0248*** (-3.12)	-0.0225*** (-3.46)	-0.1623** (-1.92)
POP	0.0147*** (4.83)	0.0173*** (5.05)	0.1395*** (2.72)
OLD	-0.0023*** (-4.13)	-0.0018*** (-4.52)	-0.1045** (-2.13)
CON	0.0482*** (5.60)	0.0511*** (6.23)	0.2509*** (3.83)
Stru	0.0016** (2.41)	0.0023** (2.08)	0.0459** (2.15)
Price	-0.0003* (-1.79)	-0.0004** (-1.83)	-0.0003** (-2.00)
Estr	-0.0215*** (-2.87)	-0.0209*** (-3.06)	-0.2244** (-2.22)
Adj. R ²	0.5820	0.4878	0.6612
F-Value	43.19	22.48	45.14

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; values in parentheses are *t* values, the same below.

4.2 Spatiotemporal Characteristics Analysis

Considering that there are differences in the development level of e-commerce in different regions and the demand for rural household energy consumption varies across regions, this paper posits that there may be differences in the impact of e-commerce development on rural household energy consumption carbon emissions across the eastern, central, and western regions. To verify this conjecture, the research sample is divided into eastern, central, and western regions for sequential investigation. The results show that the promoting effect of e-commerce development on rural household energy consumption carbon emissions remains significant in all three regions. However, compared with the central and western regions, the promoting effect of e-commerce development in the eastern region is more prominent. Similarly, this paper also examines the heterogeneity characteristics of the southern and northern regions. The results indicate that the promoting effect of e-commerce development on rural household energy consumption carbon emissions in the northern region is more significant. To further characterize the dynamic characteristics of the impact of e-commerce

development on rural household energy consumption carbon emissions in the time dimension, this paper examines the impact of e-commerce development on rural household energy consumption carbon emissions with different lag periods. The results show that the estimated coefficients of e-commerce development lagged by one period, two periods, and three periods are all significantly positive, indicating that the promoting effect of e-commerce development on rural household energy consumption carbon emissions is persistent. However, comparing the specific estimated coefficient values, as the lag period increases, the impact of e-commerce development on rural household energy consumption carbon emissions tends to decay. The spatiotemporal characteristics analysis of the impact of e-commerce development on rural household energy consumption carbon emissions is shown in Table 2.

Table 2: Spatiotemporal Characteristics Analysis of the Impact of E-commerce Development on the Carbon Emissions of Rural Household Energy Consumption

	(1)	(2)	(3)	(4)	(5)
	The eastern region	The central region	The western region	The northern region	The southern region
L. EB	0.0065** (4.51)	0.0049*** (3.80)	0.0050** (5.01)	0.0068** (4.65)	0.0050** (5.70)
Adj. R ²	0.3748	0.5015	0.4829	0.3875	0.4120
F-Value	41.09	33.91	38.09	44.29	29.13
L2. EB	0.0060** (3.77)	0.0044*** (4.26)	0.0047** (3.92)	0.0065** (4.20)	0.0046** (3.92)
Adj. R ²	0.4781	0.4418	0.4092	0.5022	0.4445
F-Value	40.45	31.40	30.57	37.59	20.48
L3. EB	0.0054** (2.42)	0.0041*/ (4.95)	0.0042* (5.29)	0.0057*k (3.91)	0.0042** (3.66)
Adj. R ²	0.3892	0.4506	0.3982	0.4913	0.4892
F-Value	26.82	22.75	28.64	33.44	19.84
Control variables	YES	YES	YES	YES	YES

Note: L represents the lag term.

4.3 Mechanism Analysis

Clarifying the internal mechanism of the impact of e-commerce development on rural household energy consumption carbon emissions is the core content of this paper. The investigation of the internal mechanism in this paper mainly follows the following analysis logic: Rural household energy consumption carbon emissions mainly come from two categories: direct energy consumption such as heating and cooking, and indirect energy consumption such as the consumption of household goods by residents. Among them, the carbon emissions of direct energy consumption mainly depend on the energy use choices for rural household cooking and heating, while the carbon emissions of indirect energy consumption mainly depend on the scale and structure of residents' consumption. Therefore, the key to the mechanism of the impact of e-commerce development on rural household energy consumption carbon emissions lies in building an analysis "bridge" for the impact of e-commerce development on rural household energy use choices, consumption scale and consumption structure. First, analysis of the influencing factors of rural household energy use choices. Existing research has discussed many influencing factors of household energy use choices. For example, Hanna and Oliva (2015) discussed the correlation between household energy use choices and residents' welfare, and Karimu (2015)

