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Energy

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https://doi.org/10.1016/j.energy.2023.129551

Energy 287 (2024) 129551

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Off-farm employment and household clean energy transition in rural China: A study based on a gender perspective

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A R T I C L E I N F O

Handling Editor: Dr P Ferreira

JEL classification:
D12
O13
J22

Keywords:
Clean energy
Energy transition
Gender
Off-farm employment
Rural China

A B S T R A C T

Although numerous studies in developing countries have increasingly focused on the important implications of off-farm employment for the success of rural energy transition, it is easy to ignore the fact that determining who to employ in off-farm sectors can impact household energy transition decisions differently. Based on the nationally representative data from the Chinese General Social Survey (CGSS) 2015 survey, this study tries to fill the gap and examines the interaction between off-farm employment decisions between couples and household clean energy consumption in rural China by providing a new view towards gender. The results show that two-paycheck households consume more clean energy than other household types. Off-farm employment of women is a key factor driving the household clean energy consumption to a higher level, and wage-employed wives contribute more to these decisions than self-employed ones.

1. Introduction

Energy transition is widely believed to offer a rare win-win opportunity to rural households in regards to welfare improvement. Higher energy efficiency prominently benefits household quality of life based on improvements in comfort, convenience and productivity with modern energy [1] (win 1). Moreover, sustainability of energy use promises to decrease indoor air pollution and other pollutants that compromise human health [2] (win 2).

Off-farm employment is regarded as a key determinant of household energy transition, and the positive effects have been highlighted by many researchers [3–7]. Based on the New Economics of Labour Migration (NELM), the effects of off-farm employment on farm production may be separated into a (negative) household labour loss effect and (positive) income gain and risk reduction effects [8]. These three major impacts can also be regarded as key mechanisms through which off-farm employment affects a household's energy transition [9–12]. Rural households who lose labour for performing agricultural activities have been found to collect less straw, fuelwood or animal residues [13]. Households with one or more migrants are also less likely to have enough labour to collect traditional fuels because of a more distinct separation of living and work location [14]. Empirically, the research of Behera and Ali [3] in Bhutan found that self-employment of household heads increases a household's modern energy (gas and electricity) expenditure. Because off-farm employment implies an additional income source that is not correlated with the income obtained from the farm, in household intertemporal decisions, families with off-farm jobs tend to keep lower precautionary savings because of more stable expected gains and lower liquidity constraints, which provides incentives for investing in durable goods, including energy facilities [9,15]. More empirical evidence supports that rural households engaged in off-farm employment are more able to expand their energy expenditure and are more likely to consume more efficient but expensive fuels, such as gas or electricity [10,11,16–18], thus promote the rural energy transition [5,6].

However, these research findings are not enough to infer that the household energy transition is caused by off-farm employment. Not only because there are confounders that influence household energy use and employment decisions simultaneously [6,19], but also because household energy transition can reversely influence household employment

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https://doi.org/10.1016/j.energy.2023.129551
Received 27 June 2022; Received in revised form 25 August 2023; Accepted 31 October 2023
Available online 6 November 2023

decisions. Compared to the employment decisions for husbands, wives' employment decisions can be reversely influenced by household energy use structures. Because time-consuming responsibilities that are typically run by women (e.g., childcare, firewood collecting and cooking of food) [20–23], the job choices for wives are highly related to the efficiency of these indoor activities [11,24,25]. One of the most important factors that influence the efficiency of cooking, heating and firewood collecting is the household energy transition. To the best of our knowledge, most previous studies examine whether one or more household members work in off-farm sectors (as a result of migration, self-employment or local off-farm employment) rather than examine who works in these sectors.

In this study, we hold the core point that although off-farm employment is considered a household-level decision in NELM, actual employment decisions are likely to differ between different individuals within a household [23]. Therefore, besides the influences of household employment choices on energy use, we add the effects of the reverse impact of energy transition on intra-household labour allocation in the analytical model. By focusing on the gender allocation of labour, the new conceptual framework tries to explicitly model the nexus between household energy consumption decisions and intra-household off-farm employment decisions. Different from previous studies, this study employs Dubin-McFadden model to address the confounder issue in estimation and use of simultaneous equation model to examine potential reverse causality bias. These theoretical and empirical works contribute to filling the research gap and providing more reliable evidence for the causal link between off-farm employment and household energy transition.

Based on the nationwide dataset from the Chinese General Social Survey (CGSS), the impacts of off-farm employment on household energy consumption are estimated. Empirical results illustrate the significant role of off-farm employment in household energy transition. The present study also portrays the image of Chinese rural women in real life. Considering women are still left responsible for more relatively indoor activities, female off-farm employment can be a key factor driving household clean energy consumption to a higher level. With a new gender-specific insight provided on the research map, the development of strategies pushing for energy transition is expected to be beneficial by encouraging female off-farm employment.

2. A framework: off-farm employment and clean energy transition

2.1. Household energy transition

Based on previous studies, employment status can influence energy consumption decisions by agricultural labour reduction, income improvement and risk reduction [9–12]. For most small farmers, there is no hiring and firing in agricultural production, and getting paychecks is regarded as one of the major features of working in off-farm sectors. Different from most existing studies, this paper focuses on the impact of gender allocation of labour on household energy consumption. Thus, we set our sights on the employment status of the couples in married households, without consideration of the employment status of other family members. We define households where husband and wife are both employed in off-farm sectors as two-paycheck households, while ones where only husband or wife is engaged in off-farm activities are termed one-paycheck households. Similarly, the household where both husband and wife are engaged in on-farm activities is defined as no-paycheck household. Potential omitted variables biases are taken into consideration. This paper hypothesis that two-paycheck households consume more clean energy than the other two types of households.

