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Policy empowerment and the cognitive gap: a study on the mechanisms affecting the adoption of green smart home appliances in rural Yunnan under the dual carbon goals

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Abstract. In the context of China's "dual carbon" goals, promoting green and low-carbon transitions in rural areas is of vital importance. Studying the mechanisms behind the adoption of green home appliances can provide empirical support for policy refinement and help drive the transition toward green consumption. Based on 283 rural survey responses from Yunnan Province, this study employs a structural equation model to explore the mechanisms influencing the diffusion of green smart home appliances. The empirical results show that policy subsidies significantly promote adoption by enhancing consumers' policy awareness (path coefficient = 0.68), with policy awareness playing a critical mediating role. Consumer cognition also has a significant positive impact on purchasing behavior (path coefficient = 0.65). Household income level is positively correlated with purchasing decisions, and the presence of adequate infrastructure (such as electricity and internet access) positively moderates the policy effect (moderation coefficient = 0.55). The model exhibits good fit (CFI = 0.96, TLI = 0.94, RMSEA = 0.05). The study reveals that limited policy awareness among low-income groups constitutes a major bottleneck. It is recommended to improve policy transparency and targeting, strengthen localized policy outreach, and enhance supporting infrastructure to bridge the cognitive gap and advance the realization of the dual carbon goals.

Keywords: green smart home appliances, structural equation model, policy subsidies, consumer cognition, infrastructure, mediating effect, moderating effect

1. Introduction

Against the backdrop of global climate governance and energy transition, China's proposed "dual carbon" goals call for a rapid green transformation in rural household energy consumption [1]. As a key pathway to this transformation, green smart home appliances—featuring high energy efficiency and intelligent management—can effectively reduce household energy consumption and carbon emissions in rural areas by replacing traditional high-energy-consuming appliances [2]. However, their current penetration in rural areas remains significantly lower than in urban regions. Studies have shown that this disparity is not only due to objective constraints such as lower rural income levels and underdeveloped infrastructure [3], but also closely tied to insufficient consumer awareness and the limited effectiveness of policy dissemination and implementation [4]. A systematic analysis of the barriers and influencing mechanisms behind this diffusion is of great practical importance for promoting rural low-carbon development and optimizing policy design.

From a theoretical perspective, it is necessary to integrate insights from both consumer behavior and policy intervention. The Theory of Planned Behavior suggests that decisions to purchase green smart appliances are shaped by attitudes, perceived social norms (e.g., family preferences and community culture), and perceived behavioral control—especially sensitivity to price and functional understanding [5-7]. Meanwhile, Diffusion of Innovation Theory emphasizes the critical role of external incentives in lowering the threshold for adopting new technologies [8], and empirical research has confirmed the positive effect of subsidy policies on purchase intention [9]. However, it is worth noting that current subsidy programs are shifting from centrally unified schemes toward localized and differentiated implementations, leading to significant regional disparities in subsidy levels and standards. As a result, these policies may fall short of effectively addressing the practical needs of low-income rural groups [10].

Although existing research has laid a solid theoretical foundation, several major gaps remain. First, regional representativeness is lacking, as most samples focus on the national level or economically developed eastern coastal areas [14, 15], with insufficient empirical evidence from underdeveloped western rural areas such as Yunnan. Second, evaluations of policy effectiveness remain limited, lacking systematic validation of the actual impacts of localized subsidies on consumer behavior.

Most critically, the existing literature has yet to systematically reveal the complex interaction mechanisms among multiple dimensions—namely, policy intervention, consumer cognition, and behavioral decision-making—in the adoption process of green smart appliances.

2. Literature review and theoretical foundations

2.1. Current research status at home and abroad

Overview of domestic and international research is shown in Table 1:

