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Labor Off-Farm Employment and Farmers' Cooking Clean Energy Use: Evidence from Rural China

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Abstract: (Motivation) With the transfer of labor force and the continuous improvement of household income, the household energy consumption structure is also changing. (Gaps) However, few studies have explored the correlations between labor off-farm employment (LOE) and farmers' cooking clean energy (CCE) consumption. (Methodologies) Using survey data of 8198 farmers in 27 provinces from China's labor dynamic survey in 2016, the IV-Probit model was used to analyze the impact of LOE on CCE use, and the mediation effect model was used to examine the specific mechanism of action between them. (Results) The results found that: (1) LOE accounted for about 39%, and farmers' utilization rate of CCE accounted for 40%. (2) LOE has significantly promoted the use of CCE by farmers, and this action mechanism is mainly realized through three paths, that is, per capita annual cash income, social relationship network, and family population structure. (3) The heterogeneity analysis results showed that the head of the household having a university education or above, the family being located in rural areas and mountainous areas, and LOE will have a greater positive impact on the farmers' CCE use. (Policy) From the micro perspective of LOE, this study can deepen our understanding of LOE and CCE use decisions, and then provide a reference for the rational allocation of labor resources and farmers' CCE-related policy formulation.

Keywords: labor off-farm employment (LOE); cooking clean energy (CCE); rural areas; China

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1. Introduction

Since the reform and opening-up of the country, China's social and economic development has increased rapidly. However, the ecological environment in the vast rural areas has been deteriorating day by day and the rural environmental risk is increasing day by day, which has caught the attention of scholars [1–4]. Indoor and outdoor air pollution brought about by unreasonable rural energy structures is the most serious environmental problem in China [5–7]. Rural Chinese residents use solid fuel as their main cooking energy source, which has many serious consequences, such as decreased air quality, raising farmers' health risks, forest degradation, and poverty traps [1,8–10]. To improve the rural ecological environment, the rural revitalization strategy of the 19th National Congress of the Communist Party of China was proposed to establish a clean, low-carbon, safe, and efficient energy system [1,4,11–13].

China is a largely agricultural country—nearly half of the population lives in rural areas. In the vast rural areas, farmers still use fuelwood, straw, and coal, and other solid fuels as their main cooking energy sources [14–16]. In rural China, 307 million people still rely on biomass to cook, and about 33 percent still have no access to CCE [2,17,18]. It has

been proven that air pollution caused by non-clean energy use leads to neonatal weight loss and malnutrition, increased coughing and breathing difficulties in adults, and even causes diseases such as lung blood cancer, hypertension, and blindness [19–21]. It can be seen that farmers' CCE is an important link to reducing environmental pollution and improving residents' health, so it is crucial to clarify the drivers of CCE.

Among the available studies, there are more studies on clean energy for farmers' cooking in the academic community. First, basic household characteristics, including household size, age, gender, and education level, etc., have been proven to have significant impacts on the energy consumption needs and choices of farmers [22–28], followed by household economic characteristics, particularly household income. For example, some studies found that household income can significantly promote the conversion of household cooking energy [29–36]. The "energy ladder" theory suggests that, as income rises, the consumption of clean energy for household cooking will change along the "energy ladder", moving from biomass to commodity energy [30]. Other studies suggest that income does not affect the choice of clean energy consumption for household cooking as much as the "energy ladder" model assumes, suggesting that biomass consumption has significant "Giffen" commodity characteristics, i.e., consumption decreases as income increases [31,32]. Other studies suggest that the effect of income on household energy consumption is insignificant because the relationship between fuelwood consumption in rural areas is not obvious, since rural households collect fuelwood themselves and do not obtain it through market exchange, and fuelwood consumption in rural areas does not conform to market behavior [33]. Third, the factors of resource availability, geographical features, topographical features, and the availability of resources that also determine rural energy consumption [2], and the amount and variety of resources in each location are directly related to the local resources available in that area [34,35]. Fourth, policy and market factors have been found to have an effect—with the acceleration of economic development, urbanization, and industrialization, energy has begun to change to commodity energy in the process of transformation; the price of commodity energy, the proximity of markets, the density of distribution points, etc. will affect the farmers' CCE consumption [36]. Additionally, national policies have an important influence on the consumption of energy, and the structure of energy consumption often varies greatly under different policies [37,38]. However, there have been relatively few quantitative studies on LOE and CCE [2]. Even the limited quantitative studies, most of which focused on the effects of income levels, urbanization, etc., on the use of CCE in rural households [7,39,40], have not been explicitly conducted on LOE. From the available studies, few micro-empirical studies have explored the direct impact of LOE on CCE [41,42]. Therefore, it is urgent to further explore what kind of correlation exists between non-farm employment of the general rural residential labor force and clean energy use for cooking.