Energy transition is regarded as an important decision where many factors besides off-farm employment have to be considered by a family. In terms of physical capital, based on the 'Energy Ladder' hypothesis, good economic well-being shifts households towards better-quality energy. Mounting discussions about the effect of economic growth on energy transition can be listed, and household income and energy price serve as key factors incontrovertibly influencing energy consumption [17,18,26,27]. Location decides the endowment of natural resources that households can obtain. The studies of Chen et al. [4] and Mekonnen et al. [13] both found that households living in mountain areas remain to rely on biomass energy. In China, more coal and less gas are used in western regions [28,29]. Simultaneously, based on the great temperature differences between southern and northern China in winter, households living in different regions may have diverse winter heating requirements, which will affect household energy consumption directly.

Considering human capital, factors including age, health and education level are found to have significant effects on energy consumption, for the rise of clean energy affordability is rooted in higher human capital [3,20,30]. Household size also should be considered in order to represent household time endowment [14,31]. Few studies are concerned with the impact of investment in children on household energy consumption, but in most Chinese households, the investment in a children's development can be as important as that in the family's livelihood [32,33]. With the underdeveloped credit market in rural China, households with more children have to save more money to meet their children's future needs, and they are assumed to have less budget for energy transition. A special and exogenous feature of households is rooted in the Chinese Hukou household registration system. This system has been roughly divided into two types: rural hukou and urban hukou. The households with rural hukou are often at a disadvantage in energy transition, since the inequality of welfare and opportunities caused by the differences in hukou status acts as a key factor in energy inequality [28].

The preferences of a representative household regarding energy transition are captured by a function of household employment status and other essential components:

$$Energy = f(Employment, age, education, hukou, health, household\ size, children, income, price, heating, location) \quad (1)$$

where Employment stands for the employment status of households. The age, education level, hukou status, health, household size, ratio of children, income in last year, electricity price, winter heating use and location are all characteristics that can be considered exogenous to household energy decisions.

2.2. Intra-household employment choices

Based on the Harris-Todaro model, off-farm employment is affected not only by household or individual 'push factors', but also by some exogenous push and pull factors. According to the research of Van den Broeck and Kilic [23], exogenous push factors entail different forms of stressors, such as extreme weather events and natural disasters. In the short term, natural hazard may push labour out of farm sectors to reduce risks. Asset ownership is also recognised as a significant push factor [6,34]. However, there also some studies which show that the more rural properties owned by occupants, the lower the motivation of seeking jobs in urban areas [35]. Pull factors include high remittance expectations and the attraction of urban amenities. High-wage levels in urban areas can attract more labour to participate in off-farm activities, and the popularity of the internet also provides a channel for them to obtain employment information [36,37]. Some studies suggest that access to the internet can increase household modern energy consumption because of the convenience of online shopping [6]. When access to the internet is only defined as a channel to obtain information, it serves as an exogenous factor that affects residents' employment choice.

In contrast, there also some factors that motivate residents to stay in the village. Consider one unique characteristic of rural China: the longer the time of residence in a rural place, the greater the attachment to the rural environment and life, and thus, the lower the willingness to search for off-farm employment. Additionally, especially for women, there is a traditional social norm that husbands are responsible for work outside and wives are bound to take on more housework. This social norm is less likely to induce women to make the transition to off-farm employment. Equation (2a) gives the general off-farm employment function as:

$$Employment = f(age, education, hukou, health, household\ size, children, location, hazard, wage, internet, asset, residential\ time, social\ norm) \quad (2a)$$

where the six variables *hazard*, *wage*, *internet*, *asset*, *residential time* and *social norm* stand for exogenous factors influencing the employment decision. Other variables are the same as those in the energy consumption function.

Besides these factors, access to modern energy is regarded as a key factor in human development, for it enables people to have off-farm economic opportunities and achieve higher productivity [38]. However, the effects of energy use on the employment choices of wives and husbands are often different. Considering the traditional social norm of the higher housework responsibility for women, as we reviewed in the Introduction, in many developing countries, women still face substantial drudgery due to the use of biofuels [20,24,25]. Compared to the employment for men, those researches have emphasised the key effects of energy transition on female employment. For example, Pachauri et al. [11] claimed that, especially for women, traditional energy selection led to an opportunity cost associated with the time which could have been spent more productively on incoming-earning activities. Thus, the effects of energy use on female off-farm employment should be highlighted in the discussion of simultaneous interactions between intra-household employment choices and household energy transition. Equation (2b) gives female off-farm employment function as:

$$Employment^{w} = f(Energy, age^{w}, education^{w}, hukou^{w}, health, household\ size, children, location, hazard, wage, internet, asset, residential\ time, social\ norm) \quad (2b)$$

where $Employment^{W}$ stands for the employment status of wives, while, age^{W}, $education^{W}$ and $hukou^{W}$ stand for the age, education level and hukou of the wives, respectively.

In conclusion, we hypothesise that at the intra-household level, female off-farm employment can promote household energy transition. Simultaneously, household energy transition can push women to engage in off-farm activities.

3. Data and methodology

3.1. Data description

The data for this study are taken from the Chinese General Social Survey (CGSS) which was conducted in 2015. The survey began in 2003 and was sustained for 10 rounds until 2015. The sample for each round of data collection covered more than 10,000 households and was designed to represent the nation as a whole, as well as the rural and urban areas.[1] All sample households were administered questionnaires asking detailed information on a wide range of topics, including education, occupation, assets, consumption, expenditures and other household and individual socio-economic characteristics. An Energy Module was included in the survey as a special feature in 2015. With this detailed nationwide dataset, it is possible to conduct a profound analysis of the interactions between female off-farm employment and energy consumption.

