www.rericjournal.ait.ac.th

Understanding the Rural Households' Renewable Energy Consumption: From Measuring to Incentivizing

Wang Bo*, Chen Yalin*,[1], Feng Rong Rong* and Zhu Wenqi[#]

ARTICLE INFO

Article history:
Received 11 November 2024
Received in revised form
18 March 2025
Accepted 24 March 2025

Keywords:
Decarbonizing policy
Difference-in-difference
Propensity score matching
Renewable energy consumption
Rural household

ABSTRACT

Rural decarbonizing is considered a crucial part of the broader decarbonization. However, there is few research measure the rural households' renewable energy consumption (REC) intention systematically. To fill the gap, taking the China rural region as instance, this paper designs and validates a scale measuring the intention of households' REC by the framework of the extended planning behavior theory (E-TPB). Based on the scale, further surveys were respectively implemented in 2019 and 2023, providing the sampling data for examining the impact of decarbonizing policies from the perspective of quasi-natural experiment. The difference-in-difference (DID) method, combined with propensity score matching (PSM), are applied to verify the policies' impact on the intention factors, which illustrate the driven-path of REC intention forming. The findings suggest that implementing decarbonizing policies significantly promotes rural households' REC. Additionally, factors such as "subjective norms", "moral norms", income, and education positively influence the adoption of REC in rural households. However, "perceived behavioral control" has an inhibitory effect on REC. By measuring rural households' REC intention, the acceptance and effectiveness of existing decarbonizing policies can be assessed, providing a basis for further adjustment.

1. INTRODUCTION

As global climate change and environmental concerns continue escalating, more nations are elevating decarbonization. In response, China unveiled its strategic goal of achieving a "carbon peak" and "carbon neutrality" (collectively referred to as "dual carbon") in 2020. Central to realizing this objective is to advance renewable energy consumption [1]. Rural regions traditionally rely on carbon-intensive energy sources such as wood, coal, and natural gas for heating and cooking. However, despite this reliance on traditional energy, rural areas have significant potential for adopting renewable energy, particularly solar and wind power. Since 2000, the annual growth rate of per capita energy consumption in rural China has surged to 11.0%, far surpassing the urban rate of 5.0%, underscoring the immense, untapped potential for energy consumption in these areas. This highlights the opportunity to optimize energy consumption behaviors in rural households, which could promote the development of renewable energy, reduce dependence on traditional sources, and alleviate environmental pollution.

As electricity transmission and distribution reforms deepen, the development of centralized rural grids with decentralized loads is becoming increasingly restricted. In response, distributed renewable energy microgrids, based on the concept of "self-generation and self-consumption," are emerging as a sustainable solution to meet the energy needs of rural residents. By 2020, the reliability of rural electricity grids in China had reached 99.8%, with an electrification rate of 18%, effectively providing stable power supply services to rural areas. Alongside this progress, the comprehensive utilization of crop straw and the expansion of rural biogas systems have steadily increased. In 2019, over 103,000 rural biogas projects were operational, generating 850 MWh of electricity annually, positioning China as the global leader in biogas usage. The gap between the consumption of clean renewable energy and biomass energy is steadily narrowing, marking a fundamental shift in the energy consumption structure of rural households. Fully utilizing renewable energy sources such as wind, solar, and biomass has become crucial for promoting the low-carbon transformation of the energy system and supporting the ecological development of rural areas. To effectively encourage renewable energy consumption in rural households, it is essential to study not only the economic factors, such as income and energy prices, but also the non-economic factors, including individual attitudes, social cognition, and policy that may affect consumption intentions.

* School of Management Science and Engineering, Nanjing University of Finance and Economics, Nanjing, Jiangsu, China.

[#] Nanjing Research Institute, Huawei Technology Co., Ltd., Jiangsu, China.

[1]Corresponding author:
Tel: +86 2586718339.
Email: chen.yalin@nufe.edu.cn

Therefore, given rural households' energy consumption plays a crucial role in decarbonization, this paper identifies and examines the determinants that influence the REC, as well as the mechanisms among these determinants from the perspective of pro-environmental behavior analysis. Moreover, this research endeavors to rigorously evaluate the efficacy of the decarbonizing policies in stimulating households' REC based on the quasi-natural experiment supported by two-phase surveys.

2. LITERATURE VIEW

The REC has emerged as a pivotal global strategy for addressing climate change, safeguarding ecological environments, and ensuring energy security [3]. Numerous scholars have delved into the analysis of factors influencing rural REC. Most studies consistently affirm that economic growth, livelihood, technology and environmental concerns, etc., fostered the REC [4]-[6]. However, the existing research needs to design the scale measuring the rural REC, providing a systematic framework for evaluating the prevalence and determinants of sustainable energy practices. REC is a pro-environment behavior (PEB) due to its decarbonizing ability. To measure the REC intention, the Theory of Planned Behavior (TPB) and the norm-activation model (NAM) are often used [7]-[8], which can develop a comprehensive measuring framework. In [9], a general research framework for the psychological factors of pro-environmental behavior based on TPB was developed. In [10], the influence of social norms formed by different cultures on the development of pro-environmental behavior based on NAM was investigated, establishing an initial paradigm for studying PEB within the NAM framework. In [11], a comparative research was conducted, which illustrated that the psychological dimensions used in TPB were more effective in predicting behavioral intentions. A significant amount of research based on TPB has validated the effectiveness of this prediction [12]-[15]. Given that TPB insufficiently considers factors related to emotions, such as negative or positive feelings and stress states [16], many scholars have expanded and refined the TPB model to improve its ability to predict and explain social behavior. Based on TPB, in [17], the demographic characteristics was incorporated into the research framework of psychological factors related to pro-environmental behavior, which has been subsequently applied to studies on recycling, energy conservation, and residential renewable energy investments [18]-[20]. Considering that personal moral norms (PMN) are key determinants of pro-environmental behavioral intentions [21] , Many scholars integrated personal moral norms into the TPB model, examining the psychological influences on decision-making behavior through four dimensions [22]. Therefore, considering the altruistic nature of farmers' renewable energy consumption, we extend the theory of TPB by integrating personal moral norms thereby enhancing the TPB model and providing a more comprehensive description of the psychological factors influencing farmers' decision-making. So, the extended theory of TPB which named E-TPB consists of four elements: attitude, subjective norms, perceived behavioral control and moral norms.