With the acceleration of Chinese urbanization, LOE has become a common social and economic phenomenon. According to statistics, the number of migrant workers in China in 2020 was 288 million [43,44]. With the increase in non-farm employment of rural laborers and the increase in farmers' income, the concept of energy consumption is also changing, prompting a significant change in energy consumption and the consumption structure in rural areas of China [45]. LOE has significantly optimized the structure of rural domestic energy consumption and improved the living standards of farmers. The impact of LOE on farmers' CCE is mainly reflected in the following three aspects: first, LOE leads to less dependence of farm households on agriculture, households engaged in non-farm employment correspondingly reduce the time required for agricultural activities and leisure time, and households are more likely to choose convenient commodity energy, making the consumption of biomass energy sources, such as fuelwood and straw, lower [21]. Secondly, the employment situation of the household directly affects the economic situation of the household. LOE raises the household income of farming households, prompting them to pursue a higher quality of commodity energy [46]. Third, the different occupational categories of LOE, the things they are exposed to, and the labor hours they put in will be

different, which will likewise affect the consumption choices of household energy [47]. For example, Ma et al. [46] and Cheng et al. [26] found that LOE brings about income growth and improved living standards, and changing consumption awareness will directly or indirectly affect or change the decision on clean energy use among farmers. Therefore, when humans are under great pressure from resources, the environment, population, and society, it is of great practical significance to explore the impact of CCE use on the sustainable development of energy [48].

Based on this, this study used sample survey data of 8198 farmers from 27 provinces in China in 2016, from the micro perspective of LOE, and built Probit and IV-Probit econometric models to explore the impact of LOE on CCE use—the specific mechanism of action was further analyzed using the mediation effect model, which can deepen our understanding of China's LOE and CCE use decisions, and then provide a reference for the rational allocation of labor resources and the formulation of policies related to farmers' CCE use. The marginal contribution of this study, compared with previous studies, is as follows: First, limited studies have focused on the impact of LOE on CCE, but these studies did not deeply analyze the influence mechanism between the two—on this basis, a deeper analysis of the intermediary mechanism is conducted. Second, the research has dealt with the endogenous problems caused by the causality of LOE and farmers' CCE well to ensure the credibility of the research results. Third, the sample of 8198 farmers covered 27 provinces in China. Compared with previous small-scale sampling surveys, the results of this study may be more universal and targeted for formulating relevant policies at a larger scale (national, provincial, etc.).

2. Materials and Methods

2.1. Research Hypotheses

Since the reform and opening up of the country, the adjustment of the economic structure has made China's social economy develop rapidly. At the same time, the rapid urbanization process and the improvement of agricultural productivity have led to the emergence of a large amount of surplus rural labor. With the relaxation of national policies, this idle labor is choosing to work in cities to seek a better life [44,49,50]. However, due to the dual economic and social structure caused by China's household registration system, even if the rural labor force migrates from the countryside to the city on a large scale and participates in urban construction, it is difficult to truly integrate into the city, and the labor force is ultimately tending to produce and consume in the countryside [51]. As one of the important approaches to rural revitalization in China, LOE has played an important role in increasing residents' income, narrowing the gap between the rich and poor, and improving residents' quality of life [46]. On the one hand, with the increasing amount of LOE, farmers' consumption understanding will continue to improve and rural energy consumption will gradually increase, which will directly or indirectly affect and change the consumption structure of rural residents [46,52,53]. On the other hand, in terms of the distribution of labor time, LOE reduces the time for agricultural activities and increases leisure time, which will encourage farmers to choose more convenient clean energy, thus reducing the consumption of biomass energy, such as firewood and straw [21,53,54]. Based on this, hypothesis 1 was proposed:

H1. *LOE has a significant positive impact on CCE.*

With the acceleration of China's urbanization process, a large amount of the rural labor force is moving into cities, and the non-agricultural employment rate of the rural labor force is becoming higher and higher [55]. The economic status of farmers is closely related to the employment status of the labor force, and the improvement of economic status is conducive to the optimization of the household energy consumption structure [56,57]. For example, He [51] found that if a family's livelihood is dominated by migrant workers, the traditional biomass energy in its household energy consumption will gradually decrease. Meanwhile, Shao et al. [42] and He et al. [51] found that, although migrant workers are

employed in urban workplaces, it is difficult for them to really settle down in cities due to the limited resources and welfare they receive, which forces them to send money back to their hometown for consumption. Démurger and Wang [58], Han and Wu [47], and Lin and Zhao [55] found that, with a more stable off-farm income for farmers, they would reduce their precautionary savings and increase their marginal propensity to consume. It can be seen that the income of workers from off-farm labor employment increases the income of rural families, and people's living standards are improving day by day. LOE changes the thinking and behavior of farmers by influencing the economic status of families, and then influences the decision-making regarding CCE. Based on this, research hypothesis H2a is proposed:

H2a. *LOE is mediated by the per capita annual cash income, which has a positive and significant effect on the use of CCE.*

Migrant workers will come into contact with all kinds of people and expand their social network through interaction, thus influencing their daily behavior decisions [44]. On the one hand, compared with rural farming, the workplace of LOE involves more interpersonal interaction, which is more conducive to the transmission of information and the improvement of residents' awareness of energy consumption, thus influencing CCE consumption decisions [55,59,60]. On the other hand, LOE can promote the accumulation of human capital among migrant labor and the expansion of their social relationship network, which is conducive to the renewal of farmers' understanding of energy use and effectively improve their utilization rate of CCE [3]. Based on this, hypothesis H2b was proposed:

H2b. *LOE, through the social relationship network, has a positive and significant impact on the use of CCE.*

A large amount of population migration caused by LOE will change the population structure of households living in rural areas, thus affecting household energy consumption decisions [2,7,48]. After the young labor force leaves for work, the family cooking and energy decisions fall on the elderly who stay at home [2]. On the one hand, older people live in rural areas all year and their living environment is relatively closed. They are accustomed to using traditional biomass energy (such as straw) due to its low cost and easy access [2]. On the other hand, the elderly will be more inclined to use traditional energy as their learning ability degrades and they are slow to receive new ideas from clean energy. In addition, the use of clean energy will cost more [59]. Based on this, hypothesis H2c was proposed:

H2c. *LOE, through the family population structure, has a negative and significant impact on the use of CCE.*

The distribution diagram of the research theory diagram is shown in Figure 1.

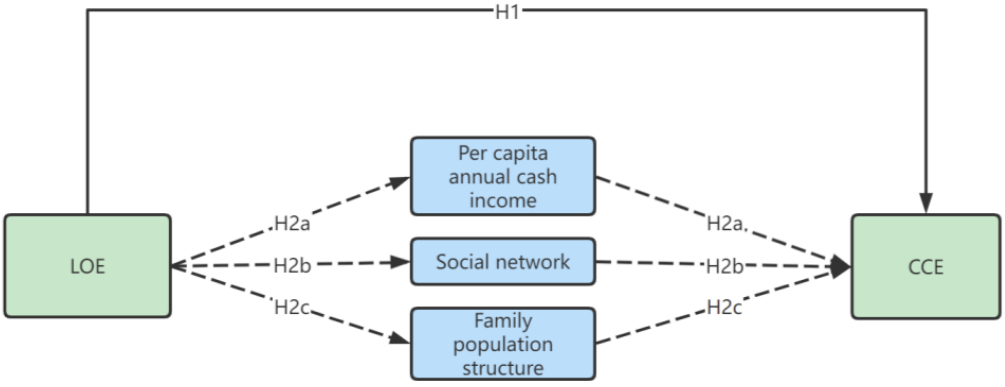

Figure 1. Mechanism map of LOE and CCE use.

2.2. Data Source

The data used in the study came mainly from the China Labor-force Dynamics Survey (CLDS) conducted by Sun Yat-sen University in 2016. The data included individual questionnaires, a family questionnaire, and a village questionnaire. To ensure the typicality and representativeness of the samples selected from the survey, the study was mainly sampled using the PPS sampling method—for more information, please see: http://css.sysu.edu.cn (accessed on 5 July 2022). Since this study only focused on the use of CCE, only rural samples were retained for the study. After processing samples with missing values and extreme outliers, a total of 8198 farmers in 231 villages entered the subsequent analysis.