In the 2015 round, a total of 10,968 urban and rural households were interviewed, and about one-fourth of that sample was selected randomly for the Energy Module. By selecting the samples whose household head's answer to the question "What is your marital status? (1 = Single; 2 = Living with a partner; 3 = Married; 4 = Stay separated; 5 = Divorced; 6 = Others)" was 2 or 3, we limited our sample to the 1,152 rural households with married household heads for which data on their employment status and energy consumption were collected. Information on off-farm employment was available for household heads and their spouses only. The question was "What is your employment experience and current employment status? 1 = Off-farm employment now; 2 = Farming now, off-farm employment before; 3 = Farming now, no off-farm employed experience; 4 = no job now. We focus on their employment status during the survey. Whether the wives are self-employed or wage-employed was obtained from a more detailed question "What kind of job are you doing now? 1 = Have own business; 2 = Employed by an identified host; 3 = Informal employment without an identified host; 4 = Working in the own family business with wage; 5 = Working in the own family business without wage". The respondents who answered 1 and 5 are regarded to be self-employed and the respondents who answered 2, 3, and 4 are considered to be wage-employed.

The household types are presented in Fig. 1. Approximately one-third of these households (476) worked in farming activities only, while the other two-thirds (676) were engaged in off-farm activities. Very few households (51) decided to send the wife to employment in off-farm sectors but leave the husband in the farm sector. This decision is consistent with rural household employment in most developing areas. In order to reflect the more general household employment characteristics, the sample households where only the wife is engaged in off-farm activities are dropped in order to simplify the models. We define one-paycheck household as households where the husband is off-farm employed but the wife is involved in farming only.

In the Energy Module, respondents were asked to report the types, units and physical quantity per unit of household biomass energy (including animal manure, crop residue and fuelwood), coal, gas (including LPG and natural gas) and electricity consumption. A number of studies use household energy expenditures as indicators of energy transition [6,30]. But results of those studies may be affected by changes in energy prices. Using the CGSS 2015 survey data allows us to compare real energy use levels among different households in different areas [11,39]. To do so, we calculated the quantities of energy consumption by converting the units to kgce (kg standard coal equivalent) per capita. Coal-based electricity generation and assumptions regarding the carbon-neutrality of biomass fuels make the clean energy definition complex. In this paper, we only focus on indoor air pollution and thus define gas and electricity as clean energy. Therefore, the energy transition is defined as the transformation from traditional biomass fuels or coal to gas or electricity.

The control variables included in the energy consumption models are age, education of husband, hukou of husband, education of wife, hukou

[1] More details of Questionnaire design and sample selection can be found from http://cgss.ruc.edu.cn/English/Documentation/Questionnaires.htm and http://cgss.ruc.edu.cn/English/Documentation/Sampling_Design.htm.

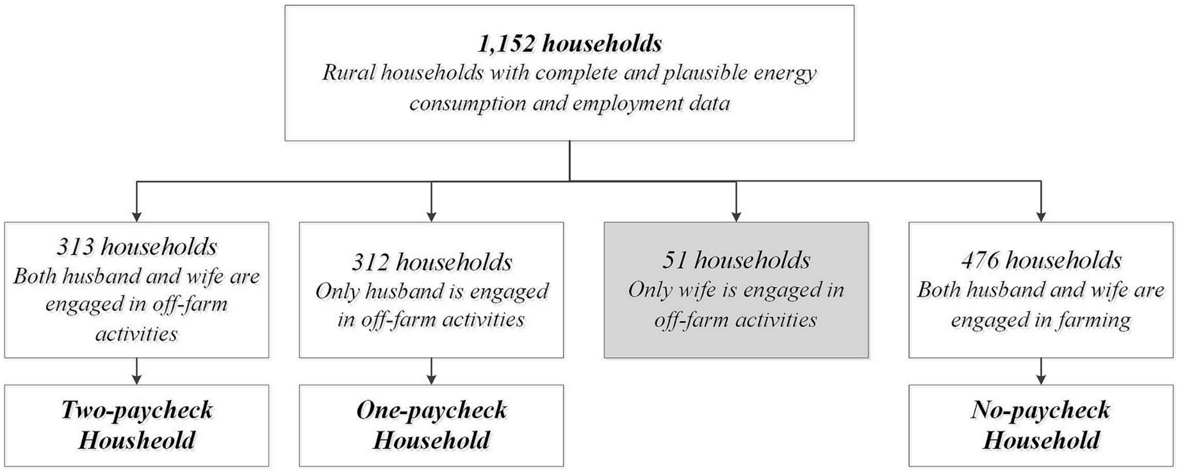

Fig. 1. Household types distinguished in this study.

of wife, family health condition, number of children, income level and location variables. These control variables are common in the existing literature on rural household decisions, especially in the decision of energy consumption (e.g., Chen et al. [14], Behera and Ali. [3], Qiu e al. [31]). Since the ages of husbands are similar to the ages of their wives, we chose to control the average age of husband and wife in the model to avoid possible collinearity problems. In the employment decision model, social norm, internet, natural hazard, local residential time, asset and urban wage level are added as control variables. Natural hazard and urban wage level are both provincial variables whose data are taken from *China Statistical Yearbook (2015)*. The definitions and descriptive statistics of the variables are presented in Table 1.

3.2. Methodology

At the household level, the Dubin–McFadden (D–M) model has been used by Liao and Chang [40], Mansur et al. [41] and others to deal with the endogeneity bias caused by omitted variables in the fields of employment and energy consumption. In this study, we use the OLS regression model to estimate the impact of off-farm employment on clean energy consumption and use the D-M model as a robustness check addressing the potential omitted variables bias.