To mitigate climate change, carbon control policies have been implemented to incentivize rural REC practices. However, research has yet to assess the effectiveness of policies since they require rigorous testing and evaluation. One such method is conducting quasi-experiments [23], which provides an opportunity to gauge the impact of carbon control policies on rural households. Unlike traditional randomized controlled trials, which are frequently impractical for policy analysis due to ethical, logistical, or political limitations, quasi-experiments offer a robust alternative ideally suited to this context. Within this quasi-experimental paradigm, two widely adopted techniques stand out: the difference-in-differences (DID) method and propensity score matching (PSM) [24]. The DID approach quantifies the net effect of a policy by comparing changes in outcomes—such as shifts in renewable energy consumption behaviors—between a experimental group (*e.g.*, households in pilot regions subject to the policy) and a control group (*e.g.*, those in non-pilot regions unaffected by the policy) before and after its implementation. In parallel, PSM addresses selection bias by pairing individuals across these groups based on similar observable characteristics, such as income and educational level, thereby enhancing the comparability of the samples and the precision of the resulting evaluation.

The subsequent sections of this paper are structured as follows. Initially, based on the theory of extended planning behavior (E-TPB), we design and verify a scale to measure the intention of rural households' REC. Subsequently, by combing the DID and PSM techniques, we implement a quasi-natural experiment to examine the impact of decarbonizing policies through a two-phase survey. This experiment explores influential factors affecting REC intention. Lastly, we present recommendations to enhance REC in rural areas.

3. HOW TO MEASURE THE RURAL HOUSEHOLDS' INTENTION OF RENEWABLE ENERGY CONSUMPTION?

3.1 The Theoretic Framework

In order to realize the sustainable development, economic transformation, and political requirements, China introduced the "dual carbon" goals in 2020. This initiative is a comprehensive policy that spans various fields, including the economy, society, and the environment, with the aim of promoting sustainable development and reducing carbon emissions. The "dual carbon" policy has driven industrial restructuring and optimized energy consumption. Under this framework, governments at all levels have implemented a series of supportive policies and measures to encourage the development of renewable energy, such as subsidies, tax reductions, and other incentives for farmers who use renewable energy. Additionally, technical and financial support is provided to encourage the adoption of renewable energy by farmers. Therefore, this paper proposes the following hypothesis:

H1: The "dual carbon" policy exerts a positive impact on farmers' intentions to consume renewable energy.

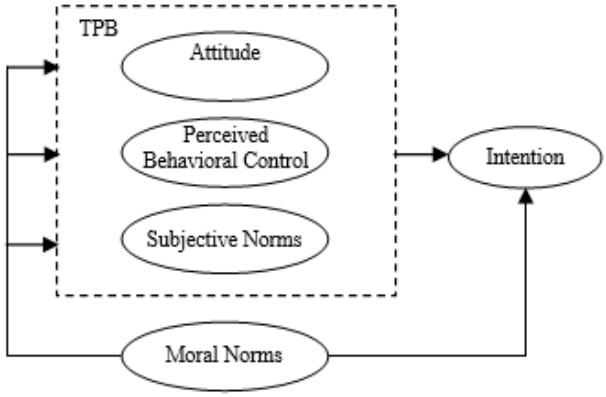

Fig. 1. Analysis framework based on the E-TPB.

The theory of the Extended Theory of Planned Behavior (E-TPB) is composed of four main components, as illustrated in Figure 1: attitude, subjective norms, perceived behavioral control, and moral norms. The following provides a detailed discussion of these four dimensions and the corresponding research hypotheses.

Attitude: It refers to the degree of acceptance that farmers have toward renewable energy consumption behavior, which reflects the intrinsic motivational beliefs regarding renewable energy consumption. Behavioral beliefs consist of belief strength and outcome evaluation. In this study, the farmers' attitude towards renewable energy consumption is mainly determined by their understanding of renewable energy, their expected outcomes of renewable energy consumption, and their corresponding acceptance or resistance. The following hypothesis is proposed:

H2: A positive attitude towards renewable energy will positively drive farmers' intention to consume renewable energy.

Subjective Norms: It refers to the perceived social pressure when farmers choose to consume renewable energy, primarily originating from normative beliefs and motivation to comply. In this study, the subjective norm factors include relevant subsidy policies and neighborhood influence. The following hypothesis is proposed*:*

H3: The subjective norms related to renewable energy consumption will positively drive farmers' intention to consume renewable energy.

Perceived Behavioral Control: It refers to the difficulties and obstacles farmers perceive in implementing renewable energy consumption, reflecting their perceptions of the ease or difficulty of performing the behavior or factors hindering its execution. The resources and potential costs associated with renewable energy consumption will form the farmers' control beliefs. Therefore, in this study, the "perceived control" factor is defined primarily as the factors that hinder renewable energy consumption, and the following hypothesis is proposed:

H4: Perceived behavioral control related to renewable energy consumption will suppress farmers' intention to consume renewable energy.

Moral Norms: It refers to personal social-friendly behavior guidelines that are internalized due to societal opinion and public pressure. The environmental moral norms of farmers are primarily formed through the promotion of sustainable development concepts and the social atmosphere of valuing and caring for the environment. In the context of rural renewable energy consumption, farmers' personal moral norms reflect their intention to invest in and maintain renewable energy consumption to reduce pollution and carbon emissions, as well as their willingness to bear the potential opportunity costs. The hypothesis regarding the influence of personal moral norms on renewable energy consumption intention is as follows:

H5: Moral norms positively influence farmers' intention to consume renewable energy.

Since the four components of E-TPB cannot be observed directly, the corresponding observing variables are constructed based on relevant research, combined with the current situation of rural REC. The initial scale is formed by using the Likert five-grade scoring method, as shown in Table 1.

Given the individual and regional cultural differences that may indirectly influence attitudes, subjective norms, perceived behavioral control, and moral norms, it is imperative to gather data on personal and familial attributes (denoted as X0, X00). A preliminary survey was executed from the 21st to the 27th of November, 2019, yielding a collection of 90 samples. The initial reliability assessment revealed that the Cronbach's α coefficients for variables X1, X2, and X3 fell short of the 0.8, thereby failing to meet the established reliability criteria. Consequently, the scale was revised. Exploratory factor analysis excluded measurement variables X14, X15, X22, X212, X213, and X31, which exhibited factor loadings below 0.300 or were statistically insignificant (p-value > 0.05). Furthermore, questions with ambiguous phrase were refined. The revised scale demonstrated Cronbach's α coefficients exceeding 0.8 for all latent variables, thereby signifying enhanced reliability. Additionally, the scale successfully passed the Kaiser-Meyer-Olkin (KMO) and Bartlett's sphericity tests, thereby validating its capacity to measure rural households' REC intentions effectively.

Table 1. Initial scale.