2.3. Methods

2.3.1. Basic Estimation Model

The goal of this study is to explore the impact of LOE on CCE. The dependent variable is whether farmers use clean energy, which is a dichotomous variable, and the Probit model was used for estimation.

$$Prob(Y_i = 1|X_i) = Prob(\alpha_0 T_i + \beta_0 X_i + \varepsilon_i > 0|X_i) \quad (1)$$

where Y_i is a dependent variable, with a value of 1 meaning that the farmers use clean energy and a value of 0 meaning that the farmers do not use clean energy; T_i is the core explanatory variable of this study—LOE—which uses the number of family laborers out of the total number of households; X_i is a control variable; α_0 and β_0 are estimated parameters of the model; and ε_i is the error term.

There may be a causal relationship between LOE and CCE, which leads to the core independent variable of labor off-farm employment being the endogenous variable. The iv-probit model will be used to estimate this, which can be divided into two stages. In the first stage, the regression equation of the impact of instrumental variables on LOE was constructed to fit the predicted value of clean energy used by farmers in cooking. In the second stage, the predicted values of LOE and CCE were regressed, and the consistent estimation results of the exogenous conditions of the explanatory variables were obtained. The estimation equation was as follows:

$$Prob(Y_i = 1|X_i) = Prob(\alpha_0 IVT_i + \beta_0 IVX_i + \varepsilon_i > 0|X_i) \quad (2)$$

In the formula, each variable is similar to (1), and IV represents the instrument variable of the model. Stata 16 was used to estimate the models.

2.3.2. Mediation Effect Model

When analyzing the effect of the independent variable X on the dependent variable Y, if the independent variable X needs to influence the dependent variable Y through variable M, then variable M is called the mediating variable, and the effect exerted by variable M is called the mediating effect. There are multiple methods for a mediation effect test, and the more common include the stepwise test regression coefficient method, Sobel test, and Bootstrap test. Referring to the studies of Liu and Ling [60] and Qu [61], this study was proposed to test the mediation effects by stepwise regression, with the equations estimated as follows:

$$Y = cX + \varepsilon_1 \quad (3)$$

$$M = aX + \varepsilon_2 \quad (4)$$

$$Y = cX + \beta M + \varepsilon_3 \quad (5)$$

where Y is the variable of whether farmers use clean energy for cooking, X is LOE, M is the per capita annual cash income, social relationship network, and family population structure. The entire process of the model was conducted in Stata 16.0.

2.4. Mediator Variable

The objective of this study is to explore the correlation and influence mechanism of LOE and CCE use, and some key variables should be measured, as follows:

(1) Dependent variable. The dependent variable of this study is CCE use, which reflects the living energy consumption structure of rural residents. Referring to Carter et al. [62], Ma et al. [46], and Tian [11], this study divided farmers' cooking energy into clean energy, such as natural gas, gas, solar energy, and biogas, and non-clean energy, such as firewood and coal. Farmers were marked as 0 when using solid fuels, such as firewood and coal, as the primary energy source for cooking, and when using natural gas, gas, solar energy, and biogas as the main cooking energy sources, they were marked as 1.

(2) Focus variable. The core independent variable of this study was the proportion of LOE, using the total non-farm labor force divided by the total household labor force. Among them, according to the statistical caliber of the National Bureau of Statistics, the labor force works for at least 6 months a year, and does not consider less than 6 months.

(3) Mediator Variable. According to the theoretical analysis, LOE may have an impact on CCE use by affecting the per capita annual cash income, social relationship network, and family population structure. Therefore, the per capita annual cash income, social relationship network, and family population structure were selected as the intermediary variables to investigate the intermediate transmission mechanism of the impact of LOE on the use of CCE. Among them, the per capita annual cash income referred to the per capita annual cash income of families in 2016. The social relationship network was measured by the annual family gift expenditure in 2016, and the population structure was measured by the ratio of the elderly and children to the total family population.

(4) Tool variable. In theory, there may be a causal relationship between LOE and CCE use; moreover, the core variable of LOE is the endogenous variable. To address the possible endogenicity of model estimation, referring to the research of Shuai et al. [42], Xu et al. [49], and other studies, this study used the village labor off-farm employment ratio as the instrumental variable for LOE, mainly based on the following considerations: First, the LOE of farmers will be affected by the LOE of other farmers in villages—the fact that other laborers in the same village go out to earn money will have an obvious driving effect on the LOE, which this makes the tool variable and the endogenous variables highly correlated. At the same time, the LOE of other farmers in the same village is independent of the investigated farmers in CEE, so it theoretically also meets the exclusivity requirements.

(5) Control variable. The basic situation between rural communities varies greatly, which, in turn, impacts CEE in rural households. To test the robustness of the attention variables, referring to the research of Hou et al. [23], Sheng et al. [47], Zhang [54], and other studies, some factors that may affect household CEE use were studied as control variables, which mainly included: the age of the head, the sex of the head, degree of education, per capita income, support ratio, the distance between farmers and the town center, whether the topography is that of big cities of villages, and other indicators.