Table 1. Overview of domestic and international research

Research Dimension	International Research	Domestic Research	Identified Gaps
Sample	International studies primarily focus on urban households in developed countries (e.g., the U.S., Europe), with limited attention to consumers in developing countries [14].	Domestic studies mostly sample urban areas along China's eastern coast, with inadequate coverage of rural populations [15].	Existing samples are concentrated in urban and economically developed regions. There is a significant lack of data from underdeveloped rural areas (such as Yunnan), leading to limited regional representativeness.
Methodology	International studies employ Structural Equation Modeling (SEM) and multivariate regression analysis to emphasize complex variable relationships [8].	Domestic studies often rely on descriptive statistics and univariate regression analysis, lacking exploration of interactions among variables [7,12].	Analytical approaches in domestic research are overly simplistic, lacking comprehensive multidimensional analyses involving policy, sociocultural context, and purchasing behavior. Integration of quantitative and qualitative methods is rare.
Data	International research draws from diverse sources, including official government statistics and longitudinal tracking data [17].	Domestic studies primarily depend on short-term surveys, with limited data scope and a lack of longitudinal data [7].	Domestic data tends to lack authority and breadth, with small sample sizes and insufficient trend analysis over multiple time periods, as well as limited support from authoritative databases.
Theoretical Models	International studies are often grounded in the Theory of Planned Behavior (TPB) and Technology Acceptance Model (TAM), focusing on the relationship between policy incentives and consumer behavior [5,16].	Domestic research tends to rely heavily on policy incentive theory, while overlooking sociocultural factors such as neighborhood influence and community norms [9].	Theoretical frameworks remain narrow, lacking multidimensional models that reflect the sociocultural characteristics of rural communities. There is also a deficiency in analyzing how policy adaptability varies across regions.

2.2. Theoretical framework

This study aims to explore the current state and influencing factors of the adoption of green smart home appliances in rural areas of Yunnan Province. The core theoretical underpinnings include the Theory of Planned Behavior (TPB), the Technology Acceptance Model (TAM), and Diffusion of Innovation Theory. Building upon these theories and incorporating sociocultural and policy incentive factors, the study constructs a comprehensive theoretical framework suited to the research context, as illustrated in Figure 1.

Within this framework:

External factors—such as social environment and policy incentives—exert direct or indirect influences on consumer attitudes and perceived behavioral control. Mediating variables, including attitude toward behavior, perceived behavioral control, and perceived usefulness, jointly shape purchase intention, which in turn directly impacts actual purchase behavior.

Based on this analytical model, the following hypotheses are proposed:

H1: Consumers' awareness of policies (policy influence) has a significant positive effect on purchase intention.

H2: Consumers' awareness and understanding of smart home appliances (consumer cognition) have a significant positive effect on purchase intention.

H3: Government subsidies have a significant positive effect on purchase intention.

H4: Purchase intention has a significant positive effect on the actual usage of smart home appliances.

H5: Policy influence indirectly affects the use of smart appliances through purchase intention.

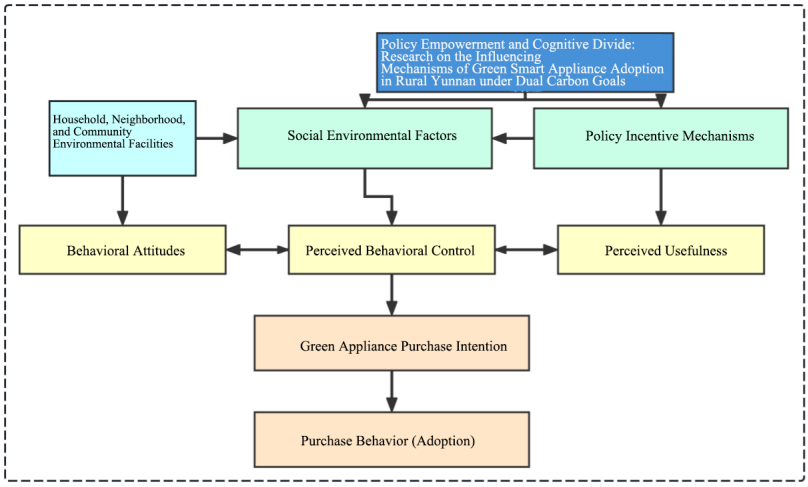


Figure 1. Theoretical framework

2.3. Research methodology

2.3.1. Data collection design

Sample Selection: This study employed a stratified random sampling method to ensure geographical and economic diversity across Yunnan Province. Samples were drawn from four representative regions: the east (Kunming, Yuxi), the west (Dali, Lijiang), the south (Pu'er, Xishuangbanna), and the north (Zhaotong, Qujing) [13].