Factors	Measured variables	References
Personal characteristics	X0. age	[25]
	X02. Gender	[26]
	X03. Education level	[27]-[28]
Family Features	X001. Number of permanent residents	[27]
	X002. Per capita income	[29]
Attitude	X11. Understanding of renewable energy	[30]
	X12. Renewable Energy Basics	[31]
	X13. Regional ecological environment perception	[32]
	X14. Training in power generation technology	Self-design
	X15. Equipment maintenance technical training	
Subjective norms	X21. Energy Poverty Alleviation Plan	[32]
	X22. Maintenance Subsidy Scheme	[31]
	X23. Subsidy supporting biogas digesters	[29]
	X24. Subsidy supporting distributed photovoltaic	[25]
	X25. Subsidy supporting energy-saving equipment	[26]
	X26. Subsidy supporting hydropower stations	
	X27. Self-generated power online for profit	
	X28. Neighborhood promotes biogas digesters	Self-design
	X29.Neighborhood promotes distributed photovoltaic	
	X210. Neighbors concern about environmental issues	
	X211. Proportion of neighbors who have installed biogas digesters	
	X212. Proportion of neighbors who have installed photovoltaic power generation equipment	
	X213. Attention to renewable energy topics	
Perceived behavioral control	X31. Burning straw is punished	[32]
	X32. Biogas pool construction area	[29]
	X33. Biogas pool construction cost	
	X34. Future maintenance of biogas digester	
	X35. Distributed photovoltaics occupy an area.	Self-design
	X36. Distributed photovoltaic equipment cost	
	X37. Future maintenance of distributed photovoltaic	
	X38. Uncertain profit from surplus electricity	
Moral norms	X41. Straw burning harms the environment.	[32]
	X42. Burning firewood harms the environment.	[21]
	X43. Coal burning harms the environment	[10]
	X44.Distributed photovoltaics clean the environment.	Self-design
	X45. Wind power helps clean the environment	
Renewable energy consumption	Y11. Intention to build biogas pool	
	Y12. Intention to install distributed photovoltaic	Self-design
	Y13. Wind power consumption intention	

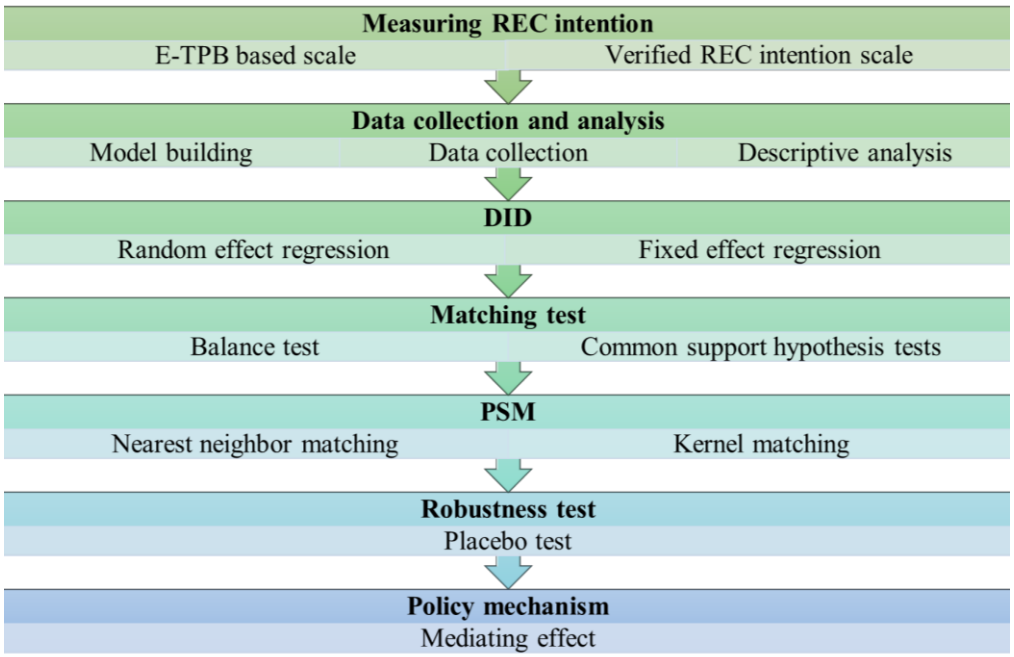

Fig. 2. Empirical research flow chart.

Based on the preceding analysis, we proceed with an empirical investigation of the "dual carbon" policy's effect. Figure 2 presents an experimental flow chart, which shows all the links and concrete practices of the empirical research part of this paper. In the subsequent section, we first illustrate the research methodology and then evaluate the results of "dual carbon" policy effect on the renewable energy consumption in the rural China. Further, we will study the mechanism of action of policy.

4. A QUASI-NATURAL EXPERIMENT TO TEST THE EFFECTIVENESS OF CARBON

4.1 Methodology

This paper regards the implementation of the "Dual carbon" policy as a "quasi-natural experiment". The "Dual carbon" policy was formally introduced in September 2020, which serves as the pivotal event year. Utilizing the scale designed in the former section, a quasi-natural experiment was conducted through surveys in 2019 and 2023. Following the proclamation of the "dual carbon goals" in 2020, the data procured in 2019 were designated as the control group. Conversely, the data collected in 2023 were categorized as the experimental group.

The Difference-in-Differences (DID) model can be approached for two purposes. First, it effectively quantifies the causal impact of policy implementation. Second, given that policies are often exogenous, DID mitigates potential endogeneity. Therefore, the following regression model tests whether the policy can influence the REC of rural households.

$$y_{it} = \alpha_0 + \alpha_1 Post_t + \alpha_2 Treat_i + \alpha_3 Post_t \times Treat_i + \alpha_n X_{it} + \varepsilon_{it} \quad (1)$$

$$y_{it} = \beta_0 + \beta_1 DID + \beta_n X_{it} + \lambda_i + \theta_t + \varepsilon_{it} \quad (2)$$

Where Equation 1 is the baseline difference-in-difference model. y_{it} denotes the REC intention of the *i*-th farmer at time *t* (*i* = 1, …, *n* and *t* = 0,1) and is the explained variable of the model. $Treat_i$ is a dummy variable used to determine the policy intervention, which distinguishes between the experimental group ($Treat_i$ = 1 for households influenced by the "Dual Carbon" policy) and the control group ($Treat_i$ = 0 for unaffected households). Additionally, $Post_t$ is the indicator variable of policy pilot, it equals 1 in the experimental group and 0 in control group. The core explanatory variable ($Post_t \times Treat_i$) is the interaction term of the policy dummy variable and time dummy variable. X_{it} is a column vector of additional control variables. Equation 2 is the difference-in-difference model which considers time and individual fixed effects. To enhance the robustness of our conclusions, we introduce fixed effects λ_i (individual fixed effect) and θ_t (time fixed effect). λ_i controls for individual-specific factors that remain constant over time and impact renewable energy consumption behavior. Meanwhile, θ_t accounts for time-specific factors that do not vary across individuals but influence households' willingness toward renewable energy consumption. Lastly, the stochastic disturbance term ε_{it} captures unobserved factors affecting the model.