The estimation of the energy consumption equation in OLS regression model can be expressed as follows:

$$Energy_i = \alpha_0 + \alpha_1 Employment_{2i} + \alpha_2 Employment_{1i} + \alpha_3 X_i + u_i \tag{3}$$

where $Employment_{2i}$ and $Employment_{1i}$ are dummy variables of employment by a two-paycheck household and a one-paycheck household, respectively. X_i is a vector of control variables including age, education^H, hukou^H, education^W, hukou^W, health, household size, the ratio of children, income in last year, electricity price, winter heating use and location. α_1 and α_2 measure the effect of off-farm employment on clean energy consumption relative to no-paycheck households. u_i is the error term.

The D-M model includes two estimation steps [42]. First, a Multinomial Logit (mlogit) regression model is used for estimating the off-farm employment choice equation:

$$P(Employment_i) = \beta_0 + \beta_1 X_i + \beta_2 Z_i + \varepsilon_i \tag{4}$$

where P ($Employment_i$) is a polychotomous variable representing the employment choice (including three choices: two-paycheck household = 1, one-paycheck household = 2, no-paycheck household = 3) of household *i*. X_i is similar to the vector in equation (3). Z_i is a vector of exogenous variables which are excluded from the energy equation but can influence households' employment decision. $\mathcal{E}_i$ is an error term.

Second, estimation of the energy consumption equation is based on equation (3) with 'selection correction terms' added to each households' employment function. By including the selection correction terms, we adjust for self-selection bias errors in u_i.

At the individual level, we rewrote the household-level variables $Employment_{2i}$ and $Employment_{1i}$ as $Employed_i^H \times Employed_i^W$ and $Employed_i^H \times Farming_i^W$. The interactions between clean energy consumption and female employment choice decisions can be represented by the following two equations:

$$Energy_i = \alpha_0 + \alpha_1 Employed_i^H \times Employed_i^W + \alpha_2 Employed_i^H \times Farming_i^W + \alpha_3 X_i + u_i + v_i \tag{5}$$

and

$$Employed_i^W = \gamma_0 + \gamma_1 Energy_i + \gamma_2 Employed_i^H + \gamma_3 Q_i + \gamma_4 Z_i + \delta_i + \eta_i \tag{6}$$

where $Employed_i^H$, $Employed_i^W$ and $Farming_i^W$ are all dummy variables which describe employment choices of husbands and wives. u_i and, v_i are an error term and an unobservable, idiosyncratic shock, respectively. Q_i is a vector of control variables which may influence female employment choice (including age, education level and the hukou of wives, health, household size, the ratio of children and location of households). δ_i is unobservable, idiosyncratic shock and η_i is an error term. It is clear that $Energy_i$ and $Employed_i^W$ are theoretically interdependent. Although $Employed_i^W$ is a dummy variable, the estimators obtained with a Probit model or Linear probability model (LPM) generally have only small differences without the consideration of heteroscedasticity bias. Thus, we evaluated the potential impact of clean energy consumption on female employment choice and the effect of off-farm employment on clean energy consumption by estimating two-stage least square (2SLS) regression models with instrumental variables based on OLS and LPM models.

Given that $Employed_i^W$ in equation (5) is included as an interactive term, the instruments in the energy equation have been calculated as $Employed_i^H \times I_i$. However, the dependent variable in that equation also changed simultaneously; the reduced-form equation for clean energy consumption can be expressed as follows:

$$\left(1 - \varphi_6 Employed_i^H\right) Energy_i = \varphi_0 + \varphi_1 Employed_i^H \times Employed_i^W + \varphi_2 Employed_i^H \times Farming_i^W + \varphi_3 X_i + \varphi_5 Employed_i^H \times I_i + \xi_i + \sigma_i \tag{7}$$

where ξ_i and σ_i are the unobservable, idiosyncratic shock and the error term. The new estimations would become $1/(1 - \varphi_6 Employed_i^H)$ times

Table 1
Variable definition and descriptive statistics.

Variable		Mean (S.D.)	Min	Max
Dependent variables				
Log clean energy consumption	Logarithm of (Household gas and electricity consumption per capita in 2015, in kgce, +1)	4.961 (1.000)	0	9.053
The ratio of clean energy consumption	The ratio of clean energy to total energy consumption	0.624 (0.389)	0	1
Two-paycheck household (Employed^H × Employed^W)	1 if husband and wife are both off-farm employed, 0 otherwise	0.284 (0.451)	0	1
One-paycheck household (Employed^H × Farming^W)	1 if only husband is off-farm employed, 0 otherwise	0.283 (0.451)	0	1
No-paycheck household (Farming^H × Farming^W)	1 if husband and wife are both farming, 0 otherwise	0.432 (0.496)	0	1
Independent variables				
Age	Average age of husband and wife in years	52.332 (13.502)	21	89.5
Education^H	Schooling of husband in years completed	7.429 (3.335)	0	19
Hukou^H	1 if husband holds a rural hukou, 0 otherwise	0.916 (0.277)	0	1
Education^W	Schooling of wife in years completed	5.540 (3.998)	0	19
Hukou^W	1 if wife holds a rural hukou, 0 otherwise	0.939 (0.239)	0	1
Health	Self-grading of family health status (1–5 means from worst to best)	3.478 (1.128)	1	5
Household size	The number of family members living at home (person)	4.116 (1.452)	2	10
Children	The share of children (≤18 years old) in the household (%)	10.240 (16.961)	0	75
Income	Log (Total household income in 2014, inYuan)	10.017 (1.146)	5.707	15.202
Electricity price	Price of electricity (Yuan/kWh)	0.749 (0.158)	0.2	0.8
Winter heating use	1 if household uses heating in winter, 0 otherwise	0.439 (0.497)	0	1
Social norm	1 if wife is considered to take on more housework than husband, 0 otherwise	0.674 (0.469)	0	1
Internet	1 if household can search information on internet, 0 otherwise	0.190 (0.392)	0	1
Natural hazard	Total number of natural disasters occurred provincially in 2014	396.544 (702.783)	0	2470
Residential time	Years spent by household in current residence	47.314 (18.244)	0	89.5
Assets	Total number of household real estates	1.128 (0.434)	0	5
Urban wage	Log (Provincially wage level in 2014, in Yuan)	10.800 (0.102)	10.650	11.535
Location (East)	1 if household is located in Beijing, Hebei, Jiangsu, Zhejiang, Fujian and Shandong, 0 otherwise	0.196 (0.397)	0	1
Location (Centre)	1 if household is located in Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan, 0 otherwise	0.334 (0.472)	0	1
Location (West)	1 if household is located in Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai and Ningxia, 0 otherwise	0.320 (0.467)	0	1
Location (Northeast)	1 if household is located in Liaoning, Jilin and Heilongjiang, 0 otherwise	0.150 (0.357)	0	1