3. Results

3.1. Descriptive Statistics of the Variables

Table 1 shows the variable definition and the descriptive statistics results. According to Table 1, only 40% of the 8198 farmers used CEE, and LOE accounted for 39% of the total household workforce. In terms of the control variables, the head of the household was around 55 years old and the average length of education was only 7.02 years. Children aged 6 and younger and elderly people aged 65 and older accounted for 17% of the population. The average per capita annual cash income per family in 2016 was 9777.2 Yuan, and the

average distance between the village and the nearest township center was 5.9 km. Only 9% of the farmers lived in the suburbs of large cities, with the village terrain being mainly plains and hills.

Table 1. Variable definition and descriptive statistics results.

Variables	Definition	Mean	SD [1]
CCE	Whether farmers use clean energy (0 = No, 1 = Yes)	0.40	0.49
LOE	LOE is a proportion of the total household labor force (%)	0.39	0.38
Age	Age of the head of the household (age)	55.24	12.95
Sex	The sex of the household head (0 = female; 1 = male)	0.89	0.31
Education	Head of the household's education level (year)	7.02	3.42
Support ratio	Proportion of children aged 6 and younger and elderly 65 and older among the population (%)	0.17	0.27
Income	Per capita annual cash income (Yuan/Person b)	9777.20	17,545.53
Distance	Village distance from the nearest township center (km)	5.90	6.09
Suburbs	Big metropolitan suburbs (0 = No, 1 = Yes)	0.09	0.28
Topography	Village terrain (1 = plain, 2 = hills, 3 = mountains)	1.82	0.83

[1] Note: a SD = Standard deviation; b 1 $ = 6.47 Yuan in 2017.

3.2. Model Results

As shown in Table 2, Model 1 is the result of probit regression without adding any control variables, and Model 2 is that after the addition of control variables based on Model 1. In order to solve the endogenous problem, the IV-Probit model used regression, and Model 3 shows the relationship between the rural LOE and LOE. Model 4 is the regression result of the addition of relevant control variables according to Model 3, Model 5 shows the correlation between LOE and whether farmers use CCE, and Model 6 is the regression result of the relevant control variables added to Model 5, so the final result of the model will be subject to Model 6. According to the overall significance test statistics of the model, all models were significant at the 0.01 level. Meanwhile, there was no serious problem of multicollinearity among the model's independent variables (the correlation coefficients among the model variables were all less than 0.7), and subsequent regression analysis could be performed. In addition, to exclude the effect of heteroscedasticity on the model results, a cluster robust standard error was used for each model.

As shown in Table 2, regardless of whether endogenous problems were dealt with, there was a positive and significant relationship between LOE and whether farmers used CEE, and the results were extremely stable. In terms of the results of Model 6, for every 1% increase in LOE, the probability of farmers using CCE increased by an average of 1.091%, and hypothesis H1 was verified. This shows that labor transfer is conducive to the transformation of the energy consumption pattern, increased household energy consumption expenditure, and affected the choice of clean energy for household cooking [25]. Additionally, in line with the study of Ma et al. [46], they found that labor off-farm employment can significantly promote the use of clean energy for cooking by farm households. The possible reasons are as follows: On the one hand, with the increase in the amount of LOE, farmers' income has increased, and their understanding of energy consumption has continued to change, prompting farmers to use CCE. On the other hand, off-farm employment not only brings about changes in farm household income, but also affects the distribution of labor in the household, and thus the household energy consumption of farm households [45,47]. In terms of control variables, the increased age of household ownership significantly reduces the probability of farmers using CCE; families with a female householder are more likely to use CCE than those with a male householder; a higher education level of the household head will significantly increase the probability of CCE use; and the proportion of the elderly and children will significantly increase the probability of farmers to use clean energy. At the same time, the increase in the per capita annual cash income will significantly increase the probability of farmers' CCE use. Consistent with Sheng et al. [47], household income

is a significant variable affecting household clean energy adoption. With the increase in income, households will turn to cleaner cooking fuel. The distance from the town center will significantly reduce the probability of farmers' CCE use—this is consistent with Fan et al.'s [22] research that, due to geographical barriers, the use of clean energy for cooking by peasant households is limited; in addition, living in the suburbs of big cities will significantly increase the probability of CCE, and villages with plains or hills will have a higher probability of CCE use than in mountainous villages.