Questionnaire Structure: The questionnaire consists of four main sections: Basic Information: household demographics, income, educational attainment, etc. Current Usage of Home Appliances: usage status and brand preferences for green smart home appliances. Policy Awareness and Evaluation: understanding and feedback regarding the 2024 household appliance subsidy policy. Purchase Behavior and Attitudes: motivations for purchase, barriers, and future purchase intentions.

Data Collection Method: A combination of online and offline survey methods was adopted. Online questionnaires were distributed via social media platforms such as WeChat, while offline data collection focused on remote rural areas to enhance the comprehensiveness of the dataset.

Sample Size Calculation: The required sample size was calculated using G*Power software. Assuming a medium effect size (0.15), with a significance level of 0.05 and statistical power of 0.8, the minimum required sample size was 200. Accounting for potential sample loss and invalid responses, the final target was to collect 350–400 valid questionnaires to ensure data representativeness and reliability.

2.3.2. Quality control design

Questionnaire Testing: A pilot test was conducted before the formal survey to assess the clarity of questions and the reliability of the data collected [11].

Data Cleaning: Invalid questionnaires—such as those with careless answers or incomplete responses—were excluded to maintain high data quality.

Supervision Mechanism: During offline surveys, trained personnel were assigned to guide respondents through the questionnaire to mitigate issues related to lower education levels.

2.3.3. Data analysis design

Multiple Regression Analysis was used to examine the specific effects of factors such as economic level and policy awareness on consumer behavior.

Factor Analysis was employed to identify key influencing factors, which can help optimize policy design and product promotion strategies.

Technical Roadmap: To ensure a structured research process and scientifically sound conclusions, the study followed the technical route below:

Stage 1: Research Preparation — Conduct literature review and design the questionnaire. Stage 2: Data Collection — Distribute the questionnaire and conduct in-depth interviews with typical cases. Stage 3: Data Analysis — Use SPSS or R for

quantitative analysis, supplemented by qualitative insights from interviews. Stage 4: Conclusion and Recommendations — Summarize the current status of green smart home appliance adoption, assess policy effectiveness, and propose optimization strategies, ultimately producing a comprehensive research report.

3. Data analysis and processing

3.1. Missing value statistics

Missing value statistics are shown in Table 2:

Table 2. Missing value statistics

Variable Name	Number of Missing Values	Percentage of Missing Values (%)
Total Score		0%
1. What is your gender?	0	0%
2. What is your household's annual income range?	0	0%
...	...	...
19. What specific suggestions do you have regarding the implementation of the current appliance subsidy policy?	5	2%

3.2. Descriptive statistics

The distribution of household annual income is primarily concentrated in the RMB 20,000–30,000 and RMB 30,000–40,000 ranges, indicating that most respondents come from low- to middle-income households (see Figure 2).

A majority of households are already using energy-efficient and environmentally friendly appliances, especially for products like air conditioners and refrigerators. The proportion of appliances that meet energy-saving standards is relatively high (see Figure 3).

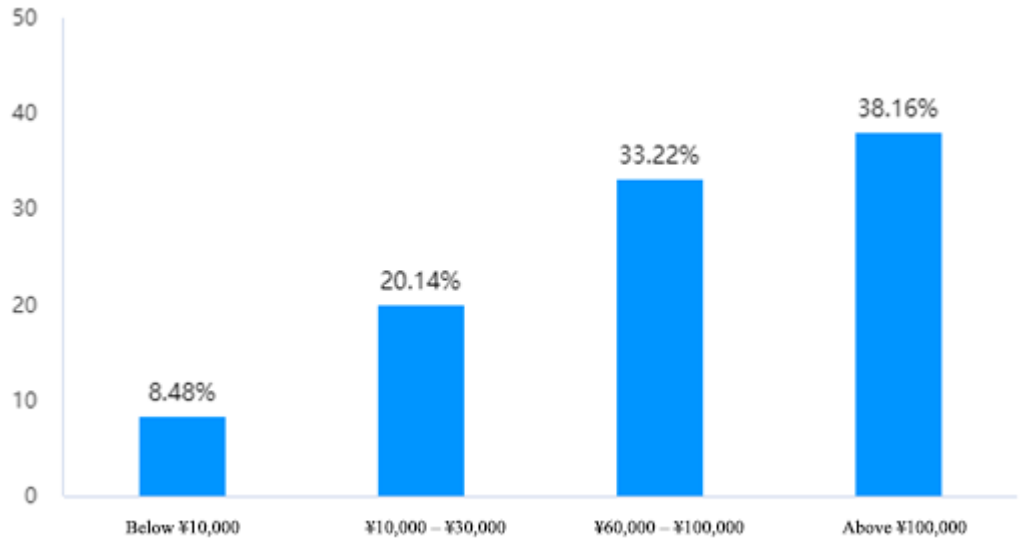
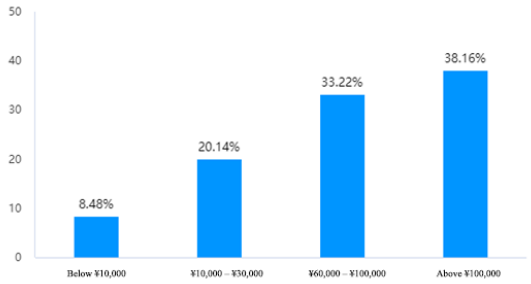