Note: Yuan is Chinese currency.

Table 2
Rural household per capita consumption of different types of energy, 2015.

	Energy		Usage rate (%)	Mean (kgce/cap)
Non-clean energy	Biomass	Livestock manure	0.69	338.24
		Crop residue	12.07	791.36
		Fuelwood	31.68	830.79
	Coal	–	22.57	432.12
Clean energy	Gas	LPG	32.03	152.82
		Natural gas	1.74	137.15
	Electricity	–	97.22	179.84

Notes: According to Chinese energy conversion standards, the conversion factors of livestock manure, crop residue, fuelwood, coal, LPG, natural gas and electricity are 0.4290 kgce/kg, 0.5000 kgce/kg, 0.5710 kgce/kg, 0.7143 kgce/kg, 1.7143 kgce/kg, 1.3300 kgce/cu.m, 0.4040 kgce/kW.h, respectively.
Data source: Chinese General Social Survey (CGSS)

the estimations in equation (5). Thus, the estimated coefficients in the 2SLS regressions may be larger than those in the OLS regressions.

4. Results and discussion

4.1. Descriptive results

Table 2 presents the usage rates and mean consumption per capita of each type of energy. The data confirm the very high usage rate of electricity in rural China, more than 97%, which is generally called a 'Chinese miracle'. The more than 100% usage ratio of different types of energy together reflects the fact that most households in rural China have mixed use of energy. The usage rates of crop residues and fuelwood remain high. In terms of mean consumption levels, biomass and coal consumption levels far exceed that of gas in rural China. These findings suggest that the energy transition of rural households in China is still far from completed.

4.2. Household employment status and household energy consumption

Table 3 presents the estimation results of the benchmark models of household employment decision and energy consumption decision, respectively. Columns (1) and (2) of Table 3 show the results of the Multinomial Logit model for different household employment choices. The estimated coefficients of the *Age and Hukou^H* variables are negatively and statistically significant, suggesting that elder households and households where husbands hold a rural hukou are less likely to be employed off-farm. Rural hukou brings migrants less support in their urban lives. The rural hukou holders face inferior access to urban public services, such as education and medicine [28]. These barriers encourage them to make more conservative career decisions. Moreover, since husbands generally play more significant roles in career decision-making in most Chinese households [22], rural hukou of husbands affect the migrant motivations of whole families. Similarly,

Table 3
Household-level regression results for employment and clean energy consumption.

	Employment selection model		Energy consumption model
	Two-paycheck household	One-paycheck household	Log clean energy consumption
	(1)	(2)	(3)
Two-paycheck household			0.178** (0.07)
One-paycheck household			0.082 (0.08)
Age	−0.040*** (0.01)	−0.024* (0.01)	−0.002 (0.00)
Education^H	0.073** (0.03)	0.068** (0.03)	0.021** (0.01)
Hukou^H	−1.970*** (0.53)	−2.607*** (0.51)	0.077 (0.17)
Education^W	0.122*** (0.03)	0.017 (0.03)	0.010 (0.01)
Hukou^W	−0.932 (0.63)	0.736 (0.74)	−0.268 (0.19)
Health	−0.070 (0.09)	−0.078 (0.08)	0.000 (0.03)
Household size	−0.014 (0.06)	−0.001 (0.06)	−0.202*** (0.02)
Children	−0.003 (0.01)	−0.002 (0.01)	−0.001 (0.00)
Social norm	−0.383** (0.19)	0.349* (0.19)	
Internet	0.414 (0.27)	−0.629** (0.30)	
Natural hazard	0.000* (0.00)	−0.000* (0.00)	
Residential time	−0.033*** (0.01)	−0.012 (0.01)	
Assets	0.494** (0.23)	0.463** (0.20)	
Urban wage	2.021* (1.16)	−0.400 (1.03)	
Income			0.126*** (0.04)
Electricity price			0.556*** (0.17)
Winter heating use			−0.188*** (0.07)
Location (East)	0.661** (0.33)	0.512* (0.30)	−0.050 (0.09)
Location (West)	−0.424 (0.28)	−0.294 (0.22)	−0.293*** (0.07)
Location (Northeast)	−0.964*** (0.34)	−1.440*** (0.30)	−0.151 (0.10)
Constant	−17.301 (12.67)	6.784 (11.28)	4.353*** (0.54)
N	1,049		1,047
LR chi 2(34)	341.44 (P = 0.000)		
Log likelihood	−882.41		
Pseudo R^2	0.212		0.155
F (13, 1086)			14.18 (P = 0.000)
Root MSE			0.935

Notes: Standard errors in parentheses.
Employment variables are compared with 'No-paycheck household'.
***p < 0.01, **p < 0.05, *p < 0.10.