The trend of households' REC in the treatment group and the control group is supposed to be roughly the same as the reference group in the absence of policy intervention according to the DID original hypothesis. The same long-term trend may not hold, which becomes the most severe endogeneity threat when applying the DID for policy evaluation. Enlightened by the

randomized trial, we apply PSM to match the samples of individuals in the treatment and the control group. This process ensures the homogeneity and consistency of the long-term trend hypothesis in DID. The core of PSM lies in assessing whether the REC intentions of households influenced by the "Dual Carbon" policy surpass those of unaffected households rather than a simplistic comparison between the experimental and control groups' REC intentions.

4.2 Data Collection and Analysis

To better observe the effects of the “Dual Carbon” policy, 590 valid questionnaires were collected, of which 240 were experimental group samples and 350 were control group samples. The key variables were double-tailed truncated at the 1% and 99% percentiles, and finally, cross-sectional data consisting of 567 observations was obtained. The dependent variable of this paper is the rural household’s REC intention. Concerning control variables are attitude (Attitude), subjective norms (Subjectivity), perceived behavioral control (Perception), and moral norms (Morality); age, gender, population, and education are used to indicate the rural households' families; and income is used to show the economic characteristics of rural households.

Table 2. Descriptive analysis.

Variable	Statistics	Behavior	Attitude	Subjectivity	Perception	Morality	age	sex	population	education	income
$Post_t$=0, $Treat_i$=0	Mean	3.68	1.98	2.31	2.63	3.12	3.04	1.36	4.47	2.99	2.89
	Std	0.57	0.62	0.72	0.66	0.67	1.07	0.48	1.48	0.7	1.65
	Medium	3.74	2.13	2.22	2.6	3	3	1	4	2.85	2
	Min	2	0.57	0.61	1	1	1	1	1	1	1
	Max	5	3.5	4.45	4.14	4	5	2	9	4.46	6
$Post_t$=0, $Treat_i$=1	Mean	3.61	2.06	2.32	2.64	3.02	2.97	1.39	4.29	2.95	3.26
	Std	0.75	0.67	0.73	0.71	0.74	1.17	0.49	1.43	0.71	1.77
	Medium	3.74	2.14	2.25	2.74	3	3	1	4	2.85	3
	Min	1	0.57	0.61	1	1	1	1	1	1	1
	Max	5	3.5	4.45	4.38	4	5	2	9	4.46	6
$Post_t$=1, $Treat_i$=0	Mean	2.53	2.06	2.45	3.31	3.79	3.12	1.24	3.82	3.71	2.94
	Std	0.66	0.54	0.76	0.82	0.83	1.16	0.43	1.14	1.17	1.82
	Medium	2.32	2	2.52	3.32	4	3	1	4	4	2
	Min	1	0.5	1	1	1	1	1	2	1	1
	Max	5	3.5	4.45	4.71	5	5	2	9	5	6
$Post_t$=1, $Treat_i$=1	Mean	2.64	1.72	2.61	3.26	3.63	3.24	1.21	3.86	3.42	2.12
	Std	0.75	0.67	0.74	0.77	0.81	1.18	0.41	1.31	1.17	1.57
	Medium	2.75	1.99	2.59	3.46	4	3	1	4	3	1.5
	Min	1	0.5	1	1	1	1	1	2	1	1
	Max	4.56	3.5	4.45	4.71	5	5	2	9	5	6

In Table 2, for the control group, prior to policy implementation, the REC intention stands at 3.68. Post-policy implementation, this intention decreases to 2.53. For the experimental group, pre-policy implementation, the REC intention is 3.61. Post-policy implementation, this intention decreases slightly to 2.64. Based on these findings, we can infer that the decline in REC intention is smaller in the experimental group compared to the control group. Interestingly, before policy implementation, the control group exhibits higher intentions than the experimental group. However, after policy implementation, despite the costs associated with equipment and the economic downturn, the experimental group shows a greater amount of green energy consumption. In summary, the “Dual Carbon” policy may foster greater REC intention. Moreover, in the experimental group, the mean values of subjective norms and moral norms after policy implementation increased to 2.61 and 3.63, respectively, significantly exceeding those in the control group. This confirms that the policy enhances consumption intention by reinforcing social pressure and environmental awareness. Meanwhile, the mean income in the experimental group declined from 3.26 to 2.12, a larger drop than that in the control group. Despite the challenges posed by income decline, the experimental group exhibited a less substantial reduction in REC intention compared to the control group. This observation suggests that the policy was partially effective in mitigating the adverse effects, likely through the application of economic compensation or psychological incentives. Nevertheless, the mean perceived behavioral control in the experimental group rose from 2.64 to 3.26, with the standard deviation expanding to 0.77, indicating that rural households’ concerns about the high costs and long payback periods of renewable energy equipment have intensified, potentially hindering long-term REC intention.

5. EMPIRICAL RESULTS

5.1 Regression

Table 3 shows the DID results. Model (1)-(4) respectively represent the regression of baseline random effects, random effects with control variables, fixed individual effects and bidirectional fixed effects. The policy effect is around a 19.76% increase in energy adoption. The interaction coefficient in models (2)-(4) and *R*-square vary, indicating that control variables have a certain influence on REC. Furthermore, age, education level, and income positively impact households' REC intention.

Table 3. Difference-in-differences regression.

	(1)	(2)	(3)	(4)
		REC		
post	-1.1452***	-1.3831***		
	(-14.4703)	(-17.1994)		
treat	-0.0702	-0.0492		
	(-1.0142)	(-0.7922)		
DID	0.1810	0.1976*	0.1472	0.1976*
	(1.4750)	(1.7537)	(1.5837)	(1.7537)
Attitude		-0.0026	-0.0045	-0.0026
		(-0.0661)	(-0.1127)	(-0.0661)
Subjectivity		0.2357***	0.2357***	0.2357***
		(6.6697)	(6.6724)	(6.6697)
Perception		-0.0108	-0.0108	-0.0108
		(-0.3133)	(-0.3148)	(-0.3133)
Morality		0.2349***	0.2368***	0.2349***
		(6.9222)	(6.9959)	(6.9222)
age		0.0425*	0.0427*	0.0425*
		(1.8584)	(1.8695)	(1.8584)
sex		0.1521***	0.1509***	0.1521***
		(2.7568)	(2.7382)	(2.7568)
population		0.0041	0.0044	0.0041
		(0.3675)	(0.3876)	(0.3675)
education		0.0965***	0.0970***	0.0965***
		(3.2966)	(3.3175)	(3.2966)
income		0.0147	0.0135	0.0147
		(0.9737)	(0.9012)	(0.9737)
λ_i	No	No	No	Yes
θ_t	No	No	Yes	Yes
R^2	0.3603	0.5031	0.5026	0.5031