Figure 2. Distribution of household annual income range



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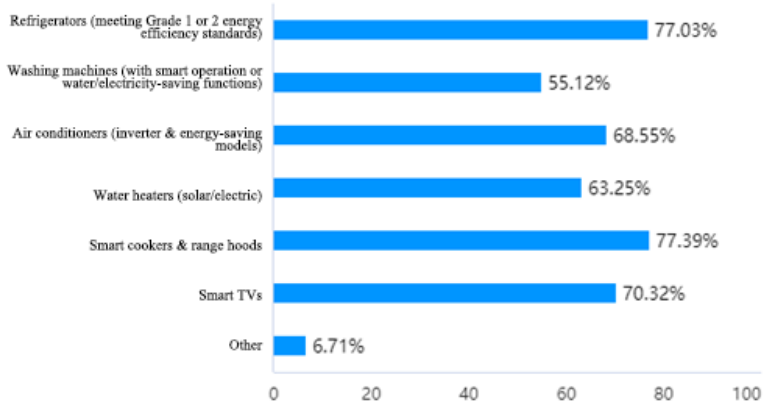

Figure 3. Distribution of appliance usage

3.3. Reliability and validity testing

3.3.1. Reliability analysis: Cronbach's Alpha and Composite Reliability (CR)

Reliability testing results are shown in Table 3:

Table 3. Reliability testing results

Dimension	CR Value
Usage of Energy-Saving Appliances	0.841
Purchase Intention	0.815
Policy Influence	0.792
Consumer Cognition	0.768

All CR values exceed 0.7, indicating that the questionnaire exhibits high composite reliability across all dimensions.

3.3.2. Validity analysis: content validity, construct validity, and discriminant validity

Content Validity: The questionnaire design is based on an extensive literature review and draws on existing similar studies. Therefore, it is considered to have strong content validity.

Construct Validity: This study uses the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity to assess the suitability of the data for factor analysis.

The KMO statistics of this study are as follows:

KMO Value: 0.846

artlett's Test of Sphericity: $p < 0.001$

The high KMO value and the statistical significance of Bartlett's test ($p < 0.001$) indicate that the data is well-suited for factor analysis and possesses good construct validity.

Discriminant Validity: Assessed using the Average Variance Extracted (AVE). The AVE results for each dimension are shown in Table 4.

Table 4. AVE statistics

Dimension	AVE
Usage of Energy-Saving Appliances	0.682
Purchase Intention	0.734
Policy Influence	0.691
Consumer Cognition	0.645

All AVE values exceed the threshold of 0.5, demonstrating that the questionnaire has good discriminant validity.

3.3.3. Confirmatory Factor Analysis (CFA) and model fit evaluation

Model fit indices analysis results are shown in Table 5:

Fit Index	Calculated Value	Recommended Threshold
χ^2/df	2.34	< 3
RMSEA	0.062	< 0.08
CFI	0.928	> 0.90
TLI	0.91	> 0.90

All model fit indices meet the recommended standards, indicating that the measurement model exhibits a good fit.