Table 2. Impact of off-farm employment on clean energy use.

Variables	Probit		IV-Probit			
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
LOE	0.625 ***	0.271 ***			1.690 ***	1.019 ***
	(0.037)	(0.044)			(0.055)	(0.135)
Age		−0.017 ***		0.001 ***		−0.017 ***
		(0.002)		(0.000)		(0.001)
Sex		−0.147 ***		−0.022 *		−0.121 **
		(0.052)		(0.013)		(0.052)
Education		0.030 ***		0.009 ***		0.020 ***
		(0.005)		(0.001)		(0.005)
Support ratio		0.029		−0.228 ***		0.207 ***
		(0.072)		(0.015)		(0.078)
Income		0.053 ***		0.015 ***		0.038 ***
		(0.009)		(0.002)		(0.009)
Distance		−0.021 ***		0.000		−0.019 ***
		(0.003)		(0.001)		(0.003)
Suburbs		0.743 ***		−0.016		0.716 ***
		(0.059)		(0.014)		(0.058)
Terrain = plain		0.328 ***		−0.000		0.288 ***
		(0.049)		(0.011)		(0.049)
Terrain = hills		0.244 ***		−0.001		0.213 ***
		(0.049)		(0.012)		(0.050)
Constant	−0.501 ***	−0.338 *	−0.000	−0.175 ***	−0.894 ***	−0.513 ***
	(0.021)	(0.195)	(0.007)	(0.053)	(0.024)	(0.194)
Village LOE ratio			1.000 ***	0.939 ***		
			(0.018)	(0.031)		
Control variables	No	Yes	No	Yes	No	Yes
Provincial fixed effect	No	Yes	No	Yes	No	Yes
Wald χ^2	283.399 ***	1594.330 ***	1515.39 ***	2173.60 ***	929.286 ***	1824.021 ***
Endogenous Wald χ^2					336.448 ***	30.065 ***
Observation	8198	8054	8198	8054	8198	8054

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

3.3. Heterogeneity Analysis

The use of farmers' CCE has the characteristics of "rationality and diversity". Among them, rationality refers to the energy consumption level of regional farmers commensurate with local resource conditions, economic conditions, living conditions, and energy supply [54]; diversification refers to the demand of certain efficiency, and the peasant energy consumption structure will be diversified [5]. In theory, the energy consumption structure of farmers will vary greatly between different regions, this difference may vary with income and education, as well as the state of energy supply. Therefore, this study divided farmers into different groups according to their education level, whether they lived in the suburbs of big cities, and the village terrain, and the IV-Probit model was further used to explore the heterogeneity of LOE in different groups.

Model 1 in Table 3 shows the return outcome of whether the household head had college education or above as the basis for grouping; it can be seen from the results that the off-farm employment of the labor force under the two groups was both significantly

related to the use of clean energy for farmers' cooking; however, it is noted that LOE for farmers with college education and below was more obvious in promoting the use of CCE (2.229 > 0.853). The possible reasons are that the education level of the household head affects the family's energy consumption understanding, environmental protection awareness, and health awareness, which leads to differences in the use of clean energy [63]. For the farmers whose household head education level was university or above, the highly educated family's ideas and consumption understanding had been greatly influenced, so the LOE was not a great way to improve their consumption understanding. For families below university education level, as the proportion of LOE increased, their awareness of living energy and environment increased and their ability to accept new things was stronger; thus, it was more favorable for farmers to choose clean energy as their living energy [2].

Table 3. Heterogeneity analysis results.

Variables	Education (Model 1)		Big City Suburbs (Model 2)		Topography (Model 3)		
	University or above	Below College	Yes	No	Plain	Hilly	Mountain
LOE	0.853 ***	2.229 ***	1.084 ***	−1.891 **	1.905 ***	−0.413	2.173 ***
	(0.142)	(0.267)	(0.134)	(0.828)	(0.152)	(0.286)	(0.152)
Village LOE ratio	0.963 ***	0.868 ***	0.940 ***	1.370 **	0.917 ***	0.974 ***	0.899 ***
	(0.032)	(0.098)	(0.032)	(0.561)	(0.051)	(0.060)	(0.065)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provincial fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald χ^2	1439.830 ***	502.878 ***	1504.014 ***	348.618 ***	1204.011 ***	567.600 ***	2656.499 ***
Endogenous Wald χ^2	17.160 ***	24.542 ***	36.411 ***	4.043 ***	70.297 ***	6.857 ***	69.576 ***
Observation	7162	861	7383	671	3579	2239	2220