*p<0.1, **p<0.05, ***p<0.01

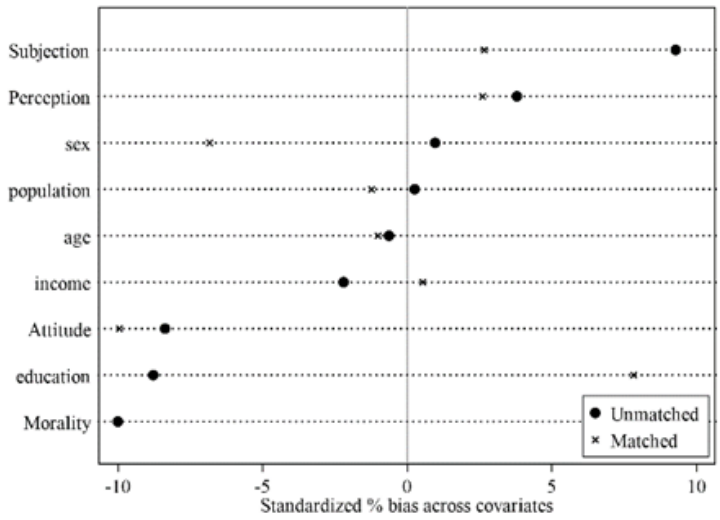

Fig. 3. Covariate standardization bias test.

In order to overcome the selection bias caused by inter-sample heterogeneity and reduce the bias of the results of the DID regression, we further constructed the control group through the PSM method. PSM effectively addresses the issue of non-common trends between the experimental and control groups prior to the policy shock year, thereby overcoming the limitations imposed by the two-period DID design. Balance test based on the assumption of score matching is shown in Figure 3. The absolute standard deviations are all below 10%, and *p*-values exceed 0.1. It indicates that no significant differences in the matching variables between the treatment and control groups. Consequently, the *t*-statistics' independent distribution conditions are satisfied. Thus, the balance test is successfully met. The common support hypothesis tests about PSM-matched data are shown as Figures 4, 5 and 6.

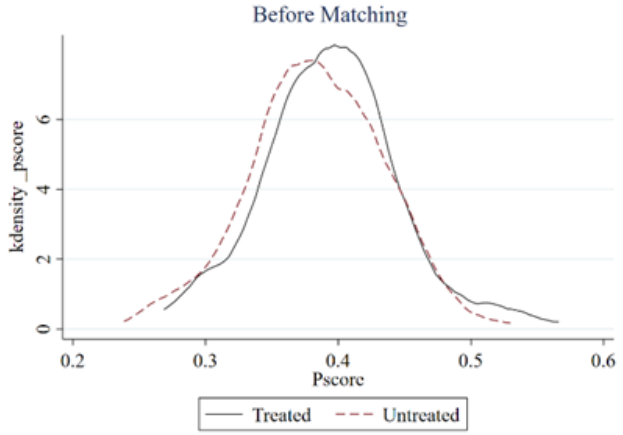

Fig. 4. Nuclear density map **of the pre-treatment group and control group**.

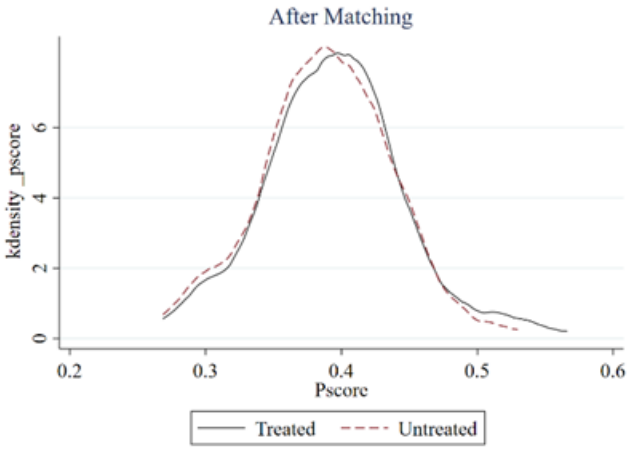

Fig. 5. nuclear density map of the post-treatment group and control group.

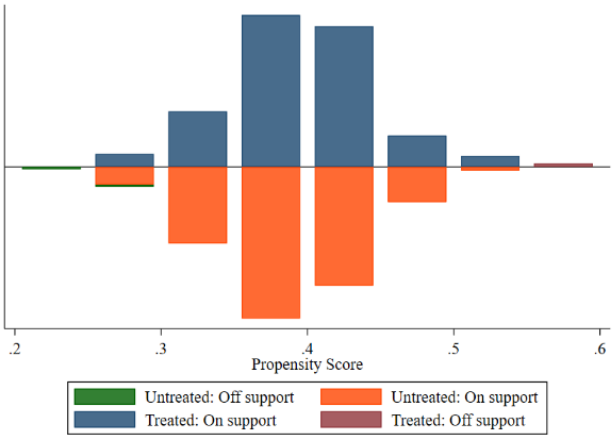

Fig. 6. Common support area.

From Figures 3 and 4, we can find that the propensity score distributions for the pre-matched samples exhibit noticeable differences and limited overlap. In contrast, the majority of propensity score values from the treatment and control groups both fall within the range of 0.3 to 0.5, indicating substantial overlap. Within this interval, most samples from both groups have been successfully matched, effectively meeting the common support condition.

In terms of control variables, the subjective norms and moral norms are positively correlated with REC at the significance level of 1%. A matched control group with 343 observations is formed by building upon PSM. Then we conduct the PSM-DID, the results are shown in Table 4.

Table 4. PSM-DID regression results.