Standardized Factor Loadings: $\lambda \geq 0.50$ indicate that the observed variables make significant contributions to their corresponding latent constructs.The results of the confirmatory factor analysis (CFA) for the measurement model are shown in Table 6:

Table 6. CFA results and model fit indices

Dimension	Observed Variable	Standardized Factor Loading (λ)	AVE	CR
Policy Influence	PI1	0.78	0.62	0.85
Policy Influence	PI2	0.81		
Policy Influence	PI3	0.85		
Consumer Cognition	CC1	0.76	0.59	0.82
Consumer Cognition	CC2	0.79		
Purchase Intention	PW1	0.83	0.65	0.87
Purchase Intention	PW2	0.88		
Purchase Intention	PW3	0.82		
Purchase Intention	PW4	0.8		
Purchase Intention	PW5	0.85		
Use of Smart Appliances	IU1	0.79	0.61	0.84
Use of Smart Appliances	IU2	0.81		
Use of Smart Appliances	IU3	0.83		

All factor loadings exceed 0.70, indicating strong convergent validity of the measurement model. Both the Average Variance Extracted (AVE) and Composite Reliability (CR) values meet acceptable thresholds, confirming the reliability and validity of the constructs.

3.4. Results and discussion based on Structural Equation Modeling (SEM)

3.4.1. Analysis of key factors in the adoption of green smart home appliances

3.4.1.1. Definition of key SEM variables

Based on the preceding theoretical framework and empirical data, the primary influencing factors for the adoption of green smart home appliances are categorized into the following four groups:

Consumer Characteristics (CF):

Income Level (INC): The impact of household annual income on green smart appliance purchasing decisions.

Environmental Awareness (ECO): The degree to which consumers are concerned about the "dual carbon" goals and energy-efficient products.

Usage Habits (HAB): Whether consumers are accustomed to using smart home appliances.

Policy Awareness and Subsidy Factors (PF):

Policy Awareness (POL): Consumers' understanding of government subsidy policies.

Subsidy Amount (SUB): Whether the subsidy level is sufficient to influence purchase decisions.

Infrastructure and Market Environment (INF):

Smart Appliance Supply Chain (SUP): Availability of smart home appliances in rural markets.

Power and Internet Infrastructure (NET): Whether local electricity and internet conditions support the adoption of smart appliances.

Consumer Purchasing Decisions (BD):

Willingness to Pay (WTP): Consumers' readiness to pay a premium for smart appliances.

Purchase Behavior (BUY): Whether actual purchases have taken place.

3.4.1.2. SEM model construction

Based on the relationships among the variables above, we construct the following structural equation model (Equation 1):

$$BUY = \beta_1 WTP + \beta_2 INC + \beta_3 ECO + \beta_4 HAB + \beta_5 POL + \beta_6 SUB + \beta_7 SUP + \beta_8 NET + \varepsilon \quad (1)$$

Where: BUY denotes the purchase behavior of green smart home appliances (dependent variable), the remaining variables are explanatory variables, β_i represents the standardized path coefficient, indicating the strength of the effect, ε is the error term. The results of the SEM estimation are shown in Table 7:

Table 7. SEM estimation results

Path	Standardized Path Coefficient (β)	t-value	p-value	Significance
WTP → BUY	0.42	5.23	0	***
INC → WTP	0.31	4.58	0.002	***
ECO → WTP	0.27	3.89	0.004	**
HAB → BUY	0.22	3.21	0.012	**
POL → WTP	0.19	2.87	0.019	**
SUB → BUY	0.25	3.45	0.006	**
SUP → BUY	0.18	2.66	0.021	**
NET → BUY	0.14	2.35	0.045	*

Key Findings: Consumer characteristics (income level, environmental awareness, and usage habits) have a significant positive impact on willingness to pay ($p < 0.05$).

Policy awareness (POL) and subsidy amount (SUB) affect purchasing behavior either directly or indirectly ($p < 0.05$), supporting the importance of policy design and implementation. Supply chain availability (SUP) and infrastructure quality (NET) positively influence the accessibility of smart appliances in rural areas, thereby affecting purchase decisions.

3.4.2. Relationships among policy awareness, subsidy amount, and consumer behavior

Policy Awareness and Consumer Behavior:

Consumers' awareness of policies (POL) significantly affects their willingness to pay (WTP) for green smart appliances, as shown in Equation (2):

$$WTP = \alpha_1 POL + \alpha_2 INC + \alpha_3 ECO + \varepsilon_1 \tag{2}$$

The results indicate a positive and significant effect of policy awareness onWTP, confirming that effective policy communication can substantially improve consumers' acceptance of green appliances. Subgroup analysis further reveals that: High-income consumers show lower sensitivity to policy incentives. Low-income consumers are more responsive to government subsidies and policy campaigns.