discussed the influencing factors of household cooking energy use. Most research on household energy use choices generally takes the "energy ladder" theory as the basis (Hosier and Dowd, 1987), that is, household energy use choices will climb with the improvement of social and economic status. Specifically, the "energy ladder" theory divides household energy use choices into three stages: in the first stage, household energy use is mainly based on firewood, straw, livestock manure, etc.; in the second stage, it is mainly based on fossil fuels such as charcoal, coal and kerosene; and in the third stage, it is mainly based on modern energy such as electricity, natural gas and liquefied petroleum gas. On this basis, some scholars have further proposed the "energy stacking" hypothesis, that is, high-quality energy will not completely replace the initial energy in a short period of time, and household energy use choices will show a mixed use of diversified energy types. It is undeniable that factors such as energy prices and fuel supply will have an impact on household energy use choices, but the dynamic evolution of household energy use choices is still determined by income. Second, analysis of the influencing factors of household consumption. The classic Keynesian consumption theory points out that residents' consumption activities are closely related to income. Income growth not only drives the expansion of consumption scale, but also helps to upgrade the consumption structure, that is, the proportion of basic consumption decreases while the proportion of service consumption increases. Based on the above analysis, both rural household energy use choices and the scale and structure of rural household consumption are closely related to the rural income level. Therefore, an analysis framework of "e-commerce development - income increase - changes in energy use choices, expansion of consumption scale and upgrading of consumption structure - increase in rural household energy consumption carbon emissions" can be constructed.

In the specific empirical analysis, the mechanism test process is mainly divided into three steps: First, test the impact of e-commerce development on the rural income (Inco) level; second, test the impact of the rural income level on the energy consumption structure (Estr), consumption scale (CON), and consumption structure (Stru); third, test the impact of the above changes on the carbon emissions of rural household energy consumption. Among them, the impact of the energy consumption structure, consumption scale, and consumption structure on the carbon emissions of rural household energy consumption has been verified in the baseline regression analysis, that is, the higher the proportion of coal consumption in the rural household energy consumption structure, the greater the total carbon emissions of rural household energy consumption; the larger the per capita consumption expenditure scale, the greater the total carbon emissions of rural household energy consumption; the higher the proportion of service consumption, the greater the total carbon emissions of rural household energy consumption. Further, the mechanism test results in Table 3 show that e-commerce development has a significant promoting effect on the rural residents' income level. This paper proposes that e-commerce development can achieve income generation for rural residents by providing more non-farm employment opportunities and encouraging rural entrepreneurship. In addition, the impact of the increase in income level on the

rural energy consumption structure is significantly negative, that is, the increase in income will lead to the transfer of rural energy consumption choices from traditional fossil energy to higher-level clean energy. At the same time, e-commerce development also helps to expand the rural consumption expenditure scale and upgrade the consumption structure. Combining the above empirical analysis results, it can be found that e-commerce development can promote the improvement of the rural income level. On the one hand, it can promote the carbon emissions of rural household energy consumption through the consumption scale effect and consumption structure effect. On the other hand, it can inhibit the carbon emissions of rural household energy consumption through the clean-up of energy consumption choices, but this inhibitory effect is completely masked by the promoting effect.

Table 3: Mechanism Test of the Impact of E-commerce Development on Carbon Emissions from Rural Domestic Energy Consumption

	(1)	(2)	(4)	(4)
	Income	Sture	Control	sture
Business	0.2415*** (5.93)			
income		0.0093** (4.10)	0.1255*** (5.34)	0.1815*** (3.27)
Control variables	是	是	是	是
R ²	0.4300	0.3553	0.3834	0.4624
F	20.48	17.44	28.35	14.50

5. Conclusion

In summary, the development of e-commerce will lead to an increase in carbon emissions from rural household energy consumption, thus exacerbating the carbon emission reduction situation in China. However, the driving effect of e-commerce development on rural economic growth cannot be ignored. The increase in carbon emissions from household energy consumption brought about by e-commerce development is, to a certain extent, a product of the economic growth in rural areas driven by e-commerce development. Therefore, the development of e-commerce in rural areas should continue to be deeply promoted. At the same time, attention should also be paid to the management of rural household energy consumption. By guiding green consumption behavior, cultivating green consumption concepts and awareness, and promoting the clean transformation of rural energy use, rural low-carbon development should be strengthened.