	(1)	(2)	(3)
		REC	
DID	0.1976*	0.1836	0.2949***
	(1.7537)	(1.4632)	(2.7056)
Attitude	-0.0026	0.0146	-0.0020
	(-0.0661)	(0.3312)	(-0.0538)
Subjectivity	0.2357***	0.1906***	0.1889***
	(6.6697)	(4.8170)	(5.8242)
Perception	-0.0108	-0.0143	-0.0523*
	(-0.3133)	(-0.3774)	(-1.7099)
Morality	0.2349***	0.2412***	0.2555***
	(6.9222)	(6.2526)	(8.4093)
age	0.0425*	0.0710***	0.0668***
	(1.8584)	(2.8467)	(3.3101)
sex	0.1521***	0.1540**	0.1538***
	(2.7568)	(2.5618)	(3.1295)
population	0.0041	0.0112	0.0164
	(0.3675)	(0.5704)	(1.0455)
education	0.0965***	0.1204***	0.1083***
	(3.2966)	(3.6582)	(3.9200)
income	0.0147	0.0378**	0.0370***
	(0.9737)	(2.2214)	(2.6036)
N	567	447	641
R^2	0.5031	0.5163	0.5544

*p<0.1, **p<0.05, ***p<0.01

The second column of Table 4 shows the results without matching, and the last two columns show the regression results under different matching methods, which includes kernel matching and nearest neighbor matching. The core finding from columns 3 and 4 remains that the 'Dual Carbon' policy significantly promotes rural households' REC intention. For control variables, subjective norms which reflect households' active attitudes toward renewable energy have a positive effect on REC significantly. Additionally, moral norms exert a positive influence on households' willingness to adopt renewable energy. Moreover, age, education level, and income all positively impact rural households' intentions, in line with the baseline model's conclusions. However, the factor perceived behavioral control hinders rural households' REC intention.

5.2 Robustness Test

A random sampling of the interaction items was conducted to investigate whether the coefficients significantly differed from the baseline estimate. The distributions of regression coefficients and t-values are depicted in Figures 7 and 8.

From Figure 7, the random sampling coefficient follows a normal distribution with a mean of 0, and only 4 sampling coefficients are greater than 0.1976. From Figure 8, most t-values are centered around 0, and only a few values are greater than the baseline regression result. Based on the above analysis, in the case of random sampling, the baseline regression coefficient 0.1976 is a low probability event, and the placebo test holds. This result demonstrates that the increase in rural households' REC after 2020 is indeed due to the implementation of decarbonizing policy, so DID results are robust.

5.3 Further Study

Through the above analysis, we can infer that the "dual carbon" policy certainly has obtained an excellent effect. However, how the policy will promote rural households' adoption of renewable energy consumption remains to be clarified. Therefore, we explored the mechanism of action by referring to the existing research methods [33]**Error! Reference source not found.**, establishing the regression model as Equation 3.

$$M_{it} = \alpha_0 + \alpha_1 DID + \alpha_n X_{it} + \varepsilon_{it} \quad (3)$$

Where, M_{it} denotes the potential intermediary variables that affect the rural households' REC intention and X_{it} is a column vector the same as Equation 1. Thus, α_1 in Equation 3 represents the influence effect of policy intervention on the intermediary variable.

The changes in the mediation variables were first examined, and the regression results of Equation 3 are presented in Table 5. Models 1-6 represent the Difference-in-Differences regressions for six potential mediation variables. The findings indicate that the subjective norms of rural households in the experimental group increased by 27%, a result that is statistically significant at the 1% level. This suggests that the decarbonizing policy plays a significant role in enhancing rural households' subjective norms regarding REC. Additionally, rural households' moral norms showed a notable increase of 32% under the implementation of the decarbonizing policy, with this effect also being statistically significant at the 1% level. These changes can likely be attributed to the active and widespread promotion of the "dual carbon" policy.

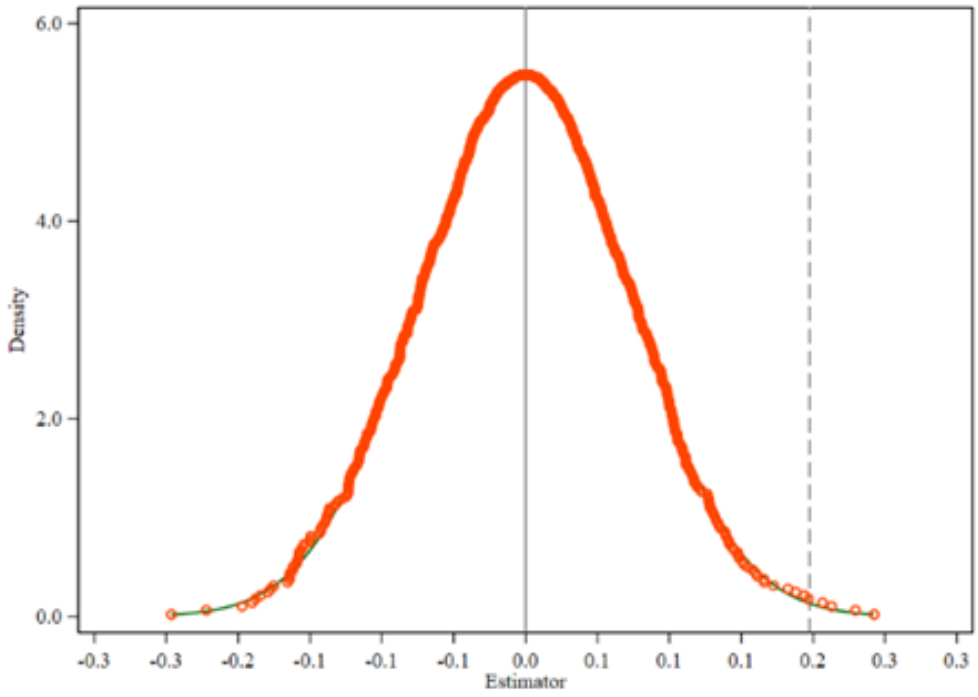

Fig. 7. The placebo test of distribution of regression coefficients.

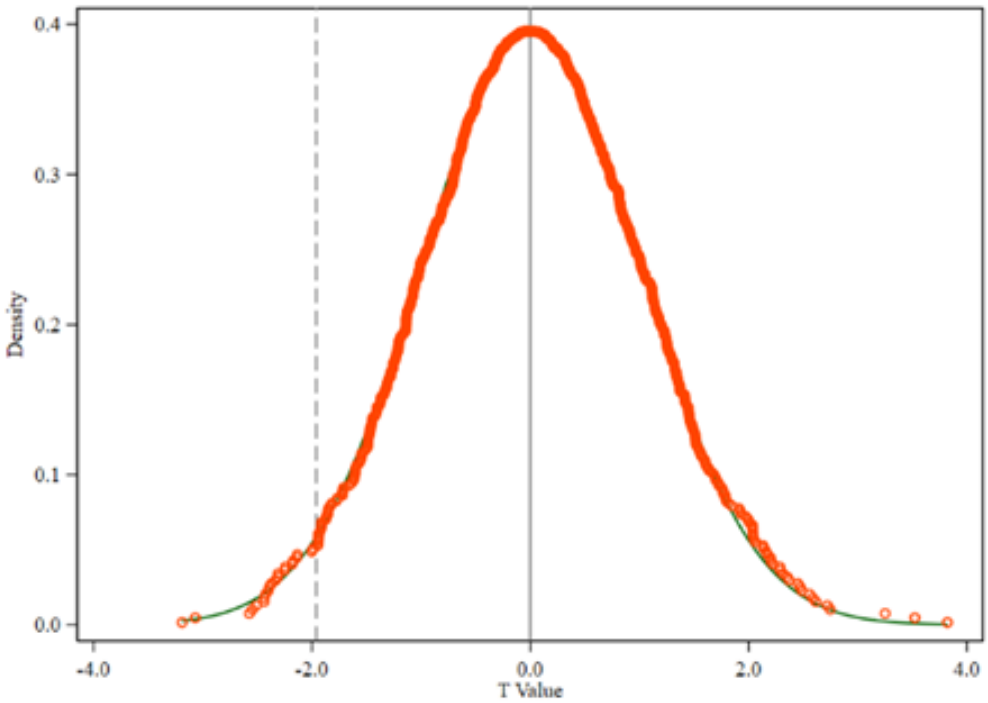

Fig. 8. The placebo of test of t-values.