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

Model 2 shows the regression of whether families lived in the suburbs of large cities as the basis of grouping. From the results, we can see that the LOE of farmers living in the suburbs of big cities was positively and significantly correlated with the use of CCE, and the LOE of farmers not living in large urban suburbs was significantly associated with the use of CCE. The possible reasons are as follows: First, the household living energy structure depends on the local energy accessibility and substitutability, and the resource endowment difference in different regions makes the household living energy transformation also different [47]. The supply of rural commodity energy is related to the region's infrastructure, transportation location, etc., and villages in large urban suburbs often have more advanced infrastructure, such as power grids and gas pipelines, as it is easier for them to share energy facilities with urban areas [2]. Secondly, farmers living in the suburbs of big cities are more influenced by the modern urban lifestyle, with a sense of health, stronger health awareness, high requirements for quality of life, higher economic strength and employment opportunities, and preference for convenient and fast clean energy [1], while some villages in mountainous areas, especially those far from cities, still lack modern energy infrastructure, such as natural gas pipelines. Thus, rural households away from cities may consume more non-clean energy than clean energy, such as natural gas.

Model 3 shows the regression results based on topography as the basis of grouping, Since the 1990s, the Chinese government has improved rural roads and power infrastructure in order to promote rural development. However, for some mountain villages, especially those far from cities, the energy infrastructure is still not perfect. As a result, rural households farther from cities may consume more traditional fuels than clean energy

sources, such as natural gas, for cooking [25]. It can be seen from the results that, for farmers living in plain and mountain villages, LOE is positively and significantly associated with the use of CCE, yet for farmers living in hilly villages, LOE is inversely related to the use of household CCE, and the correlation coefficient is not significant. The possible reasons are as follows: due to the topography and complexity of villages in different topographic areas, there are differences in the planting structure, energy endowment structure, and level of economic development, and there is obvious heterogeneity in CCE use among farmers in different areas [47]. Hilly areas are generally distributed in the transition zone of mountains or plateaus and plains. Hilly areas have abundant precipitation, which is suitable for the cultivation and growth of various economic trees and fruit trees with a high economic level; therefore, there is a strong awareness of clean energy use, so LOE has no significant impact on household CCE use [15].

3.4. Mediation Effect Analysis

This section mainly uses the mediation effect model to verify the mechanism of LOE on CCE—that is, to verify research hypotheses H2a, H2b, and H2c. Specifically, the following three paths are mainly verified: (1) LOE → per capita annual cash income → CCE; (2) LOE → social relationship network → CCE; and (3) LOE → family population structure → CCE.

Table 4 shows the results of the Sobel test of the annual per capita cash income, social networks, and family demographics in LOE and CCE use. Previous studies have shown that participation in off-farm work may increase the total family income, and the increase in family income will improve the quality of life of rural families [24]. According to the energy ladder model, with the improvement of economic status, rural households will start to use clean energy for cooking and reduce the consumption of traditional energy [23]. Therefore, this study uses household income to test the mechanism effect. As Model 1 shows, the annual per capita cash income plays a partial intermediary effect between LOE and CCE use; this shows that, with the improvement of the per capita annual cash income, the utilization rate of CCE will also increase accordingly, which confirms the hypothesis of H2a. This suggests that off-farm work can raise the income level of rural households and thus increase the affordability of clean energy consumption for cooking [25]. A possible reason is that the higher the income of LOE indicates that the household economy being better will prompt the choice of cleaner energy for household cooking [40]. As shown in Model 2, social networks play a partial intermediary effect between LOE and CCE use, indicating that the use of peasant social network increases accordingly, which confirms the research hypothesis of H2b. This suggests that LOE has expanded the farmers' social relationship network [55]—information transmission through social networks further promotes farmers' awareness of clean energy consumption [44], which then encourages them to use CCE. Farmers' participation in non-agricultural work can allow them to obtain more information from social activities. Compared with rural farming, the workplace of labor transfer involves more interpersonal interaction so as to give play to each other's advantages and flexibly adapt to the changing environment. Therefore, migrant farmers may be more likely to use clean energy. For example, Lin and Zhao [55] pointed out that the former floating population would bring back their social network when they returned to their villages. Obviously, such a social network would affect the consumption understanding of family members, thus affecting the energy consumption of families. As shown by Model 3, the family demography plays a partial intermediary effect between LOE and household CCE use; however, a significant negative correlation of family structure with CCE use was noted, showing that, with the increase in the numbers of elderly people and children in families, the utilization rate of household CCE is decreasing—this validates study hypothesis H2c. The possible reasons are as follows: On the one hand, the outflow of labor force has reduced the size of the domestic labor force, especially young and middle-aged people. The number of left-behind elderly people and children has increased. The elderly are getting older day by day, their learning ability is degraded, and their ideas are outdated [5]. On the other hand, the economy of the elderly and children in rural areas is more attached to the young