Table 4
Household-level egression results for clean energy consumption, Dubin-McFadden model.

	Two-paycheck household	One-paycheck household	No-paycheck household
	Clean Energy Consumption Decision Model		
	(1)	(2)	(3)
Age	−0.005 (0.01)	0.002 (0.01)	0.010 (0.01)
Education^H	0.034* (0.02)	0.026 (0.03)	−0.017 (0.02)
Hukou^H	−0.021 (0.29)	0.470 (0.55)	0.282 (0.57)
Education^W	−0.016 (0.02)	0.008 (0.03)	0.006 (0.02)
Hukou^W	−0.275 (0.24)	−0.144 (0.41)	−0.095 (0.44)
Health	0.111** (0.05)	−0.006 (0.06)	0.006 (0.04)
Household size	−0.171*** (0.03)	−0.231*** (0.04)	−0.191*** (0.03)
Children	−0.005 (0.00)	−0.005 (0.00)	0.004 (0.00)
Income	0.154** (0.06)	0.144** (0.06)	0.099** (0.04)
Electricity price	0.325*** (0.07)	0.399*** (0.11)	0.323*** (0.07)
Winter heating use	−0.209* (0.11)	−0.323** (0.15)	−0.150 (0.11)
Location (East)	−0.092 (0.14)	−0.184 (0.22)	−0.123 (0.20)
Location (West)	−0.004 (0.14)	−0.534*** (0.17)	−0.229* (0.12)
Location (Northeast)	−0.005 (0.22)	−0.318 (0.38)	0.274 (0.25)
m1	−0.136 (0.16)	0.540 (1.18)	−1.618** (0.73)
m2	−0.339 (0.43)	−0.114 (0.25)	−1.479** (0.70)
m3	−0.570 (0.67)	1.030 (1.30)	−0.206 (0.27)
Constant	3.640*** (0.81)	4.668*** (1.37)	2.459* (1.41)
F	4.71 (P = 0.000)	4.86 (P = 0.000)	5.18 (P = 0.000)
R^2	0.227	0.248	0.173
	Selection Model regression results are presented in Column 2–3 of Table 3		
N	291	268	440

Notes: Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.10.

husbands with a higher education level can influence household off-farm employment decisions positively because they can obtain more employment information and be more productive in finding better job opportunities [34]. The coefficient estimates of assets are also positive and statistically significant, and are consistent with the findings of Ma et al. [6] and Van den Broeck and Kilic [23]. Because asset-rich(er) households may have more resources to start own business, it will benefit these households in gaining access to self-employment or local non-agricultural employment [34].

Education experience of wives, local residential time and urban wage level also appear to have statistically significant effects on family job decisions when wives are engaged in off-farm activities. Wives are more likely to work outside the farm when they have a higher level of education, for higher human capital brings them more and greater job opportunities [23]. Given that households who have lived in rural areas for a long time are sentimentally attached to their hometowns, they are more willing to make a living of farming. Furthermore, one of the aims of working in off-farm industries is to guarantee the families' stable operation [43]. The positive coefficient of urban wage reflects the significant pull effect of remittance expectations in female off-farm employment decisions.

Column (3) of Table 3 provides the estimation results of the household clean energy consumption model using OLS. The results show that two-paycheck households consume about 17.8% more clean energy than one-paycheck or no-paycheck households. However, coefficient estimates of this model may suffer self-selection bias. The D-M model has been used to address these endogenous problems.

Columns (1)–(3) in Table 4 present the results of D-M regressions. The coefficients of *m1*, *m2* and *m3* show the correlations between employment selection residuals and energy consumption decision models.

The coefficients of *m1 and m2* in Column (3) are both negative and statistically significant, suggesting that the randomly selected clean energy consumption of the no-paycheck households is lower than the average clean energy consumption of two-paycheck households and one-paycheck households, respectively. It is consistent with the result of OLS estimation in Table 3 and indicates that households with off-farm employment tend to consume more clean energy than no-paycheck households by eliminating self-selection effects. Households which allocate more labour to off-farm activities choose more convenient and efficient energy, such as gas and electricity [3,14].

For control variables, the coefficients of *household size* and *income* are always statistically significant, not only in OLS models but in D-M models. These results illustrate that smaller and wealthier households consume more clean energy than others. The higher the electricity price, the more clean energy household consume, which may relate to the tiered pricing for household electricity in China. According to the policy, households with electricity consumption exceeding certain thresholds pay higher electricity prices [44]. On the other hand, to achieve energy equality, the Chinese government designed a subsidy policy for low-income rural households. Households under the poverty line can use 10 kWh ~15 kWh electricity per month for free. Thus, based on the residential electricity price set by each provincial government, the households who can use electricity at a lower price are often poorer ones. However, they are less likely to afford more clean energy or other modern equipment. Considering the different endowments of resources in different regions, households living in the west of China consume significantly less clean energy than those in other regions (Table 3). It may root in the lower development level and also in the abundant forest and farming resources in this region. For households where wives are engaged in off-farm activities, the impacts of the endowment of resources on clean energy consumption vanish (Table 4), which demonstrates the significant role of women in selecting traditional biomass energy.