Furthermore, Table 6 reveals negative coefficients for both attitudes and income. The decline in rural households' income, which can be attributed to the combined effects of the COVID-19 pandemic, local conflicts etc., has likely contributed to this negative trend. Additionally, an excessive focus on green practices and pollution-free technologies may have increased the financial burden on rural households, leading to a diminished attitude toward REC. In conclusion, based on the regression results presented in Tables 4 and 5, it can be inferred that subjective norms and moral norms serve as the primary mechanisms through which the carbon control policy influences rural households' renewable energy consumption, thereby constituting a mediating effect.

Table 5. Decarbonizing policy mechanism test.

	(1) Attitude	(2) Subjectivity	(3) Perception	(4) Morality	(5) Education	(6) Income
DID	-0.34***	0.27***	0.42***	0.32***	0.13	-1.08***
	(-4.09)	(2.88)	(4.23)	(3.15)	(1.12)	(-4.97)
Attitude		0.16***	-0.03	-0.01	-0.07	-0.18
		(3.33)	(-0.65)	(-0.12)	(-1.22)	(-1.61)
Subjectivity	0.12***		-0.01	0.20***	0.16***	0.20*
	(3.33)		(-0.24)	(4.47)	(3.03)	(1.94)
Perception	-0.02	-0.01		0.05	0.13***	-0.03
	(-0.65)	(-0.24)		(1.28)	(2.67)	(-0.32)
Morality	-0.00	0.17***	0.05		0.16***	0.18*
	(-0.12)	(4.47)	(1.28)		(3.42)	(1.92)
Education	-0.04	0.10***	0.01***	0.13***		0.19**
	(-1.22)	(3.03)	(2.67)	(3.42)		(2.34)
Income	-0.03	0.03*	-0.01	0.04*	0.05**	
	(-1.61)	(1.94)	(-0.32)	(1.92)	(2.34)	
R^2	0.05	0.12	0.07	0.11	0.10	0.08

*p<0.1, **p<0.05, ***p<0.01

6. SUMMARY AND SUGGESTION

Enhancing the capacity for distributed renewable energy consumption in rural areas is crucial for promoting rural energy transformation and optimizing the energy structure in these regions, ultimately improving the energy use for rural residents. Rural energy consumption is characterized by its widespread, decentralized nature, a diverse range of energy sources, and weak energy infrastructure, making it a complex issue that intersects with economic, social, and ecological factors. Currently, the renewable energy consumption of rural households plays a positive role in optimizing the energy structure. Therefore, this paper designed and verified the scale measuring the rural households' REC intention. Leveraging panel data from 567 rural households in 2019 and 2023, a combination of DID and PSM is applied to explore rural households' REC intention in the context of the decarbonizing policy. The findings reveal that the decarbonizing policy significantly promotes rural households' adoption of renewable energy. Furthermore, subjective norms, moral norms, income, and education all improve rural households' intentions. However, perceived behavioral control may act as an obstacle to rural households' REC intention. In other words, this paper accepts hypotheses H1, H3, and H5, while rejecting hypotheses H2 and H4. Based on the research, the following suggestions are proposed.

(1) *Clarify the Institutional Framework and Implement Responsibility at All Levels.* Public policies that incentivize renewable energy consumption can be defined as the political actions or prescribed behavioral guidelines implemented by regulatory bodies during a specific period to achieve or serve their objectives. To establish a comprehensive institutional framework that incentivizes renewable energy consumption, the following steps need to be completed: problem definition, goal setting, selection and formulation of governance tools, implementation, and determination of evaluation bodies. Currently, the main governance tools include carbon quota trading, green electricity permit trading, electricity price subsidies, and the construction of distributed microgrids. Surveys reveal that farmers have not clearly perceived the above incentive measures. Therefore, further efforts are needed to deepen the promotion of incentive policies, enhance farmers' understanding of environmental concerns, renewable energy knowledge, technology, and the potential benefits. Only when farmers realize that non-renewable energy consumption harms the environment will they be more inclined to engage in environmentally friendly behaviors.

(2) *Focus on "Behavioral Nudging" to Foster Positive Subjective Norms for Renewable Energy Consumption.* In addition to administrative intervention, it is important to invest in farmers' emotional connection to environmental issues. Subtle "behavioral nudges," such as public opinion guidance, can effectively cultivate farmers' higher awareness and perception of environmental problems, enhancing their value perception of renewable energy consumption and motivating them to take responsibility for environmental issues. In the context of rural communities, a shared value perception helps farmers spontaneously establish village rules that promote renewable energy consumption, thereby fostering deep and stable subjective norms for renewable energy consumption in both public and private domains.

(3) *Establish and Improve Policies with Special Measures and Compensation to Reduce the Perceived Risks of Renewable Energy Consumption.* The analysis of how individual and family characteristics affect farmers' intentions to consume renewable energy shows that most farmers align with the "rational person" assumption. They mainly make decisions based on their current economic situation and family conditions. If they find it economically unfeasible, they will not adopt renewable energy consumption behaviors, even if they are aware of its positive environmental impact. This reveals that farmers in economically disadvantaged regions are more sensitive to the opportunity costs of renewable energy consumption. Therefore, differentiated investment proportions, the establishment of maintenance and repair funds, and preferential treatment for surplus electricity feed-in should be implemented. Special policy arrangements are especially necessary for low-income groups to ensure their living standards are not affected. Through a series of detailed supporting measures, the perceived risks of renewable energy consumption can be reduced, thereby improving farmers' behavioral intentions to consume renewable energy.

REFERENCES

This paper is supported by the Postgraduate Research and Practice Innovation Program of Jiangsu Province (No. KYCX23_1795) and the Teaching Reform Project of Nanjing University of Finance and Economics (No. CYLXW23005).