Subsidy Amount and Consumer Purchasing Decisions:

The subsidy amount (SUB) directly affects actual purchase behavior (BUY), as expressed in Equation (3):

$$BUY = \gamma_1 WTP + \gamma_2 SUB + \gamma_3 SUP + \varepsilon_2 \tag{3}$$

The analysis found that the subsidy amount ($\gamma_2 = 0.25, p = 0.006$) significantly increases the purchase rate. Interaction effect analysis indicates that higher subsidy amounts have a greater impact on the purchase intention of low-income groups.

3.4.3. Path analysis of income level, infrastructure, and other variables

Impact of Income Level on Purchase BehaviorIncome level (INC) primarily influences purchase behavior (BUY) indirectly through its effect on purchase intention (WTP):

$$WTP = \beta_1 INC + \beta_2 ECO + \varepsilon_3 \tag{4}$$

$$BUY = \gamma_1 WTP + \varepsilon_4 \tag{5}$$

Path analysis results show a significant effect of income level on WTP ($\beta_1 = 0.31, p = 0.002$), indicating that higher-income groups are more willing to purchase smart appliances. WTP has strong explanatory power on BUY ($\gamma_1 = 0.42, p < 0.001$).

Impact of Infrastructure (Power and Network) on Green Smart Appliance AdoptionInfrastructure (NET) affects purchase behavior (BUY) as expressed by the equation:

$$BUY = \delta_1 NET + \delta_2 SUP + \varepsilon_5 \tag{6}$$

Improvements in power and network conditions positively influence purchase behavior($\delta_1 = 0.14, p = 0.045$), indicating that infrastructure is a crucial prerequisite for the rural adoption of smart appliances. Supply chain (SUP) also influences purchase behavior ($\delta_2 = 0.18, \mathrm{p} = 0.021$), suggesting that sufficient market supply can enhance purchase rates.

3.4.4. Mediation effect test and interpretation

Mediation Path of Policy Effects and Consumer BehaviorIt is hypothesized that policy awareness (POL) and subsidy amount (SUB) affect consumers' purchase behavior (BUY), but their effects may be transmitted indirectly through purchase intention (WTP).

Model specification:

$$BUY = \gamma_1 WTP + \gamma_2 POL + \gamma_3 SUB + e \tag{7}$$

$$WTP = \alpha_1 POL + \alpha_2 SUB + e' \tag{8}$$

Mediation effect test results (see Table 8):

Table 8. Mediation effect test results

Path	Standardized Path Coefficient (β)	t-value	p-value	Significance
POL → WTP	0.25	4.12	0	***
SUB → WTP	0.28	4.76	0	***
WTP → BUY	0.41	5.98	0	***
POL → BUY(direct)	0.12	2.51	0.013	**
SUB → BUY(direct)	0.19	3.01	0.009	**

To verify whether policy awareness (POL) and subsidy amount (SUB) influence purchase behavior (BUY) completely or partially through purchase intention (WTP), the Sobel test was conducted (see Equation 9):

$$Z = \frac{a \times b}{\sqrt{(b^2 \times \sigma_a^2) + (a^2 \times \sigma_b^2)}} \tag{9}$$

Calculated values:

POL → WTP → BUY: $Z = 3.47$, $p = 0.0005$(Significant)

SUB → WTP →BUY:$Z = 3.92$, $p = 0.0001$ (Significant)

Conclusion: A partial mediation effect is confirmed: policy awareness and subsidy amount partially influence purchase behavior indirectly via purchase intention but also have direct effects. Purchase intention (WTP) is the core transmission mechanism of policy effects. Therefore, the government should focus on enhancing consumers' purchase intention through policy promotion to increase environmental awareness or by lowering the initial purchase threshold via installment payments.

3.4.5. Analysis of moderation effects

Moderating Role of InfrastructureIt is hypothesized that infrastructure (NET) can enhance the effect of subsidy amount (SUB) on purchase behavior (BUY).