4.3. Female employment status and household energy consumption

In this section, results are presented of a limited sample that was used for individual-level regressions to reduce the potential sample selection bias. The households with wives aged between 20 and 50 have been selected based on the Chinese legal working age. In the labour market, especially for women, age discrimination exists and can bias the results of research on employment [45]. Although in reality, a large number of elders are still wage-employed or self-employed in the second or third sector, their various and unregulated off-farm employment makes this group less suited for the individual-level analysis. Women aged between 20 and 50 have almost equal employment opportunities and are thought to bear similar social responsibilities. Simultaneously, the regressions with the limited sample are regarded as a kind of robustness check.

Furthermore, the dummy variable *Employed wife* is replaced by *Wage-employed wife* to obtain additional insights. Off-farm employment includes not only the wage employment in off-farm sectors, but also self-employment [23]. Wage-employed women are required to work for a certain amount of time. When traditional energy collection is a major resposibility of women, they have fewer opportunities to obtain wage jobs (e.g. Scheurlen, [25]; Su et al. [43]; Mekonnen et al. [13]), while self-employed women have more flexible working time and fewer working rules and have better opportunitoies for combining the two tasks.

Table 5 shows the regressions results of the female employment equation estimated by 2SLS. Household *Winter heating use* is employed as the instrumental variable. The results in columns (1) and (3) reveal that the quality of household energy consumption has no significant effect on the employment status of women. However, when we consider the energy use structure (column (2)), we find that women in households who consume a higher ratio of clean energy are more willing to participate in off-farm activities. The coefficient of the ratio of clean energy consumption is insignificant in column (4). Combining the results in column (2) and column (4), it can be concluded that the energy use structure transition influences more on women's self-employment than on wage-employment.

On the other hand, the relatively low significance levels for the coefficients of energy use in Table 5 reveals an undeniable reality that most Chinese rural households have the chance to obtain modern energy and energy services with the extensive energy infrastructure in rural areas [4]. They have stepped over the primitive status in the 'Energy Ladder' and jumped out of the poverty trap on energy selection [7,21,39]. In

Table 5
Individual-level regression results for female employment equation, 2SLS.

	Employed wife		Wage-employed wife	
	(1)	(2)	(3)	(4)
Log clean energy consumption	0.393 (0.26)		0.076 (0.21)	
The ratio of clean energy consumption		0.360* (0.20)		0.069 (0.19)
Age^W	0.000 (0.00)	−0.001 (0.00)	0.001 (0.00)	0.001 (0.00)
Education^W	0.022*** (0.01)	0.023*** (0.01)	0.021*** (0.01)	0.022*** (0.01)
Hukou^W	0.001 (0.14)	−0.136*(0.08)	−0.005 (0.11)	−0.031 (0.07)
Health	0.025 (0.03)	0.006 (0.02)	−0.002 (0.02)	−0.005 (0.02)
Household size	0.063 (0.05)	−0.016 (0.02)	0.010 (0.04)	−0.005 (0.01)
Children	0.000 (0.00)	−0.000 (0.00)	−0.001 (0.00)	−0.001 (0.00)
Social norm	−0.128** (0.05)	−0.129*** (0.04)	−0.083** (0.04)	−0.083** (0.04)
Natural hazard	0.000*** (0.00)	0.000*** (0.00)	0.000 (0.00)	0.000 (0.00)
Urban wage	0.212 (0.34)	0.381 (0.24)	−0.122 (0.27)	−0.089 (0.23)
Residential time	−0.004** (0.00)	−0.005*** (0.00)	−0.005*** (0.00)	−0.005*** (0.00)
Assets	−0.040 (0.07)	0.026 (0.05)	−0.094* (0.05)	−0.082*(0.04)
Internet	0.082 (0.07)	0.123**(0.05)	0.064 (0.05)	0.072 (0.05)
Location (East)	0.203 (0.13)	0.078 (0.07)	0.124 (0.11)	0.099 (0.07)
Location (West)	0.094 (0.16)	−0.040 (0.07)	−0.076 (0.12)	−0.102 (0.07)
Location (Northeast)	0.009 (0.14)	−0.011 (0.11)	−0.183* (0.11)	−0.187*(0.10)
Constant	−4.235 (3.00)	−3.697 (2.59)	1.340 (2.37)	1.444 (2.44)
Instrumental Variable	*Winter Heating Use*			
F(16,513)	7.41 (P = 0.000)	10.47 (P = 0.000)	6.56 (P = 0.000)	6.52 (P = 0.000)
R^2	0.107	0.217	0.175	0.170
Root MSE	0.523	0.440	0.413	0.414
Anderson canon. corr. LM statistic	5.387 (P = 0.020)	41.347 (P = 0.000)	5.387 (P = 0.020)	41.347 (P = 0.000)
Cragg-Donald Wald F statistic	5.268	43.407 (>10% maximal IV relative bias)	5.268	43.407 (>10% maximal IV relative bias)
N	530	530	530	530

Notes: Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.10.

Table 6
Individual-level regression results for clean energy consumption.

	The ratio of clean energy consumption			
	(1)	(2)	(3)	(4)
Employed wife	0.247 (0.16)			
Wage-employed wife		0.344* (0.19)		
Two-paycheck household			0.327* (0.17)	
Two-paycheck household with wage-employed wife				0.466** (0.22)
One-paycheck household			−0.178* (0.10)	−0.170* (0.09)
Control variables	*YES*	*YES*	*YES*	*YES*
Location	*YES*	*YES*	*YES*	*YES*
Constant	−0.257 (0.27)	−0.317 (0.28)	−0.076 (0.28)	−0.182 (0.29)
Instrumental Variables	Social norm, Residential time, Assets		H_Norm, H_Time, H_Asset	
N	519	519	519	519
F	11.90 (P = 0.000)	11.16 (P = 0.000)	11.12 (P = 0.000)	9.69 (P = 0.000)
R^2	0.213	0.157	0.207	0.082
Root MSE	0.337	0.349	0.339	0.364
Anderson canon. corr. LM statistic	22.497 (P = 0.000)	18.024 (P = 0.000)	26.143 (P = 0.000)	17.674 (P = 0.000)
Cragg-Donald Wald F statistic	7.567 (>20% maximal IV relative bias)	6.008 (>30% maximal IV relative bias)	8.840 (>20% maximal IV relative bias)	5.876 (>30% maximal IV relative bias)
Sargan statistic	1.276 (P = 0.528)	0.201 (P = 0.905)	1.795 (P = 0.408)	0.060 (P = 0.970)

Notes: Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.10.

other words, almost all the rural households have the ability to obtain clean energy. Wives are no longer strapped in traditional energy collection.