REFERENCES

[1] Yang F. and C. Li. 2024. The Status Quo, Dilemma, and Transformation Path of the Carbon Neutrality-Related Policy of the ASEAN. *Sustainability* 16(3): 1348.

[2] Liu G., Du S., Gao Y., Xiong X., Lombardi G.V., Meng F., Chen Y., and Chen C., 2024. A study on energy-water-food-carbon nexus in typical Chinese northern rural households. *Energy Policy* 188: 114100.

[3] Li M., Liu X., and Yang M., 2024. Analyzing the regional inequality of renewable energy consumption and its driving factors: Evidence from China. *Renewable Energy* 223: 120043.

[4] Anton S.G. and A.E.A. Nucu. 2020. The effect of financial development on renewable energy

consumption. A panel data approach. *Renewable Energy* 147: 330-338.

[5] Athari S.A., 2024. The impact of financial development and technological innovations on renewable energy consumption: Do the roles of economic openness and financial stability matter in BRICS economies?. *Geological Journal* 59(1): 288-300.

[6] Gyimah J., Yao X., Tachega M.A., Hayford I.S., and Opoku-Mensah E., 2022. Renewable energy consumption and economic growth: New evidence from Ghana. *Energy* 248: 123559.

[7] Fazal S.A., Hayat N., and Al Mamun A., 2023. Renewable energy and sustainable development—Investigating intention and consumption among low-income households in an emerging economy. *Sustainability* 15(21): 15387.

[8] Ateş H., 2020. Merging theory of planned behavior and value identity personal norm model to explain pro-environmental behaviors. *Sustainable Production and Consumption* 24: 169-180.

[9] Kaiser F.G., Wölfing S., and Fuhrer U., 1999. Environmental attitude and ecological behavior. *Journal of environmental psychology* 19(1): 1-19.

[10] Schultz P.W. and L.C. Zelezny. 1998. Values and pro environmental behavior: A five-country survey. *Journal of Cross-Cultural Psychology* 29(4): 540-558.

[11] Harland P., Staats H., and Wilke H.A., 1999. Explaining pro environmental intention and behavior by personal norms and the Theory of Planned Behavior 1. *Journal of Applied Social Psychology* 29(12): 2505-2528.

[12] Duong K.T., Nguyen T.T., and Do T.A., 2022. The relationship between the factors influencing energy-saving behaviors in households in Urban Vietnam. *International Energy Journal* 22(3): 291-302.

[13] Defloor B. and B. Bleys. 2017. Understanding pro-environmental behavior using the theory of planned behavior. In *12th International Conference of the European Society for Ecological Economics*.

[14] Verma V.K. and B. Chandra. 2018. An application of theory of planned behavior to predict young Indian consumers' green hotel visit intention. *Journal of Cleaner Production* 172: 1152-1162.

[15] Correia E., Sousa S., Viseu C., and Leite J., 2022. Using the theory of planned behavior to understand the students' pro-environmental behavior: a case-study in a Portuguese HEI. *International Journal of Sustainability in Higher Education* 23(5): 1070-1089.

[16] Londono J.C., Davies K., and Elms J., 2017. Extending the Theory of Planned Behavior to examine the role of anticipated negative emotions on channel intention: The case of an embarrassing product. *Journal of Retailing and Consumer Services* 36: 8-20.

[17] Botetzagias I., Dima A.F., and Malesios C., 2015. Extending the theory of planned behavior in the context of recycling: The role of moral norms and of demographic predictors. *Resources, Conservation and Recycling* 95: 58-67.

[18] Gao L., Wang S., Li J., and Li H., 2017. Application of the extended theory of planned behavior to understand individual's energy saving behavior in workplaces. *Resources, Conservation and Recycling* 127: 107-113.

[19] Ru X., Wang S., and Yan S., 2018. Exploring the effects of normative factors and perceived behavioral control on individual's energy-saving intention: An empirical study in eastern China. *Resources, Conservation and Recycling* 134: 91-99.

[20] Engelken M., Römer B., Drescher M., and Welpe I., 2018. Why homeowners strive for energy self-supply and how policy makers can influence them. *Energy Policy* 117: 423-433.

[21] Parker D., Manstead A.S., and Stradling S.G., 1995. Extending the theory of planned behavior: The role of personal norm. *British Journal of Social Psychology* 34(2): 127-138.

[22] Kim Y.G., Woo E., and Nam J., 2018. Sharing economy perspective on an integrative framework of the NAM and TPB. *International Journal of Hospitality Management* 72: 109-117.

[23] Gill-Wiehl A., Brown T., and Smith K., 2022. The need to prioritize consumption: a difference-in-differences approach to analyze the total effect of India's below-the-poverty-line policies on LPG use. *Energy Policy* 164: 112915.

[24] Zhang K., Zhu P.H., and Qian X.Y., 2024. National information consumption demonstration city construction and urban green development: A quasi-experiment from Chinese cities. *Energy Economics* 130: 107313.

[25] Zhao X.Y., 2015. The impact of livelihood strategy on the farmer's living energy consumption pattern: a case of Gannan Plateau. *Acta Ecologica Sinica* 35(5): 1610-1619.

[26] Zheng X.D., 2017. Research on consumers' participation willingness of community supporting agriculture. *Economy and Management* 31(04): 33-38.

[27] Shi Q.H., Peng X.H. and Zhang Y., 2014. Research on rural energy consumption in China -- a case study of rural households in Shanxi, Guizhou and Zhejiang provinces. *Journal of Management World* 05: 80-92.

[28] Zheng J., Dang Y., and Assad U., 2024. Household energy consumption, energy efficiency, and household income–Evidence from China. *Applied Energy* 353: 122074.

[29] Qiu H.G., Yan J.B., Li D.W., and Han W., 2015. Residential energy consumption in rural China: current situation and determinants for future trend——an empirical study based on filed survey data of 4 provinces. *China Soft Science* 11: 28-38.

[30] Böhringer C., Landis F., and Tovar Reaños M.A., 2016. Cost-effectiveness and incidence of renewable energy promotion in Germany. *SSRN Electronic Journal*.

[31] Narayan S. and N. Doytch. 2017. An investigation of renewable and non-renewable energy

consumption and economic growth nexus using industrial and residential energy consumption. *Energy Economics* 68: 160-176.

[32] Liu H. and T. Hu. 2024. Energy poverty alleviation and its implications for household energy consumption and health. *Environment, Development and Sustainability* 26(4): 10063-10083.

[33] Wang Z., Wu M., Li S., and Wang C., 2021. The effect evaluation of China's energy-consuming right trading policy: Empirical analysis based on PSM-DID. *Sustainability* 13(21): 11612.