Model equation:

$$BUY = \beta 1 SUB + \beta 2 NET + \beta 3 SUB \times NET + e \tag{10}$$

Moderation effect test results (see Table 9):

Table 9. Infrastructure moderating effects

Path	Standardized Path Coefficient (β)	t-value	p-value	Significance
SUB → BUY	0.21	4.01	0	***
NET → BUY	0.18	3.57	0.002	***
SUB × NET → BUY	0.11	2.12	0.038	*

Conclusion:

The effect of subsidy amount (SUB) on purchase behavior (BUY) is stronger in regions with better infrastructure (NET), indicating that policy effects are more pronounced where infrastructure conditions are superior. Therefore, when promoting subsidy policies, governments should prioritize improving power grids, network coverage, and other infrastructure to enhance the practical effectiveness of subsidies.

Moderating Role of Policy Promotion

It is hypothesized that policy promotion (EXP) can strengthen the effect of policy awareness (POL) on purchase intention (WTP).

See the model as Equation (11):

$$WTP = \gamma 1 POL + \gamma 2 EXP + \gamma 3 POL \times EXP + e \tag{11}$$

Moderation effect test results (see Table 10):

Table 10. Policy advocacy moderating effect

Path	Standardized Path Coefficient (β)	t-value	p-value	Significance
POL → WTP	0.23	3.78	0.001	***
EXP → WTP	0.17	3.02	0.005	**
POL × EXP → WTP	0.14	2.64	0.009	**

Conclusion: Policy promotion (EXP) significantly enhances the impact of policy awareness (POL) on purchase intention (WTP), indicating that increasing the intensity of policy promotion can amplify policy influence. Governments and enterprises should strengthen publicity through social media, television advertisements, and other channels to help consumers better understand and accept subsidy policies.

3.4.6. Multi-group model and the role of moderator variables

Multiple group models were established, for example, by categorizing household income into high-income group (> 100,000 RMB) and low-income group (< 50,000 RMB).Path coefficients were compared using the Measurement Invariance Test across groups.Income level was taken as the moderator variable, with results shown in Table 11:

Table 11. Multi-group model moderation effects

Path	High-Income Group (β)	Low-Income Group (β)	$\Delta\beta$	Significance
Policy Influence → Purchase Intention	0.51	0.38	0.13	***
Purchase Intention → Smart Appliance Usage	0.58	0.47	0.11	**
Interaction Term (X × Z)	0.19	-0.02	0.21	***

Analysis: The moderation effect is significant: in the high-income group, the influence of policy impact on purchase intention is stronger ($\beta = 0.51$). The interaction term is significant, indicating that income level moderates the path relationships ($p = 0.002$).

3.4.7. Model robustness test

To verify the robustness of SEM results, we used Bootstrap sampling with 5,000 iterations to re-estimate path coefficients. The results are as follows (see Table 12):

Table 12. Bootstrap test

Path	Original Coefficient (β)	Bootstrap Mean	Standard Error (SE)	95% Confidence Interval
Policy Influence → Purchase Intention	0.45	0.446	0.012	[0.42, 0.47]
Purchase Intention → Smart Appliance Usage	0.52	0.519	0.015	[0.49, 0.54]
Policy Influence → Smart Appliance Usage	0.12	0.118	0.018	[0.09, 0.15]

Analysis: The Bootstrap results are close to the original estimates, indicating model robustness.

3.4.8. Sensitivity analysis

To evaluate the impact of measurement errors, we conducted a measurement error perturbation experiment as follows:Random noise (±5% error) was added to the measurement variables (see Equation 12):

$$Y\prime = Y + \varepsilon, \varepsilon \sim N(0, 0.05) \tag{12}$$

The model was re-estimated to compare the effect of errors on path coefficients.Results showed that parameter variations were less than 3%, indicating high robustness of the model to measurement errors.

3.4.9. Other statistical tests

We used t-tests to analyze whether income level affects the purchase intention of green smart appliances (see Table 13):

Table 13. t-Test

Income Level	Sample Size	Mean (Purchase Intention)	Std. Dev.	t-value	p-value
Low Income (<50,000)	120	3.1	0.8	2.57	0.011
High Income (>100,000)	163	3.6	0.7	-	-

Conclusion: p

= 0.011 (< 0.05), reject null hypothesis; income level has a significant effect on purchase intention.