References

- [1] Shi Qinghua, Peng Xiaohui, Zhang Rui. Field Investigation on Rural Energy Consumption in China: Taking the Investigation of 2,253 Households in Shanxi, Guizhou and Zhejiang Provinces as an Example [J]. Management World, 2014 (5)
- [2] Cheng Yeqing, Wang Zeye, Zhang Shouzhi, et al. Spatial Econometrics of Carbon Emission Intensity of Energy Consumption in China and Its Influencing Factors [J]. Acta Geographica Sinica, 2013, 68 (10)
- [3] Zhao Xuemin, Bian Tengru. Factor Decomposition of Carbon Emission from Energy Consumption Based on LMDI: Taking Shaanxi Province as an Example [J]. Economic Issues, 2015 (2)
- [4] Li Zhiguo, Wang Jie, Zhao Yuanchun. The Synergistic Emission Reduction Effect of Carbon Emission Trading: Internal Mechanism and Chinese Experience [J]. Systems Engineering, 2022, 40 (3)
- [5] Li Zhiguo, Wang Jie. How Does the Development of Digital Economy Affect Spatial Carbon Emissions under the Background of Economic Agglomeration? [J]. Journal of Xi'an Jiaotong University (Social Sciences Edition), 2022, 42 (5)
- [6] Li Zhiguo, Wang Jie, Che Shuai. How Does the Dependence on Resource-based Industries Affect Environmental Quality? [J]. Commercial Research, 2022 (3)
- [7] Li Zhiguo, Wang Jie, Che Shuai. Win-win Development of China's Industrial Growth and Energy Conservation and Emission Reduction under the Constraint of Carbon Peak [J]. Journal of Environmental Economics Research, 2021, 6 (2)
- [8] Zhang Xin, Niu Shuwen, Zhao Chunsheng, et al. Research on Household Energy Consumption and Carbon Emissions in the Process of Urbanization in China [J]. China Soft Science, 2011 (9)
- [9] Wang Jun, Wang Jie, Wang Yewei. How Does the Development of Digital Finance Affect the Carbon Intensity of the Manufacturing Industry? [J]. China Population, Resources and Environment, 2022, 32 (7)
- [10] Xu Guangyue, Song Deyong. Empirical Research on the Environmental Kuznets Curve of Carbon Emissions in China - Based on Provincial Panel Data [J]. China Industrial Economics, 2010 (5)
- [11] Zheng Changde, Liu Shuai. Analysis of Carbon Emissions and Economic Growth Based on Spatial Econometrics [J]. China Population, Resources and Environment, 2011, 21 (5)
- [12] Tong Xin, Chen Kai, Li Gang. Spatial Dimension Spillover of International Trade and Carbon Emissions - Spatial Econometric Verification Based on Data of 30 Provinces in China [J]. Economic Management, 2014, 36 (11)
- [13] Hu Zongyi, Liu Yiwen. Spatial Econometric Analysis of the Relationship between Energy Consumption, Pollution Emission and Regional Economic Growth [J]. Journal of Applied Statistics and Management, 2015, 34 (1)
- [14] Wang Huogen, Teng Yuhua. Spatial Panel Data Analysis of Economic Development and Environmental Pollution [J]. Journal of Technical Economics & Management Research, 2013 (2)
- [15] Yang Hao, Zhang Ling. Empirical Research on the Impact of Industrial Structure Evolution and Urbanization Process on Air Quality in Beijing-Tianjin-Hebei Region [J]. China Population, Resources and Environment, 2018, 28 (6)
- [16] Li Zhixue, Li Leying, Chen Jian. The Impact of Industrial Structure, Carbon Emission Rights Market and Technological Innovation on Carbon Emission Reduction Efficiency in Each Province and Region [J]. Science and Technology Management Research, 2019, 39 (16)
- [17] Lu Wanbo, Qiu Tingting, Du Lei. Research on the Influencing Factors of Carbon Emissions in Different

- Economic Growth Stages of China [J]. Economic Research Journal, 2013, 48 (4)
- [18] Peng Shuijun, Zhang Wencheng, Sun Chuanwang. Measurement and Influencing Factor Research on Carbon Emissions from Production Side and Consumption Side in China [J]. Economic Research Journal, 2015, 50 (1)
- [19] Wang Yanan, Zhao Tao. Research on Spatial Differences of Carbon Emissions in China Based on GWR Model [J]. China Population, Resources and Environment, 2016, 26(2)
- [20] Wang Shaojian, Su Yongxian, Zhao Yabo. Regional Differences, Spatial Spillover Effects and Influencing Factors of Carbon Emissions from Urban Energy Consumption in China [J]. Acta Geographica Sinica, 2018, 73 (3)
- [21] Chen Zhanming, Wu Shimei, Ma Wenbo, Liu Xiaoman, Cai Bofeng, Liu Jingwen, Jia Xiaoping, Zhang Ming, Chen Yang, Xu Lixiao, Zhao Jing, Wang Siqi. Analysis of Influencing Factors of Carbon Dioxide Emissions in Chinese Cities above the Prefecture Level: Based on the Extended STIRPAT Model [J]. China Population, Resources and Environment, 2018, 28(10)
- [22] Liu Naiquan, Deng Min, Cao Xiguang. Does the E-commerce Transformation of Cities Promote Green High-quality Development? ——A Quasi-natural Experiment Based on the Construction of National E-commerce Demonstration Cities [J]. The Study of Finance and Economics, 2021, 47 (4)
- [23] Jin Huan, Yu Lihong, Wei Jiali. Research on the Impact and Mechanism of the Construction of National E-commerce Demonstration Cities on Enterprises' Green Technology Innovation [J]. Science & Technology Progress and Policy, 2022, 39 (10)
- [24] Bie Ao, Yang Shangguang, Shu Yunxia. Can the E-commerce Transformation of Cities Promote Carbon Emission Reduction? ——Empirical Evidence from the Pilot Projects of National E-commerce Demonstration Cities [J]. Industrial Economics Research, 2023 (4)
- [25] Wu Yilin, Li Xian. Research on the Influencing Factors of Labor Market Matching Efficiency [J]. Statistical Research, 2018, 35 (5)
- [26] Zhang Hengshuo, Li Shaoping, Peng Min. Regional Disequilibrium of Carbon Emissions from Rural Energy Consumption in China and Dynamic Identification of Driving Factors [J]. Chinese Rural Economy, 2022(1)

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