Consistent with the household-level results, social norm and longer residential time pull women into agricultural production. Relatively asset-rich women are also less likely to seek wage jobs. These results are in line with the study by Shi et al. [34] and Van den Broeck and Kilic [23]. People generally prefer a solid and stable life instead of leaving their home, unless facing some intractable challenges. In those cases, the internet serves as an important information channel for job searching.

To explore how women's employment status influences the transition of household energy use, Table 6 presents the 2SLS regression results for the limited sample. Social norm, Residential time and Assets are employed as instrumental variables. In columns (1) and (2), the effects of wives' employment status are considered separately. Only the coefficient of *Wage-employed wife* is positive and significant. These results suggest that wage-employment of women can promote household energy structure transition whereas self-employment of women has no effect.

In columns (3) and (4), the effects of wives' employment status are considered together with their husbands' employment status. The coefficients of *Two-paycheck household* and *Two-paycheck household with wage-employed wife* are both positive and statistically significant. Ceteris paribus, the ratios of clean energy consumption in two-paycheck households are 32.7% higher than in other households. These results provide new evidence that the off-farm employment of both husbands and wives is a significant incentive for household energy clean transition. The estimated coefficient of *Two-paycheck household with wage-employed wife* is larger and more significant than the coefficient estimated for *Two-paycheck household*. Ceteris paribus, the ratios of clean energy consumption in two-paycheck households with wage-employed wife are 46.6% higher than in other households. This result further illustrates the female time allocation constrained explanation of household energy consumption. Self-employed wives have more time to collect traditional energy or adopt energy services, and their households therefore consume a lower ratio of clean energy than families with wage-employed wives.

5. Conclusions and policy implications

Although the impacts of off-farm employment on energy transition in rural areas have been widely analysed, especially in developing countries, some important research gaps are still worthy of being filled. To address these research gaps, this paper provides a new gender insight into the energy transition by examining the female off-farm employment implications of household energy choices. In the empirical part, based on the data of the Chinese General Social Survey (2015), the Dubin-McFadden model is employed to address the potential omitted variables bias and a simultaneous equation model is used to address the potential reverse causality bias.

The empirical results illustrated that husbands generally tend to work outside the farm to obtain more income, but emancipating women from agricultural production can be more beneficial to household energy transition. Specifically, two-paycheck households consume about 17.8% more clean energy than one-paycheck or no-paycheck households. The impact is stable under several robustness checks. Taking into consideration the reverse effect of energy transition on female off-farm employment, ceteris paribus, the ratios of clean energy consumption in two-paycheck households are estimated to be 32.7% higher than in other households. The ratios of clean energy consumption in two-paycheck households with wage-employed wifes are estimated to be even 46.6% higher than in other households. Wage-employed wives therefore contribute more to the energy transition than self-employed ones, possibly because their time allocation is less flexible.

Clarifying the role of female off-farm employment in household energy transition is important in the context of China as well as other developing countries facing challenges of climate change response and rural development, as it can provide a feasible plan to promote the rural clean energy popularisation. Development policies that pay more attention to the increase of female off-farm employment opportunities contribute to reducing the gender inequality of rural employment and to expanding women's autonomy in time allocation. Further research on less-developed regions can apply and extend our analytical framework to better understand the nexus between women's empowerment and energy transition. This will be beneficial for achieving a win-win situation in rural economic development and environmental protection in less-developed regions. Furthermore, the case of rural China illustrates that the nationwide popularisation of electricity facilities can help rural women escape from 'time poverty', which may promote a positive self-perpetuation process in the interaction between off-farm employment and energy transition.

There are three major limitations of this study. First, all conclusions are valid only for households that are living in rural areas. The energy choice behaviour of households that migrated to urban areas for employment, but formally still reside in rural areas, are cannot be analysed with the data set that was used. However, the influence caused by the reduction of permanent residents on energy investment efficiency in rural areas is also a significant policy issue faced by most developing countries. Therefore, a macro-level analysis of the interaction between urbanisation and energy transition would provide a useful addition to our research. Second, unmarried children form a large share of the migrant labour force in rural China. These off-farm workers provide an important contribution to household remittances income. Unfortunately, little information is available in our dataset on the employment status of unmarried adults in the households. Future research may focus on this particular group to provide a fuller picture of the impact of off-farm employment on household energy clean transition. Finally, we use cross-section data to test the impact of off-farm employment on household energy consumption. This dataset is insufficient to describe thedynamics of energy transition. In particular, the time accumulation effect of employment and energy consumption decisions cannot be taken into account.

CRediT author statement

Huayi Chang: Conceptualization, Methodology, Software, Writing-Original draft preparation; **Nico Heerink:** Supervision; Writing-Reviewing and Editing; **Junbiao Zhang:** Supervision; Data collection; **Ke He:** Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

Support for this research is provided by the National Office for Philosophy and Social Sciences (20AZD091) and China Scholarship Council (202006760036).

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