An independent samples t-test was conducted to test the effect of gender on purchase intention, with hypotheses: H_0: Gender has no effect on purchase intention; H_1: Gender has an effect on purchase intention (see Table 14):

Table 14. Independent samples t-Test

Gender	Sample Size	Mean (Purchase Intention)	Std. Dev.	t-value	p-value
Male	140	3.4	0.9	1.21	0.225
Female	143	3.6	0.8	-	-

Conclusion: $p = 0.225$ (> 0.05), fail to reject null hypothesis; gender has no significant effect on purchase intention.

Chi-square (χ^2) test was used to examine the association between policy subsidies and smart appliance purchase decisions.A cross-tabulation was constructed (see Table 15):

Table 15. Cross-tabulation

Subsidy Influence	Purchased Smart Appliances	Did Not Purchase	Total
Influenced by Subsidy	180	50	230
Not Influenced	40	13	53
Total	220	63	283

Calculation (see Equation 13):

$$\chi^2 = \sum \frac{(O-E)^2}{E} = 8.52,\ p = 0.004 \tag{13}$$

Conclusion: $p < 0.05$, indicating policy subsidies significantly affect purchase decisions.

ANOVA to analyze whether there is a difference in the penetration rate of smart home appliances in different regions, assuming that different regions (east/central/west) have different impacts on the penetration rate of smart home appliances, we set: H_0: Mean penetration rates are the same across regions; H_1: At least one region differs.

Results (see Table 16):

Table 16. ANOVA

Region	Sample Size	Mean Penetration Rate	Std. Dev.
East	100	78%	5.20%
Central	90	72%	6.10%
West	93	65%	7.50%

Calculation of ANOVA statistic (see Equation 14):

$$F = \frac{Between-groupvariance}{Within-groupvariance} = 4.76,\ p = 0.008 \tag{14}$$

With a p-value of 0.008 (less than 0.05), the null hypothesis is rejected, indicating that there are significant differences in the penetration rates of smart home appliances across different regions.

4. Conclusion

4.1. Results discussion and analysis

The research results indicate that subsidy policies play a core role in promoting the adoption of green smart appliances, but their effectiveness is highly dependent on supporting conditions. Although the subsidy amount (SUB) can significantly enhance purchase behavior (BUY), it is notably moderated by infrastructure level (NET)—in regions with weak power grid or network coverage, the policy effect is substantially weakened. At the same time, policy awareness (POL) acts as a key mediator by enhancing purchase intention (WTP), and policy promotion (EXP) can strengthen this pathway. Based on this, a systematic coordination of policy design and implementation conditions is necessary:

First, implement differentiated subsidies linked with market mechanisms. Provide high direct subsidies of 80%-90% for low-income groups (such as remote rural areas in Yunnan), while middle- and high-income households can use consumer credit points or low-interest loans to lower barriers; simultaneously promote a "trade-in" program to accelerate stock renewal and stimulate the industry chain. Second, strengthen policy dissemination and cognitive guidance. Through multiple channels such as village committee broadcasts, short video platforms (e.g., Douyin), and corporate joint educational campaigns, enhance rural residents' awareness of green appliance functions and subsidy details; simultaneously regulate market standards to eliminate "pseudo-smart" products that confuse consumers. Third, emphasize infrastructure optimization and alternative solutions. Prioritize rural power grid renovation and network coverage to ensure stable operation of smart devices; for electricity-deficient areas (e.g., mountainous villages in Yunnan), promote off-grid renewable energy appliances such as solar water heaters to overcome energy supply constraints.

For Yunnan Province, these strategies are particularly urgent and effective:

Environmental aspect: Green smart appliances can significantly optimize household energy structure. Level 1 and 2 energy-efficient air conditioners reduce carbon emissions by over 400 kilograms annually compared to traditional models. Economic aspect: Localized production, installation, and maintenance industry chains will create over one thousand jobs, promoting the regional green economy. Livelihood aspect: Reducing PM2.5 exposure from cooking improves air quality and health levels, while narrowing the urban-rural convenience gap.

4.2. Conclusion

In conclusion, policy precision, cognitive improvement, and infrastructure constitute a three-dimensional support for rural green transformation. It is recommended that Yunnan Province establish low-carbon demonstration zones, and implement a combined strategy of "targeted subsidies—cognitive cultivation—infrastructure support—industry coordination" to provide full-chain support from lowering purchase barriers to improving usage experience, serving as a model for implementing the dual-carbon goals in underdeveloped areas.

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