and middle-aged children; because of their limited ability to pay and tendency to stay in the countryside, they are more dependent on traditional solid fuel [2]. At the same time, the elderly people living in rural areas to make a living from agriculture will be more inclined to use the straw and firewood left by the planting industry [58].

Table 4. Influence mechanisms of off-farm employment on clean energy use.

Variables	LOE → Income → CCE (Model 1)			LOE → Social Relationship Network → CCE (Model 2)			LOE → Population Structure → CCE (Model 3)		
	CCE	Ln (Income)	CCE	CCE	Ln(Gift)	CCE	CCE	Ln (Support Ratio)	CCE
LOE	1.050 *** (0.132)	0.771 *** (0.238)		1.050 *** (0.132)	0.769 ** (0.380)		1.050 *** (0.132)		
Ln (income)			0.058 *** (0.009)					−0.068 *** (0.025)	
Ln(gift)						0.010 ** (0.004)			
Ln(Support ratio)									−0.115 * (0.070)
Province		Yes			Yes			Yes	
Control		Yes			Yes			Yes	

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

4. Conclusions

Based on data from the China Labor Force Dynamics Survey (CLDS), this study investigates the impact of LOE on CCE in 8198 farm households in 27 provinces of China, and attempts to find specific mechanisms of action. Through the previous empirical analysis and discussion, the study mainly obtained the following conclusions:

(1) Among the 8198 peasant households, the proportion of LOE was 39%, and the overall utilization rate of CCE was not high, accounting for 40%.

(2) The benchmark analysis results showed that LOE can significantly promote the use of CCE. Specifically, while the other conditions remain unchanged, with every 1% increase in the proportion of LOE 1%, the probability of farmers using CCE increased by an average of 1.019%. The results of the heterogeneity analysis indicated that if the household head has a university education or above, and the family is located in large urban areas or rural areas in mountainous areas, LOE will have a greater positive impact on CCE use.

(3) Through the mediation effect, the internal mechanism of the influence of LOE on the adoption of CCE was further analyzed. The results show that LOE has significantly promoted the use of CCE, and this action mechanism is mainly realized through three pathways: per capita annual cash income, social relationship network, and demographic structure.

In the context of "double carbon", energy transition has become an important development strategy to achieve the coordinated and sustainable development of the national economy, society, and environment. Promoting the use of clean energy for home cooking in rural areas can lead to multiple gains. First, reducing greenhouse gas emissions and achieving low-carbon development in rural areas. Second, reducing the environmental pollution caused by straw and agricultural film burning, and contributing to the construction of a beautiful countryside.

Therefore, this paper makes policy suggestions from the following aspects:

First, the government should further improve the mechanism for urban and rural labor mobility and promote the reasonable flow of rural labor between urban and rural areas through training, and ensure equal public services between urban and rural services, which will help farmers to improve their clean energy consumption by stabilizing off-farm employment and increasing their wage income. Second, the government should vigorously promote the implementation strategy of clean energy in rural areas and strengthen the construction of energy infrastructure in remote areas. For example, through financial subsidies, they should vigorously develop biogas, solar, and wind power, improve the

environment and conditions for using clean energy for cooking, and promote the transformation and upgrading of energy for cooking. Third, the government should provide reasonable guidance and publicity to enhance residents' awareness of the use of clean energy in cooking. To be specific, farmers' awareness of environmental protection can be strengthened through training and technology promotion so that farmers can understand the relationship between the use of clean energy and physical health, so as to fully realize the urgency and necessity of choosing clean energy, and promote the transformation of their energy consumption to clean and sustainable energy.

There are certain shortcomings in this paper. First, with the deepening of marketization, industrialization, and urbanization, the degree of part-time employment of farmers has been increasing. Part-time farmers can also increase their household income levels through off-farm employment, which can affect the use of clean energy for cooking by farm households. The impact of part-time employment on farm households' CCE use can be further explored in the future. Second, labor migration is a dynamic process, and panel data can reveal the effect mechanism between labor migration and household clean energy use to a certain extent, so further in-depth research is needed.

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